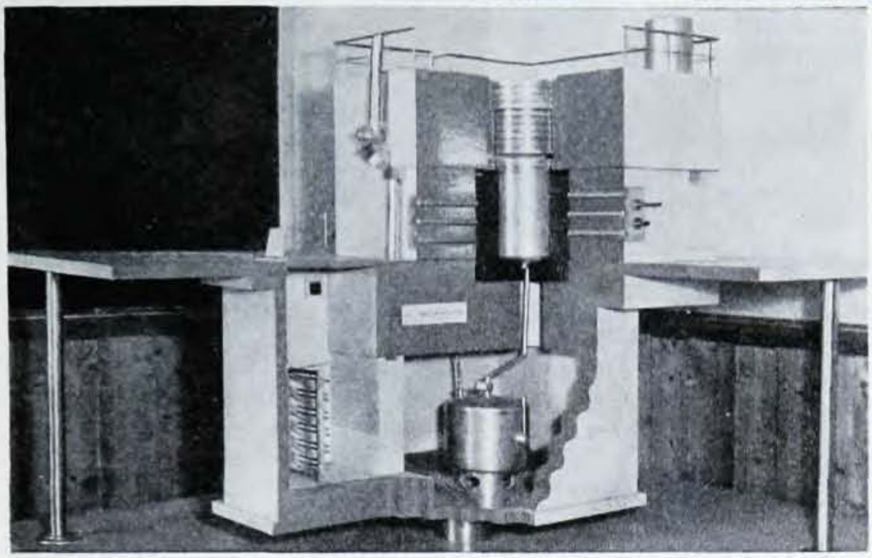
Visiting and resident physicists meet in Norway: left to right, A. Weinberg (Oak Ridge), G. Randers (JENER), J. V. Dunworth (Harwell), B. Trumpy and O. Dahl (Bergen). Shown below is display model of Norwegian-Dutch heavy water reactor at JENER.



By A. W. McReynolds

Nuclear Research in NORWAY

DURING a year spent in Norway as a Fulbright research scholar, I attended two scientific conferences which, between them, perhaps cover the scope of physics there. One, the annual meeting of Norsk Fysisk Selskap (the Norwegian Physical Society), was national in character and rather like an American Physical Society meeting minus some of the congestion and simultaneous sessions. The other, the first international conference on nuclear reactors, represents a step toward future scientific cooperation in that field. It was attended by delegates from nineteen different nations, and was arranged by JENER, the Norwegian-Dutch "Joint Establishment for Nuclear Energy Research". This account of physics in Norway (and some observations about Sweden) is as viewed through the eyes of a guest for the year at the JENER nuclear reactor laboratory—but first perhaps we should start back at the Fysisk Selskap meeting and visit some of the institutions whose work was reported.

That meeting was representative both in its small size in contrast with our APS meetings and in that it was held in a brand new research building, typical of the rapid building of science research labs in the past few years since wartime occupation. Hosts for that year were the University of Bergen and the Christian Michelson Institute, which shares the same buildings. Although the attractive west coast city of Bergen, a well-protected harbor surrounded by a ring of hills, dates back to the Viking days of around 1000 A.D. both of these institutions are relatively new.

The University was opened in 1949 and already has a well-established and active physics department headed by B. Trumpy. The emphasis is on cosmic rays and on nuclear physics, for which a 1.5 Mev Van de Graaff and a 50 Mev betatron have been installed. In the past two years the 1.5 Mev machine has been used with both proton and deuteron beams to study reactions in light elements, such as (d, n) reactions in Li and B, and (p, γ) reactions in boron. Studies of photodisintegration of the deuterons were made with photographic emulsions wet with heavy water. The betatron has energy variable in steps of 30 kev for investigations of fine structure in yield curves, and has been used in studies of Li^7 (γ, p) He_6 and Li^7 (γ, t) He^4 reactions. The cosmic-ray intensity, separated into a soft and two hard components, has been continuously registered for several years. Variations have then been analyzed for correlations with barometric conditions and with variations of the earth's field during some 40 magnetic storms.

The Christian Michelson Institute for Pure and Applied Research was endowed around 1930 by a bequest from the late statesman Michelson, who was prime minister at the time Norway and Sweden separated their governments in 1905. Its activities are about equally divided between humanities and sciences. At present in sciences there are two research professors (called members), both physicists, each heading a group of co-workers. Helmer Dahl works in the field of electronic instrumentation, microwave communications, and servo mechanisms, and Odd Dahl (no relation) is engaged in various developments of physical equipment. The range of projects undertaken recently

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by O. Dahl's group, for example, extends from a utilitarian but ingenious photo device for separating male and female herring before canning, through a heliostat and high resolution spectrometer for the new astrophysics observatory, to designs of the 20 Bev proton synchrotron for the CERN lab in Geneva. Design work on the synchrotron was divided among laboratories in the various member nations with Dr. Dahl in general charge. He was also principal designer for the heavy water reactor at JENER, but more about that later.

It was in the just-completed building of the Christian Michelson Institute that the physical society meetings were held. They consisted of two days of short technical papers (only one session at a time) attended by about 40 assembled physicists, mostly from the Bergen, Trondheim, and Oslo areas. All sessions of course were in Norwegian. As the only foreigner there, I was gratified and a little surprised to find myself able to follow both the physics lectures and the after dinner speeches at the banquet, but a little dismayed at the ease and unanimity with which the assemblage switched to English for discussion of a paper for which I was co-author. Almost all Scandinavians speak some English, and scientists are more fluent than average. The subject matter of the conference was the year's research activities, which are discussed here along with the individual laboratories mentioned. As at APS meetings there was an evening banquet, with after-dinner speakers, and (unlike APS) wine with the meal. This year it was held in an interesting historic building, the dining hall from the living quarters of some of the Hanseatic League merchants of several centuries ago. A number of such buildings still remain along the waterfront, dating from the fourteenth and fifteenth centuries when Bergen, like other northern coastal cities, was controlled more by the Hanseatic League than by the national government. The all-male assemblage of physicists was in accord with the custom of that time, when the merchants who dined together there were prohibited from marrying in order to prevent their assimilation into the community.

A few hundred miles farther north from Bergen lies Trondheim, 32 hours by boat along the rugged coastline, or by car a fascinating 350 miles of mountainous roads, with four ferry crossings of fjords. In Trondheim, third largest city after Oslo and Bergen, is the Norges Tekniske Høgskole (technical college). The physics department works, on the theoretical side, with problems of scattering of neutrons, mesons, etc. under Prof. Wergeland. Among experimental facilities, a Van de Graaff generator has recently been completed. Through a connected institute, the Association for Industrial and Technical Research, the applied research problems of industry are taken up, particularly in the field of hydroelectric power, the country's major energy source.

Across the high snow-covered (except summer) central plateau and mountain regions from the west coast lies Oslo, which bears about the same relation to the country as New York plus Washington to the U. S. It too is a seaport, at the end of a long fjord extending south to the Skagerrak. If you arrive any time December to March, Oslo will also be snow- and ice-covered, but very decoratively so, and with no visible discomfiture of either the acclimated and sure-footed populace, or their equally sure-wheeled vehicles. The main physics establishments here are the University of Oslo and, 15 miles north on the road to Trondheim, the adjacent labs of the Forsvarets Forsknings-institutt (Defense Research Laboratory) and the JENER laboratory, which is better known locally as Institutet for Atomenergi, or IFA.

THE educational sequence through which a student would go in Norway (or elsewhere in Scandinavia) is somewhat different from that in the U. S. The average student, having finished the elementary school in 7 years at the age of 14, and having elected to continue beyond the first middle school exam, completes his "artium" at 19. In the last two years he had several alternative fields of concentration, such as humanities, or languages and sciences. Now having graduated from school, he has officially become a "student". Many of course stop their education at this stage, asserting their student status only every independence day by appearing in their black tasseled student caps. If they continue their studies at the university (say in physics), about four years are occupied with studies of a major and two minor subjects, physics, math, and chemistry or mechanics. The system is not to study all in parallel but to concentrate on each successively (recent changes have introduced some overlap). No smaller exams are required, all being determined by a final written and oral exam in each subject. Having completed this "adjunkteksamen" he may now continue further study, concentrated on his field of specialization for two years or more, also completing an original thesis. At the end of this period, after again passing written and oral exams, "embetseksamen", and submitting the thesis, he acquires the degree of Cand. Real. (candidatus realium, indicating a degree from the science faculty) which seems to be somewhere between our MA and PhD. He is now 25 or 26 and has completed formal university training. His next step, the PhD, is a harder one than in the U. S. and fewer continue that far. There remains the need to submit a thesis, but an extensive one including a number of related research projects which form a coherent and thorough study of some field. Having held a teaching or research position for several years while carrying this out, at age 35 comes the big day. Clad in tails, dress shirt, and white tie, he faces an official first and second opponent (specialists in the field) to defend his thesis. Passing this exam secures his degree, and on the quality of exam and thesis depends whether he will find a position as "amanuensis" (roughly, assistant professor) or "dosent" (roughly, associate professor). The academic profession is a highly respected one, particularly the position of professor, which is accorded only to the most senior, perhaps more sparingly than full professorships here. Perhaps we Fulbright professors appeared deficient in dignity, years, and wisdom, by contrast.

But what about the university and its research? In the University of Oslo, the principal and oldest (1811) educational institution, physics is impressively well housed. The newest building is the four-floor two-wing brick chemistry and physics institute at Blindern, on a hill about two miles from the mid-city location of the other university buildings. Since the institute was completed only in 1935, with an eye to the future, it allows adequate room for a number of research groups, as well as classes and student labs. A particularly active research field is diffraction. In Prof. Hassel's group, the electron diffraction apparatus for gas studies is among the best in the world, and allows study of several higher order reflections. It has been applied particularly to cyclohexane molecules and their addition compounds. Electron diffraction techniques are supplemented by microwave spectroscopy and by x-ray diffraction. Cooperative neutron diffraction work has been started in collaboration with the JENER staff. Here too there is a pressure Van de Graaff, identical with the one at Trondheim, both having been built under Prof. Tangen's direction. Sørenson and his collaborators use nuclear emulsions exposed in balloon flights up to 90 000 ft in cosmic-ray studies. Their recent studies have been on the observation of energetic alpha particles in cosmic-ray stars, and on heavy mesons. In theoretical work Prof. Hylleraas is well known here as in Norway. Under Prof. Rosseland the study of astrophysics has always been an important one at the university, and is now expanded by the completion of a new solar observatory at Harestua, 35 miles north from Oslo, with a 29.2 m focal length tower telescope. Their long base-line spectrograph and vertical spectroheliograph were developed by the Christian Michelson Institute, already described. Several radio antennae, the largest 7.5 m diameter, for recording at 55, 200, and 545 mc, are used in simultaneous radio and optical observations of solar phenomena. A special interest of the astrophysics group has been observations on northern lights from Nordlys-Observatoriet located in Tromsø in north Norway, far inside the Arctic Circle.

Other buildings are under construction adjacent to the Blindern institute to house a new research center consisting of several separate institutes. The largest of these is the Central Institute for Industrial Research, an organization affiliated with the university and planned to undertake research and other technical problems for industry, somewhat like the Mellon Institute. Other eventual parts of the research center include for example the Geotechnical Institute and the Building Research Institute. Funds for these institutes, which have their own scientific staffs, come partly from the national government and partly from industries. The funds are managed through a government agency with the somewhat awesome name "Norges Teknisk-Naturvitenskapeilige Forskningsraad" which translates to "the Royal Norwegian Technical Scientific Research Council". These funds are partly direct appropriation but about one million dollars per year come from the interesting source of "Norsk Tipping", an official government football betting pool. Perhaps that is an idea for support of our underfinanced National Science Foundation.

HAVING succeeded in starting our Citroên (since Oslo is warmer than most places so far north) and having negotiated safely the 15 miles of snowy and hilly roads, we arrive at Kjeller and the single guard who stands watch over the entrance to FF (defense research lab) on the left, and IFA (the reactor lab) straight ahead. Under a Dutch and a Norwegian flag, flying from twin flagpoles ahead, lie the physics and chemistry buildings of the joint Dutch-Norwegian atomic energy laboratory. On the hill just beyond sits a green building housing the heavy water reactor. Until 1945 these buildings had been occupied by Nazi troops, but soon after the end of the occupation, several Norwegian scientists undertook to establish here a defense research laboratory. One division of the lab, concerned with atomic energy research, soon became a separate organization, the Institutt for Atomenergi, which set about energetically to construct a nuclear reactor. Under the guidance, particularly, of G. Randers and Odd Dahl, plans and construction proceeded rapidly, even without benefit of the many technical data on previous reactors still unavailable for security reasons. One motivation for entry into the reactor field was the plentiful supply of heavy water from Norway's Norsk Hydro Co., which was the world's main producer. Uranium was a different story though; Norway had none. This obstacle was soon solved however by the formation of a fruitful partnership with Holland, where the late Prof. De Haas had been foresighted enough to purchase a large quantity of uranium from Czechoslovakia in 1939, and artful enough to retain it through the occupation. IFA (Institutt for Atomenergi) and FOM (Stichting voor Fundamenteel Onderzoek der Materie) became JENER (Joint Establishment for Nuclear Energy Research), with a joint atomic energy commission of three members from each country, plus the director, as a governing body. Its heavy water reactor, which started operation in August 1951, became the first one to be developed outside the larger countries, U. S., Britain, Canada, France, and, presumably, Russia. It now operates regularly at 300 kw power and 9×10^{11} n/cm^2/sec central flux.

With increasing interest of many countries in developing their own reactors, the flux of neutrons in Norway has generated a flux of foreign visitors through the lab. The roster of nationalities of short-term visitors reads like a roll call of the UN. During the past two years there have been usually four or five foreign visitors at any time on longer stays to participate in research. During my stay the countries represented by such participants were England, Switzerland, Sweden, Italy, Yugoslavia, and the U. S. This of course does not include Holland, which as a full partner has contributed a number of scientists to the staff. In this mixture of nationalities it has proved most convenient for all (particularly me) to adopt English as the official language of the institute.

As in other reactor labs, research reaches into several fields. In the physics and chemistry departments basic research concerns properties of the reactor such as "neutron" temperature and fission gamma spectrum, as well as studies of crystal structures by neutron diffraction, and cross-section determinations with monoenergetic neutron beams. (My own activity was in initiating and developing neutron spectrometer equipment for some such experiments.) The isotope division performs irradiations to obtain tracer isotopes for Norwegian, Swedish, Dutch, and other research groups, and other irradiations like, for example, seeds and plants to be studied by plant geneticist Knut Mikaelsen. Hardly to be distinguished from the basic research is the work of the reactor development division, which has concentrated on studies of the kinetics and behavior of the present reactor. Determinations of cross sections for capture and fission are of course of immediate interest for their purposes. The next goal is the development of an experimental power reactor, probably to be built in Holland. Much work has already been done in this direction, and has led to international cooperative experiments with both Switzerland and Sweden. Both of these countries have reactor building programs of their own and can profitably pool efforts in solving common technical problems, using the Kjeller reactor for experiments. Switzerland is cooperating in heat exchange experiments for future fuel elements, and Sweden in exponential experiments in preparation for their own power reactor. Another collaborator is the Yugoslavian "Institute for Nuclear Studies, Boris Kidric", which has maintained two of its physicists at Kjeller for long periods of reactor research. Dr. Dahl from Bergen now spends much time at JENER in designing the new 10 mw power reactor model.

Naturally enough, Oslo was the site for the first international conference on atomic energy. On invitations from JENER, 19 countries sent delegates to a conference in October 1953 on heavy water reactors. Those represented included nearly all of western Europe, plus the U. S., Canada, Brazil, Israel, and India, all delegates being scientists concerned with their countries' atomic energy programs, and many of them members of the atomic energy commissions. Each of these countries has special reason to be interested in nuclear energy. Some, like Israel or Italy, have a limited supply of other fuels. Norway, although well endowed for the present with hydroelectric power, has a large shipping industry which might profit from nuclear power. India has plentiful supplies of raw materials. A number of technical papers were read, mostly on reactor research and development. U. S. delegates described the CP-5, MTR, and homogeneous reactors. This conference also laid the groundwork for future collaboration by proposing a European Atomic Energy Association which has since been established with Sir John Cockcroft as president and director Randers of the JENER lab as executive vice president. Both have been active at the UN in planning this year's international conference.

A FEW MILES to the east of the JENER lab lies the border of Sweden, and straight east across the country one comes to Stockholm and Uppsala, centers of much of the scientific work. With apologies to Sweden for a comparatively scanty coverage, I should like to mention observations from a week's visit there. Analogous to the JENER lab in Norway is AB Atomenergi in Stockholm, a corporation controlled partly by the government and partly by various industrial corporations. It seems the knotty problem of government or private ownership has been at least partly resolved. Here too is an experimental heavy water reactor rather similar to the Norwegian-Dutch one. An unusual feature of this reactor is its location in a cavern dug out 100 ft deep in solid rock, with concrete dividing walls and floors for the surrounding labs. With the added safety factor of this well-shielded location, it was considered safe to have the reactor located conveniently in the northern suburbs of Stockholm (and a more pleasant location than Stockholm is hard to find). Completed during 1953, the reactor is now operating at low levels for kinetic studies, in which modulation is accomplished both by usual methods and by a pulsed T (d, n) He neutron source with tritium target inside the reactor. Other basic studies have been determination of the hydrogen capture cross section for neutrons, and neutron multiplication in almost critical lattices of natural uranium in water. Plans for a power reactor are well under way.

Only a mile from Atomenergi is the Nobel Institute of Physics, directed by Manne Siegbahn. Here many experimental physics researches have been brought to a fine art—a few years ago optical spectroscopy and the development of fine gratings, currently nuclear physics, particularly precise β-ray spectroscopy studies of nuclear energy levels, and cyclotron research. Recently their cyclotron has been applied to acceleration of heavy ions, such as C and N, for bombardment of heavy elements to make transuranic elements. North of Stockholm, in the University of Uppsala, is another accelerator lab where their 200 Mev synchrocyclotron, a model of neat design, is being used for cross-section studies in this range. At the same university is an excellent x-ray diffraction laboratory under Prof. Hägg whose studies of inorganic structures and developments of apparatus are familiar to physicists in this country.

To get back to JENER where most of my year was spent—did we leave Oslo a few lines back in darkness, ice and snow? It isn't always so. Just a few months later, the skis are put away and there come balmy summer days so long there is no night between. It is partly that which makes a year's stay in Norway a delightful experience, but also the hospitality of the people and the feeling of being in a healthy climate of international scientific cooperation, which one hopes will continue elsewhere too.