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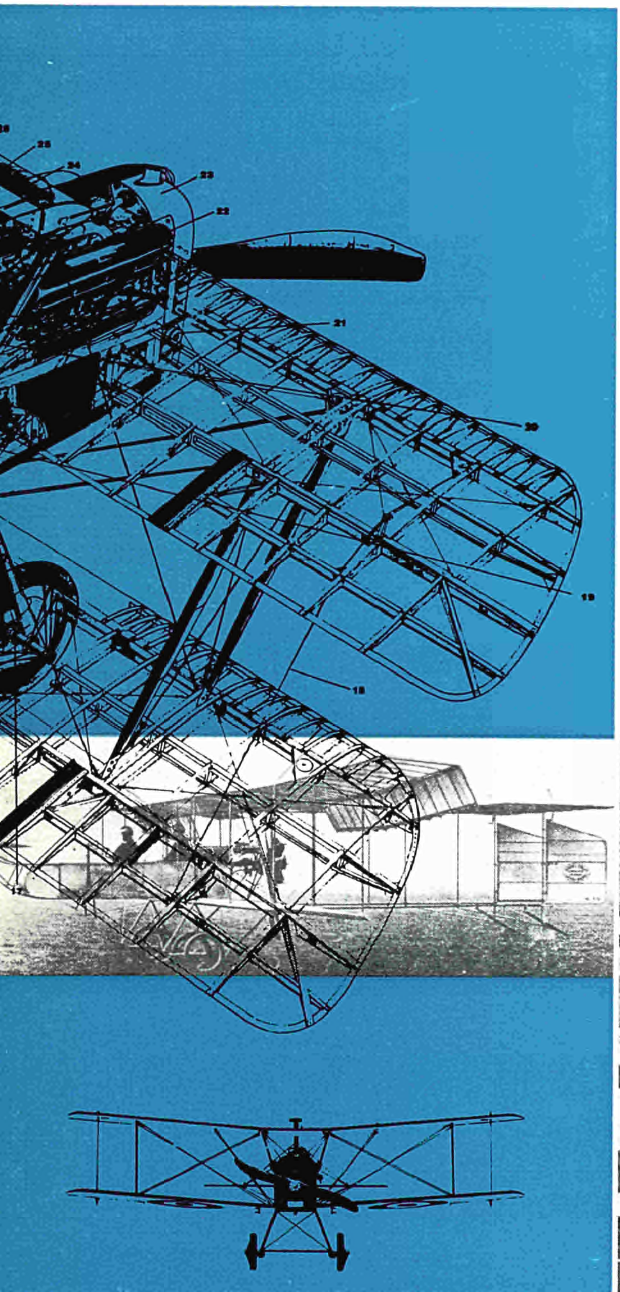

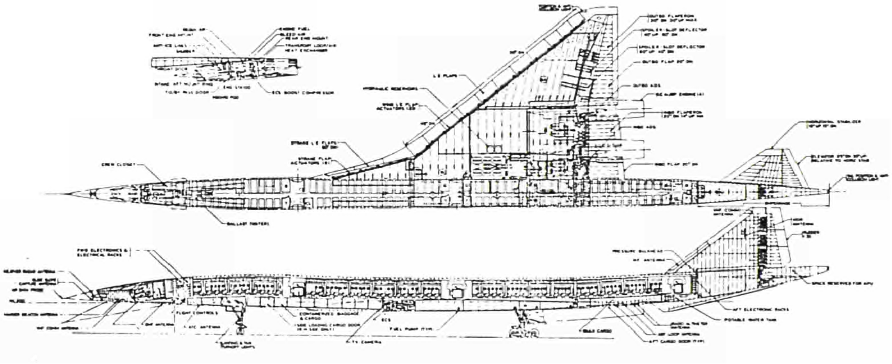

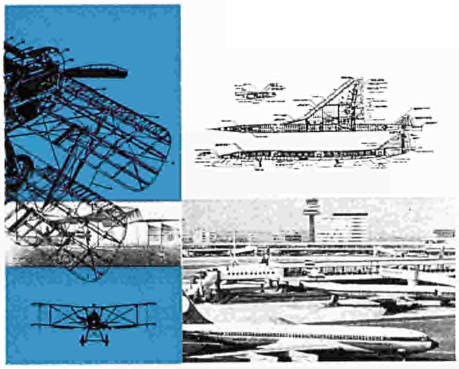

Is the Community's aerospace industry competitive?

CONTENTS

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Scientific and Technical Review of the European Communities (ex-Euratom-Review)

1970-2

The memorandum on the European Community's industrial policy recently forwarded by the Commission to the Council of Ministers (a summary of which will be found on pages 61 and 62) gave particular prominence to the advanced-technology industries, for over the long haul it is these industries which will hold the key to Western Europe's industrial expansion.

It is a well-known fact that development work in these industries involves such colossal spending that in many cases this cannot be done on the national level. The case for international cooperation is quite self-evident by now. By way of illustration, the aviation sector may be said, without undue exaggeration, to be teeming with agreements between firms of various European countries. Unfortunately, cooperation is frequently seen to be of a very superficial character, having little beneficial effect on industrial structures. In the coming years, therefore, an important task will devolve upon the Community as regards furthering cooperation in such a way that this process will be accompanied by the emergence of more competitive industrial structures.

Another task, still more difficult, will be that of creating a genuine common market for the products manufactured by the advanced-technology industries. As everybody knows, the present situation is marked by a more or less complete hiving-off of the domestic markets, each of the governments concerned being prompted by the desire to make sure that its own industry at least has the run of the existing home outlets. Since the Member States themselves are among these industries' largest customers, the Commission proposes, as a first step, that purchasing policies should be coordinated.

A third major task to which the Commission has drawn attention consists in determining a common policy for cooperation with non-member countries in the technological field. How often, indeed, have we seen Member States negotiating entirely on their own, and thus not only depriving themselves of the benefits which would accrue from a closing of the Community ranks but also actually giving the impression that they are competing among themselves in dealings with non-Community countries?

The situation in the Community's aerospace industry

The aeronautical and space industries of the Community are undergoing a transformation. The magnitude of current projects has already rendered international cooperation essential, but will there not be a long-term trend towards a basic revamping of the existing structures?

LOUIS GRAVIGNY and DANIELE VERDIANI

THE YEAR 1969 was marked by three events in the aeronautics and space field which, in their different ways, made a great impression on world public opinion: the two landings on the Moon, the test flights of the *Concorde* and the appearance at the Paris Air Show of the *Boeing 747*.

The development of the *Boeing 747* and the *Concorde* will obviously not go down in history as events of such importance as the lunar landings, but they are nonetheless significant as stages in the history of aviation.

The *Apollo programme* and the *Boeing 747* are achievements of the United States; the *Concorde* is European. It is a cheering thought to note that Europe has a place in the big league of advanced technology. At the same time, its aerospace industry is not without its difficulties. Let us consider the conditions in which it has to operate, the problems it is facing and the outlook for the future.

The role of the aerospace industry in the economy

When a country or group of countries decides to carry out major programmes of research and production in the aeronautics and space fields, it must also, because of the high level and diversity of the technology in these fields, boost developments in other fields, notably electronics. This stimulus to technology in many industrial fields and, in a more general sense, the fall-out effect of aerospace work on the economy are very apparent in the United States owing to the amount of work which has been done.

Moreover, network planning, a new feature of aerospace programmes, is endowing American management with an efficiency such that its lead over other countries may well increase even further.

In the United States finally, cyclical fluctuations have for some years now been negligible, which is (to some extent) due to the very large investments made in the aerospace field under long-term planning programmes, this being a sector with a long economic cycle. The same is not true of Europe, where government aid has often been sporadic and has not formed part of a large-scale programme aimed at stabilising the general economic cycle at a high level.

Output and market of the Community's aerospace industry

It might be advisable first of all to compare the Community's industry with those of Britain and the United States. Total output figures for 1967 are shown in Table 1.

Another noteworthy feature of the Community's aerospace market in 1967 was the breakdown of orders among the different customers, namely:

63.2% : government (civil and military orders, including those placed by the national carriers and their subsidiaries);
2.3% : private buyers;
34.5% : exports.

Research and development expenditure was met as to 89% out of public funds, 11% only being privately funded. At the same time, in some member countries, especially France and Italy, direct participation by the state accounts for a considerable proportion of the aerospace firms' capital.

It can therefore be seen that the state plays a major role in the aerospace industry, its prime interest being a planned programme of investment and production based upon demand.

However, before this aspect is discussed, a few additional comments are required:

— public expenditure on aerospace products for military and civil purposes appears either to be growing, or at least maintaining its present level, in relation to the GNP;

— in general, Europe's level of technological sophistication would seem sufficient to satisfy all requirements, as is illustrated by the outstanding performance of the *Concorde*, the *Mirage G* and the *Harrier;*

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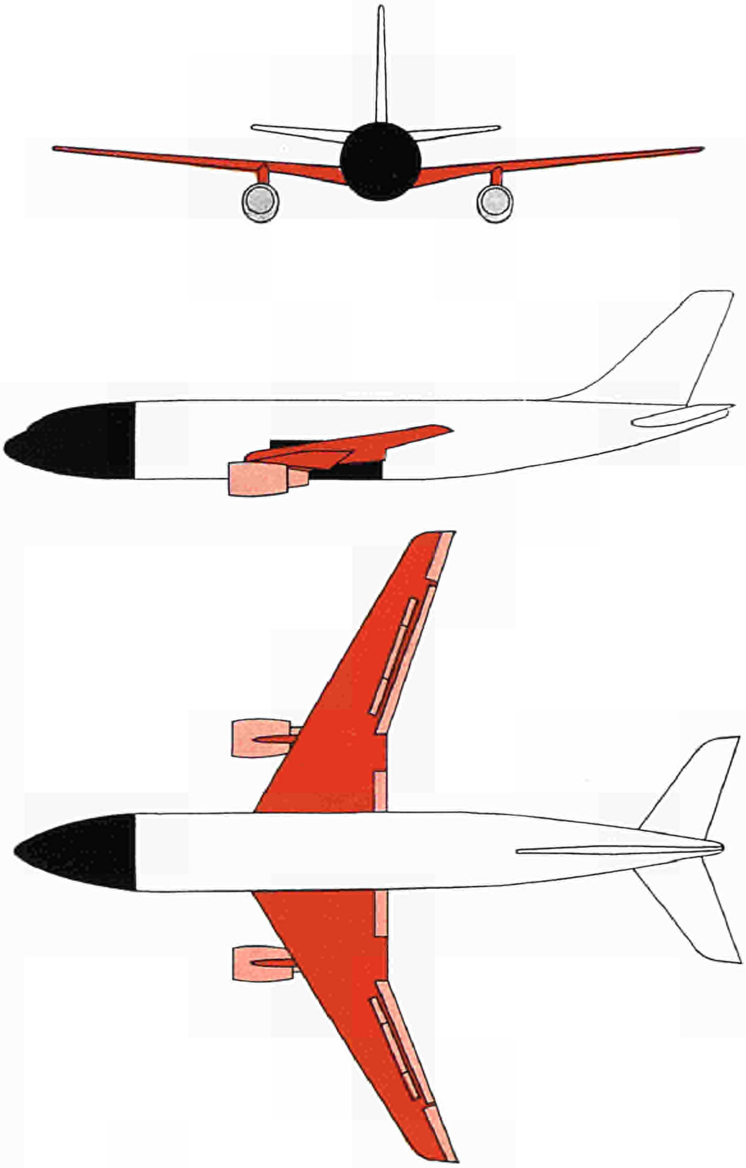
* Most of the facts quoted in this article are taken from a report by *SORIS*, Turin, containing the results of a survey carried out on behalf of the Commission of the European Communities.



The A 300 B Airbus, *a twin-jet, short/medium-range subsonic aircraft.*

- *Normal range with full load: 2,200 km.*
- *Maximum cruising speed: 945 km/h.*
- *237 passengers in a mixed layout.*

The aeroplane has been developed jointly:

- SNIAS *(France) are responsible for the parts marked in black, i.e. the forward and centre fuselage and the wing centre section; they are also responsible for the assembly, furnishing and flight clearance of the aeroplane;*
- Deutsche Airbus *are constructing the main part of the fuselage, the fin and the tailplane (shown in white);*
- *the British firm of* Hawker-Siddeley *are building the wings and the engine pylons (marked in red);*
- *the firm of* Fokker-VFW *are supplying the moving surfaces (marked in pink);*
- *a choice of several versions will be available:*

A 300 B *with* General Electric CF6 *engines or* A 300 B *with* Rolls-Royce RB 211 *engines.*

— in the military sphere European production is easily able to cope with requirements (e.g. the *MRCA 75*);

— demand in the civil field has both intensified and diversified and it seems unlikely that the American industry is able to offer the wide range of products needed to meet this demand, so the way is open to European industry to gain a foothold in certain fields;

— Europe can make an important contribution to space research, but urgent problems of selection and organisation must first be solved.

Certain conditions necessary for drawing up a programme for this sector are therefore met. However, in drafting such a programme, aimed at making the European industry as efficient as its American counterpart, it is important to take into account current projects, whether these are at the stage of planning, prototype construction or test flights.

Since these projects establish the general trend of activities for the next decade, it is important to study the ways in which the existence of the Community might make itself felt at the production and marketing levels, especially with regard to aeronautical equipment. The Community ought to make special efforts to promote structural changes and greater productivity.

Structural problems of the Community's aerospace industry and current programmes

Let us first look at the average size of European companies since the series of mergers which took place between

Table I: *Output of aerospace industries of the Community, United Kingdom and United States in 1967.*

	$ million	%
Germany	261	1.0
Belgium	27	0.1
France	1,250	4.7
Italy	160	0.6
Netherlands	60	0.2
Community	1,758	6.6
UK	1,610	6.0
US	23,258	87.4
Total	26,626	100.0

Table II: *Cost per unit as a function of the quantity produced. The index 10 corresponds to the total cost of a series of 100 units. The term "manufacturing costs" covers actual work, raw materials, parts and components and overheads; "launching costs" includes research and development, tooling, establishment of the production line and sales and promotion.*

Units produced	Fabrication costs	Launching costs	Unit cost
1	9.63	200.00	209.63
30	8.35	6.66	15.01
100	8.00	2.00	10.00
200	7.85	1.00	8.85

1960 and 1970. They are still small, the turnover of each of the five leading American firms alone amounting to one-and-a-half times the total turnover of the entire aerospace industry of the Community—and with a smaller labour force at that.

Also, the Community's aerospace industry is marked by a high degree of financial concentration combined with a relative scattering of the means of production. This situation does not help to cut costs, as could be done if there were more efficient management and optimum mass production, combining the benefits of quantity and speed of production.

The cost curve as a function of the quantity produced is shown in Table II. It will be seen that the difference between the cost of fabricating thirty units and that of fabricating a hundred units is 4.2% per unit, whilst the equivalent difference in the respective launching costs is 70%, the total cost differential being 33%.

It is therefore clear that the critical factor in any aeronautical programme is the launching cost, so that an outright grant covering 50% of the launching costs brings down the break-even point from the hundredth to the fifty-fourth unit.

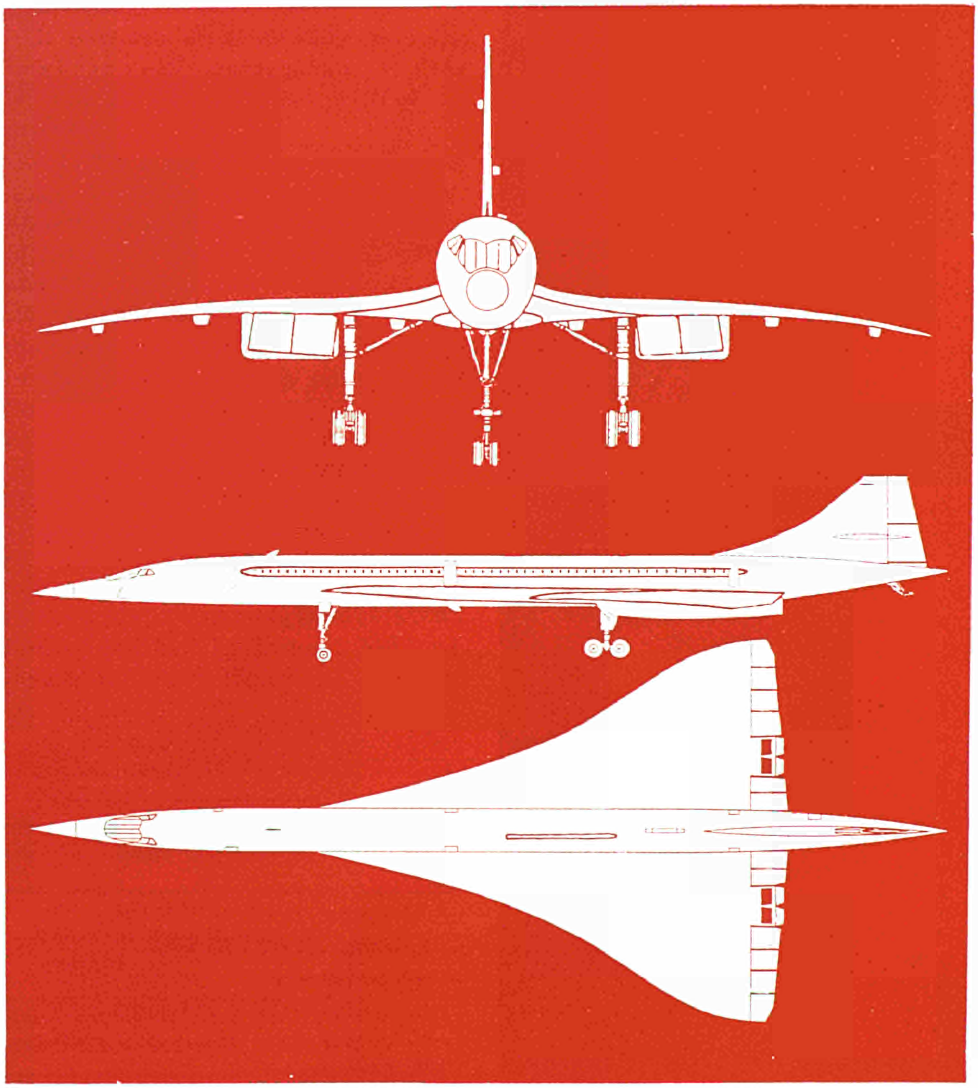
In addition, small batches cannot be turned out at high speed because they do not justify expensive tooling, so that the most economic solution is to spread production over long periods. There is, however, the by no means inconsiderable risk of being unable to meet delivery deadlines or of having to acquire new machinery which cannot be written off over the life of the entire series, and this can have a very adverse effect on the profitability of the whole programme. Long runs, on the other hand, permit high rates of production, since large-scale tooling is possible which can be easily amortised because of the large quantities produced. This difference in the size of production runs is unfortunately one of the respects in which Europe is lagging behind the United States. Since 1955 the average run has been:

	Military aircraft	*Civil aircraft*
US	1,409	492
Europe	456	138

The question of increasing the size and speed of production runs is related both to the attempt to determine the optimum dimensions of the sector within the Community and to the concentration, specialisation and rationalisation of plant at all levels.

A policy of concentration seems essential to the space and aeronautical equipment industry, which at present is divided up into many competing national concerns, mostly dependent upon the United States for their technology.

In the construction of engines and airframes, cooperation between undertakings in different member countries would appear to constitute a suitable approach to the problem while not offering a final solution, for, although European agreements for cooperation in the field of aeronautics over the last decade have yielded favourable results, they cannot be regarded as reliable instruments for enabling European industry to become competitive with its counterpart in the United States. Quite apart from the additional cost involved in aligning methods and standards for R&D and production plant and



Concorde, *a supersonic four-engined, long-range jet.*

- *Maximum range with full load: 8,000 km.*
- *Maximum speed: Mach 2.2.*
- *Cruising speed: Mach 1.6.*
- *128 passengers.*

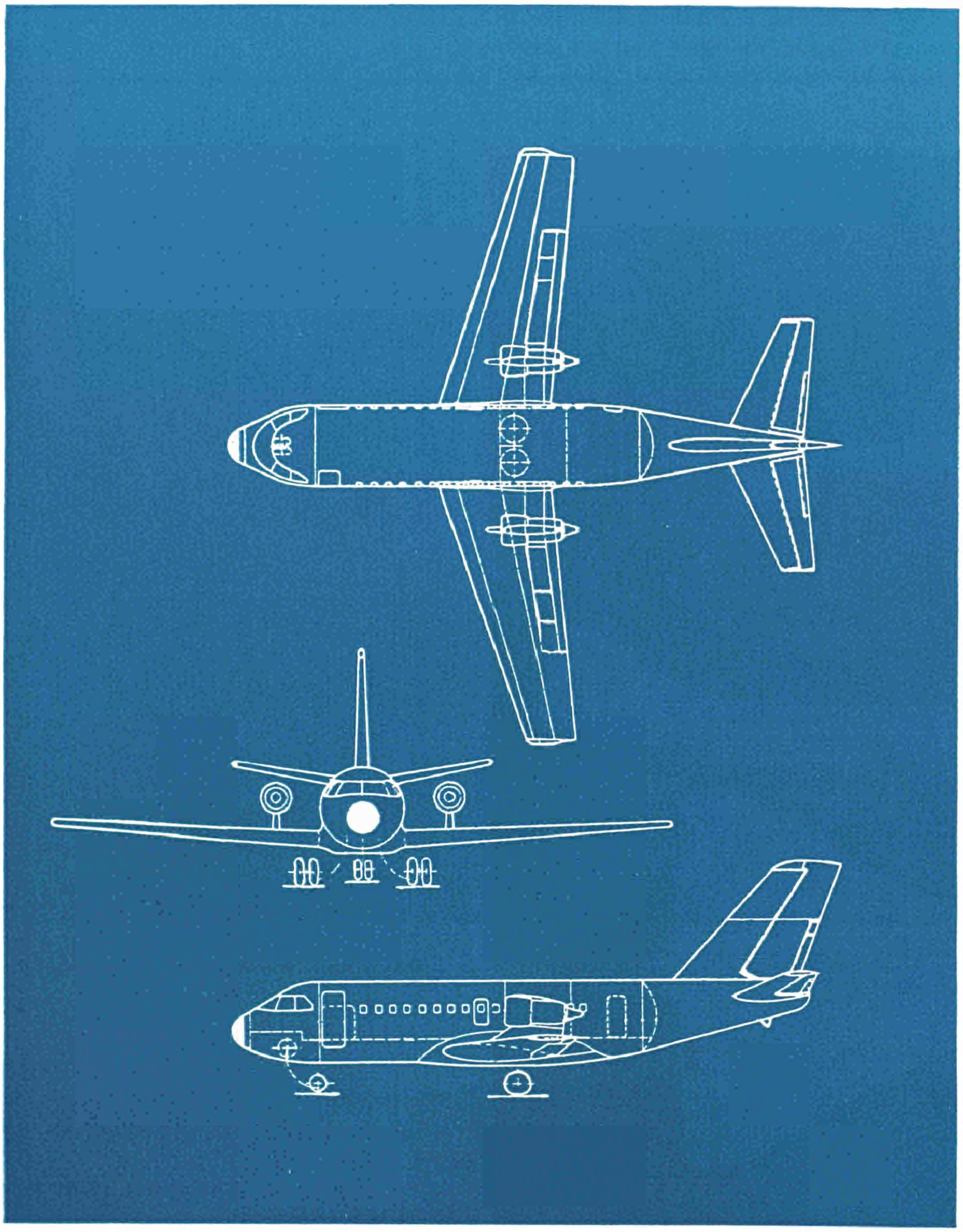
The aeroplane has been developed jointly:

- *the airframe by* SNIAS *(France) and* BAC *(UK);*
- *the engines by* Rolls-Royce *(UK) and* SNECMA *(France).*

testing apparatus (expenditure often running at 10-20% or even 30-35% if there are several versions of a single project), the value of such agreements has often suffered from sluggish decision-taking and the safeguarding of immediate national interests, which can go so far as to lead to the setting up of two production lines.

In this respect it would seem advisable for aerospace concerns and governments to combine their efforts in order to ensure maximum coordination of resources and demands on a multinational basis.

Such action, which would be tantamount to adapting the structure to the product and not vice versa, would have to take account of the present or potential R&D, production and marketing strength of the different firms in the member states. It would also be advisable, as was stated earlier on, to consider the state of progress of current large-scale projects within the Community, such as *Concorde, Fokker F 28, VFW 614,* short or vertical take-off techniques, *Airbus A 300 B* and *Mercure* in the civil aircraft field, and *MRCA 75, Mirage F 1, Mirage G* and



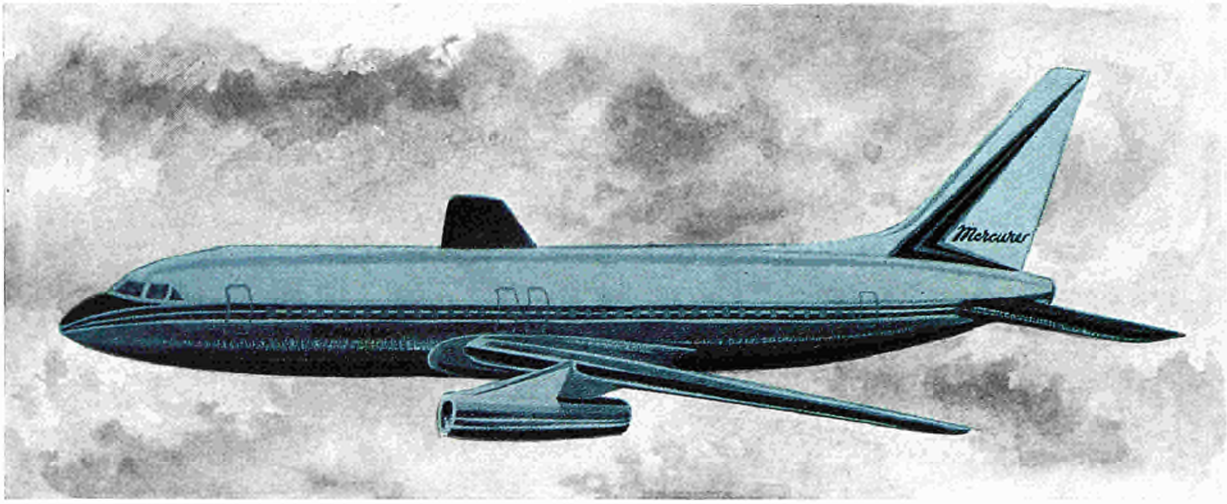
VFW-614, *a twin-jet, short-haul aircraft.*

— Maximum range: 1,000 km.

— Cruising speed: 530 km.

— 40 passengers.

The aircraft has been developed jointly by VFW-Fokker *(Bremen) and* Fokker-VFW *(Amsterdam).*



Mercure, *a twin-jet, short-haul aircraft.*
— *Range: 1,500 km.*
— *Cruising speed: 925 km/h.*
— *134 passengers.*

The aircraft is being built jointly by Avions Marcel Dassault *(France),* SABCA *(Belgium),* Aeritalia *(Italy),* CASA *(Spain) and* Fabrique Fédérale d'Emmen *(Switzerland).*

helicopter programmes for military purposes.

It is worth while recalling here the breakdown of participation in the *A 300 B*, *Mercure* and *MRCA 75* projects:

— *A 300 B:* 47% France *(Sud-Aviation)*, 47% Germany *(Airbus GmbH: Messerschmitt-Bölkow-Blohm* — 60%, *Dornier* — 20%, *Fokker* — 20%) and 6% Netherlands *(VFW-Fokker);*

— *Mercure:* 70% France and 30% the other countries participating. Half of the French budget is borne by the State, to be repaid out of the revenue from series production (making up 56% of the total cost of the programme and 20% by *Avions Marcel Dassault* (14% of total cost). The other partners contribute as follows: *Fiat* — 10%, *SABCA* (Belgium) — 8% (half of the *SABCA* capital is held by *VFW-Fokker* and half by *Dassault-Belgique-Aviation),* CASA (Spain) — 6% and *Fabrique Fédérale d'Emmen* (Switzerland) — 6%. It can be seen that the contribution of the French government is supplemented by funds from private industry within the Community (32%) and non-member European countries (12%). It can also be seen that the French, Dutch, German and Italian industries are all participating in the *Mercure* project to some extent;

— in the case of the *MRCA 75* (multi-role combat aircraft, due around 1975), Italian industry will be responsible for 14.4% of the airframe, German industry for 48.4% and British industry for 37.2%, *Rolls-Royce* supplying the power plant.

These examples show that the European industry is engaged upon important joint projects, especially in the realm of civil aviation.

However, despite the considerable impact, particularly of the *A 300 B* and *Mercure* programmes, it is evident that the few groupings achieved either via the link-up of interests between *VFW-Fokker*, *SABCA* and *Dassault* or as a result of the ad hoc organisations set up, for example, in Germany for the *Airbus*, have not led to the structural reorganisation at the European level which would enable the industry to compete successfully with non-member countries.

Table III : *Productivity in Europe and the United States (index 1=Community).*

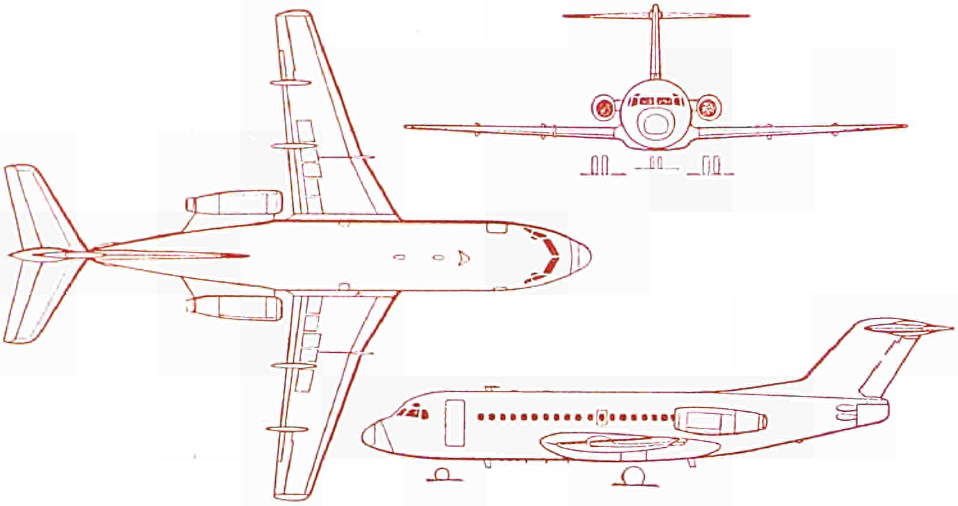
	Community	UK	US
Value of output per employee	1	0.68	1.95
Added value per employee	1	0.68	1.99
Labour cost	1	0.68	1.79

Outlook for 1970-1980

Future prospects should be studied in the context of competition on a world-wide basis, at least as far as civil aviation is concerned.

Here it is worth while comparing the European and the American industries from the standpoint of competitiveness (see Table III for the 1966 production figures).

It is clear that, in comparison with the Community, the difference in value added per person employed, in the United States, more than makes up for the higher cost of labour.



Fokker F.28 Fellowship, *twin-jet, short-haul aircraft.*

- *Maximum range with full load: 1,945 km.*
- *Cruising speed: 686-836 km/h.*
- *60 passengers.*

The aeroplane has been developed jointly by Fokker *(Netherlands) and* MBB *and* VFW *(Germany).*

Since there is every reason to think that the difference in the cost of labour will tend to diminish rapidly, the rise in productivity must help to compensate for the loss of the relatively small advantage in the form of lower labour costs. It is unlikely that the level of productivity in the United States will manage to make any great strides in the next decade, since management has already been rationalised to such a high degree.

A major objective of the Community's industry should thus be to step up productivity, with the aim of reaching present United States level by 1980 at the latest.

If we take this as a provisional aim for the purposes of this study, we must examine the effects which this would have for the general level of activities within the sector. Consideration must be given to the size of the labour force and the total volume of production thus created; the logical extension of this would be to examine the degree to which the theoretical volume of production achieved was balanced by the possible outlets in the different sectors of space, civil aviation and military aeronautics.

The programme drawn up for the Third European Space Conference (Spaey programme) provides valuable pointers as to the theoretical possibilities open to the aerospace industry.

Certain theories can be put forward on the demand in the field of military aviation, with due allowance for the probable curve of military aeronautical spending in relation to the GNP.

The large-scale civil projects under way within the Community, and airline needs in terms of aircraft types, are such that sufficiently accurate estimates of both internal and export demand can be made.

It is difficult to carry these reflections any further. This analysis of the situation has yet to be discussed with the governments of the member countries in the light of the general guidelines for industrial policy laid down in a memorandum which the Commission recently sent to the Council. Without any wish to anticipate the results of these discussions, it can be pointed out that if certain conditions are met, Europe's aerospace industry should be able to raise its productivity and reach the targets it has set itself, while maintaining manpower at its present strength.

EUSPA 9-5

Nuclear energy in the United States

After the boom years 1966-68 orders for nuclear power plants have fallen off in the United States. Is this a lasting phenomenon or merely a temporary lull?

The author has based this assessment of the nuclear energy situation in the US on impressions and information recently gathered on the spot in the course of meetings he had with representatives of electricity generating companies, private research centres, the Atomic Energy Commission *and the* Federal Power Commission.

JEAN LECLERCQ

The drop in orders

The number of orders for nuclear power plants in the US in 1969 was the lowest since 1965. Table I and the corresponding graph show the trend in orders, the figures being arranged according to the year the contract was signed.

In January 1970 four orders were placed for a total of 3,915 Mwe but, despite this, it is not anticipated that the figure for the whole year will be higher than about 10,000 Mwe.

How is this trend to be interpreted?

Before this question is answered it is interesting to note that if, instead of arranging the figures according to the year the order was placed, it is done according to the planned commissioning date, then a somewhat different situation emerges.

On the basis of this criterion, Table II shows the figures for orders placed up to the start of 1970.

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At first sight it would appear that we are faced with another "bell" curve, showing that after a sharp rise in orders interest in the use of nuclear energy for electricity production in the US is falling off sharply.

In fact, however, any interpretation of the trend based on commissioning dates must take into account that only the first few years are complete and that possibly from 1974 and certainly from 1975 new orders will be added to those figures and will thus modify the apparent trend in Table II quite considerably.

The trend in costs

The main factor accounting for these fluctuations is the relationship between the anticipated cost of nuclear and conventional plants.

It is undeniable that the construction costs of nuclear power plants have risen substantially in the last few years. At the start of 1966 the cost, including the first core and interest during construction, was in the most favourable cases hardly ever higher than $ 100 per kwe, but now the figure is over the $ 200 mark.

The *Atomic Energy Commission (USAEC)* admit that the particulars of total costs compiled by them should be treated with some circumspection and are not really suitable for the purposes of comparison. But if one takes just the very large plants (around 1,100 Mwe, or to be exact between 1,050 and 1,150 Mwe), then one arrives at prices which average about

$ 155 million in 1966 (6 plants)
$ 165 million in 1967 (8 plants)
$ 180 million in 1968 (8 plants)
$ 220 million in 1969 (4 plants)

A third fact confirming this trend can be found in the report recently submitted to the Congress *Joint Committee for Atomic Energy* by Philip Sporn. According to this report the price of fossil fuels at which nuclear power is still competitive has risen from 22-24.8 US cents per million Btu (1) in 1968 to 28-29.5 cents at the end of 1969 (2).

Future outlook

This trend has definitely had a depressing effect on the yearly order-books. The question is, however, what the possible future repercussions of this trend are and to what degree it will confirm the falling-off in orders which the tables below apparently forecast.

In the first place it should be noted that the figure of 28-29.5 cents per million Btu given by Philip Sporn still leaves room for a certain amount of development in the nuclear energy field. In the US the cost of fossil fuels

---

1. Btu=*British thermal unit* or 0.252 kilocalories. So 22-24.8 cents per 10^6 Btu corresponds to $ 0.88-1.00 per 10^6 kcal, $ 6.10/tce (tonnes coal equivalent at 7,000 kcal/kg) or $ 8.80-10.00/toe (tonnes oil equivalent at 10,000 kcal/kg).

2. Or $ 1.10-1.20 per 10^6 kcal, $ 7.80-8.20/tce or $ 11-12 per toe.

delivered to power plants varies considerably depending on the area; it ranges between 18 and 43 cents per million Btu for natural gas and the price bracket for coal is roughly similar. Even within the same state the difference in price can be quite large. In Michigan, for example, the cost of fossil fuel of whatever type varies between 26-35 cents/million Btu. In the two cases quoted above the highest competitive price which Philip Sporn gives, i.e. 29.5 cents, is just in the middle of the price range.

As to the future, although the heat is on to increase the consumption of coal in power stations, on the other hand the stricter regulations recently introduced concerning safety in mines will have an effect which must not be underestimated. These will involve a considerable increase in costs which in certain cases could be as much as 75%.

As far as natural gas is concerned, the recent reduction in reserves—these have dropped from 18 years' consumption in 1960 to 12-13 years' now—can be attributed to the fact that with the level of profitability guaranteed by present prices, producers are no longer pursuing a proper exploration policy. This reduction in reserves does not represent the actual geological situation but is more a result of the fact that at present prices suppliers are wary of entering into long-term contracts with power stations, mainly because they anticipate an increase in domestic demand, for which they can charge more.

In the case of fuel oil, its consumption is very limited apart from a few areas and it is still essentially a by-product, so it would appear unlikely that the measures recently introduced will result in a reduction in prices or in an expansion of its role in the field of electricity production.

These various trends towards higher costs are bound to benefit nuclear energy, even assuming that present price levels are maintained.

On the other hand, however, what is the situation with regard to the increasing cost of nuclear power plant construction? Since this factor has been more pronounced than in the case of conventional power plants it has given rise to a difference which has put nuclear installations at a disadvantage.

What are the prospects for future development? The flood of orders in 1966, 1967 and, to a certain extent, 1968 caught the industry on the hop and caused the work to pile up such that delays arose in plant construction. It is quite apparent now that after the present back-log or orders has been cleared all the constructors will be over-equipped, which would induce them to submit tenders containing conditions more favourable to the clients than those resulting from present-day boom prices. In this case, then, prices would either drop or else remain at their present level in spite of inflation.

Despite the falling-off in orders the *USAEC* still regards their latest estimate of electronuclear power in the US in 1980 as completely valid. It should be remembered that from a forecast published in 1962, which put the figure at 40,000 Mwe, this has risen successively to 75,000 in 1964, 95,000 in 1966 and then finally to around 150,000 Mwe in 1967.

This can be reached by yearly orders of a fairly modest level by American standards, say 12-15,000 on average, figures which are distinctly lower than that for 1967, which was around the 26,000 Mwe mark.

The sporadic nature of development

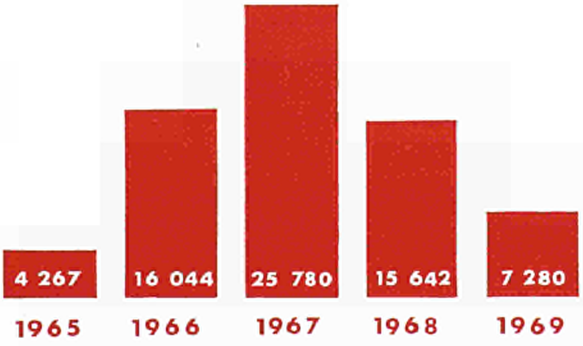
Although the final position with regard to nuclear development will most likely be more or less as forecast, it is likewise probable that the curve representing the orders placed each year will continue to fluctuate quite considerably.

It should be noted in passing that these movements are partly due to the artificial character of the year-by-year breakdown. For instance, if the four orders placed in the first three weeks of 1970 had come in 1969, which could quite easily have happened, then instead of having figures of 7,300 Mwe for 1969 and perhaps 10,000 in 1970, these would have been 11,000 Mwe and perhaps only 6,000 Mwe respectively.

On the other hand, it emerges from Table III that the fluctuations in orders

Table I: *Trend in nuclear power plant orders placed in the US between 1965 and 1969.*

Year	Number of plants	Net power (Mwe)
1965	7	4,267
1966	20	16,044
1967	31	25,780
1968	17	15,642
1969	7	7,280



for nuclear power plants can be seen in the context of the variations, which are nearly as marked, though not necessarily concomitant, in the decisions relating to thermal power plants as a whole.

The irregular rhythm followed by orders for nuclear power plants has various repercussions.

The first is shown in the fluctuations which up to now have affected the prospection and exploitation of uranium deposits. The renewed activity which followed the boom in orders in 1966-67 has already given way to a decline in prospecting; as a result specialised personnel have been dismissed and drilling equipment lies idle. The fact that new deposits have not been discovered at a sufficient rate owing to a lack of incentive in a depressed market could have awkward consequences for this industry in the US and could also lead to a major increase in costs when there is another upward trend in the nuclear market.

In the other sectors of the fuel cycle, where there has been considerable investment, certain minor adjustments may well reduce this effect. Certain decisions will be reviewed, leading either to an extension of the time-scale involved or even to the cancellation of some projects. Nevertheless an excess of supply over demand will persist locally which will probably have a more serious effect on those firms not integrated into the large reactor construction companies.

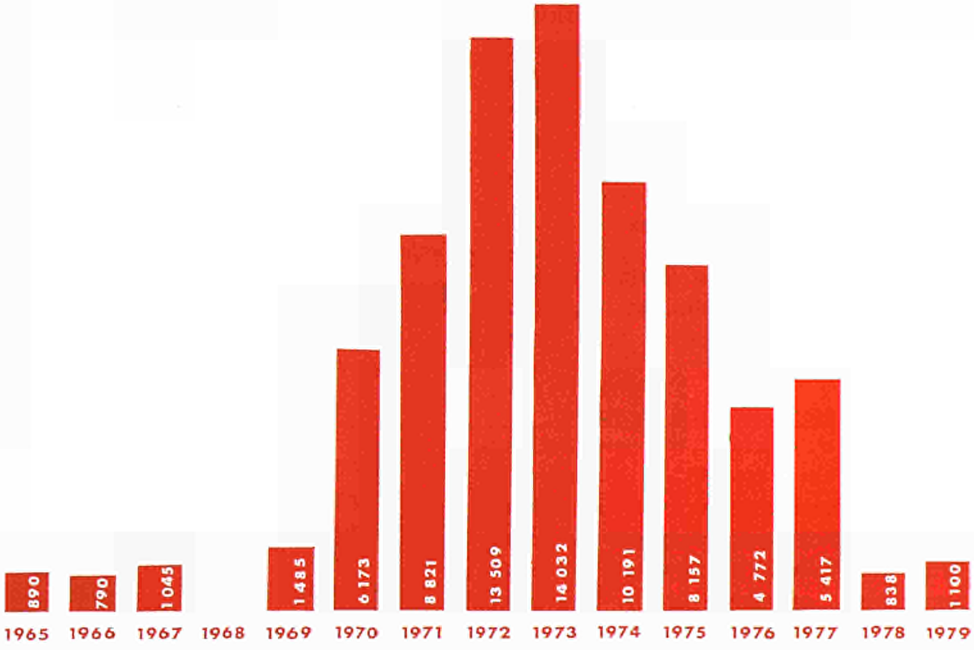
As to the latter it has already been pointed out that in a year or two the investment made with the aim of removing the supply bottle-necks in reactor vessels, turbines and other main components will result in excess capacity. This in turn will almost certainly cause more intense economic competition both between the individual firms themselves and between nuclear and conventional means of electricity production.

Environment and safety problems

There is another factor which cannot fail to affect the development of nu-

Table II: *Distribution of nuclear power plants ordered in the US up to the start of 1970, arranged according to commissioning date.*

Year	Number of plants	Net power (Mwe)
ready by 1965	7	890
1966	1	790
1967	3	1,045
1968	0	0
1969	4	1,485
1970	10	6,173
1971	12	8,821
1972	16	13,509
1973	16	14,032
1974	12	10,191
1975	10	8,157
1976	4	4,772
1977	5	5,417
1978	1	838
1979	1	1,100



clear energy in the US but at the moment it is difficult and premature to say how it will make itself felt. This is the growing attention being paid in public and official circles to the problems of environment and industrial safety.

This will certainly give rise to legal obligations with regard both to the safety of personnel and the general populace and to the different forms of pollution (atmospheric, thermal, etc.); the prospect of this has led to some pussyfooting on the part of the utilities.

Their immediate fear is that more stringent nuclear safety standards will result in more time being necessary for completing formalities and also in the need for a considerable increase in investment. On the other hand, the economic effects of solving the problem of thermal pollution will be almost identical, whatever the type of fuel. Finally, and this is the most important point, there is a very high degree of uncertainty with regard to the long-term consequences of applying strict regulations to mining safety and to the atmospheric pollution caused by coal and oil fired power plants.

Over the long haul and insofar as these safety and pollution problems are being dealt with under conditions which are producing similar effects in both the conventional and nuclear fields, it seems likely that their repercussions could well benefit the latter.

The choice of reactor types

During the last few years the situation with regard to the use of different types of reactor has been considerably simplified.

Light water enriched uranium reactors have reached the production stage and have established themselves in a dominant position over the other systems. They are marketed by four firms and Table IV shows the present breakdown of construction projects and orders among these four.

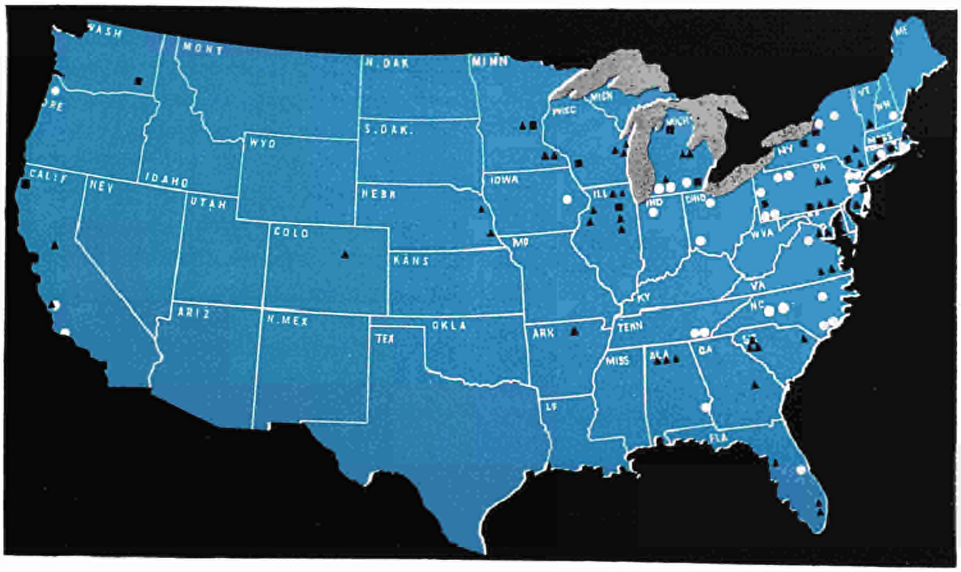
It will be observed, by the way, that, of the large US construction companies, the net power figure shown for the company with the least orders —*Combustion Engineering*—is appreciably higher than that of the largest European company—*Kraftwerk Union* —which, apart from the six power plants already built (representing 800 Mwe), at present has orders on the books for six reactors with a total net capacity of 3,980 Mwe.

In the US there is widespread agreement on the fact that light water reactors will remain on the electricity plant market until the arrival of fast reactors and even after that they could remain economically viable for a certain time. As for the other types of thermal reactors, the general opinion is that their penetration of the market will depend solely on their economic merits.

Generally speaking the outlook for heavy water reactors is not regarded as favourable mainly because no US constructor is interested in this type.

Of the advanced reactors the only type in view is the high temperature gas cooled reactor marketed by *Gulf General Atomic;* its chances, or so it is thought, will depend on the promotion and marketing campaign mounted.

The molten salts reactor is seen as being an excellent design from the technical standpoint and offers considerable advantages, especially that of using the thorium cycle, but its chances of being produced commercially are poor, owing to a) the absence of any industrial support at present, and b) the fact that no constructor can be



Nuclear power plants in the United States

■ *in operation* ▲ *under construction* ○ *on order* found who would be prepared to give this support in the future.

Finally the *USAEC* is still continuing with the development of the light water breeder reactor *(LWBR)* advocated by Admiral Rickover. This system is meeting with serious problems especially with regard to the fuel behaviour necessary to reach the performance required by the design. Furthermore, although one electricity producer—*Consolidated Edison* — has expressed interest in this type, no constructor seems inclined to sink any capital in it.

Remaining uncertainties

As compared with two or three years ago, it is now possible, therefore, to get a much clearer picture of the prospects for the use of nuclear energy in the US for electricity production. Apart from any question of technological development, however, several very important factors of uncertainty remain, in particular:

- US oil policy and its effect on the price of heavy fuel oil, the latter being a possible serious competitor of nuclear energy;
- the absence of any decision on a) the question of the ownership of isotope separation plants and b) the enlargement of uranium enrichment capacity and future prices for enrichment work;
- the attitude to be adopted with regard to environmental protection, although if this factor became highly restrictive it would perhaps prove less of a handicap to the use of nuclear energy as such than to the expansion of electricity consumption or even to that of energy regardless of its form.

⁂

Although the uncertainties mentioned above must be borne in mind, a strong long-term growth in the demand for electrical energy will probably be maintained and this will necessitate the use of all the sources economically available. Since the reactors in operation are functioning very satisfactorily, there is great faith in the US in the increasingly important role which nuclear energy promises to play.

EUSPA 9-6

Table III: *Decisions on the construction of thermal power plants in the US.*

	Fossil fuel		Nuclear*		Total
	Mwe	%	Mwe	%	Mwe
1965	15,928	73	6,009	27	21,397
1966	20,096	47	22,477	53	42,573
1967	32,320	55	26,460	45	58,780
1968	24,600	62	14,803	38	39,403
1969 (estimated)	27,000	79	7,000	21	34,000

* The figures shown for nuclear power plants do not agree with those for orders as shown in Table I. This is because the order is normally placed after the decision to build has been taken.

Table IV: *Light water power reactors ordered in the US up to the start of 1970, arranged according to construction company.*

Company	Type	Number of plants	Net power Mwe
General Electric	BWR	38	29,792
Westinghouse	PWR	36	28,391
Babcock & Wilcox	PWR	12	9,209
Combustion engineering	PWR/BWR	10	8,535

Hydrogen, key to the energy market

Nowadays nuclear energy is used primarily in the form of electricity. Why not also use it to produce hydrogen — a clean and versatile form of energy?

GIANFRANCO DE BENI and CESARE MARCHETTI

Up to now practically the only source of primary energy available to man has been the sun. Plants convert it into chemical energy by breaking down water and combining the hydrogen with carbon dioxide taken from the air. This chemical energy goes to feed the biosphere where it is ultimately transformed into heat, apart from a small amount which is accumulated in deposits in the form of coal or oil. Our civilisation would be inconceivable if the crumbs from this great feast of energy indulged in by the sun and the green plants had not been kept for us for millions of years by these precious deposits. We should still be crossing the oceans in sailing ships and using wind or water power to drive our industry.

Enter the atom

The discovery of the fission of the uranium atom, however, opened up for mankind a vast reservoir of energy which was completely independent of the sun/green plants/biosphere cycle and which was potentially very economical. When breeder reactors have proved themselves commercially, for instance, a gram of uranium will produce about the same amount of energy as a ton of oil. The important thing is that the cost of the raw material will be negligible and the energy price will therefore be governed essentially by considerations of nuclear reactor technology. But the history of technological processes shows that their cost decreases in time according to exponential laws. There will therefore come a time—we are in fact already there—where the descending curve representing the price of nuclear heat will intersect the curve representing the cost of heat produced by conventional fuels—coal and oil—the latter having stayed constant in recent years.

The structure of the energy market

On the other hand, in one respect nuclear energy is highly inconvenient compared with the standard forms of energy—it lacks flexibility. It is produced in the form of heat and, to keep down the cost, it is produced in large plants. Furthermore, heat cannot be transported over great distances and the majority of uses to which energy is put (as, for example, in the propulsion of an aeroplane or car) involve a large number of small, separate units.

An intermediate product therefore has to be found which is adapted to the market situation.

For this reason the projects related to the development of the peaceful uses of nuclear energy have up to now been concentrated almost solely on the conversion of this heat into electric current. This is an almost ideal intermediate since it is produced in large units and has a highly ramified distribution network. But electricity can only meet about 20% of the energy needs of a technologically developed society, which limits the role nuclear energy can play in the total energy supply.

Having been especially struck by this fundamental problem, we set out, three or four years ago, on an attempt to find the technological means whereby this nuclear heat could be put into a "package" which was suitable, at least partially, for the remaining 80% of the energy market.

The intermediates

The conclusions arrived at in this study, which are shortly to be published, are that hydrogen can be an extremely flexible intermediate which would make it possible to penetrate the whole of the market without any sudden changes in technology being necessary. In certain cases the substitution is a straightforward matter; town gas, for example, already contains 50-90% hydrogen. In other cases it would seem to be a more complex operation, but in keeping with the normal course of technological development.

In the United States, for example, in an attempt to avoid atmospheric pollution the firm of *Allis Chalmers* is carrying out a study on electric automobiles driven by ammonia batteries. These seem to be quite a promising proposition—from an economic point of view as well. Ammonia can be produced very easily from hydrogen and air. Another point to be noted is that it was hydrogen that was used as the fuel to take man to the Moon. It would be surprising if the spin-off from space technology could find no useful application in the field of air transport.

Hydrogen's gradual penetration of the energy market is, of course, a fascinating problem, but this would be too lengthy to discuss here. Instead, let us look at the position as it exists

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at the moment. Hydrogen already has a large market, corresponding, broadly speaking, to half that for electricity (on the basis of the primary energy necessary for the production of both products). On the other hand, this market is essentially tied in with the production of ammonia and the hydrogenation of oil products and is therefore concentrated in large units which in their turn warrant hydrogen production in large units.

If, taking the calorie as the reference unit, a comparison is made between the price of hydrogen for the uses mentioned above and that of the heat produced by a large nuclear reactor, it can be shown that there is a factor of about five in favour of the nuclear calorie. The price situation is given in Table **I**.

To "package" thermal energy in the form of hydrogen naturally involves investment costs and also losses, but this factor of five, which is in fact tending to increase, provides a very effective incentive. This is why, about two years ago, our ideas and analyses were concentrated on one fundamental question, namely that of how this hydrogen was to be produced.

The present production method consists of either reducing water by means of coal or by partially oxidising and cracking oil products. The most important reactions are shown in Table II. The reactions here use not only the reducing power of coal, i.e. the strong tendency of oxygen to combine with the carbon in the coal to form CO_2, but also the energy released by combustion. The reactions taken as a whole are endothermic and a certain quantity of energy is necessary for the running of the plant.

A simple and obvious solution consists in using a nuclear reactor to provide the necessary heat, this being possible at a very advantageous price. In this way the difference is gained between this price and the price of the fuel that would have had to be burned to produce the heat by normal methods. This possibility has already been dealt with in this journal by Siebker and Martin (see *euro-spectra* Vol. VIII (1969) No. 2 pp. 34-38).

We wanted to go beyond this possibility, for two reasons:

1) The quantity of nuclear heat which can be introduced into the systems under consideration is fairly low —15 to 20% depending on the system. The low cost of nuclear heat therefore has only a slight influence on the price of the product and any advantage gained can easily be cancelled out as the result of small variations in the price of conventional fuels (see Table **III**).

2) With this system one has always to rely on classical sources of energy and there is thus no hope of nuclear energy gaining anything more than a very thin slice of that challenging 80% of the market.

If this way is ruled out then, there is in fact only one other course left open: the decomposition of water.

The decomposition of water

It is in fact precisely this process which nature uses to obtain chemical energy from solar energy so that the biosphere (and our civilisation) can function. In the first place the water is broken down by light energy picked up by chlorophill. Oxygen is liberated and the hydrogen "hydrogenates" carbon dioxide and thus triggers off the chemical cycle.

The decomposition of water can be seen as a very elegant process for the

Table **I**: *Illustrative prices of heat.*

	mills/Mcal	
Nuclear heat	1.0	(1)
Natural gas	1.7	(2)
Coal	2.1 — 3.0	(3)
Heavy fuel oil	1.2 — 1.6	(4)
Hydrogen (conventional process)	5.2	

(1) For a plant of the order of 2,500 Mwth.

(2) Price of Dutch natural gas, January 1970.

(3) Community price of flaming coal, March 1970.

(4) Community price of heavy fuel oil, February 1970.

Table II: *Two reactions by which hydrogen is at present produced: the reduction of water by carbon and the oxidation of methane.*

$$\left\{\begin{array}{l} C+H_2O \rightarrow CO+H_2 \\ C+\frac{1}{2}\,O_2 \rightarrow CO \\ CO+H_2O \rightarrow CO_2+H_2 \end{array}\right.$$

$$CH_4+\frac{1}{2}\,O_2 \rightarrow CO+2H_2$$

accumulation and transfer of energy, these, as we have seen, being our main aims.

Water can be found practically everywhere at prices which in general are very reasonable; transport costs for hydrogen are the same as those for methane. Another point: combustion gives just one end product—water. This holds out the prospect of a radical solution to the problem of pollution which has resulted from the intensive use of conventional fuels: there will be no acute poisons produced such as CO, or chronic ones such as SO_2, or "secular" ones such as CO_2. This is not to mention the host of products—possibly carcinogenic and at all events very unpleasant—which industry passes off to the atmosphere through the incomplete combustion of coal and oil.

However, all this lyricism about clean air must not blind us to the hard facts of economic life.

Table III: *Illustrative costs of hydrogen production by different processes.*

	Conventional process	Methane + nuclear heat	Nuclear heat + Mark 1 process
Methane	2	1.6	—
Nuclear heat	—	0.2	2
Oxygen	0.7	—	−2
Capital and running costs	(2.5)	(2.5)	(2.5)
Total in mills/Mcal	5.2	(4.3)	(2.5)
Total in mills/Nm³	13	(10.8)	(6.3)

For the first two processes a yield of 100% is assumed (an optimistic hypothesis); for the third a yield of 50% is anticipated (the theoretical yield being 75%).

Price of the primary energy: methane: 2 mills/Mcal; nuclear energy: 1 mill/Mcal.

Price of the oxygen: 11 mills/Nm³.

The running and capital costs are taken as being equivalent for the three processes. Even if the production costs for the third process were to double, they would still only be about the same as for the other processes.

"Direct" processes

Our water must be decomposed in a way which is economical, i.e. competitive. This fact eliminates the simple solution to the problem—electrolysis. This process, although technically perfected, has unfortunately the disadvantage of wasting energy because of the numerous transformations which the latter has to undergo in changing from its primary state as heat into its chemical form. Furthermore each of these transformations requires equipment involving high investment costs. The difference in price between the hydrogen calorie and the nuclear calorie (represented by the factor of five mentioned above) is to a great extent cancelled out by these two facts.

It should be noted that electrolysis can still play a role in the use of off-peak energy produced by nuclear power plants but it must also be remembered that our aim is more ambitious, namely to decide the technical methods necessary to cater satisfactorily for the whole of the energy market. Off-peak energy constitutes only a fraction of the electrical energy produced, which, as we have seen, will in any case cover only 20% of primary energy consumption.

We thus arrive at the crux of the problem: how can we decompose water as "directly" as possible so that the price of the nuclear heat is not multiplied by a factor any greater than our factor of five (unless a convenient way of selling the oxygen can be found, to steelworks for example, in which case the factor can be increased to around seven)?

The water can be directly broken down by thermal cracking by heating it to an appropriate temperature. Unfortunately the necessary temperature is rather high—of the order of 2,500—3,000°C. The reactors designed for

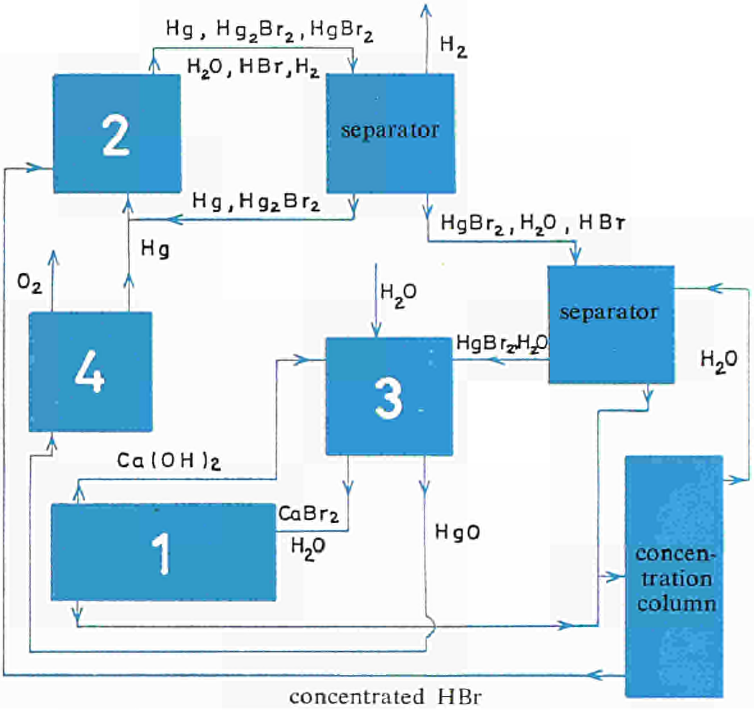

Figure 1:
Mark I process; flow diagram.

space rocket propulsion which are now being developed in the United States can reach temperatures of around 2,000°C. The same temperatures can be attained with the reactors which are to feed thermionic converters.

From a technical viewpoint it is not a simple problem to get over these remaining 500-1,000°C, but, apart from this, the price of the calorie produced by these reactors does not seem to be sufficiently low for the application contemplated here. Nevertheless it is worth while paying careful attention to their development.

Another possibility, which is very tempting, is to use the heat produced in fusion reactors, for it would be incredible to think that after having been able to produce fusion at 100,000,000°C it was not possible to find a way of obtaining 3,000°C, somewhere in the system, in order to decompose water vapour.

In view of the foregoing, the real key to the problem in the case of fusion lies perhaps in the possibility of transferring the energy using the fast neutrons produced. The latter would carry the energy to a specific place in the chemical plant.

A very important advantage of cracking water at 2,500-3,000°C is that theoretically its yield is unity. This advantage has economic repercussions and also means that there is no problem of heat loss. This problem can be collossal in the case of the plants envisaged, which would produce tens of thousands of thermal megawatts.

Of the nuclear reactors the *HTR* type now produces heat at the highest temperature. The fuel is graphite-clad, the coolant used is helium and the outlet temperature reaches about 800°C.

Not wishing to pursue futuristic methods, we therefore set ourselves the task of attempting to solve the problem by using heat available at temperatures lower than 800°C. What a heuristic approach would suggest under the circumstances was quite straightforward: to decompose water in two stages, each of which can be activated thermally at temperatures below 800°C.

According to the laws of thermodynamics this is theoretically possible and the total yield of the operation, using heat between 500 and 800°C, will be close to 75%.

The Mark 1 process

After several months of research at Ispra a process, christened Mark 1, was found which satisfied these conditions. The main reactions of the process are shown in Table IV. A block diagram of the sequence of operations is given in Figure 3.

What are the advantages of this type of process?

1) The only raw materials it uses are water and nuclear heat.

2) The energy is transformed into its final state without any intermediate stages, as is the case with electrolysis—a fact which has a beneficial effect on both efficiency and investment.

3) Another substance, namely oxygen, is produced, which can play an important role, as we shall see later.

The Mark 1 process was discovered about two years ago. In the meantime research has been carried out on the reactions given in Table IV. These are fairly uncommon reactions and consequently the information on them in the literature is very limited.

The kinetics and equilibrium values shown in the results appear very promising for application on an industrial scale. The materials used will, however, present difficult problems in view of the fact that aggressive compounds have to be handled at high temperatures.

Other possible cycles

Obviously there was nothing against carrying out parallel research on other possible processes, either by sticking to the 800°C limit or by raising it. It is anticipated that the development of *HTR* reactors will result in the use of higher temperatures, especially if development of the gas turbines associated with these reactors is stepped up.

One of these processes, which employs iron and coal as its working materials, is shown in Table V. The materials are not used up but are continually recycled. It appears to be a

Table IV: *Essential reactions in the Mark 1 process.*

1) $CaBr_2 + 2\,H_2O \rightarrow Ca(OH)_2 + 2\,HBr$	at	730°C
2) $2\,HBr + Hg \rightarrow HgBr_2 + H_2$	at	250°C
3) $HgBr_2 + Ca(OH)_2 \rightarrow CaBr_2 + H_2O + HgO$	at	100°C
4) $HgO \rightarrow Hg + \frac{1}{2}\,O_2$		

simple process and uses cheap materials but it, too, presents problems, one being the temperature of 1,400°C needed for the partial decomposition of the iron oxide.

These new possibilities were set out and discussed at a meeting held at Ispra on 12 December 1969. Present were representatives of several major constructors of hydrogen production plant, firms specialising in the problems of transporting hydrogen and certain chemical firms using hydrogen.

The meeting resulted not only in a fruitful exchange of information but also in a discussion on the best means of implementing concrete industrial projects. Now that the value of the new potential offered by hydrogen has been generally recognised it only remains to establish the main lines to be followed by a research and development programme in the next few years and to find the best way of dividing up the work involved between the Ispra Research Establishment and industry.

The part coal plays

We shall now try to answer a question asked above: what is the best use for the oxygen produced at the same time as the hydrogen? In the case of existing industries there will be no difficulty provided they are well situated. Steelworks, in particular, consume very large quantities of pure oxygen in the production of steel by the lance-process and also in blast-furnaces. But there is another proposal which is worth putting forward. A century ago, Mendeleieff suggested winning coal by gasifying it immediately in the mine itself. However, the process never gained a foothold because if air is blown in as an oxidising agent the product has too low a calorie content as a result of the nitrogen which dilutes it. If, on the other hand, oxygen is blown in, the product is too expensive because of the cost of the oxygen. But oxygen obtained as a cheap by-product could make this unusual method of exploiting the Community's mining resources an economic proposition.

As we have seen, the Mark 1 process could make it possible in the near future to develop and perhaps even totally revolutionise the energy market by using hydrogen.

A certain amount of research still remains to be done to make the process industrially viable. From the data now available, however, we have reason to believe that this research should be a profitable investment.

Finally it must not be forgotten that, besides the economic prospects, this gradual introduction of the use of hydrogen holds forth the hope of a totally pollution-free atmosphere.
EUSPA 9-7

Table V: *Essential reactions in a hydrogen production process using iron and carbon as catalysts.*

1) $C + H_2O \rightarrow CO + H_2$	at	700°C
2) $CO + 2\,Fe_3O_4 \rightarrow C + 3\,Fe_2O_3$	at	250°C
3) $3\,Fe_2O_3 \rightarrow 2\,Fe_3O_4 + \frac{1}{2}\,O_2$	at	1,400°C

Literature: Luxembourg patent No. 60,372 dated 18.2.1970. Inventor: Gianfranco de Beni.

The heat pipe, a new heat transfer system

The heat pipe is a new heat transfer system which outwardly resembles a simple heat conductor but on the inside contains a two-phase circulation system which is maintained by capillary forces. The most striking characteristics of the heat pipe are its relatively high heat transport capacity at practically constant temperature, its function as a heat flux transformer and its independence of the presence of a gravitational field.

HELMUT NEU

HEAT TRANSFER plays an important part in many fields of technology. In a very large number of physical processes heat is generated. This may be intentional as, for example, as a result of the slowing down of the fission fragments in a nuclear reactor — or undesirable but unavoidable, as in the conversion of solar energy into electricity by means of photo-electric cells. The problem is always that of removing a given quantity of heat per unit of time from one place (the heat source) to another (the heat sink).

Heat transfer systems

There are various physical processes by which heat transfer occurs. The most important ones from the technical point of view are thermal conduction in solids and heat transport by flow media (liquids, vapours or gases).

Let us consider the case of heat conduction. Heat is undirected kinetic energy of atoms or molecules and electrons. In atomic terms, heat conduction means an exchange of energy between "hotter" atomic particles and their "colder" neighbours. The quantity of heat transferred is determined essentially by the temperature gradient. Unfortunately, conduction is not very effective as a method of heat transfer, except over very short distances at very high temperature gradients, which, however, are irrelevant here. For instance, a copper rod 1 cm in diameter and 50 cm long, in which the temperature difference between the two extremities is 200°C, transmits a heat power (heat quantity per unit of time) of only about three calories per second, or, in electrical units, approximately 13 watts, although copper is one of the best heat conductors (see Fig. 1).

On the other hand, a loop containing a single-phase flow medium (liquid or gas) can transmit a very high heat power. In this case, of course, the heat transfer takes place not by conduction in the medium but by the transport of the medium itself: its heat content, or heat enthalpy, is increased at the heat source and the additional enthalpy is removed at the heat sink. As in the case of conductivity, since the enthalpy increases linearly with the temperature of the medium, heat transfer in a single-phase system can only take place when there is a relatively large temperature difference between the heat source and the heat sink. To take another numerical example: a liquid-sodium-filled loop with a tube diameter of 1 cm and a temperature difference of 200°C can transmit a heat power of some 80 kw over long distances (many metres). This is about 6,000 times as much as in the case of conduction, given the same diameter and temperature difference. In fact we are dealing here with one of the most effective heat transfer systems.

With the new system, the heat pipe, the heat power is admittedly not so high: for a tube diameter of 1 cm, for example, powers of up to a few thousand watts can be transmitted over a distance of 50 cm. As compared with a loop, however, the heat pipe has the advantage of not requiring a pump, it is outwardly indistinguishable from a heat conductor and it functions with a very small temperature difference between the heat source and the heat sink (usually only a few degrees).

What is a heat pipe?

The principle of the heat pipe is an ingenious combination of four long-familiar physical phenomena: 1) the evaporation of a liquid, 2) the condensation of a saturated vapour, 3) the surface tension of a liquid and 4) the surface wetting of a solid by a liquid. The first two phenomena are made use of in "evaporation cooling", the last two provide the capillary force which serves to maintain a two-phase circulation (see Fig. 2).

Evaporation and condensation are, of course, phase transformations in which there is a change in the energy content, but not in the temperature, of the substance. If the finer points are disregarded, both processes can be said to take place at practically the same temperature. The reason is that in the phase transformation it is not the kinetic energy of the molecules which changes but their potential energy (the bond energy of the vapour molecules is very much lower than that of the liquid molecules). A certain quantity of heat — the specific heat of evapor-

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The numbers in the text refer to the Euratom patent list (see p. 60).

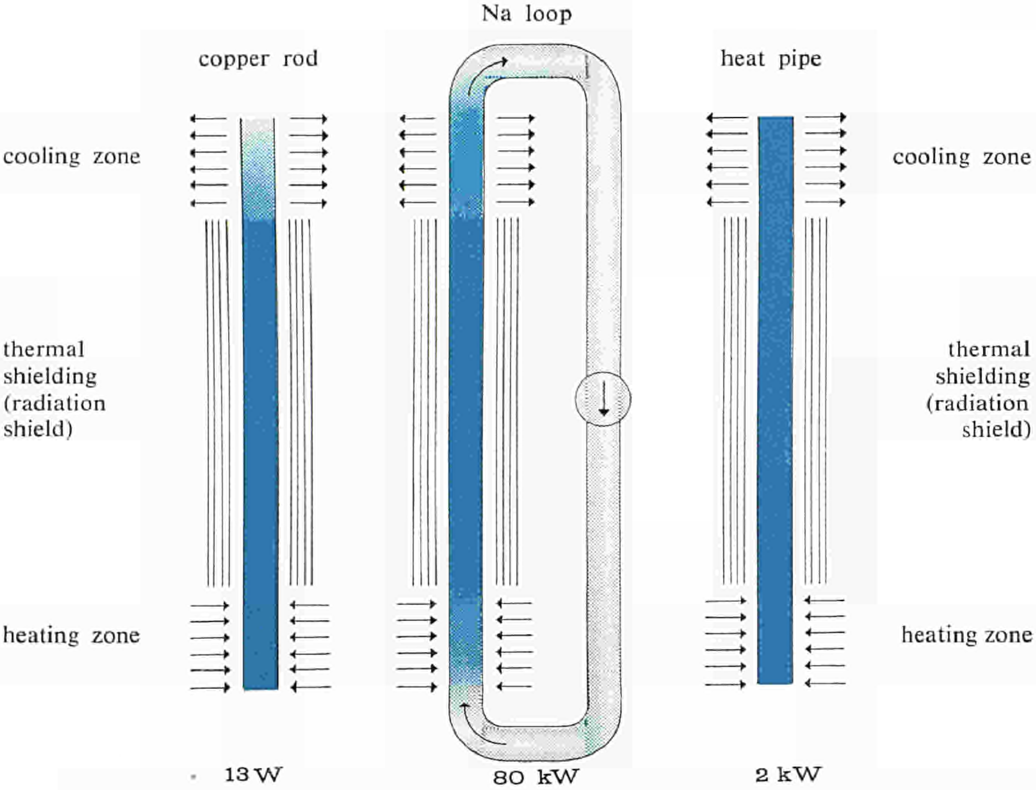


Figure 1: *Comparison of the heat power transmitted and the temperature distribution in three different heat-transfer systems.*

Heat power: *The numerical values relate to a rod or inside tube diameter of 1 cm and to a length of 50 cm for the copper rod and the heat pipe. The flow velocity in the working section of the circuit is taken as being 5 m/sec. Heat losses between the heating zone and the cooling zone are ignored (thermal shielding).*

Temperature distribution: *In the copper rod the temperature decreases linearly from 800°C at the end of the heating zone to 600°C at the beginning of the cooling zone; in the liquid loop the temperature rises from 600°C to 800°C in the heating zone, remains constant as far as the cooling zone and then drops in the latter zone from 800°C to 600°C; the heat pipe has practically the same temperature of 800°C throughout its entire length, i.e. both in the heating zone and in the cooling zone.*

ation — must be supplied per unit mass of liquid in order to turn the liquid into vapour. The same quantity of heat, known also as the latent heat, is released again during condensation of the vapour. Consequently, if a given quantity of liquid is continuously caused to evaporate at one end of a closed tube, the vapour will flow towards the opposite end, where, if the temperature is only slightly lower, it will condense back into a liquid. In this process the latent heat is transported along the tube. This form of heat transfer is known technically as "evaporation cooling".

The surface tension of a liquid is caused by differences in the forces of attraction between the molecules according to whether the latter are situated inside the liquid or at the surface. As a result the surface molecules are subjected to forces acting at right angles to the surface of the liquid. In other words, the surface molecules possess greater potential energy than those in the interior. Since a closed physical system always attempts to assume the state of minimum potential energy, a liquid always attempts to assume the smallest possible surface (mercury globules are an example of this).

The wettability of a solid surface in contact with a liquid depends primarily on the difference in surface tension between the wetted solid and the wetting liquid. If the difference is positive, wetting generally occurs (e.g. glass and water); if it is negative (e.g. glass and mercury), there is usually no wetting. Pronounced wetting is characterised by the formation of a liquid film on the solid.

The combination of surface tension and wettability results in the phenomenon of capillary force. Everyone is aware that water rises up a narrow glass tube (see Fig. 3). The same applies to the "open" capillaries used in heat pipes (see Fig. 5). The vegetable kingdom makes use of this process: in porous soil the ground water is drawn up into the plant roots. This shows that capillary force can serve for the transport of liquids.

The idea of combining evaporation cooling with liquid transport by capillary forces was first formulated by R.S. Gaugler of *General Motors* in a U.S. patent specification of 1944, though he did not confirm it experimentally. It was not until 1963 that this was done, independently of Gaugler, by G.M. Grover and his co-workers of the *Los Alamos Laboratories*. Grover, who was seeking solutions to the problem of heat transfer in power units for space travel, gave the new system the name of "heat pipe". He used a sealed evacuated tube to the inner wall of which was attached a finely woven mesh of metal wires (see Fig. 4).

In Europe the new idea was first adopted (1) and further developed by the Ispra Research Establishment (2, 3). Instead of the wire mesh the Ispra researchers initially made use of fine longitudinal grooves (4) in the inside surface of the tube, an arrangement which, although an improvement from the calculation standpoint, possesses a number of disadvantages as regards manufacture. Today the heat pipe has been taken up by numerous laboratories in the U.S.A., Europe and, since about a year ago, the U.S.S.R. as well. As capillary structures, use is made not only of grooves and metal wire meshes (wicks) but also of sintered metal powders, sintered metallic fibres and fibre glass (see Fig. 5). The vessels are not restricted to a cylindrical tubular shape but can in principle be of any geometry. They have been constructed in glass, ceramic material, copper, steel, nickel, tungsten, niobium, molybdenum, tantalum, rhenium and refractory metal alloys. Among the working fluids that have been employed are methanol, acetone, water, hydrocarbons, mercury, caesium, potassium, sodium, lithium, lead, indium, bismuth and silver.

Transmitted heat power

Let us consider the question of how a heat pipe must be constructed in order that at a given working temperature it may carry the maximum heat power with a low temperature drop.

From the principle discussed above it follows that:

transmitted thermal power = mass of working medium transported per unit of time × latent heat per unit mass.

The latent heat per unit mass is a material property which is only slightly temperature-dependent. For most working fluids it amounts to a few hundred calories per gramme, except in the case of sodium (approx. 1,000) and lithium (approx. 4,700).

The mass of working medium transported per unit of time, or the "mass flow", depends on many factors, principally on the surface tension of the liquid, the effective capillary diameter, the vapour density and the geometry of the heat pipe. This will now be explained in greater detail:

If the influence of the earth's gravity is disregarded, i.e. if we consider the heat pipe as operating either in space or horizontally on the earth, then the only driving force for maintaining the circulation of liquid and vapour is capillary force. The pressure balance in the circuit is such that the maximum capillary pressure is equal to the sum of the total pressure drop in the vapour and that in the liquid (see Fig. 6). The capillary pressure in a closed or open capillary is for its part proportional to the surface tension and inversely proportional to the "effective" diameter of the capillary (equal to the geometrical diameter in cylindrical tubes only).

The surface tension of pure liquids is in turn a weakly temperature-dependent material constant, though the numerical values for the various work-

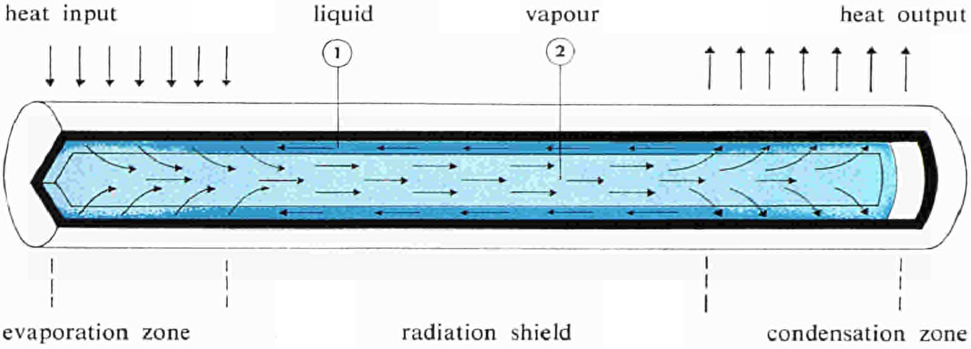
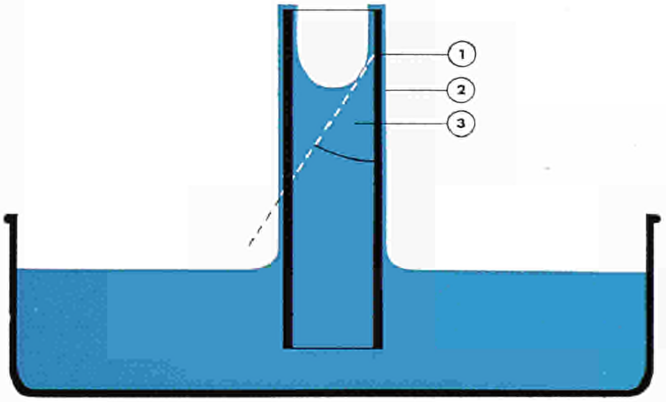


Figure 2: *How a heat pipe works. In its simplest geometrical form a heat pipe consists of a closed evacuated tube the inside wall of which is covered with a capillary structure containing a working fluid. A continuous heat supply in the evaporation zone causes the liquid (1) to evaporate out of the capillary structure. Owing to a small pressure difference the vapour (2) flows towards the slightly colder condensation zone, where it condenses on the capillary structure. As a result of the capillary force acting in this structure the condensed liquid is transported from the condensation zone back to the evaporation zone, where it again evaporates. The portion of the heat pipe situated between the evaporation zone and the condensation zone has to be thermally insulated in order to prevent heat losses; in the high-temperature range, use is generally made for this purpose of a radiation shield composed of a large number of strongly reflecting foils.*

Figure 3: *Explanation of capillary force: In a narrow tube (capillary) (1) a wetting liquid rises to such a height that the capillary force balances the weight of the liquid column in the tube. The capillary force can be interpreted as the result of the attempt by the liquid film (2) on the capillary wall to reduce its surface (on the model of a stretched rubber diaphragm). The capillary pressure is proportional to the surface tension of the liquid, proportional to the cosine of the wetting angle (a measure of the wettability) (3) and inversely proportional to the diameter of the tube.*



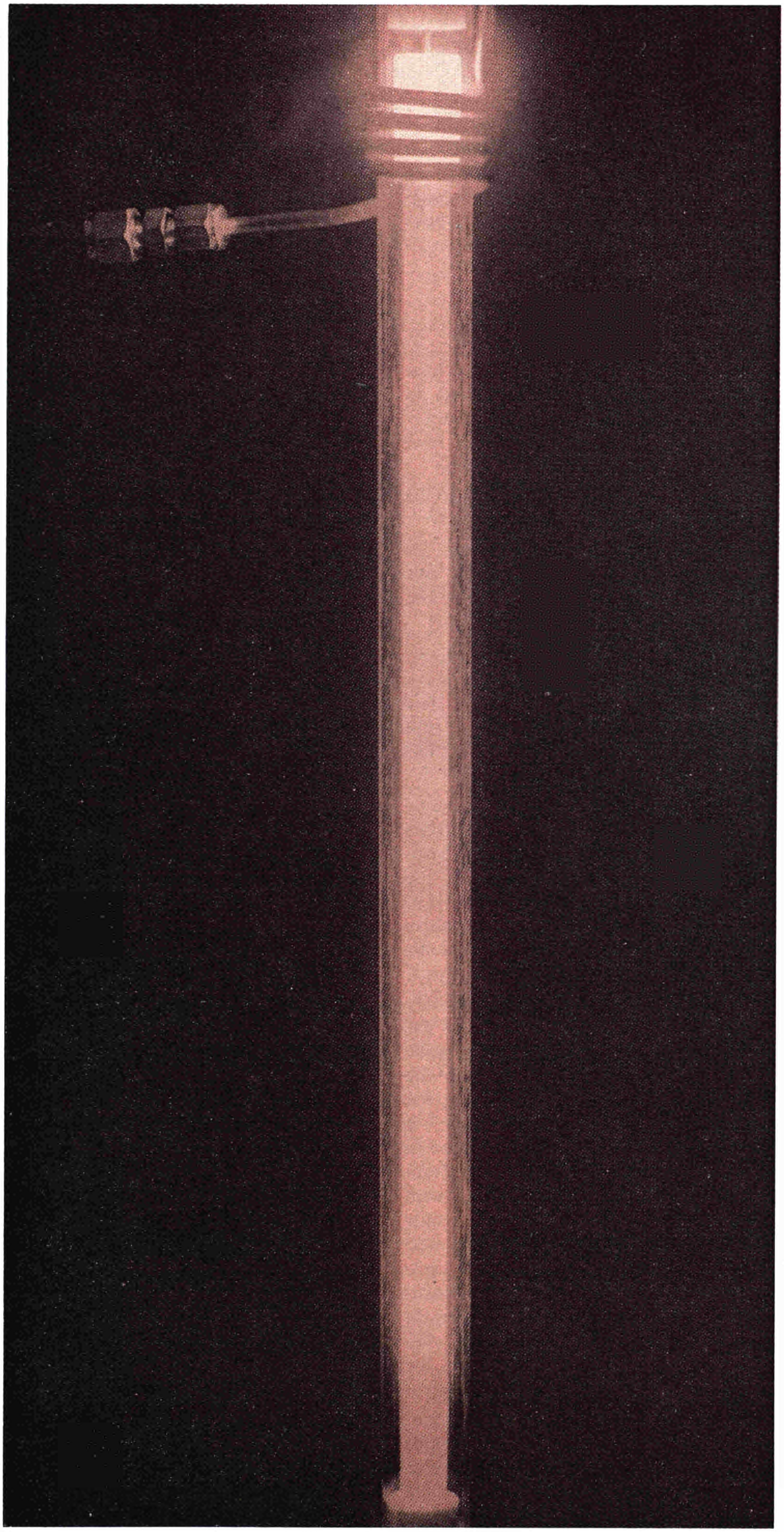
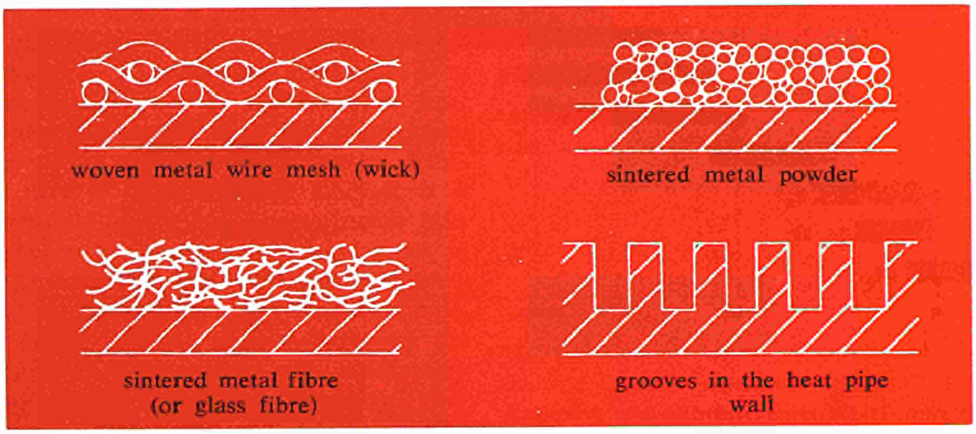


Figure 4: *One of the first heat pipes in operation.*
The heat pipe (length 38 cm, diameter 1.2 cm), which is enclosed in an evacuated quartz tube, is constructed in niobium and uses lithium as the working fluid. Heat is supplied at the upper end by means of a high-frequency coil and is removed by radiation from the other parts of the heat pipe. The lithium vapour, which flows from top to bottom, condenses on the walls and the condensate is drawn upwards, against *gravity, by the capillary forces in a metal wire mesh (wick), attached to the inside wall of the tube.*
It will be noted that an absolutely uniform temperature (1,100°C) prevails over the whole length as far as the lower portion, where a lithium pole of poor heat conductivity has formed. (It was subsequently learned how to prevent this.) (Los Alamos Laboratories, 1964).

Figure 5: *Capillary structures for heat pipes.*
In "open" capillaries, as used in heat pipes, a capillary force is exerted along the capillary according to the differing radius of curvature of the liquid surface. In the heat pipe this radius is smaller in the evaporation zone than in the condensation zone.



ing media vary greatly (for silver it is about 50 times as great as for ammonia). A rule of thumb states that the higher the vaporisation temperature of the medium, and hence (as we shall see later on) the operating temperature of the heat pipe, the greater is the surface tension.

Should the capillaries be made as thin as possible in order to obtain high capillary pressures and consequently a high mass flow? Actually, there is an "optimum" effective diameter for the capillaries. Why? In fact the capillaries serve also as flow channels for the liquid. As is well known, friction resistance in a liquid increases very sharply as the pipe diameter decreases. Thus, although very narrow capillaries produce high capillary pressures and therefore permit somewhat higher pressure drops in the liquid, they lead to only very low flow velocities and hence a small mass flow. (Attempts are being made in what are called "arterial" heat pipes (5) to pass the liquid through wide channels external to the capillary structure, and thus to transport large quantities with small friction losses of liquid; some of these attempts have met with success.)

The optimum capillary diameter for maximum heat flow is in most cases a few tenths of a millimetre. This in turn gives the order of magnitude of the capillary pressures: they are well under one atmosphere. For example, a closed cylindrical capillary with a diameter of 0.2 mm has a capillary pressure of about 10 mm Hg for water and about 30 mm Hg for lithium. It follows that the pressure drop in the liquid and in the vapour must be of the order of a fraction of an atmosphere, too.

This has certain consequences as regards the vapour pressure required. If the system is to transport the largest possible vapour quantity for a small pressure drop (small temperature gradient), the vapour density and, consequently, the vapour pressure must not be too low. The lower limits are around 100 mm Hg; only in the case of sodium and lithium is it possible, owing to the high specific heat of evaporation and the relatively high surface tension, to work with lower pressures. On the other hand, the vapour pressure cannot be raised *ad lib.* Particularly when high operating temperatures (over 1,000°C) are employed, the strength of the wall

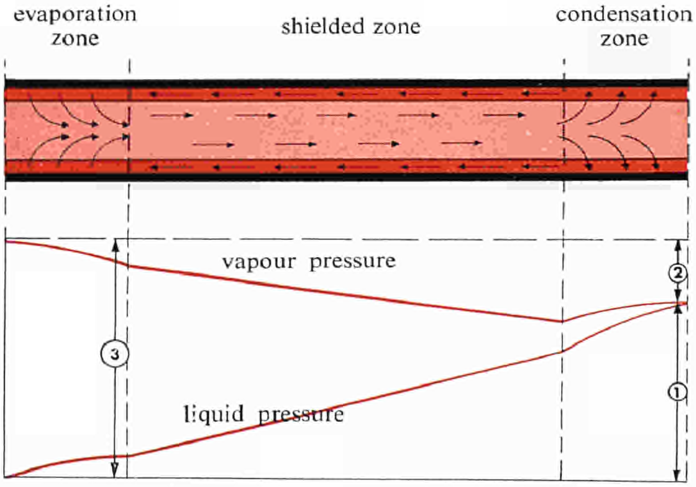


Figure 6: *Pressure diagram of a heat pipe in gravity-free space.*
The total pressure drops in the liquid (1) and in the vapour (2), due to friction forces, must be offset by the pressure of the capillary force (3) in order to maintain the flow.

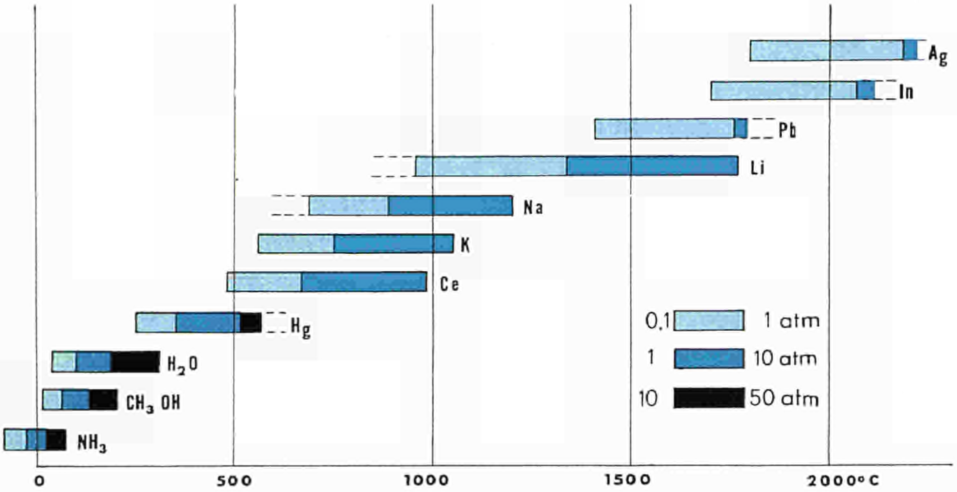
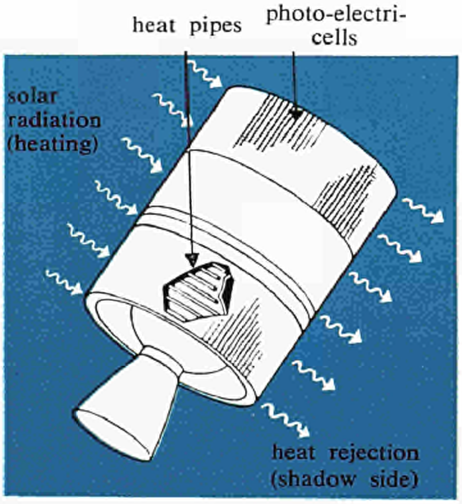


Figure 7: *Diagram showing the principal working fluids for heat-pipe operation at various temperatures, with numerical data for the vapour pressures. In general, adequate heat transfer is attainable only at vapour pressures above 0.1 atmospheres except in the case of sodium and lithium. The upper limit of the vapour pressure is determined by the strength of the wall material.*

Figure 8: *Temperature homogenisation by means of heat pipes.*
Solar radiation gives rise to temperature differences in a satellite's skin which have an adverse effect on the functioning of the photo-electric cells mounted there. Annular heat pipes embedded in the skin enable these temperature differences to be reduced to a few tenths of a degree (NASA's ATS-E *space research project).*



material limits the vapour pressure to a few atmospheres. As can be seen from Fig. 7, a sufficient number of working fluids is available to cover the entire range of temperatures from about —50 to 2,000°C, with the exception of the technically quite interesting zone between 250 and 350°C, where the vapour pressures are too high for water and rather low for mercury. For this zone it might be possible to use organic liquids, provided that they met certain requirements (e.g. chemical stability, no fouling). With the aid of liquid nitrogen, oxygen or even helium, it is presumably possible for heat pipes to function in the cryogenic temperature range as well.

In principle, all elements and chemical compounds possessing the necessary vapour pressure at the desired operating temperature can be used as working fluids. However, the choice must also take account of other factors such as chemical stability (6), compatibility with the wall material, wettability of the wall material, lowest possible melting point and least possible vapour pressure at the melting point in order to avoid sublimation and the resultant start-up difficulties. These questions cannot be discussed in detail here; interested readers are referred to the relevant literature (e.g. literature (c)).

The dependence of the mass flow on the length and diameter of the heat pipe is of a rather complex nature. With unaltered capillary structure, according to whether the pressure drop is greater in the vapour or in the liquid, the relationship between the transmitted heat power and the diameter of the heat pipe will be more nearly linear or quadratic. If the capillary structure is altered and optimised the heat power increases more than quadratically. It decreases in inverse proportion to the length of the heat pipe, though this is not entirely true in the case of relatively short heat pipes (length/diameter ratios of less than about 10) owing to the altered flow conditions in the vapour.

What heat powers can in fact be attained? By way of answer here is a numerical example: in an experiment, conducted at Ispra, a heat power of 6.75 kw was measured in a 50 cm-long horizontally operated lithium-filled heat pipe with an inside tube diameter of 7.6 mm at an operating temperature of 1,500°C. This is equivalent to a heat power density of some 15 kw per square centimetre cross-sectional area of the inside tube!

The temperature drop across the heat pipe was not measurable. From the vapour pressure curve, the temperature drop in the vapour can be estimated at less than 1°C. If account is taken of the temperature drop between the vapour and the heat pipe wall and of the heat conduction in the wall, we find that there is a temperature difference of about 5°C between the two ends of the heat pipe. If it were desired to transmit the same thermal power by means of a copper rod of the same dimensions, we should require a temperature difference of more than 180,000°C, which could not possibly be attained!

Applications

By no means every new and interesting idea in the world of physics finds a correspondingly wide field of application. This fact is often overlooked by enthusiastic scientists. Cases in which the technological breakthrough follows very much later are becoming increasingly rare. What, then, is the position as regards the heat pipe?

In the United States the possibilities for its application have been systematically investigated, chiefly by *RCA* and firms engaged in space research. In the latter field an early application can certainly be expected. In earth-bound technology, however, nothing is yet known about a large-scale commercial use. This situation may change when the majority of engineers have become better acquainted with the new system.

No attempt will be made here to draw up a list of possible applications. In the following paragraphs, however, examples are given which will serve to shed further light on some properties of heat pipes that are important from the practical point of view. These relate above all to such aspects as the homogenisation of surface temperatures of solid structures, heat flux density transformation and the use of the heat pipe as a thermostat.

Temperature homogenisation

From the way in which the heat pipe works it is immediately apparent that it can be fed from a non-homogeneous heat source (i.e. one that varies in intensity from one point to another), but that at the output end the device itself functions as a homogeneous heat source. At points where the heat supply is greater slightly more liquid evaporates than at points where it is less. There is also nothing to prevent the construction of rod-shaped or annular heat pipes containing several heat sources and/or heat sinks. On the other hand, as already explained, the temperature differences between the evaporation zone and the condensation zone are minimal: the heat pipe is practically isothermal.

One of the first technical applications of the heat pipe will presumably be in the homogenisation of the temperature at the outer skin of satellites. Some of the *NASA* and *COMSAT* projects provide for the installation of heat pipes for temperature equalisation on the sun side and the shadow side (see Fig. 8). An experiment carried out jointly by the *Los Alamos Laboratories* and *NASA* in 1967 confirmed that a heat pipe works exactly the same in space, where there is no gravity, as in a laboratory on earth.

Thermionic energy converters (see *Euratom Bulletin* Vol. V (1966) No. 1, p. 24) require a heat supply in which the temperature is as homogeneous as possible, if maximum efficiency is to be attained. If it is desired to heat these converters with hot combustion gases, in which the temperature distribution is inevitably very uneven, it is possible to obtain a homogeneous heat source by incorporating heat pipes in the converter itself. (At the high operating temperature of the heat pipe, namely 1,500°C, there is, however, the problem, to which no satisfactory solution has yet been found, of preventing the ingress of hydrogen into the heat pipe, which results in an effective shortening of its life.)

At Ispra, heat pipes have been successfully used in physics experiments requiring surfaces with a very uniform temperature distribution. In the field of physics there undoubtedly are possibilities of which little use has so far been made from heat pipes.

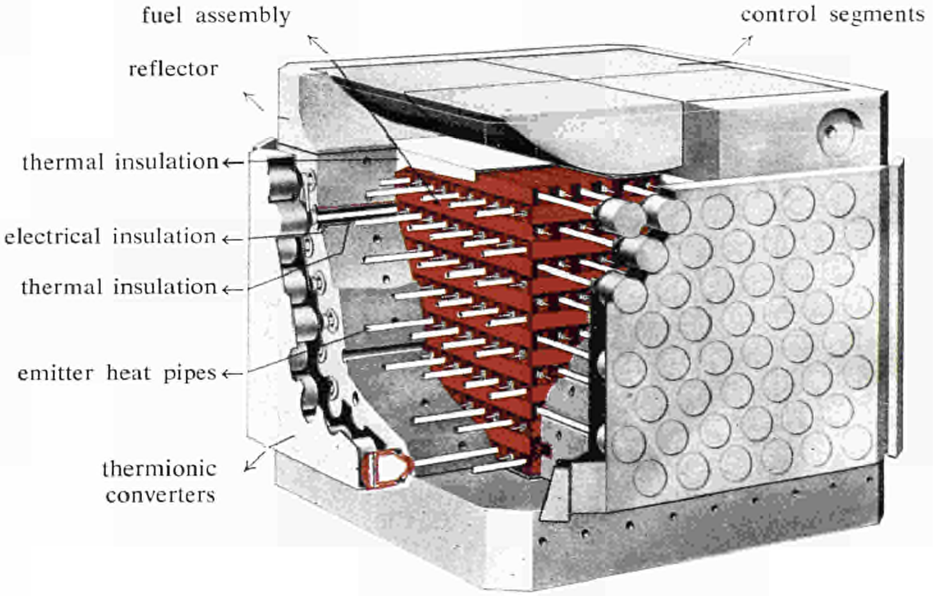
The heat pipe as a heat flux density transformer

The evaporation and condensation of the liquid in a heat pipe are separate processes which do not influence each other directly. They can therefore take place when the heat flux density (i.e. heat quantity per unit time and unit area) of the heat source and that of the heat sink are different. It is only necessary for the local heat

Figure 9: *Application of the heat pipe as a heat flux transformer in a nuclear reactor. The heat from the core of a thermionic reactor is absorbed at low heat flux density (=heat quantity per unit of surface area and time) and is removed at high flux density via the reflector to the energy conversion system, which consists of four thermionic converter sets located at the four lateral surfaces.*

The heat pipes serve also for temperature homogenisation: despite the fluctuating heat supply in the core, all the heat pipes and converters operate at a uniform temperature.

(Conceptual study on a thermionic reactor for power supply in space, Ispra, 1968) (15).



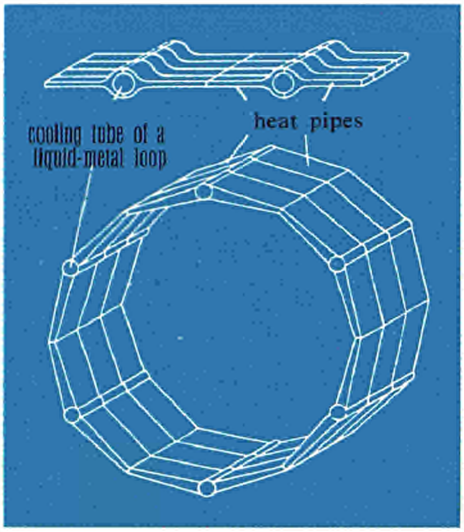


Figure 10: *Plane and cylindrical arrangement of radiators for the rejection of residual heat into space. The heat pipes serve for the isothermal distribution of the heat flow as well as for the rejection of the heat. (Concept by* Technische Hochschule, *Brunswick.)*

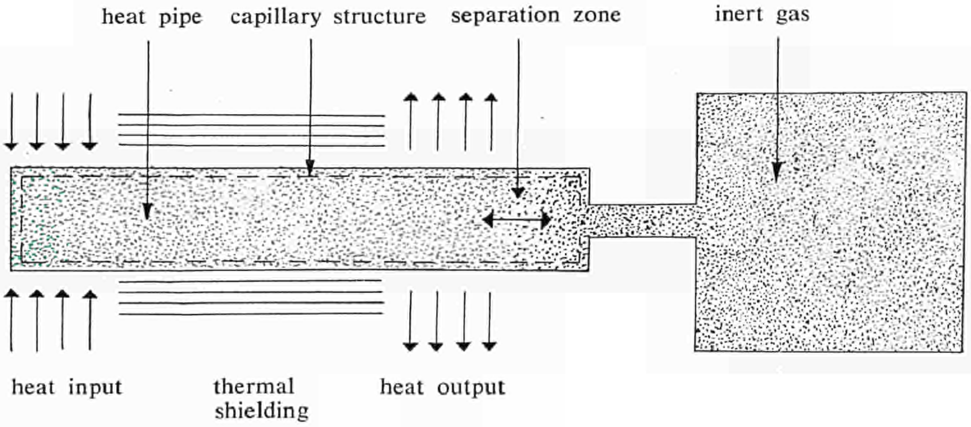
flux, that is to say the product of the flux density and the surface area to remain constant. In various experiments transformation ratios of up to 1: 10 have been achieved.

As a result of heat flux density transformation a consumer requiring a given heat flux density can be adapted to a source having a different heat flux density. By way of example, the previously mentioned thermionic converters need a relatively high heat flux density of about 100 watts/cm^2 in order to attain a high efficiency; with the aid of heat pipes they can be adapted to a source having a lower heat flux density, such as a radioisotope of low power density (e.g. strontium-90) or a reactor core (see Fig. 9).

The heat pipe will presumably assume great importance for the construction of radiators in space. The problem that arises here is that of radiating heat without having too high a temperature in the heat generator (e.g. a power supply system). The radiated heat flux density decreases in accordance with a high power of the temperature (theoretically, the fourth power). Large radiating surfaces are therefore required. It is, however, undesirable for the radiators to be heavy, since the transport costs would then be too high. As compared with conventional heat conduction systems (fins), the heat pipe results in a saving of weight owing to the very much smaller temperature drop across the radiating surface; as compared with a loop, the heat pipe is lighter because of the lesser quantity of working fluid contained, the absence of a pump and the smaller minimum thickness of the meteorite shield, since each heat pipe functions independently. Since, however, the heat pipe is limited as regards axial heat transport, the most advantageous system for the radiation of high thermal powers consists in combining a liquid-metal loop for the supply of waste heat at a high heat flux density with a heat pipe system for heat distribution and rejection at low heat flux density (see Fig. 10).

Theoretically, heat pipes could also bring advantages in the case of recuperative heat exchangers in gas loops, since the undesirable temperature drop is greatly reduced at a lower thermal flux density. Here, however, economic considerations are involved which have

Figure 11: *The heat pipe as a thermostat. If a heat pipe is connected to a gas reservoir (inert gas) and put into operation, vapour and gas will be separated rather sharply (separation zone). Regardless of the heat quantity supplied, the temperature of the heat pipe —in a certain region—will always be such that the vapour pressure corresponding to that temperature (only dependent on the material) is equal to the gas pressure. Any change in the quantity of heat supplied merely results in a shift of the vapour/gas separation zone and hence to an alteration of the heat-rejecting surface area. If the gas pressure remains constant while the heat supply varies, the temperature of the heat pipe likewise remains constant.*



not yet been clarified. The same applies to the use of heat pipes in air-cooled radiators such as are required in power station cooling towers or in electronic equipment.

By means of suitable capillary structures it is possible to obtain very high heat flux densities in the evaporation zone of a heat pipe; in a lithium-filled heat pipe, for example, a value of 500 w/cm^2 has been measured. If very high heat flux densities occur at certain points in an apparatus and it is difficult to remove them by conventional methods, the heat pipe provides an elegant means of transforming them into lower heat flux densities.

The heat pipe as a thermostat

In technology it is frequently necessary to maintain an object at a certain temperature regardless of whether the heat supply varies with time. An example of this is the use of relatively short-lived radio-isotopes as heat sources for thermo-electric or thermionic generators. How is it possible to obtain a constant heat flux density and consequently a constant input temperature of the generator, despite the fact that the output of the heat source is steadily decreasing? In the first place it is obvious that only a part of the initially available heat power can be utilised; the other part, which drops sharply at the beginning and comes down to zero at the end of the operation time goes straight to heat losses. Since the temperature and the heat flux density are to be kept constant, the only remaining means of control is to reduce the heat-emitting surface.

An elegant system for effecting automatic regulation of the cooling surface consists of a heat pipe connected to an inert-gas reservoir. The vapour stream in the heat pipe drives the gas towards the condensation zone, only a relatively thin vapour/gas mixing zone (separation zone) being formed (see Fig. 11). Heat transfer can take place only in that part of the heat pipe where vapour condenses. If the gas pressure remains constant while the heat supply changes, then the vapour pressure and the temperature of the heat pipe must likewise remain constant, and this is only possible if there is a corresponding shift of the vapour/gas separation zone and, consequently, a change in the heat-emitting surface area. Good stability of the gas pressure would only be obtainable if a very large gas reservoir were used. This technical difficulty can be circumvented in various ways such as by installing displacement devices in the condensation zone or using a bellows-type gas reservoir.

Outstanding problems

Even though the physical mechanism of the heat pipe is now thoroughly understood, many problems remain to be solved as regards calculation, construction and material behaviour.

No satisfactory calculation basis from the engineer's point of view has yet been worked out. This is due, among other things, to the difficulty of determining the characteristics of the various capillary structures with simple formulae. The optimum number of wire mesh layers in a wick structure is decided more or less on the basis of experience. There are also a number of unresolved points in the theory of the flow process.

The manufacture of the heat pipe, and particularly of the capillary structure, cannot be described in detail here; it is rather difficult and differs from one laboratory to another (12, 13, 14).

In many applications the decisive factor is the "lifetime" of the heat pipe. This depends largely on the compatibility (corrosion) of the wall material with the working fluid. Let us take a closer look at a particular corrosion mechanism resulting in a mass transport of wall material.

Although externally the heat pipe is admittedly a static device, internally it contains a two-phase loop. To give some idea of the quantity of liquid transported: in a heat pipe operating on water, annually approximately 14 cubic metres of water are evaporated and recondensed per kw of power transmitted. The large mass flow over a long operating period explains the mass transport of wall material from the condensation zone to the evaporation zone that has been observed, especially at high operating temperatures (above 1,200°C): a certain amount of wall material, be it ever so minute (a few p.p.m.) is always dissolved in the working fluid. (Experiments have shown that the solubility depends largely on the content of impurities, particularly oxygen, in the wall material.) The dissolved wall material is left behind after evaporation. The "pure" condensate, however, can dissolve fresh wall material and entrain it to the evaporation zone. The result is a gradual plugging of the capillary in the evaporation zone and eventual burn-out (see Fig. 12).

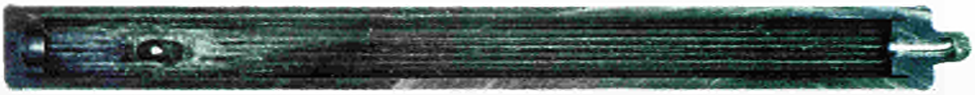


Figure 12: *Burn-out in a heat pipe. Longitudinal section through a heat pipe operated with lithium at 1,500°C. As a result of mass transport of the wall material (niobium) the grooves in the heating zone became plugged, thus cutting off the liquid flow. The cessation of evaporation led to severe overheating in the heating zone and to perforation of the wall (Ispra, 1968).*

Owing to the material problems the "lifetime" of high-temperature heat pipes is at present rather short (at the most a few months at temperatures above 1,500°C); intense efforts to increase it are in hand at Ispra. In the 600°C-1,000°C temperature range mass transport and other corrosion phenomena are no longer limiting factors. At *BBC*, Heidelberg, a sodium heat pipe has been operating for more than 18,000 hours at a temperature of 850°C.

What additional problems will be encountered in any subsequent technological application, remains to be seen.

EUSPA 9-8

Literature: (1) *First patent:* R. S. Gaugler: Heat Transfer Device, *U.S. patent 2,350,348 (1944).* (2) *First experiment:* G.M. Grover, T.P. Cotter, G.F. Erickson: Structures of very high conductance, *Journal of Applied Physics, 35 (1964), p. 1990.* (3) International Symposium on Thermionic Electrical Power Generation, London, Sept. 1965 *(organised by ENEA and IEE).* (4) Joint AEC/Sandia Laboratories Heat Pipe Conference, *Oct. 1966, Report No. SC-M-66-623 Sandia Laboratories, Albuquerque, New Mexico.* (5) Second International Conference on Thermionic Electrical Power Generation, *Stresa, May 1968, EUR 4210.* (6) 4th Intersociety Energy Conversion Engineering Conference, *Washington DC, Sept. 1969 (Copyright Am. Inst. of Chem. Engineers).*

Euratom patent list: (1) *US Patent 3,402,767:* Heat pipes. (2) *Brevet français 1.455.672:* Système de refroidissement pour réacteurs nucléaires. (3) *Brevet français 1.451.700:* Convertisseur thermo-ionique. (4) *British Patent 1,125,485:* Heat pipes and a method of making capillary inserts therefor. (5) *Brevet belge 730.534:* Procédé de fixation de treillis... (6) *Brevet belge 732.959:* Métal réfractaire... (7) *Brevet belge 731.626:* Centrale nucléaire pour station spatiale. (8) *Brevet belge 732.178:* Centrale nucléaire pour station spatiale. (9) *British Patent 1,128,944:* Vapour pressure gauge and calorimeter for high temperatures. (10) *Brevet français 1.588.622:* Convertisseur thermo-ionique. (11) *Brevet luxembourgeois 57.482:* Anordnung zum Stabilisieren der Temperatur einer geheizten Fläche. (12) *Brevet belge 730.535:* Procédé de fixation de treillis... (13) *Brevet belge 733.434:* Procédé d'élimination d'oxygène... (14) *Brevet luxembourgeois 59.904:* Verfahren zur Herstellung von Wärmeleitrohren. (15) *Brevet belge 732.179:* Réacteur nucléaire à tubes de dissipation de chaleur. (16) *US Patent 3,414,475:* Heat pipes. (17) *Deutsches Patent 1.281.594:* Heterogener Siede-Kernreaktor. (18) *US Patent 3,378,454:* Nuclear fuel arrangement. (19) *British Patent 1,158,916:* Thermionic converter with heat pipes... (20) *Deutsches Patent 1.290.264:* Thermionisches Konverter-Brennelement für Kernreaktoren. (21) *Brevet luxembourgeois 57.483:* Vorrichtung zum Wärmetransport.

The Commission has recently published the following **technical notes:**

> The Commission's *technical notes* give descriptions of original results obtained under the Euratom research programmes. Their purpose is to enable firms to decide whether they should consider industrialising these results. Copies can be obtained on request from: The Commission of the European Communities, DG XIII-A, 29, rue Aldringer, Luxembourg.

— 55: *Automatic device for removing rivets from tubes* — This is a pneumatically-operated machine developed for use on spent fuel elements taken from nuclear reactors, in cases where optical inspection is difficult. The drift stroke is automatically triggered as soon as a probe senses the centre of the rivet.

(Patents: German 1,271,512; French 1,322,835; British 955,381)

— 330: *Metal-spraying apparatus* — This is a simple appliance which can cover the entire surface of a number of similar parts in one operation, exposing the surface gradually to the vapour source and producing a uniform metal deposit.

A reciprocating motion is imparted to the parts being treated, which are also rotated about their axis. They are arranged concentrically around the vapour source.

The equipment is suitable for metal-spraying parts of varied shape, particularly elongated, cylindrical and rectangular workpieces.

(Patents: French 1,440,590; British 1,105,016)

— 456: *An electrical level-gauging system for liquid metals* — A system has been developed which makes use of the electrical resistance of the liquid metal in the metal vessel. It is extremely simple as regards the amount of equipment fitted to the metal vessel, which is confined to a small number of electrical leads and potential-measuring wires. This enables the method to be used even at high annealing temperatures. In addition, there are no restrictions on inside diameter, no penetrations in the vessel walls, but merely the above electrodes fixed to the outside of the vessel.

The electrical accessories also include nothing unusual. A differentiating circuit can be used to derive control signals, e.g. for the automatic operation of valves. This circuit also provides a more sensitive indication of boiling.

— 541: *Winch-and-cable control system for a nuclear reactor control rod* — The cable drum has a driving pulley coupled to it. In the event of a scram the drive pulley is uncoupled, enabling the drum to run freely. The pulley is then driven on at a slower rate until it finally re-engages automatically with the drum.

(Patents: German 1,263.941; French 1,440,765; British 1,136.118)

— 599: *Working chamber for use with toxic gases, particularly glove boxes* — This mobile chamber consists of two sections, with a horizontal joining line, which can be telescoped by means of a motor. A rubber sleeve is fitted for gas-tightness. A chamber of this kind need not be disassembled in order to be placed in hot cells and can easily be adapted to different manipulator heights. It is thus suitable for use as a transit container for moving toxic (radioactive) substances from one working area (hot cell) to another.

(French patent 1,431,844; US patent 3,456,812)

NEWS FROM THE EUROPEAN COMMUNITIES

Moves towards a Community industrial policy

Twelve years after it was founded, and having completed the transitional period which saw the common market for goods come into being, the Community is starting on a new stage of growth. It is imperative to work out a common industrial development policy to build up what might be termed a European industrial fabric, in order to ensure the irreversible foundations for Western Europe's economic and, shortly, political unity, continued economic expansion and a reasonable degree of technological independence with regard to the major non-member countries.

These are the opening lines of an important memorandum on the Community's industrial policy which the Commission of the European Communities submitted to the Council of Ministers in March 1970. It consists of five parts in all :

- general principles and guidelines;
- situation of industry in the Community;
- improvement of firms' environment;
- Community industry's capacity for adjustment;
- promotion of the advanced technology industries.

Passing the customs union and farm policy milestone. It has perhaps not been realised how dangerously the Community would be threatened with obsolescence if it did not succeed in advancing beyond its present stage of customs union and farm policy. Today, customs duties are no longer the only nor even the principal instrument of commercial policy; in the new advanced technology industries, foreign competition takes the form of investments and technology rather than of direct exports. Hence, as experience has shown, the industries which make use of the major new technologies do not have the benefit of the customs union—being dependent for their development upon government funds and public orders—except insofar as they succeed in breaking the straitjacket of national compartmentalisation. Economic integration has not yet sufficiently affected the structures of firms and the leader industries.

It is certain that the industrial policy of the highly developed economies will have to be increasingly orientated towards qualitative aims, related to the new model civilisation which the European Communities must help to bring into being. These aims are as follows: the progressive reduction of the multifarious gaps which still divide men up according to their socio-professional, regional or national groups; the improvement of working conditions and cultural standards; the preservation of an increasingly threatened natural environment; the fight to prevent excessive concentrations of power or economic activity, and solidarity with less privileged geographic areas of the planet.

In view of these aims the Commission proposes the following *five basic guidelines* for the Community's industrial policy:

Completion of the unified single market, in order to enable all firms and all products to benefit fully from the existence of a large market. To this end the Commission requests:

- *The rapid removal of the technical barriers to intra-Community trade* (only one directive in this sense was approved in 1969, whereas 44 had been proposed) and the adoption of common methods of analysis and standardisation of regulations for the protection of natural environments, in order to ensure that scattered national initiatives do not lead to the *appearance of new restrictions.*
- *Free access to public contracts:* the practice of reserving these contracts for firms of the same country deprives certain key industries in the Community of the advantage offered by a large common market. The sectors hit include notably industries producing certain capital goods and public transport equipment and, more generally, those manufacturing many types of technologically advanced equipment. Here public contracts account for the bulk of the output of the firms concerned. But de facto fragmentation of the market is still the rule, and, as open tendering is impossible, compliance with the Treaty is extremely difficult to ensure. Nuclear power plants and aviation are cases in point. The Commission proposes that arrangements should be made to concert purchasing policies in these sectors, the aim being not to impose new restrictions upon buyers, but rather to alleviate those to which they are now subject, and to ensure the effective establishment of a single market in technologically advanced products.

Unification of the legal, taxation and financial systems, in order that industry may draw all the advantages it is entitled to expect from the existence of the Community. The following measures are needed here:

— rapid adoption of the "European company" statute, of a law governing corporate groups, of the "groupement d'intérêt économique", etc.;

— tax law concerning mergers, harmonisation of tax laws, etc;

— creation of a common capital market, modernisation of banking machinery, etc.

Reorganisation of firms. A higher degree of concentration is needed in many sectors, this being allowed on condition that genuine competition is retained.

A powerful merger movement is already under way in the Community. But it is noticeable that industrialists tend to favour mergers within their own nation or with enterprises of non-member countries, and only to a much lesser degree with firms of another Member State. The conjunction of these two phenomena—concentration at the national level and takeovers by enterprises of non-member countries—could, if not checked, impair or annihilate the chances of achieving a common European policy for industrial development.

The relative lag in European industrial development and the keen competition from outside firms, either through direct exports or through the subsidiaries they have set up in the Community, make the creation of transnational European enterprises essential and urgent, particularly in the advanced technology industries. This is often impeded by political, legal and psychological obstacles. In order to offset these difficulties, the Commission considers that the European Investment Bank could offer aid in financing the regrouping of firms in different Member States.

In the advanced technology sectors, the size of the public contracts for which firms are invited to tender lays increasingly heavy responsibilities on the public authorities. The Commission therefore suggests that Community development contracts be introduced, priority being accorded to firms which have decided to engage in transnational cooperation and reorganisation.

While the Commission condemns the so-called "fair return" principle, it is nevertheless aware of the need to maintain some balance between the industrial interests of the Member States in such delicate matters. But the balancing of interests should be on the widest possible basis, and the Commission proposes that regrouping in progress or planned should be examined, in the appropriate setting, if a Member State or the Commission so requests.

The organisation of these adjustments, which must be speeded up in the interests of industrial, and hence of economic and social progress.

The considerable reduction of the labour force in some sectors must be offset by the creation of new employment in more dynamic industries. It is therefore necessary to encourage as vigorously as possible the industrial exploitation of new discoveries and of technological forecasts, together with the reinforcement of action taken in a regional planning context. In order to complete the measures now being adopted, and in particular the reform of the Social Fund, the Commission insists on the need for improved business management and calls on Community industries to take the initiative in creating a "European management and training foundation".

Extension of Community solidarity to cover economic relations with non-member countries. In particular, the Community should take action in the following fields: export credits and subsidies, non-tariff barriers, protection of the natural environment, raw materials and energy supplies, promotion of investment, statute for multinational companies and technological cooperation.

An analysis can be found on pages 34 - 40 of the problems besetting the Community's advanced technology industries today, or rather one of them, namely the aerospace industry, which is considered to be typical.

NEWS FROM THE EUROPEAN COMMUNITIES

Indexing seminars

In March 1970 the Commission of the European Communities held a seminar in Luxembourg on the indexing methods used for the computer processing of scientific and technical documentation. This seminar, the second of its type, was part of the training activities of the Directorate-General for the Dissemination of Information.

A third seminar on indexing will take place during the autumn of 1970 and also a seminar on methodology retrieval in automated documentation systems.

Steps towards greater cooperation in the fast reactor field

At its meeting of 20-21 April 1970 the Council of Ministers of the Six decided to set up a coordinating committee which would group together those responsible for national fast reactor development programmes and representatives of the Commission of the European Communities.

This decision is a move towards the implementation of the Council's resolution of 6 December 1969 regarding Euratom's future activities (see *euro-spectra* vol. IX (1970) no. 1, p. 28).

The Committee has been instructed to study and promote the maximum possible coordination and cooperation between the various programmes.

Investigation of radioactive lightning-conductors

The radioactive lightning-conductor is one of the oldest applications of radioactive elements. Invented by Szilard in 1914 it has been produced commercially in Europe for more than 30 years. The number in present use in the Community countries is between 5,000 and 10,000.

These facts are recalled in a report recently published by the Commission (EUR 4292 f) which includes the results of a study carried out by the Belgian organisation *Controlatom* on the radiological aspects involved in the manufacture and use of radioactive lightning-conductors.

Perhaps for the very reason that this application is so old, it has passed almost unnoticed from the health physics angle.

It emerges from the study that the risks from this type of conductor are very slight but that in a large number of cases the users are unaware of certain basic precautions.

Promoting radiometric methods in the textile industry

A Community pilot plant for promoting the use of radiometric methods in the textile industry has recently been set up by the *Institut für Textiltechnik der Technischen Hochschule Aachen*, Germany, under an agreement signed by the Commission of the European Communities (*Eurisotop* Office), the *Wirtschaftsministerium of Nordrhein-Westfalen, Gesamttextil* and the *Technische Hochschule Aachen*. The object of the scheme is to adapt radiometric techniques to suit the practical demands of the textile industry, so as to smooth the way for the automation and rationalisation of production processes and the improvement of the quality of textile products.

Its other aims are to be the training of specialists, the encouragement of the development and use of nuclear techniques and the case studies of the application of radiometry in the textile concerns.

At the first meeting of the plant's programme committee, which took place in Brussels on 15 April 1970, it was decided that the first work undertaken by the plant would be to set up a catalogue of the present applications of radiometry in the Community's textile industry. Furthermore, a certain number of study projects are to be drawn up on which decisions could be made at the next meeting, scheduled for 30 June 1970.

Power reactors in operation, under construction (*) or planned (**) in the Community

1. The total net electric capacity of the nuclear power plants in operation, under construction or planned is 18,749 Mwe, broken down as follows :

a) Proven-type reactors		
Gas/graphite		
Chinon 1 (EDF 1)	F	70
Chinon 2 (EDF 2)	F	200
Chinon 3 (EDF 3)	F	480
St. Laurent 1 (EDF 4)	F	480
St. Laurent 2	F	515*
Bugey 1 (St. Vulbas)	F	540*
G 2 Marcoule	F	40
G 3 Marcoule	F	40
ENEL (Latina)	I	200
Boiling water		
KRB (Gundremmingen)	D	237
KWL (Lingen)[1]	D	174
VAK (Kahl)	D	15
ENEL (Garigliano)	I	150
GKN (Dodewaard)	N	52
KKW (Würgassen, Weser)	D	640*
KKB (Brunsbüttelkoog)	D	770*
ENEL 4 (Mezzanone-Po)	I	780**
KBE (Badenw./EVS Philippsburg)	D	864*
Pressurised-water		
KWO (Obrigheim)	D	328
SENA (Chooz)[2]	F	266
ENEL (Trino Vercellese)	I	257
BR 3 (Mol)	B	10
KKS (Stadersand Elbe)	D	630*
S.E.M.O. (Tihange s/Meuse)[3]	B	870*
Centr. Nucl. de Doel (Doel s/Escaut)	B	780*
PZEM (Borssele)	N	450*
RWE(Biblis/Rhein)	D	1,150*
BASF (Ludwigshafen	D	1,200*
b) Advanced converters		
Heavy water		
MZFR (Karlsruhe)	D	50
KKN (Niederaichbach)	D	100*
EL 4 (Monts d'Arrée)	F	70
CIRENE (Latina)	I	32**
High temperature		
HKG (Schmehausen)	D	300**
AVR (Jülich)	D	13
KSH Schl. Holstein	D	22*
Sodium/zirconium hydride		
KNK (Karlsruhe)	D	19*
Nuclear-superheat		
HDR (Grosswelzheim)	D	22
c) Fast breeders		
Phenix (Marcoule)	F	233*
SNR (Weisweiler)[4]	D	300**
d) Type not yet decided		
Kernkraftwerk Neckar (Lauffen)[5]	D	p.m.
ENEL 5 (...)	I	650**
Chem. Werke HÜLS + VEW (Marl)	D	600**
Fessenheim 1	F	850**
KKW Schmehausen (Westfalen)	D	600**
GKM + Badenwerk (Kirschgarthausen)	D	800**
GKB Bayernwerk + Isaramperwerke	D	700**
S.E.P. (Dodewaard)	N	600**

2. Percentage breakdown of the reactors in operation and under construction, according to type

Gas/graphite	2,565 Mwe	21,5 %
Boiling water	2,902 Mwe	24 %
Pressurised water	5,941 Mwe	50 %
Heavy water	220 Mwe	2 %
Other advanced converters	76 Mwe	0,5 %
Fast breeders	233 Mwe	2 %
	11,937 Mwe	100 %

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1. Excluding conventional superheat 2. Franco-Belgian power plant (50/50) 3. With French participation (EDF) of 50 % 4. Breakdown of participation: Germany 70 %, Netherlands 15 % and Belgium 15 % 5. Participation and commissioning date not yet settled 6. Including 400 Mwe for steam supply.

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NEWS FROM THE EUROPEAN COMMUNITIES

Nearly 400 delegates at coking conference

On 23 and 24 April 1970 the Commission held two information days on coking. Nearly 400 research workers and representatives from the coke producing and using industries, from 17 European countries, were able to compare und collate their experience in this field.

It was shown that, with the aid of the research schemes that have been carried out, it has been possible in the last few years to increase both the output and the productivity of the Community's cokeries, whilst at the same time reducing the heat required and making increasing use of lower grade coal. Furthermore, this development is far from being finished. By using the most sophisticated techniques available, including computers, it is hoped that the yield from conventional ovens will be doubled.

European conference on the use of radiation and isotope techniques in the building industry

The conference in Brussels on "the use of radiation and isotope techniques in the building industry" which is being organised by the *Eurisotop Office* will not be held in July as originally planned *(euro-spectra* vol. VIII (1969) no. 4, p. 128), but on 28-29 October 1970 instead.

Directive on air pollution due to petrol engines

Since the beginning of the year the Council of Ministers of the Six has adopted several directives aiming at the elimination of technical obstacles to trade in the motor industry.

The directive on air pollution due to petrol engines merits special attention since it is of the utmost concern to the economy, public health and the protection of the environment. A number of laws were about to be enacted or to take effect in the Member States, and differences between them would subsequently have caused serious obstacles to trade in motor vehicles. The requirements of the directive have removed this hazard, since the Member States are bound to conform to them.

Of the most sophisticated methods of measurement currently employed — American and European methods — the Council has endorsed the Commission's proposal and adopted the European methods.

The American cycle is based on the use of the large cubic capacity American vehicle on American urban road systems — and neither of these factors resembles what is found in Europe. The power/weight ratio of European mass-production vehicles is very much lower than that of American vehicles and does not permit compliance with the acceleration conditions required by the American cycle. The American regulations are meant for a much more homogeneous range of vehicles than exists in Europe and apply primarily to the unburnt hydrocarbons, while in Europe the emphasis is rather on cutting down carbon monoxide emissions. These are the reasons, together with other highly technical considerations, which justify the choice made by the Commission and adopted by the Council.

The directive specifies three types of test to which vehicles must be submitted: the type 1 test is for monitoring the average toxic gas emission in a congested urban area after starting from cold; the type 2 test concerns carbon monoxide emission when the engine is idling (the volumetric carbon monoxide content in the exhaust gases must not exceed 4.5 %); the type 3 test relates to crankcase gas emissions.

One of the procedures laid down is to enable prompt adaptation of the requirements of the directive to technological change so that people will be guaranteed permanent and optimum protection.

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