PHYSICS IN EUROPE

Industry's role—present and future

Following the US example, government financing of industrial research laboratories—on a customer-contractor basis—is a growing trend in Europe.

Joseph Evans, William H. Forster and Lord Penney

In European industry, just as in the US, physicists are of course ubiquitous, with activities that are fairly representative of all scientists. But a number of questions can be posed about the European industrial physicist, and we hope to provide some of the answers here. Although many of these answers will be true of Western Europe generally, we shall often refer to the UK, where we know the situation best. Some of the questions we wish to examine are: How many industrial physicists are there? What do they do, and how are they doing it? Under what type of organization, and with what funds, do the industrial laboratories in which they work operate? What is their role in the great contemporary issues, energy and the environment? And finally, what is the future of physicists in industry?

The total number of qualified physicists in the UK was about[1] 28 500 at the end of 1972. Half of those qualified were members of the (British) Institute of Physics. Of the members, 23% are engaged in the public sector (government laboratories, nationalized industries, etc.), 35% in education and about 30% in private industry. Of the latter about two-thirds are involved in electrical, electronic, computer or aerospace fields. Twenty-four analogous physics organizations in Europe not including the USSR had a combined membership[2] of about 19 500. Making the (risky) assumption that the UK ratios apply across continental Europe, there are probably about 75 000 qualified physicists in Europe today (including UK) of which around 20–25 000 are engaged in industry. What do these physicists do?

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Physics for sales and profit

A general trend is discernible in all of Western Europe, following a similar trend some years ago in the US. Splendid R&D laboratories engaged in prestigious research, much of it fundamental, were common in the 1950's and early 60's. This situation hardly exists any longer. Instead, the most successful companies scrutinize their R&D budgets in exactly the same way they examine advertising, marketing, public relations or capital spending: They ask for a return on the investment. Industrial physicists are thus now trained to define their mission, which is simply to contribute to the attainment of the company's goals.

The primary goals are usually to increase sales and profit: Subsidiary ones may involve reducing costs, increasing productivity, improving product quality and minimizing pollution. The industrial physicist thus sees himself as contributing to the creation of wealth, rather than discovering truth. He may do—and frequently does—first-class physics on the way, but his aim is to solve problems rather than add to the stock of knowledge. He has, of course, an intense interest in seeing that the stock of knowledge *is* increased but he no longer regards this as *his* responsibility, leaving this side of things increasingly to his university colleagues.

To make his distinctive contribution, the industrial physicist must communicate with the general managers, mainly businessmen. Since these busy executives do not understand the physics in detail, the physicists have to learn more and more about business. Most physicists find this fascinating, and often go on to more management-oriented careers in the company. Thus a new feature of industry is that firms look more and more to their laboratories in the search for staff for their commercial units.

In a well run company, the technical director or director of research is well informed on the week-by-week conduct of the business—sales, orders, profits, inventories, competitor activities, market intelligence and so on. Most factories have a technical department that provides support on existing products, on adapting or improving products and processes, and sometimes on developing completely new products.

In large organizations there are also one or more central research laboratories, which have a strategic role in support of the enterprise. In an expanding field like electronics (or, to be more specific, telecommunications), large concentrations of physicists work in the central laboratory. Their roles include the development of new products (usu-

The Wylfa Nuclear Power Station at Anglesey, North Wales, which became operational in 1971, provides 1 180 MW of electrical power. Projections of energy needs often turn out to be incorrect almost before the ink is dry, but energy is enormously important to industry and society. Britain is now in the process of going to a pressure-tube reactor system with light-water cooling and heavy-water moderation.

ally the next generation but one), the creation of new business and the build-up of patents and know-how. Where "upward" communication is good, they also illuminate technical options for top-management decision making, continuously surveying and evaluating the technical activities of other firms, universities and governments on a world-wide scale.

The development of new telecommunications products usually involves the exploitation of new materials and components—the driving force for the last decade has been the new opportunities offered by semiconductors. The equipment designer nowadays sees the cost of all his materials increasing at an alarming rate, with the sole exception of silicon integrated circuits. He therefore designs his products so as to maximize the complexity of the electronics to save on other hardware. Physicists are heavily engaged in this activity, as well as in increasing the repertoire of solid-state electronic components. The strategy here is to review the various families of materials—semiconductors, dielectrics, ceramics, glasses, and so on—to find one that exhibits some interesting phenomenon. The researcher then seeks to optimize the phenomenon to produce a useful device that performs some function such as light emission, microwave oscillation or frequency selection. Hand in hand with the exploration and exploitation of physical phenomena go two other activities: the preparation of the basic material in pure, well-characterized, reproducible form and the refinement of processing technology such as mechanical shaping, polishing, diffusion, deposition, pattern defining, and so on. In all of this work the physicist will be found alongside chemists, metallurgists, mathematicians and electronics engineers.

Organization and funding

Industry of course does not exclusively analyze the work proceeding in its R&D departments into "physics," "chemistry," and so on, but thinks of a team of scientists and engineers as one group. Organization in a responsive central laboratory will be flexible and organic, by discipline (chemistry, microwave, and so on), by business area (passive components, line transmission) and by project (optical communication, electronic private automatic branch exchanges). All three have advantages: Organization by discipline keeps specialist skills topped up to high professional standards, area grouping is an excellent basis for interaction with the company commercial net and project-centered organization achieves predefined results as part of a well prepared plan.

Funding too will be varied, again because no one method has overwhelming merit. A very effective system is to have a combination of three methods, "central levy," "contracted job" and government contract income. The central levy is an internal tax, on sales, of all the manufacturing operations. It is obligatory: the factory pays whether it uses the laboratories or not. Smart factory managers quickly realize this and accordingly react by taking advantage of them. Contracted job funding increases the coupling between factory and laboratory, the factory being the "customer" and the laboratory, the "contractor." A useful combination of these sources of funding is to have 50% from the levy, 25% from contracted jobs and the remaining 25% from government.

Government has supported R&D in industry widely since the war. Traditionally, this has been in defense areas, covering both weapons systems and related hardware, and advanced electronic components. The advantages of defense funding are numerous: coupling to the potential customer (procurement orders), access to valuable technical information (the "need to know") and support on speculative R&D ahead of commercial time scale.

In the UK particularly, the existence of large government laboratories active in advanced R&D gives further benefits. The highly competent staff of these laboratories monitors the industrial contracts and thus maintains a high technical standard. From the firm's point of view, this amounts to a free technical audit of its R&D program by experts who are not only active researchers themselves but who are also aware of everything relevant going on in all the other firms. Finally there are significant advantages to the firms, as well as to the country, of the research "consortia" (see box on the next page) set up in specific areas, for example gallium arsenide material, acousto-electronics and so on, which help to avoid costly duplication and reinvention by

About those consortia . . .

The consortia are groups of representatives from industry and government that meet for the purpose of pooling information a specific topic.

The **gallium-arsenide consortium** covers preparation, evaluation and applications of this and related compounds (gallium arsenide phosphide, gallium aluminum arsenide), mainly for solid-state microwave devices. The representatives, who come from major electronic firms—a chemical supplier, the Post Office and two other government establishments—rotate their meetings among various laboratories. The scientists interchange samples and report on their measurements and analyses, often forming close personal relationships.

A similar group, also in the UK, the **acousto-electronics consortium,** provides a forum for discussing government-sponsored and, at the companies' discretion, company-funded work on acoustic surface devices. While its objectives are to avoid duplication of effort and to stimulate informal interactions between engineers with common problems, the consortium sometimes also makes cooperative decisions. Once a year this group meets with its French counterpart in the **Anglo–French consortium.** Organized alternately in France and the UK by research organizations of their respective ministries of defense, this consortium provides a platform for a wider interchange.

BRITISH PETROLEUM

Offshore oil drilling in the Celtic Sea. These men are inserting a "bumper sub," which compensates for the motion of the vessel, into the drilling string. The Nordic Offshore Drilling Company's *Havdrill,* which is on long-term charter to British Petroleum, is drilling a "wildcat" well.

the firms and governments taking part. In recent years intra-European cooperation has been encouraged in this field. For example, a considerable amount of Anglo–French collaboration in defense component R&D now goes on, both in government and industry.

Government support for civilian R&D

A general tendency these days in Europe, again following the US, is for defense R&D to receive less emphasis and for civilian research support to grow. The exception here is West Germany, where considerable government support of R&D for nonmilitary industrial development has already been evident for some years. In the UK, however, this trend, stemming largely from the disappointment of many political commentators who saw an indifferent performance in the national economic growth rate despite a high national investment in research, has only recently become prominent. The government therefore set out to foster industrial R&D with a view to securing significant technical benefits for the nation.

In line with the White Paper,[3] Government departments ("customers") are to define their requirements and the firms ("contractors"), to advise on the feasibility of meeting them, and to undertake the work. In particular, the objectives must be spelled out "in such a way that the progress of the work can be controlled in financial and technical terms." So far, seven main "Requirements Boards" have been set up covering chemicals and minerals; computers, systems and electronics; engineering materials; fundamental standards; mechanical engineering and machine tools; metrology and standards, and ship and marine technology. In addition, the chief scientist of the Department of Industry chairs an *ad hoc* board to deal with areas not covered by the others. (Aviation and space are dealt with separately.) The aims of the boards are to identify areas in which government R&D support would give most benefit and to increase the part that industry can play in government decision making. The boards are composed of industrialists (50%), academics (15%) and government officials (35%). They have considerable financial resources to deploy, augmented by asking contractors to share the total cost of projects. These boards have been in operation for just over one year, and it is rather early to see how well they will operate; so far, however, the government appears pleased with their progress.[4]

The great environment debate

Recent public concern over energy, materials resources and environmental pollution have brought the activities of industry and, by implication, industrial scientists sharply into the arena of public debate. The creation of national wealth by the application of technology has been an exponentially accelerating process, which has in turn induced such rapid social change that we see today a social revolution in full flood. Dire warnings of the impending exhaustion of our limited reserves of certain key materials, such as copper, nickel and oil, as well as concern with environmental pollution resulting from the rapid increase in industrial activity, have caused a sharp public swing against science and technology. This was reflected, for instance, in the falling rate of applications to the British universities for undergraduate places in these subjects.[5] On the other hand, the scientific community itself is profoundly convinced that only the judicious application of more science and better technology offers any valid solutions to Man's difficulties. Most scientists have, however, refrained from entering this public debate, and companies too have generally shied away from making their own views known.

There are signs that this will change: The more responsive and responsible organizations are now studying the techniques of the communications media so that their views can be effectively presented to the public. It is clear, that, in a democratic state, industrial companies do not set the national goals. These are set by the citizens working through the normal political institutions, including, of course, the executives, scientists and other employees of industrial firms. Some of us feel that industrial scientists and managers have been remiss as citizens in not taking these duties seriously enough. Many parts of industry, however, have made, and will continue to make, a major contribution in advising what is possible—the means and the economic attractiveness of the choices open. Industry is skilled at identifying a potential need and matching to it a technical possibility to make a profit.

Public opinion also exerts pressure in the area of environmental pollution caused by industrial wastes and, to a lesser extent, by modern "chemical" agriculture. Government laboratories have a useful role in determining standards and developing the instrumental techniques needed to monitor pollution. Industry can best respond when given clear ground rules, with taxes or penalties for infringing them. In fact, the knowledge needed to solve most technical problems largely exists; the real problem is to find the money to apply it. This money can only come from state aid (i.e. taxes) or higher prices—in the end the consumer always pays. The scientist's job is to evaluate the real cost of any proposed improvement, and to estimate as accurately as possible the associated risk of not carrying it out.

Energy: fossil, nuclear, solar

The recent Arab oil policy, and especially the phenomenal jump in prices, has caused most Europeans to have a clearer understanding of the crucial importance of energy to our society and how its cost affects nations, companies and individuals. Forecasts of energy needs and supplies in Europe and its countries have been the subjects of many official reports and academic studies in the last quarter century. There seems to have been an impish perversity in the way events have proven their conclusions false almost before the printing ink was dry!

Certain statements about European energy over the next ten or twenty years, however, can be made with some certainty. Coal industries, which were inexorably diminishing in importance, are now visibly revitalized under transformed, confident management and labor. The expeditious development of North Sea oil has assumed much greater importance to Western Europe, especially in the economies of Britain and Norway. District heating from the waste heat of power stations, although relatively minor, is becoming more attractive; research to increase the distance at which heat can be distributed is certainly worth considering. Western Europe has embarked on a large program of building light-water nuclear power stations using enriched uranium fuel, mostly using technology under license. Britain is going its own way with a pressure-tube system using light-water cooling and heavy-water moderation, broadly similar to the Canadian system.

Britain and France have diffusion plants, and there is an international company (with official backing between Britain, Holland and West Germany) developing centrifugal separation plants. Although there is an effective security screen about the exact status of these, there are indications that Europe might be able to supply its own needs

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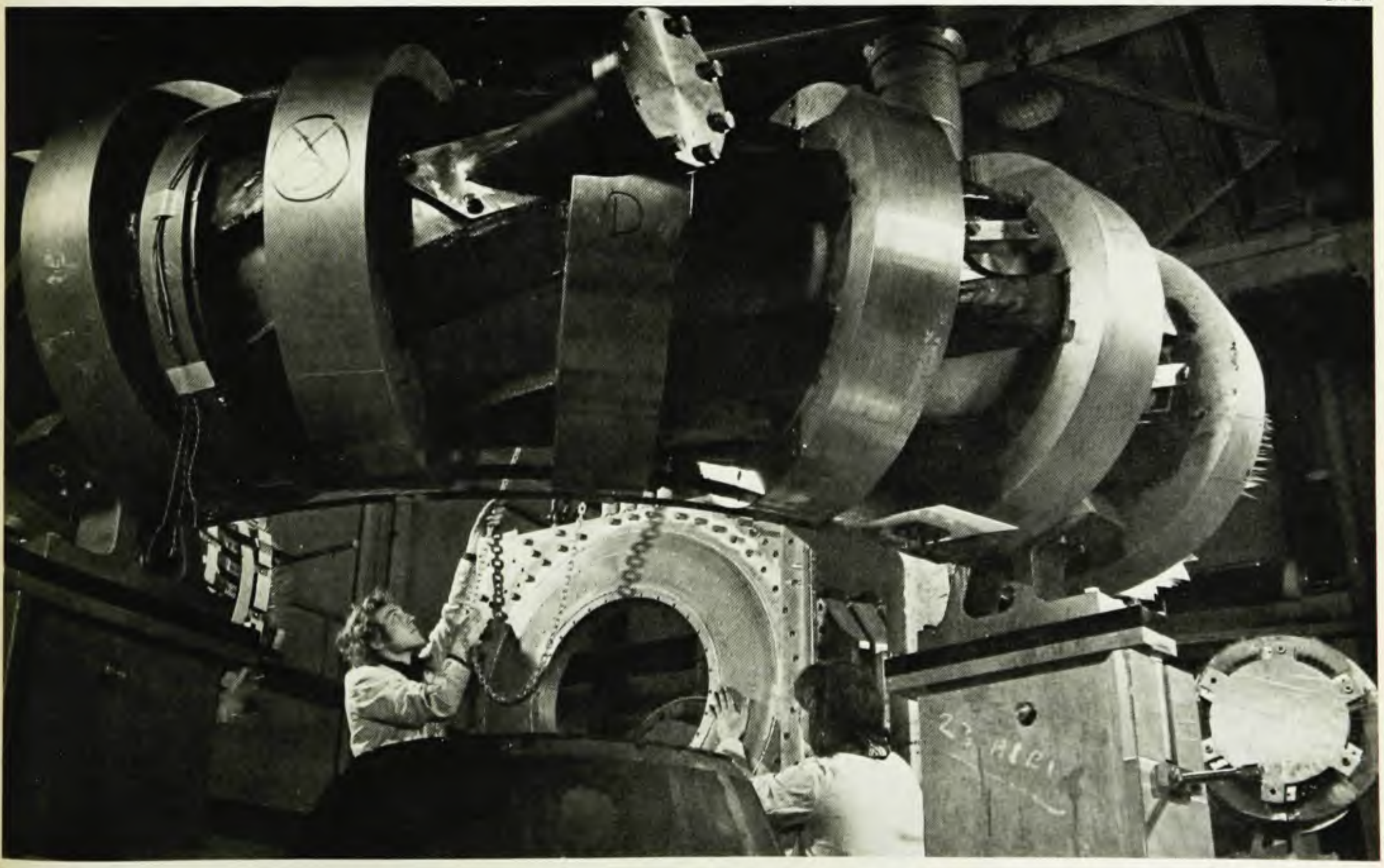


The CLEO Stellarator at Culham Laboratory is designed to study the confinement of high-temperature plasma for nuclear fusion. The 24 coils, one of which is being moved into position, and the helical conductors visible above combine to produce the confining magnetic field.

for enriched uranium within two decades. A large and advanced effort in Britain, France and West Germany is matching, if not leading, the US and the Soviet Union on the fast breeder reactor.

The large European effort on fusion research is well coordinated with the world effort. Any considerable advance in the promise of fusion power, in the present climate of opinion, would lead to a sharp expansion of the effort. There is also considerable interest in production plant for desalination, and in using heat for industrial purposes, powered by nuclear power stations built for that purpose.

The European nuclear-power programs will require additional scientists and engineers right through the technological spectrum. University departments will have to teach something about nuclear power, slanted according to the particular discipline or speciality within a discipline. There are many opportunities for useful academic research, either within the university or in collaboration with the staffs of national or international laboratories. The high standards of physical and engineering integrity demanded in nuclear power has given an impetus throughout industry for improved methods of nondestructive testing. We confidently expect further progress in this area.

There has been interest in, but little finance for, developing new ideas such as large-scale devices for making electricity from solar energy. On the other hand, the sharp rise in the cost of energy is leading to a general effort by industry to use energy more efficiently. The savings may well prove to be large and make forecasts of primary fuel needs overgenerous.

Transportation and communications

There is a growing realization in Europe that certain services cannot be made to pay and that they will have to be supported by large subsidies from public funds on the argument that these services meet an essential "social need." It appears to be difficult for the politicians to release the funds without the management of the services being subjected to tight government controls. Two obvious examples are the railroads and the postal service.

Not only do most members of the public wish to see these services continued at an efficient level, even though this adds to taxes, because they want to use the services, but also from the social point of view that such labor-intensive industries help to avoid unemployment. It is difficult to predict whether the injection of large sums of government money into services that meet a social need will accelerate or slow down possible advances in technology. With passenger trains, which most affect the railroads' public image, many advances in technology could be envisaged, the extreme case perhaps being a fully automatic commuter system using magnetically levitated cars driven by linear motors. With the postal services, electronic mail between busy business offices must be technologically possible now, but such a service would skim off some of the best-paying mail traffic, thus making the mail even more unprofitable. These examples illustrate how social pressures, exerted through the democratic processes, can affect the priorities of some parts of industry in regard to technological decision making.

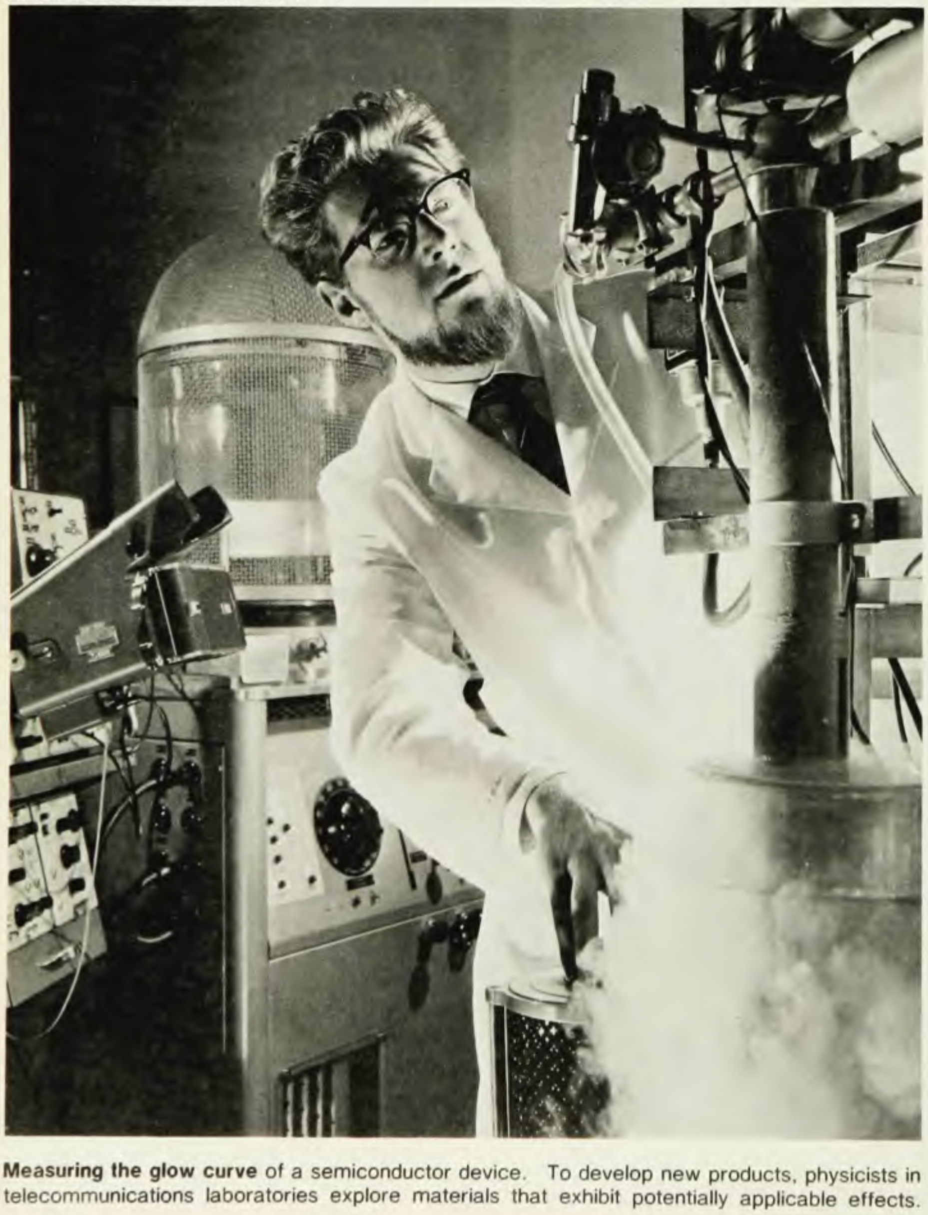
The telecommunications industry, profitable both to operators and to manufacturers, gives essential public services, needs enormous capital investment in most European countries over the next few decades and has a rich and expanding technology. Physics will be very relevant to the industry as it has been in the past. Furthermore, improved telecommunications may be a sensible way to help reduce our requirements for energy and transport, probably two major areas of concern to European governments today.

The future of the physicist in industry

Materials substitution, recycling and the design of products to minimize their use of energy and material are tasks of increasing urgency. The scope for employing young physicists therefore appears enormous. A recent survey[6] of 1973 UK physics graduates showed nearly a quarter entering industry. This is greater than the two previous years, with the gain apparently at the expense of teaching. Furthermore, a high proportion expressed satisfaction with their career prospects. However, six months after graduating, 10% of all physicists still had not found a job.

Recent economic difficulties in the UK have led to what is hoped was the temporary phenomenon of graduate unemployment. Under these circumstances some physics graduates turned

STANDARD TELECOMMUNICATION LABORATORIES



Measuring the glow curve of a semiconductor device. To develop new products, physicists in telecommunications laboratories explore materials that exhibit potentially applicable effects.

to careers where their physics knowledge was not employed. In this respect they followed their liberal-arts colleagues who rarely expect to use their specialized knowledge in their jobs. Thus, recent graduates have been anxious to secure employment quickly, and a satisfactory proportion have entered industry.

The future, however, is much more disturbing. At university admissions, there has been a distinct (in some colleges, catastrophic) turning away from science and technology in favor of the social sciences. The reduction in pay differentials between technicians in industry and new graduates of the same age is causing young people to question whether the hard and sustained effort required in science or engineering at the level of a first degree is worth the struggle. Furthermore, the very low maintenance grant received by graduate students has discouraged many from staying on for higher degrees. As a result, funds available for such work now for the first time exceed those applied for.

It is therefore safe to predict that *in three or four years' time there will be an acute shortage of good science and technology graduates entering the job market,* at least in the UK. This will undoubtedly be reflected in the high rewards they will be able to command.

The rapid expansion of university education after the war, particularly the creation in the UK of a large number of new universities, has led to a marked increase in university–industry contacts. The universities of course provide industrial R&D's main raw material—graduates. In exchange, several science and engineering chairs in the new British universities have been filled by recruits from industry and government establishments. The departments led by these men usually do very good research, with great benefits for industry. Some good collaborative programs have been set up between industry and the universities (and in some cases government laboratories as well).

Industrial representatives also sit on many of the advisory bodies set up by the government as part of its university–research grant administration. Although these contacts are valuable, most industrialists feel that their views, while politely heard, are usually not implemented, so that a great deal of research that purports to be directed toward commercial exploitation has very little hope of being used.

Europe, the US and the multinationals

How do the parts of West European industry that are closely concerned with industrial physics compare with those in the United States? Western Europe has always been good at creative *basic* science and technology—and there is every reason to suppose that this creativity will persist. On the other hand, Europe has been self-critical about its success in *applying* science and technology to manufacturing industry.

UKAEA

European fusion research is coordinated with the world effort. This view of the CLEO Tokamak at Culham Laboratory shows the toroidal plasma confinement device in the background, with diagnostics area in foreground.

There is a lot to be said for the view[7] that the US government prefers to use private industry for innovation, whereas European governments tend to support state-controlled R&D. In the last five to ten years, Europe has learned a lot from the US about the management of industry. Business schools now seek to emulate some of the famous American schools. Greatly improved management skills are now found in most parts of European industry, including R&D departments.

Superficially, European industry and American industry are beginning to look alike, allowing for variations in Europe and a few national characteristics. One very important difference remains, and will probably remain for many years: The market available to an expensive technological product in America is much bigger than that in Europe. For example, most European countries want to use telephone equipment with a system based on their own R&D, using their own designs and made in their own factories.

Economic forces have compelled Europeans for the most part to buy and operate American civil aircraft and computers. Britain and France have produced a fine aircraft in the Concorde, but they are anxiously waiting to see if it has a commercial market. There is still in total a very large European R&D effort in computers and aerospace, and this will probably continue, with large demands on physics.

The Common Market does indeed have a common market, but this large market may not cause, as it would fifty years ago, a reduction in the number of firms making similar technical products and a growth in the size of the survivors. Europe will see advantages and disadvantages in this situation, but as concerns very sophisticated products with enormous development costs, Europe will either have to leave them to the US or put some of the costs on the taxpayer's bill.

In our opinion, multinational companies bring great advantages to industrial R&D. Both within Europe and between Europe and the USA, the multinationals act as bridges between national styles and practices. In general, Europe is a cost-effective place to do research: Educational standards are high, costs low and the national governments generally cooperative. On the other hand, the US is a large marketplace, not just for products but also for ideas, information and know-how. Both communities benefit from the free interchange among their R&D people. The exchange of R&D ideas between Europe and Japan is also increasing steadily, with similar but slower trends also between Europe and Russia and between Europe and China.

The social relevance of physics

What appears to be happening piecemeal around Europe is the unplanned growth of a more explicit relationship between industry and the community. While industry's primary goal is to manufacture and sell good products at a profit, it is also expected to take greater account of social responsibility to the community at large and to its own workers. This it does most willingly but, if necessary in some respects, under pressure. A satisfactory solution will take time but the incentive and the benefit are clear for industry, for physicists and for physics.

References

1. Physics Bulletin, March 1973, page 169.
2. European Physical Society memorandum, July 1971.
3. "Framework for Government Research and Development" (White Paper), Command 5046, HMSO, London (1972).
4. Report of the Research Requirements Boards, Department of Industry, HMSO, London (1973).
5. Physics Bulletin, June 1974, page 224.
6. Physics Bulletin, July 1974, page 281.
7. Van Riemsdijk, H. A. C., Speech given at the Annual Conference, European Industrial Research Management Association, Brussels, May 1974. □