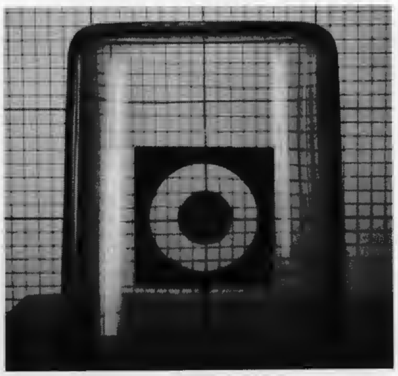
Review

SUMMER 1969

OAK RIDGE NATIONAL LABORATORY



THE COVER: Target of selenium-78 deposited on a hydrocarbon film by vacuum-condensation. Amount per cm^2: 1 microgram; for use at High Voltage Lab on tandem Van de Graaff. For other target fabricating techniques, read article on page 1.

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Review

OAK RIDGE NATIONAL LABORATORY

VOLUME 3, NUMBER 1 **SUMMER 1969**

OAK RIDGE NATIONAL LABORATORY
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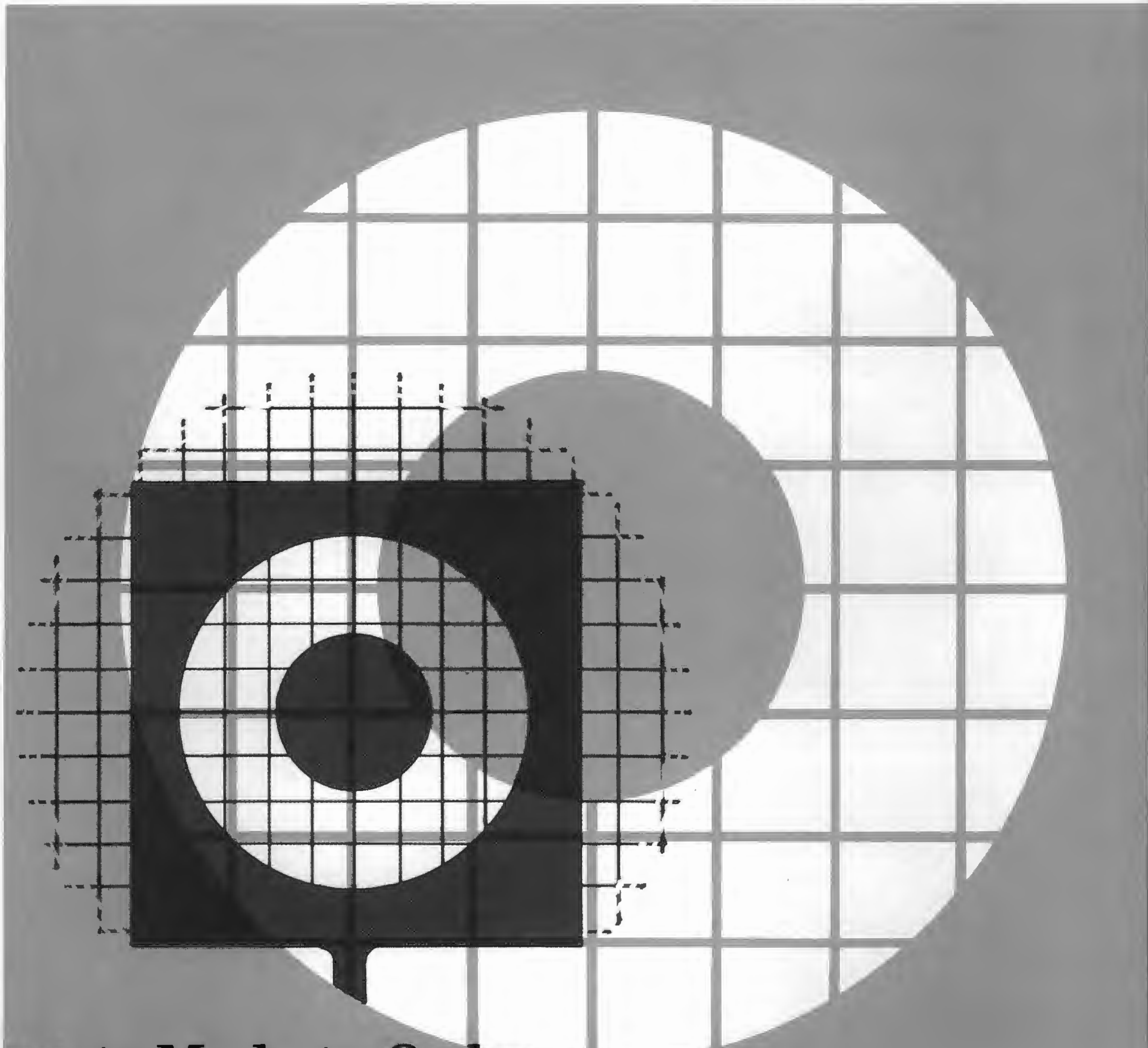


Targets Made to Order

By E. H. Kobisk

THE ISOTOPES DIVISION of ORNL under the direction of John Gillette has the most diverse isotopes handling facilities in the world, including the largest stable isotopes separation facility. For this latter purpose, calutrons are used (located in the Y-12 area) which are giant mass spectrometers capable of processing multigram quantities of these isotopes. About one third of the Isotopes Division personnel, under the direction of Leon Love, pursue the task of isotopic enrichment by the technique of electromagnetic separation and associated chemical processing.

Because isotopes of high enrichment are difficult to prepare, the monetary value of these materials can be great and the quantities available for research can be very limited, in some cases less than a gram. For example, the cost of the isotope silicon-30 having an isotopic purity of over 90% (as en-

Ed Kobisk, a Chicago native, came to the Isotopes Target Laboratory in 1961 from K-25, where he had spent eight years in the Technical Division and one year in the Recruiting Program. His undergraduate work was done at the University of Illinois, and his two master's degrees are in physical chemistry (Illinois Institute of Technology) and industrial management (University of Tennessee). He recounts here a story of ad hoc ingenuity that has few parallels. In meeting the requests of scientists here and outside ORNL, the personnel of the Isotopes Target Laboratory have exercised a versatility and invention that would be hard to top. As Ed says of his staff's accomplishments, "The impossible may take a little longer . . ."

riched by the calutron) is $3.90 per milligram, a price nearly 8,000 times that of the highest purity single crystal silicon metal commercially available, about $0.50 per gram. The most expensive calutron-separated stable isotope is potassium-40 whose value, at an isotopic enrichment of 84%, is $1,400 per milligram. It is apparent from these data that whatever use is made of these materials the application must be conservative and employ very small quantities.

The chemical forms of separated isotopes are normally those having high chemical and physical stability, such as powdered oxides, some carbonates, occasionally halides, nitrates, or the elements. The choice of chemical form for a given isotope is usually governed by its ability to withstand storage under atmospheric conditions for long periods of time. As might be imagined, however, the usual forms are not always compatible with the needs of people who want to use isotopes in nuclear or solid state physics experiments.

Among the many users of stable and radioisotope materials are physics laboratories involved in studying nuclear structure. Experimentalists using huge accelerators, such as the tandem Van de Graaff and Isochronous Cyclotron at ORNL, require the use of isotopes for their research. Such accelerators located in many national laboratories and major colleges and universities throughout the world number more than 2,000.

The accelerator method of nuclear physics experimentation involves bombardment of known nuclei (frequently a separated isotope) with ionic particles or subatomic projectiles. Both the atom density in the target and the energy of the projectiles must be known for meaningful experimental information to be obtained. Interpretation of the interactions between these two bodies unlocks the mysteries of composition and energy distribution within the atomic nucleus. The Isotope Target Laboratory of the ORNL Isotopes Division prepares samples containing specific nuclei in known atom density and in appropriate physical and chemical form so that nuclear interactions may be studied.

The usual form of a target used in accelerator research is that of a thin film, so thin as to make cellophane or tissue paper grossly thick by comparison. Films as thin as one to 10 millionths of a centimeter are frequently used for this purpose to avoid disintegration of the target during bombardment. Disintegration can be caused by vaporization of target material due to energy dissipation of the projectiles in the target during bombardment; thin films are usually poor heat conductors. Actually only one projectile in millions "reacts" with a target nucleus; the other particles merely pass through the film without significant interaction and minimal energy loss. Targets in thin-film form are necessary to permit reaction products, such as scattered projectile particles or recoil nuclei, to be emitted from the target without significant change in their energy or direction.

The dream of every accelerator physicist is to have an exactly countable number of atoms of a single nuclear species, only a few atoms thick, spread over an area at least ten times as large as the area bombarded by the projectile beam. With this arrangement nuclear interactions could be studied with perfect resolution. Of course this is an unrealistic condition, but such perfection is the goal of the target fabricator; every effort to produce such a target is made so that the most meaningful results in this very important realm of nuclear physics research can be obtained.

To prepare thin films one depends on the physical properties of the material itself to hold the atoms together in a regular array. Such a film must withstand the stresses and strains induced by thermal fluctuations, pressure changes, and other severe environmental conditions to which it may be subjected within an accelerator. Since dissimilar nuclei are many times undesirable and reaction products emitted both in the forward and back directions from the target must be observed, target films are frequently made self-supporting, that is, they have no backing material holding them together. The cohesion of the target atoms alone must provide support for the film, as in a soap bubble. Many techniques of chemistry, physics, and metallurgy have been used in achieving sufficient film strength. Procedures such as vacuum evaporation, electrodeposition, chemical vapor deposition, mechanical rolling, and sputtering have been employed.

In 1961 when I first arrived on the target preparation scene, the technology was in its infancy and centralized target fabrication was mostly of local interest. Four years earlier the first serious attempt at organizing such a function had been made by P. S. Baker and Ed Olszewski as a service to the physicists at the High Voltage Lab. In 1960, after three years of activity in this field, the fact that this function was of value to nuclear and solid state research on a local, national and international basis was recognized by A. F. Rupp and A. H. Snell of ORNL and T. R. Jones of the AEC's Division of Research. More emphasis was placed on this effort by adding three technical staff members and three technicians. Consolidation of isotope research sample preparation within a division whose personnel were experienced in handling valuable isotopes seemed a most expedient method of achieving the best service in the shortest period of time.

Reassignment of personnel eventually resulted in B. J. Massey directing the efforts of this modest activity under the supervision of E. Beauchamp. At that time (1961) the Isotope Target Laboratory had as its assets five major pieces of equipment and the liability of little experience. After all, where could one develop experience in preparing films that were sometimes difficult to see, almost too thin to handle, and made out of materials that most chemists had only read about in books? By 1962 some development efforts were in progress to fabricate more difficult samples and achieve more precise control on sample characteristics. When Massey retired the direction of the program fell to me.

Rolled Foils

Two techniques of thin film preparation were soon found to be the most important because of their versatility. These techniques were the rolling of metals and the vacuum evaporation of elements and compounds with subsequent condensation of vapors in film form on surfaces from which the film could be stripped.

Rolling of metals is an age-old technique used to produce foils of malleable elements by squeezing between revolving hardened cylinders. Aluminum kitchen foil is an example of the value of this technique. Although metallurgical textbooks very infrequently refer to forming foils of thicknesses less than 0.002 cm, it is this realm of thickness that forms the starting point for the rolling of accelerator target foils. The beauty of a rolled metal foil is that its physical characteristics closely approach or are identical with those of the bulk metal.

For ductile metals such as iron, copper, and nickel, cold rolling (i.e., at room temperature) is usually no problem and, of course, isotopes of these metals can be easily formed into targets by this process. However, not all elements are so cooperative. Many are highly reactive to atmospheric gases; some are soft, causing them to stick to the roll surfaces; still others are so brittle that they crack under the pres-

Kermit Campbell and cold-rolling technique.

sures required. Although heating increases the ductility of most metals, it also increases their chemical reactivity. This increased reactivity can result in an increased impurity content or even spontaneous combustion unless a protective atmosphere is used. These unfortunate circumstances warrant rejection of hot or even warm rolling in the preparation of many targets.

We soon learned that minor impurities could cause major changes in the physical characteristics of a metal and could frequently defeat foil preparation by rolling. Indeed, the reduction of impurities in starting materials to less than a few hundred parts per million was found most important. Oxygen, nitrogen, and sulfur are particularly bad actors in this respect. Many metals not only must be purified before rolling, but also must be rolled in an inert atmosphere to eliminate contamination of the metal and avoid spontaneous combustion during and after the rolling process. Developments in this process have permitted barium metal, one of the most reactive metals, to be successfully rolled into foils thin enough to see through, a thickness of about 0.00002 cm. Such a foil would instantly disintegrate on contact with air, but in a continuously purified argon atmosphere (less than 3 ppm total O_2, N_2, and H_2O) the foil remains bright and uncontaminated for short time periods.

Metals differ enough in physical and chemical characteristics to prohibit any general application of a single rolling technique. As a matter of fact, each metal requires an almost unique procedure which may even be varied for any one metal depending upon the ultimate thickness required. Cataloguing of these procedures would fill a several hundred page volume. Six years of development effort in this area have permitted two general conclusions to be drawn: 1) very slow rolling speeds (less than 40 cm per minute) with about 5–10% reduction per pass are required, and 2) pack rolling in highly polished sandwich materials is necessary. Pack rolling consists of sandwiching the metal between sheets of a different metal or plastic before it is put through the rolls of the mill. Roll packs of stainless steel, chrome-plated steel, Kel-F, molybdenum, and even tungsten have been used for this purpose. Usually foils having a thickness variation of around 2% can be formed in this manner.

Evaporated Films

When the isotopes are not sufficiently ductile or malleable for rolling into target foils or cannot be handled in the elemental form (chlorine, for example), other techniques must be used. Outstanding success in preparing targets of these materials has been achieved by vacuum evaporation of the element or a compound of the element with subsequent condensation of the vapors on a variety of surfaces. Evaporation, as one might imagine, usually requires large quantities of material. Less than 1% efficiency in vapor condensation into thin film form results when a point evaporation source is employed. Adaptation of vacuum evaporation to the forming of isotope films was made through development of tubular evaporation crucibles heated by electron bombardment so that the vapors might be directed with high efficiency toward a small area condensing surface. Harold Adair, Frank O'Donnell, and I teamed up to develop this technique.

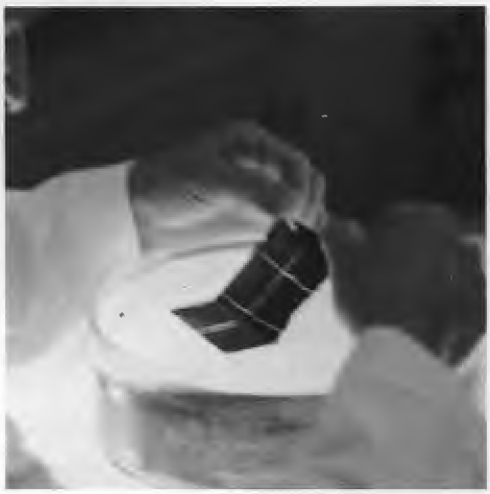
Vapor collimation is achieved by using a crucible whose internal diameter is small compared to its length. We thought that if we used a narrow cylindrical crucible whose height was about ten times its internal diameter, laminar flow (a straight line pattern parallel to the crucible axis) of vapors might be achieved for material being evaporated at the base of the crucible. Indeed this was found to be the case, with the result that we achieved evaporation-condensation efficiencies all the way from 10 to 90%.

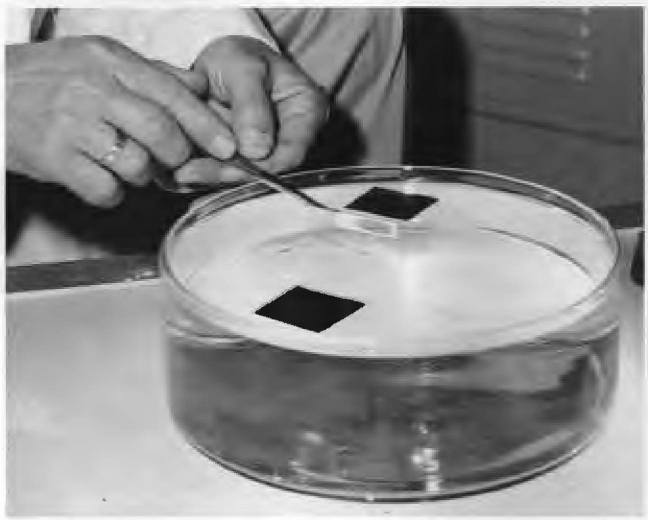
Homer Harmon holding the electron bombardment evaporation gun.

Evaporation of the elemental forms of the isotopes is ordinarily performed from tubular refractory metal crucibles. Tungsten, molybdenum, and tantalum, having very high melting points and very low vapor pressures, are most frequently used for crucible construction. Application of an electric potential of up to 1,000 volts between a hot tungsten filament and the crucible generates an electron current of almost five amperes, and can result in heating of the metallic crucibles to temperatures in excess of 3,000°C. Thermal control is easily achieved by voltage regulation. The high temperature capability of this system has made possible evaporation of almost every element in the periodic table and/or

After formation of a film by vacuum evaporation-condensation, several techniques are used to separate the film from the surface on which it is condensed. Dissolution of the substrate in an acid or base solvent is one method which has proved satisfactory provided that the dissolving medium does not attack or contaminate the film itself. Also, a soluble substrate must be found that will permit condensation of the vapors without causing discontinuities in the film. A second (and most important) technique of film stripping is the use of a water-soluble or organic-soluble intermediate film between the solid substrate and the subsequently condensed film. By immersion of this sandwich-like structure in the appropriate solvent, the intermediate layer dissolves and the condensed film floats freely on the surface of the solvent. As with substrate dissolution, there are limitations

Carl Stooksbury floating a carbon film formed by vacuum evaporation-condensation. Fifty micrograms per cm^2.





its compounds. Refractory oxides such as gadolinium oxide (vapor pressure 0.1 torr at 2,400°C) can be easily evaporated under vacuum with this apparatus. The only limitations on this process are those imposed by the crucible materials themselves and the compatibility of the material to be evaporated with the crucible. Obviously, evaporation temperatures cannot be in excess of the melting point of the crucible material, and metals or compounds which react with the crucible cannot be evaporated. However, even though this evaporation technique proved very flexible, it was not a panacea for the problems involved in preparation of thin films of all isotopes.

in this process. A soluble "parting agent" compatible with the film material and stable in a vacuum environment must be found. Most parting films are deposited by vacuum evaporation. Examples include sodium chloride, cesium iodide, and 2,5-dihydroxyquinone. Surprisingly enough, a frequently used and very satisfactory parting agent is common laboratory glassware detergent dried onto the substrate from a saturated water solution.

Vacuum evaporation-condensation methods of film preparation have proved invaluable for producing films of such nonmalleable materials as the refractory elements boron, silicon, selenium, tellurium, etc. Usually the upper thickness limit for film preparation is about 0.001 cm. However, in some cases thicknesses in excess of 0.05 cm have been produced by this method, one example being large-area foils of bismuth. The thinnest self-supporting film ever produced by vacuum evaporation condensation in our laboratory was elemental carbon with a thickness of about 50 Å (5×10^{-7} cm). Carbon films of this type, which are almost colorless and transparent, are used to strip electrons from fast-moving ionic particles in tandem Van de Graaff accelerators.

A Need for Special Equipment

Development of a wide variety of specialized hardware for use in ultra-high vacuum chambers has been a necessary corollary in the thin film program. For example, Adair has been developing an ultramicrobalance to measure the mass of film deposited during vacuum evaporation-condensation. This balance is capable of measuring a mass of up to 2.5 grams with an accuracy of 1 microgram and a precision of ±0.3 microgram. Even more remarkable is that this balance is capable of being outgassed at 450°C in the process of attaining ultra-high vacuum (10^{-10}–10^{-11} torr) without damage. The original design of this balance was developed at Euratom Laboratories' Central Bureau of Nuclear Measurements at Mol, Belgium. Adair has since made electronic improvements in this device, but the development effort is still in progress.

Other devices of more modest proportion have resulted from the effort to produce more highly uniform films. It is frequently necessary to rotate the vapor-condensing substrates and/or to cool them or heat them over a range of temperatures from 150°C to 800°C. All the associated hardware involved in performing these tasks has been or is being developed by personnel of the ITL and an engineering and craft support group under the direction of James Gibson and Ab Harrell.

Harold Adair with ultramicrobalance.

An important contribution to the improved rolling of thin metallic films is a highly sophisticated rolling mill that Gibson has recently designed and built as part of his Master's degree program in mechanical engineering. This mill permits thinner foils to be attained with thickness uniformity of around 1%. It is designed to operate in a vacuum chamber so that practically no oxidation of reactive metals can occur.

Purification of Materials

To make more isotopes available for research purposes, particularly those having high chemical reactivity and/or those whose elemental forms are difficult to achieve because of the chemical stability of their compounds, research and development efforts in high temperature chemistry are being pursued. Bill Grisham and I developed an effective and versatile technique for obtaining high purity samples of rare earth metals and alkaline earth metals. This method is known as the reduction-distillation process. Chemical reaction between a low vapor-pressure reductant metal and the oxide of a desired isotope is induced at high temperature. Subsequent exchange of oxygen from the isotope oxide to the reductant metal frees the isotope metal which is removed from the reaction mixture by simple distillation. Provided that the vapor pressure of the elemental isotope is much higher than that of other constituents of the reaction, a high purity product is achieved. As little as 15 milligrams of an isotope (as oxide) can be converted in this process with product yields as high as 95%, but usually the yield varies between 75 and 85%. Metals prepared by this process frequently contain less than 500 ppm total impurities and are ideally suited for rolling into thin foil form.

Metals distilled from the reaction zone can be condensed into thin film form as in a regular vacuum evaporation-condensation process. However, most isotope metals produced by this technique are those having high chemical reactivity and, therefore, cannot be stripped from a substrate by dissolution of a parting agent or the substrate itself. Rolling of these metals is practically the only method for producing satisfactory targets; fortunately the high purity of the distilled metals permits very thin foils (about 0.0001 cm) to be attained by rolling.

Many reactive metals prepared in target form at ITL by the method of reduction-distillation and rolling were the first samples ever prepared of sufficient purity and correct physical form for nuclear physics research. Development of preparative techniques for some rare earth metals was achieved in collaboration with S. Bjornholm of the Atomic Energy Installation of Risø, Denmark. However, extension of the reduction-distillation technique to multigram quantities and to most rare earth, alkaline earth, and alkali metals is an ITL achievement. Large quantities—as much as 60g—of distilled isotope metals have been prepared using distillation columns fabricated from tantalum metal and heated by radio frequency induction. In the base of the tantalum column, a pelletized mixture of the metal reductant and the isotope oxide is placed so that upon heating, the isotope vapors distill through a series of three or four perforated plates, each of which is cooler than the preceding plate. Impurity metals whose vapor pressures are lower than that of the product metal can be fractionally condensed on these plates and completely removed or significantly reduced in quantity.

Wm. B. Grisham with reduction-distillation equipment he designed.

Depending upon the method of condensation of metal vapors from the reduction-distillation process, polycrystals and sometimes single crystals can be prepared. Most frequently vapors are condensed on the underside of a quartz hemispherical "hat" which is hung directly over the still. The metal thus condensed is in a nearly perfect form for rolling purposes. In many cases the metal product obtained from the reduction-distillation procedure is purer

E. L. Biddle, demonstrating dry box technique for rolling foils of highly reactive materials or radioisotopes.

than that which is available from commercial suppliers. The reason for this is that the process itself is highly efficient as a purification technique and when isotopes are used, many of the impurities usually found in normal assay materials are not present; they have already been removed during isotope separation in the calutron. Combinations of calutron separations and reduction-distillations can produce materials which conform to the ultrapure metal standards required for the measurement of physical and chemical properties of an element.

Radioisotope Targets

In 1963 Hal Schmitt of the Physics Division approached John Gillette with the request that we fabricate radioisotope targets, specifically from the heavy fissile isotopes to implement the study of fission process kinetics as well as nuclear structure. The major problem involved in target fabrications with these materials was the handling of these highly toxic isotopes. As a result of this meeting, Gillette and Rupp secured additional space and obtained funding for a radioisotope target facility.

The first targets produced in this new program were thin films of $^{239}PuO_2$. The oxide was evaporated from a tubular crucible in vacuum, as described above; the vacuum chamber was contained in a glove box which, in turn, was contained within a chemical hood, the face of which was closed. Each containment zone was maintained at subatmospheric pressures to protect against accidental dispersion of the isotope. Since the targets were to be put to a use similar to that of the self-supported films of stable isotopes, it was necessary to condense the plutonium oxide on very thin carbon substrates, the composite film being no thicker than 0.00002 cm. Eventual success of this venture encouraged us to expand this technology, and over the following five years many of the facilities used in the processing of stable isotopes were duplicated in glove box enclosures for the preparation of radioisotope targets.

At the present level of technology, foils of fissile element metals and other heavy elements have been cold-rolled as thin as 0.00005 cm. Reactivity of these materials demands that an inert atmosphere be used during the rolling process to protect the metals from oxidation. By this method, the uranium and plutonium metal foils produced by ITL personnel represent the thinnest ever achieved (0.0001 cm).

Manipulations with radioisotopes are considerably more difficult, hazardous, and time consuming than those involved with the stable materials, for obvious reasons. Operations of vacuum chambers, rolling mills, and other equipment become more complex under the shielding conditions required for personnel protection.

Today preparation of radioisotope targets is not limited to the heavy elements, but includes the processing of beta-gamma emitting isotopes. Application of the reduction-distillation technique to the preparation of radioisotope metals has been highly successful. An example of this application was preparation of pure europium metal containing 34.5% ^{152}Eu. The total activity of ^{152}Eu was about 3,000 curies and thus all operations had to be carried out in a hot cell with manipulators. A Plexiglas enclosure within the cell and through which the manipulators penetrated was needed to maintain a protective argon atmosphere. The vacuum chamber, radio-frequency-heated reactor and still, and rolling mill were all enclosed in such boxes within two separate cells. With this equipment much of the distillation process was carried out without clear observation since the vacuum chamber glass was blackened by radiation damage within a few minutes after reduction-distillation was begun. The final target was an 8-gram metal ellipse formed by cold rolling the distilled europium and was the first known preparation of ^{152}Eu metal. This target was used in conjunction with an underground detonation of a nuclear device in March 1968. This experiment permitted the total energy spectrum of neutrons from the device to be used during bombardment of the target. In this manner the total neutron cross-section of the isotope was determined. In the near future a second such target may be prepared for similar purposes.

One of the most important and earliest aspects of this phase of our work has been the preparation of tritium (^{3}H) targets used to generate monoenergetic neutrons. Tritium is the lightest of all radioisotopes and is gaseous by nature. From a radiation point of view it is relatively innocuous, but because of its rapid absorption and diffusion in body tissue, it can be a hazard. Tritium targets have been prepared for more than ten years by ITL. In 1964 John Auxier and Fred Haywood of the Health Physics Division requested our services in producing a target containing tritium that could generate 10^{13} n/sec for a period of four hours under constant bombardment by deuterons. This is a common technique for producing 14.3-MeV neutrons, but the desired neutron yield was nearly two orders of magnitude greater than any yield previously reported by this method.

Development efforts over a period of four years resulted in the successful preparation of targets having an active area of 1,000 cm^2, weighing 18 kg, and containing about 2,000 curies of tritium gas. The technique for producing such a target was to coat a copper substrate with erbium metal and sorb into this reactive surface the tritium gas at an elevated temperature. The maximum neutron yield achieved using these targets was about 3×10^{13} n/sec. To generate such a neutron yield, bombardment by 75 watts of deuteron beam power on every square centimeter of target surface was required; had the targets not been water-cooled by flowing many gallons of water per minute behind the thin copper substrate, the entire target would have melted down during the process.

Frank O'Donnell at the plasma zone refiner, which makes single crystals of refractory oxides.

Future Developments

The various techniques of purification, evaporation, distillation, rolling, and other processing methods developed for use in fabrication of isotope targets can be and have been applied to the preparation of ultrapure materials, single crystals, and other physical forms frequently used in solid state physics. Over the past two years, extrapolations from target fabrication to preparation of high purity research materials have occurred with increasing frequency. Techniques such as vacuum zone refining by electron bombardment heating, plasma heating, and radio-frequency heating have all been used to purify and grow single crystals of some isotopes and their compounds. Research and development efforts in this area are now under way.

Research in the kinetics of thin film growth by vapor phase condensation is being carried out by David Braski using a special, ultrahigh-vacuum electron microscope. This instrument was developed by modifying a commercial Hitachi microscope so

David Braski at the electron microscope, with which crystal growth can be monitored.

that evaporation-condensation forming of films could be observed directly and movement of crystallites (epitaxial motion) on the substrate surface could be monitored by transmission microscopy. We believe that parameters affecting the formation of structurally strong films can be determined by this technique. In the process of these investigations, magnification of a million diameters can be attained. We have obtained motion pictures of the formation of a film during vapor condensation; information gained from such studies of film growth can be used to determine the appropriate vapor-condensing conditions needed to grow single-crystal films having a specific orientation. Some single-crystal films of gold and silver metals have already been produced. The purpose of present and future research efforts in this area is to produce such films of the refractory and rare earth metals with pre-specified crystal orientations.

Development of bulk single-crystal growing techniques and isotope purification methods by high temperature chemistry is a relatively new aspect of the target function and is expected to grow in importance within the next few years. Certainly total success has not been achieved in the preparation of all targets needed in research; as a matter of fact, some specific elements have yet to be prepared in target form and development efforts in these areas must continue. At present, much of the technology involved in research material preparations seems to be something of a "black art," but use of electron microscopy, x-ray diffraction, and other techniques should remove some of this magical aura in the next few years.

Since my association with the ITL, it has become clear to me that the service and developmental functions I have described are of importance not only to the USAEC research community but also to research efforts on an international basis. During 1961 the total effort of the ITL resulted in the preparation of 30 or 40 individual samples. Today our production has grown to about 300 samples per month, and the complexity of specifications for each sample has increased significantly. This effort now requires a personnel complement of seven technical people, seven technicians, and a corresponding number of engineering and craft support personnel.

It is gratifying to know that samples produced by the ITL have been used in more than a hundred universities, at all the national laboratories, in 20 foreign countries, and more than 50 additional research organizations not thus classified. This wide acceptance is a tribute to the combined effort of personnel in some half-dozen other divisions at ORNL: Solid State, Analytical Chemistry, Metals and Ceramics, Plant and Equipment, Physics, General Engineering, and Chemistry Divisions. Work of this kind is possible only within a large, superbly-equipped, multi-disciplined laboratory such as ORNL.

BOOKS

By Alex Zucker

The Biological Time Bomb, by Gordon Rattray Taylor. World Publishing Company, New York (1968). 231 pages + index, $5.50.

THIS BOOK IS SENSATIONAL JOURNALISM AT ITS BEST. Gordon Rattray Taylor is an English popularizer of science who in this book takes the whole of modern biology as his subject. He bombards us with new developments of great variety; the spirit of the book is, "Did you know that Professor X has just performed the miraculous experiment Y, and that the consequences for humankind are awesome indeed?" Taylor's concern for the future of the race is the thread that binds the book into a logical whole, and the conclusion seems to be that man may survive the cataclysmic consequences of the new biology, but life in a hundred years will be completely different from what we now have. This should not surprise us. The last hundred years have seen a more drastic change in the quality of life than the 5,000 years that preceded it, and most of that change is a direct consequence of developments in the physical sciences. Taylor contends that the next change will be due to the biological discoveries now being made, and that life will be changed in a highly intimate way, of immediate concern to every individual.

I will just briefly describe some of the possibilities. Take clone breeding, for example. J. B. Gurdon of Oxford University has taken the nucleus of an intestinal cell of a frog and implanted it in an unfertilized frog's egg, whose nucleus has previously been destroyed by radiation. The egg with its cuckoo nucleus was found to develop normally and has in some cases grown into a tadpole and subsequently into a normal adult frog, genetically identical to the intestine. Now a frog lends itself to this process relatively easily. The egg is large and develops outside the body. No similar experiment has yet succeeded for mammals, but at least some of the ingredients are available now. Sheep's eggs have been kept alive in low temperature storage for up to 72 hours. Cows injected with the proper hormone can be made to produce as many as 40 eggs at a time. These are then fertilized in the usual fashion, removed from the parent cow, and each is injected into the uterus of another cow. In this way it is possible to breed a champion bull and cow to produce many times the normal number of potential prize cattle. It is a matter of perfecting a technique that keeps us from breeding mammals in clones right now. The next 50 years may well see developments which will produce clones of humans, in utero, or perhaps in artificial placentas. The rest is up to one's imagination. A successful race horse, an exceptional fullback, or an inspired composer could then be biologically Xeroxed in as many copies as we desire. It is possible to imagine nine Ted Williamses on a baseball team, or a 30-man physics department composed entirely of a clone of T. D. Lees.

Before I continue to divulge the other wonders Taylor has in store for us, I want to pause and examine the prospect of clone production more closely.

This issue of the *Review* introduces a book review section. Alex Zucker, associate director of the Electronuclear Division, has written book reviews for *Physics Today* and *The Nation*, and honors the *Review* by consenting to take charge of its Books column.

The first reaction is revulsion. After all we are each an individual, all our traditions teach us that this individuality is to be nurtured and prized above all else. Just because we are different from everyone else, we are valued for ourselves alone. If I were married to one of 40 editions of the same woman, it would take a great deal to convince her that I love her for herself alone, and that the other 39 of her clone leave me cold. And possibly they would not leave me altogether cold. On the other hand, cloning is a form of immortality. If your genetic material survives intact, is death of the somatic exostructure a calamity? Many people now feel that they survive in their children; how much more desirable would it be to be immortalized in one's clone? And this raises the immediate question—who gets cloned? Are there competitive examinations, review boards, fixed criteria, or supercomputers to select the immortals?

We see from this one example that biological discoveries raise profound questions in the social sphere. There are legal, ethical, and sociological aspects in such developments that are far more urgent than similar questions raised by discoveries in the physical sciences. And what makes the matter so serious is that the new biological discoveries are nearly upon us, perhaps two or three generations away, and that we are not even making any moves to cope with them. The biological time bomb is ticking, Taylor would say, and we continue to sit blithely on top of it.

There are some exceptions to this generalization; not everyone is phlegmatic. Gerald Feinberg has recently written a book, "Prometheus," in which he advocates that people start thinking now about setting up international juries to deal with the immense social questions involved in attempts to improve the human race. There seems to be no question but that we will soon be able to engineer improvements in man himself, yet Feinberg's book has met with an astonishing amount of apathy and antagonism, and only sporadic applause. Certainly he has not yet moved mankind to any concrete action. Society faces future problems only reluctantly, first because current problems are pressing in on all sides, and second because so many problems envisaged for the future never really materialize.

Taylor has a little list. In the immediate future, say the next 20 years, he sees the following developments in human biology and medicine:

1. Transplantation of organs and perhaps limbs.
2. Tampering with the procreative processes. This includes, besides birth control, the manipulation of sperm-egg combinations such as test-tube fertilization of ova, choice of sex, etc.
3. Ability to postpone clinical death. Here we deal with the evergrowing capability of medical science to keep a moribund person from crossing the bar. The question is raised: How much effort is to be expended to keep any one person alive, when it is clear that death is only being kept at bay and recovery is impossible? Are some people worth a greater effort than others? I am sure that the medical *tour de force* marshalled by Soviet medicine to keep Nobel Prize winning physicist L. Landau alive after a car accident is not routinely available to Ukranian peasants.
4. Drugs that modify the mind. One learns a great deal about mind expanding properties of halucinogens in connection with the current drug problem. It seems possible that drugs will be developed to enhance intelligence, to regulate such emotions as aggressive behavior in criminals, and perhaps to erase significant parts of an individual's memory. For those who recoil from this kind of possibility Taylor provides reassurance in the form of a quotation by J. O. Cole, Chief, Psychopharmacology Service Center, NIH:

"I consider it unlikely that current methods can be used to develop a new drug with any specific and reliable effect on either the freedom or the control of human mental processes, although I confidently expect that new types of drugs with different effects on brain functioning and behavior will be uncovered by present drugs development methods. . . . The difficulties appear to be well-nigh insurmountable."

—Still, the possibility remains, and if not in twenty years, then in a hundred and twenty, man will be able to tinker with brain functions.

5. How long will it be before man can create life? In a sense this has already been accomplished in 1965 by Spiegelman at the University of Illinois, who put together non-living nucleic acids to produce a virus which could go on and multiply indefinitely. The crucial step in this line of development is the ability to design viruses to our specifications. These can then in principle modify the DNA of the host organism and thus lead to genetically new species.

Further in the future, but definitely possible in a generation or two are:

1. More precise methods for control of the brain including extensive mind modification, enhancement of intelligence in man as well as animals, memory editing.

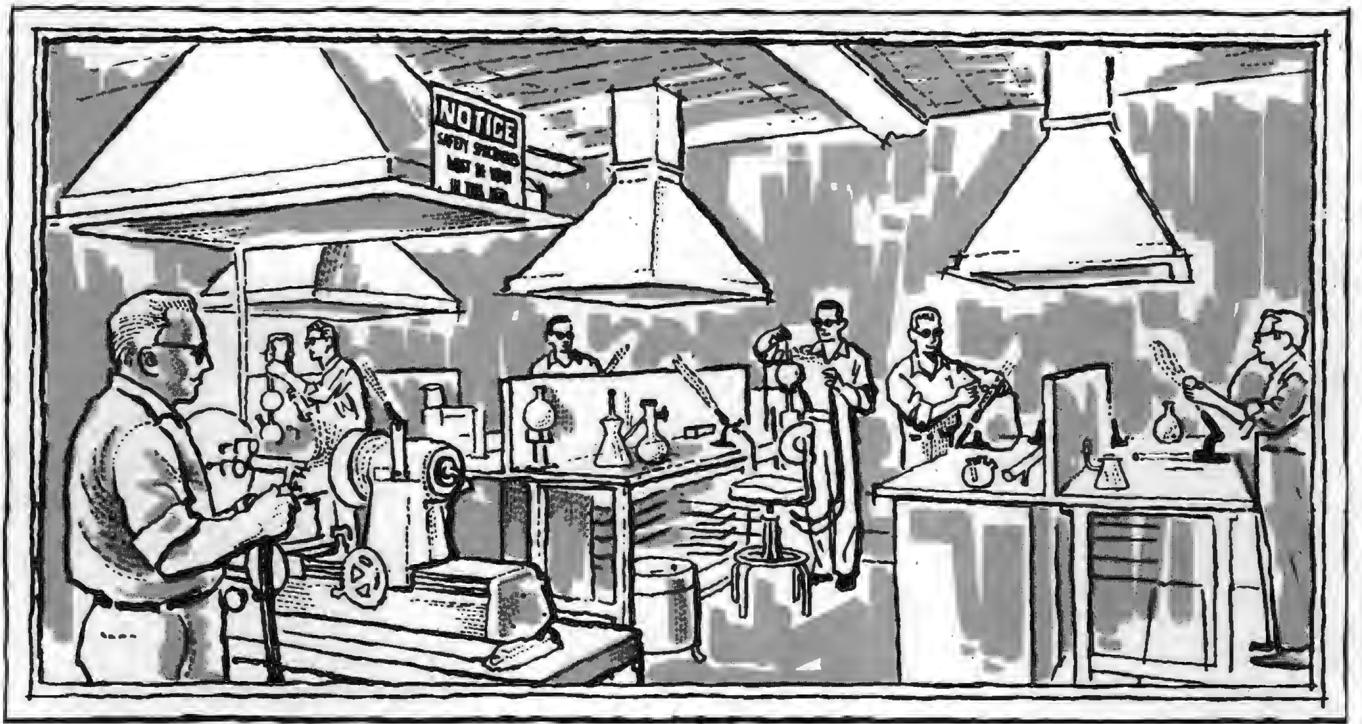
2. Extension of life. This is a broad category that deals with the possibility of induced hibernation or prolonged coma, where for example an incurably sick person is put to sleep until a cure is developed for his disease, when he is revived, cured, and presumably presented with such a whopping bill that he will drop dead on the spot. Along similar lines Taylor predicts real prolongation of life, which means an extended span of youthful vigor physically and mentally. In the next few generations a start will be made on organ regeneration in humans, and the development of cloned mammals.

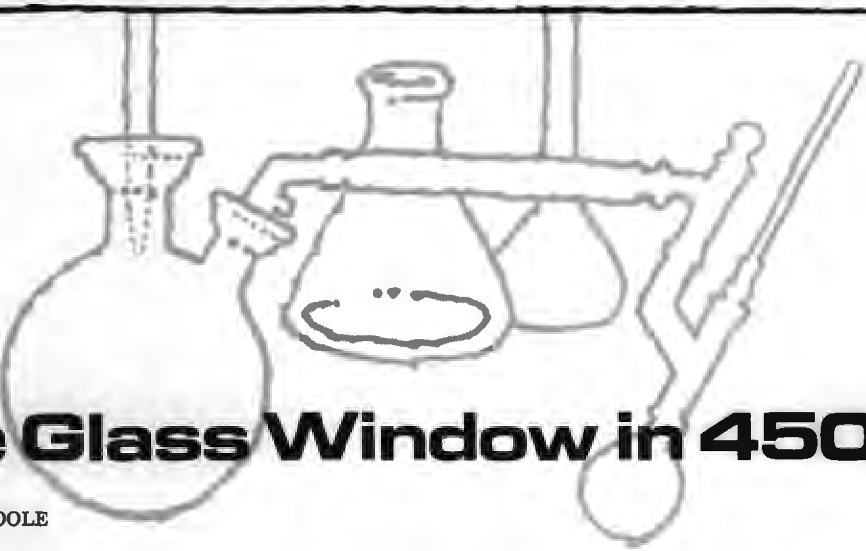
Beyond the two-generation limit lies pure speculation. But Taylor likes to speculate and he predicts such diverse inventions as disembodied brains, synthesis of complex living systems, gene insertion and deletion, brain links with other brains, with computers or directly with machines. Predictions over a long time span evidently lead to the land of science fiction, mainly because they cannot foresee completely new developments which then deflect science into completely unexpected paths.

It is easy to ridicule Taylor's time bomb. Most of the things he foresees in the next few years won't come to pass. The economics of some processes are clearly prohibitive and likely to remain so for the next few generations. The road from knowing something in principle to perfected engineering practice is long and rocky. Many things never make it, viz., the transmission of power by radio waves. But to judge the book as a try at revealed prophecy would be to miss the point. Taylor's time bomb is ticking if only a fraction of the biomedical inventions is perfected. It is ticking even if he has erred by a factor of three and the things he predicts by the year 2000 don't come to pass until the year 2050. After all, our children's children will be alive in 2050, and the decisions we make, or more importantly the decisions we fail to make now, will crucially affect their lives. His point is that the time bomb is ticking and mankind blithely ignores it. The moral questions, the legal questions, the immense social consequences if even a few of his predictions come true are staggering. And where are we now? In the gaslight age so far as the relationship between science and society is concerned. At the moment it seems to be impossible to decide whether a child born as a result of artificial insemination is legitimate or not. With the legal profession thus foundering in the shallows, what will happen when the heirs of a man who died of coronary failure sue a large hospital for $1,000,000 because a new heart was not transplanted in time. Soon life-extending methods will be practical. Youthful vigor may last to the 120th year. What are the consequences to our labor market? Yet another question is raised when we contemplate tinkering with brain functions. What happens if everybody's IQ can be raised to 150 by artificial means? Who decides to go ahead, and what kind of a world do we create this way?

The point is that biomedical research is progressing at an ever accelerating pace. If we are unprepared for the impact which is sure to come, there is the danger that a complete moratorium on science will seem like the only answer by a bewildered electorate. On the other hand, it is possible that democratic institutions cannot survive in a world where elites can be created at will, and where they can maintain themselves indefinitely by preempting the benefits of science for themselves, and keeping the majority of people in thrall by workable methods developed by the scientists in their employ.

The explosion in the physical sciences we have witnessed in the past 100 years has changed the world, the explosion in the biological sciences threatens to change man himself. Should we not now take notice?





The Glass Window in 4500

By R. W. Poole

The three ORNL glass shops comprise the largest group of science-oriented glassblowers in the Southeast. In them, 12 glassblowers work full time on the projects of every research and operations division in ORNL and Y-12. In addition, they routinely service the glassblowing requirements of Oak Ridge Associated Universities and UT-AEC farms as well as providing nominal assistance to Oak Ridge Gaseous Diffusion Plant, Paducah, and others. The equipment in these shops is the finest available and is used, although only as assisting devices, for the fabrication of jobs ranging in size from .001-in capillaries to 9-in glass pipes and even larger carboys.

Development of new or adaptation of old techniques works to the continuing advantage of all glass shop customers. Where technology cannot answer, innovation takes over. One seldom hears the phrase, "It can't be done;" instead, every request carries its challenge, to be met with maximum cus-

Dick Poole, chief glassblower for the Laboratory, recounts here an anecdotal history of glassblowing in Oak Ridge, a story in which he has taken active part since his arrival from General Electric Laboratories in the early fifties. He is also prominent on the national glassblowing scene, having served a term as president of the American Scientific Glassblowers Society. Among the other offices he has held in the Society are those of regional director, member of the board of directors, by-laws chairman, membership chairman and secretary. He is shown here giving a few pointers to Phyllis Hazzard, ORNL's lady glassblower. Like Poole himself, the accompanying article betrays a laconic devotion to the art of glassblowing.

tomer satisfaction at minimum cost. Whenever a customer supplies a design which can be altered to produce the same result in less time at less cost, we submit the alternative design for his consideration. But only if he thoroughly agrees and approves are any changes made to his design. Any such time and dollar savings accrue to the better interests of all other customers at the same time, since they serve to reduce the shop work backlog which means that all jobs are completed sooner.

Working from basic tube and rod stocks and from readily available other forms of so-called "soft" glass, borosilicate, and fused silica, our glassblowers heat, bend, blow, stretch and compress configurations singly and in combination to form some of the most complex of apparatus. No other material combines all the properties of glass at such a low cost of fabrication. The low material costs plus the speed, versatility and ingenuity of the ORNL glassblowers combine to give glassware users here an unbeatable bargain. Consider that glasses are resistant to chemical attack, thermally and mechanically strong within acceptable limits, allow visual monitoring of internal processes, lend themselves to ease of fabrication, and are cheap initially, and you have a bargain. Most of the chemical processes which have been developed at ORNL or anywhere else have been carried out within glass during bench and pilot plant studies.

In many outside operations the one person linking the hopeful investigator to the experimental equipment he requires is a competent glassblower. Fortunately for our researchers at ORNL, our glassblowers are imbued with ambition, interest and dedication. "Is this dimensional tolerance important?" "Is this geometry really needed?" "What can I do to help you?"—these are the sorts of questions ORNL glassblowers ask, and are the questions which indicate that all is well within the operation. Glassblowers at ORNL are, like all of us, paid in coin. But they also receive a payday every time that the part they made with their flame, breath, craftsmanship, sweat and tears is used and made to work for science to the better interests of us all.

Glassblowing has been interesting for a couple of thousand years. And it has been interesting at ORNL since the beginning of the Laboratory itself. When the Chemistry Division was located in old

706-A Building, the Technical Division in 706-C, and Physics was in 706-B up on the hill, there were three glass shops, one in each of those buildings. Eventually, the shops in the Technical and Physics Divisions were phased out. The remaining shop in Chemistry wasn't much of a shop by present day standards, but it got the job done—with the assistance of just about every technician, scientist and engineer who needed glassware. Many of them simply set up a torch in their own labs and set about making what they needed. And there are some doing just that to this day.

From the time of his arrival at the laboratory in 1945, Ellison Taylor, present director of the Chemistry Division, took an active interest in the glass shop, which was at that time under the jurisdiction of the Division.

Art Rupp was here in 1943 and remembers that there was the shop in 706-A, though he used nearly all stock items in his work here at that time. And although he doesn't remember much about the first glassblowers at the Laboratory, he does remember some of the people he worked with in the early forties—names like George Moore, Ernie Wollan, Don Ferguson, Dick Fox, George Parker, John Loy and Willis Baldwin, among others. And from them I have picked up some stories.

George Moore recalls that the DuPont personnel head at that time was Rupert Wentworth and that Rupert, with a youngster of his, attended a carnival in Clinton at which one of the attractions was a glassblowing show. The concession was run by a man and his wife, Robert and Marie Howell, members of the large, nationally famous glassblowing family. Rupert wasted no time hiring the couple, and they came to work in 706-A in March, 1945. By August they had discovered that scientific glassblowing lacks much of the color of show business, and moved on to a more glamorous environment.

At one time or another the Army had Special Engineering Detachment men sent in as glassblowers. One SED man was Ray Ballard who worked in 706-C, followed there by Jimmy Margiotti. Andy Machek came in under SED a month before the Howells left and went into the 706-A shop. Andy was here for quite a spell. Tony Zurek (SED) who had earlier experience with Podbelniak in Chicago came in '46 as did Bob Myrick, a civilian. Bob recalls that he had been out of the merchant marine for some time and was working at Post Sign Company in Knoxville as a sign bender. He and some of his co-workers there decided to change jobs one day and walked over to the Monsanto office where they applied for work as glassblowers in Oak Ridge. The next day Bob got a call from Ray Cook, who was in Monsanto's employment office, asking when he could come to work. He's still here.

Ralph Livingston says he did most of his own glassblowing when he first came here in 1945, including a couple of vacuum systems. Ralph became concerned with the lack of instrument makers assigned to purely research activities in those days and began a little agitation which resulted in Dave Holcomb being brought in from the Navy Department; Dave was later put in charge of glassblowing, among his other duties. Ralph was appointed to a select committee along with Ernie Wollan and others to study the needs for shops. The result of this study was a Research Shops Department set up in 1945 by Paul Kofmehl and Earl Longendorfer, who came to ORNL for this purpose. It was the beginning of the present Fabrication Department shops in the Plant and Equipment Division.

Kofmehl and Longendorfer started their new program with special attention to machinists and instrument makers, but it soon became apparent that there was a problem in glassblowing services as well. Expansion was called for in glass shop space, equipment and personnel. The first two were found easily enough, and the personnel shortage was tackled by bringing in Ernest Steed from Y-12, Fred Rustenbach from Oklahoma, and Reginald Hurley from Edgewood Arsenal. Fred was made Chief Glassblower a year later. He hired Hector Meneses from Podbelniak and two trainees, Howard Epperson and Lester Norman. This six-man crew sufficed pretty well through early 1952, when Fred, Hector and Ernie left.

The glass shop at that time was located at the street end of the old Chemistry Division "P" Shop (Machine Shop) in 3550 and was but minimally equipped. Improvisation was the order of the day. George Parker, who was then in the Technical Division, had some particularly difficult and challenging requirements. He had special need for some 25-, 30- and 50-liter spherical glass containers which he ordered from commercial outlets. To these globes it was the shop's task to add a number of

side arms, ground joints, and other specific amenities. The shop had no lathe big enough to swing the flasks, so Fred Rustenbach and the rest of the fellows would gather around and literally gang up on the job. First they'd set the flask in the open end of a trash barrel which was placed in the middle of the floor. Everyone would light a hand torch and gently begin to heat the entire upper surface of the flask. Then, as the other members of the team kept things hot, each man would take a turn at sealing on an appurtenant tube or joint. After a final heating by the task force, the flask was gingerly transported to the annealing oven for stress relief.

At about this time the Physics Division began pushing for the fabrication and chemical silvering of special Dewar flasks (vacuum bottles). Louis Roberts was the big user of this service. The men in the shop read up on silvering and evacuation processes and flung themselves into it. For some reason, Paul Kofmehl decided that the actual chemical silvering of the glassware should be carried on by instrument makers, rather than the glassblowers. He was at that time Superintendent of Research Shops of the Engineering and Mechanics Division, and his office was near the instrument makers in 3024 Building. He was a natty dresser, which may be why he eventually reversed his decision on who should do the silvering. One day he walked out of his office and into the area where his instrument makers were preparing to silver a glass Dewar flask. Just as he passed by, the silvering solution exploded, showering his clothes, a new suit, with cloth-destroying chemicals. Soon after that the glassblowers got the silvering work back again. We've still got it.

Don Ferguson came into the Technical Division in 1946 when he went to work on the bismuth-phosphate pilot plant and was later involved with the Redox and Purex processes. Don remembers the informality of the glass shop operations then, when a researcher could simply take himself over to the shop, collar a glassblower, sit down and jointly draw up the required apparatus. If it was a simple job, the researcher would just check a bin kept inside the glass shop door in a day or two to see if his job was finished and waiting for him.

Chemical Technology Division had a need for

some very precise perforated plate columns in that period and ingenuity played a good part in the fabrication of them, too. In order to achieve the required precision, the glassblower would take a piece of pyrex glass pipe and grind it out to the specified inside diameter. This was a hand operation which was carried out with a brass node affixed to the end of a long steel handle of smaller diameter. Since the pipe was usually at least four feet long by about one inch diameter, and since grinding had to be done all from one end, the glassblower was handling about eight feet of stock. By applying a grinding grain slurry and rotating the tool through the pipe, he could get a very precise ID. Meanwhile, Dave Holcomb's machinists would prepare a series of perforated steel discs with a diameter the same as the ground ID of the glass pipe, "string" them on a steel rod like so many beads, and the fun would begin. In order to put a one-inch-diameter plate column inside the one-inch-diameter pipe it was necessary to chill the plates and heat the pipe, both to proper temperatures, then quickly slide the two together. The pipe was put in an oven (or sometimes, on summer days, just laid out in the Tennessee sun) and the plate rods were put into a long box of dry ice. At the critical moment the two were put together and the chilled plates inserted down the warm glass pipe. This worked fine as long as everything was maintained in good alignment, but if

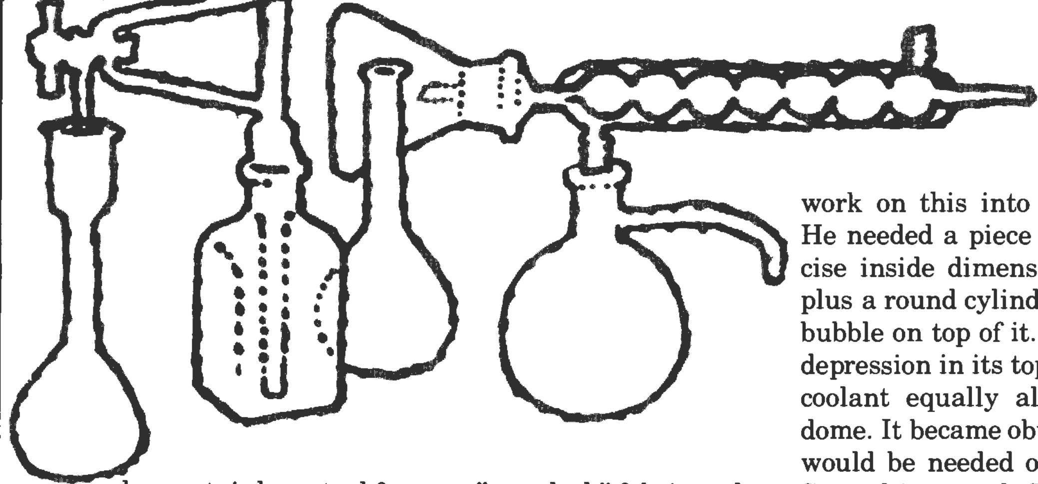
just one plate leaned slightly off the perpendicular, its thickness was enough to cause it to bind. Now the struggle was joined: get it unstuck and insertion finished, or get it unstuck and withdraw the plates. Too many times the pipe had by then cooled down or the plates warmed up enough so they wouldn't come unstuck, the glass would compress on the plates too tightly and the pipe would break. Back to grinding another piece of pipe.

In late 1951, Y-12 was looking for glassblowers, and they sent Ed Greeley, head of their glass shop, on interview trips to known glassblowing centers. At that time I was employed by General Electric in Schenectady, Ed's old stomping ground. That year he showed up there and persuaded two research glassblowers to move down to Y-12 in 1952. Later I was interested in a change, and wound up at ORNL that October, shortly after Matt Nesbit, who came from RCA in March. When Tony Zurek left to join Chemstrand in 1953, I was assigned to the Biology shop at Y-12, where I spent four and one-half good years. Work in the Biology shop is like no other. The glassblower has very intimate contact with the customer, finds himself getting involved in the details of the project, and is generally made to feel a part of the Biology "family."

In January of 1952, the ORNL main shop was moved from 3550 into the new 4500 Building. The atmosphere there remained informal, with the men in the shop pretty much taking care of the technical details themselves. By 1958 Earl Longendorfer had made a firm decision to head up the shop again with a Chief Glassblower and picked me. In February I returned to X-10 from Biology, where Howard Epperson replaced me.

P. B. Orr, now with Chem Tech, but then with Isotopes Division, was separating phosphorus-32 from elemental sulphur during this period and he collected the product in a heavy glass test tube about five inches ID by about three feet long. In order for him to remove the solidified block of residual sulphur from the test tube and re-use the tube it was necessary that the tube be made to taper out slightly toward the open end. To do this, we had

E. R. Mellon administers a finishing touch.



a large stainless steel form, or "mandrel," fabricated to the necessary dimensions, highly polished, and inserted in the prepared cylindrical glass tube. Once the ends were suitably formed, the whole rig was transported to the Y-12 foundry, where there was an oven large enough to accommodate it. There the glassblowers would attach external vacuum pumps and increase the heat in a programmed sequence. The glass tube would shrink to the mandrel, be cooled, and then be returned to ORNL, where the mandrel was removed from the tube and the tube finished and annealed. It was a whale of a job!

Quite a few heavy challenges came through the shop in those days. John Dabbs and Louis Roberts of Physics Division came up with a special requirement for an integrated set of double helium-nitrogen Dewars that would try the patience of a saint. They wanted the largest possible liquid helium and nitrogen reservoir volumes, but with the four-inch-long working end to have an OD of no more than 16 mm and an ID of no less than 10 mm. Within this space there had to be four concentric tubes, each four inches long, sealed one within the other and yet free of contact, strong enough to withstand partial pressure of 10^{-6} torr, yet with very thin walls. Lester Norman did a fine job on it and then went on to silver coat the Dewars with a clear viewing strip left on. The tip tubes were all hand drawn to specific diameters.

Through this period the glass shop was adding to its staff in order to handle the heavier work load. We hired O. J. Kingsbury, who has since left, and, pleased with our success in training Mellon, Norman and Epperson, we got Paul Hatmaker, Bill Vermillion and Gilbert McKinney in as trainees. Our optimism proved to be justified.

Not all our bright ideas turned out successfully; occasionally we would stub a toe. In the early 1960's an engineer from the Reactor Division wanted a transparent model of a reactor which would allow him to study the characteristics of coolant flow around the fuel rods. He hedged his bet by putting work on this into both the Y-12 and X-10 shops. He needed a piece of hexagonal tubing of very precise inside dimensions to contain the model rods, plus a round cylinder with an expanded dome like a bubble on top of it. The dome was to have a conical depression in its top in order to divert the upflowing coolant equally along the inside surfaces of the dome. It became obvious to us that a carbon mandrel would be needed on which to form the dome. The Special Materials Machine Shop turned out a magnificent carbon form, exact in dimension to the specifications of the prints and with allowance for the calculated heat expansion of the carbon. In the meantime, the Y-12 shop was working on the hex tube, a job they whipped by drawing a tapered hexagonal mandrel through a five-inch, medium-wall, pyrex tube of the type used on blueprint machines. The result was perfect. On the other hand, the intense heat needed for our forming process caused the glass to devitrify, a change which destroys its transparency, and this turn of events effectively killed our job. At about that time the customer relaxed his requirements, and the Y-12 shop finished up a dome by normal glassworking technique. Win some, lose some!

The early days of the transuranium separation project in Chem Tech caused a few headaches for Elder Mellon and Lester Norman. All of the glassware that was produced for that project, called Truex, was done by these two men, and they held up nobly under the disappointments of breakage and the strain of specification. Whenever several parts are required as spares for in-cell operations, they must be exact duplicates of the part they may replace. In this age, when precision of fabrication is taken as a matter of course, the bench glassblower is somewhat beleaguered by such requirements, since his is primarily an art in use of the eye, the hand and the flame, and also because glass grows and shrinks considerably and with varying predictability as its temperature changes. Many of the parts in Truex were mounted on rigid aluminum racks from which stopcocks and other parts were further held in place within aluminum cups, which were filled with epoxy cement around the stopcocks. This kept them from breaking when the taps were turned on and off by slave fingers. Elder and Lester were on this job for the better part of a year, never worked a bit of overtime on it, and met all schedules required.

In 1961 it was decided that the shop required enlargement in order to improve the quality of its services as well as meet the greater work load coming in, and to handle the more diverse types of work being requested. The expansion took in part of the chemistry machine shop and extended into space previously occupied by parts of the Analytical Chemistry Division. With this expansion the ORNL glass shop became the largest in the Southeast: in floor space, in machinery, and in manpower. At about this time Bill Ellenburg joined us from Y-12 and K-25.

In the process of remodeling, we gained a new picture window into the corridor which, as rumor has it, was Lab Director Weinberg's idea. Whoever's idea, it serves well as a physical barrier to invasion by mere spectators, yet allows full visibility to them from the hall. During several Open House ceremonies here it has provided the perfect buffer for crowd control and safety while affording maximum satisfaction to the visitors' curiosity and interest in the shop's operations. Visitor comment seems always to be about the same, the most commonly heard remark being, "Golly, that looks like interesting work!"

When the ORNL Fabrication Department accepted control of the Y-12 glass shop early in 1963, we proceeded with plans to integrate the two shops. We had as our purpose increasing the service possible to both plants. With this shift we gained Ed Greeley, Jim Kerns and Dave Creigh. This has allowed manpower exchanges when needed to meet the fluctuating demands of the two plants, and also helps to keep all of our glassblowers up to date in the different technologies required to satisfy the widely differing requests that come in.

Along in late 1965, I happened to learn the Oak Ridge Associated Universities (then ORINS) was conducting a study on skilled manpower needs in the Southeast under the auspices of the Department of Health, Education and Welfare. Wendell Russell at ORAU was the man in charge, and I called him one day. It seemed that Wendell had come up with some facts that showed there was a serious shortage of certain skilled workers in the area, including glassblowers. He asked if I would be interested in getting a glassblowing course together for them. I agreed, subject to the Laboratory's ok. At the same time, the Board of Directors of the American Scientific Glassblowers Society authorized me to cooperate with ORAU in any manner needed to set up a curriculum in glassblowing. Earl Longendorfer obtained the necessary tentative approvals for Laboratory participation and we took off. By this time the Office of Economic Opportunity under HEW had set up the needed funds and apparatus for its Training and Technology (TAT) program, under the combined auspices of OEO, University of Tennessee, ORAU, AEC, and Y-12, where the school was to be located. We trained people who were between 18 and 40 years of age, and ninety weeks later we had graduated 26 glassblower trainees, many of them women, who were snapped up by glassblower employers. These men and women are now well on their way in a useful career that promises them a good possibility for continued, above average income. Winford Spangler, son of Ott Spangler in Chem Stores, was one such trainee. He joined us in late 1967 and is now in our Y-12 shop. Ed Greeley and Bill Vermillion participated fully in this teaching program. I consider it one of the most fulfilling jobs I've ever had.

Glasswork at the Y-12, Biology, and ORNL shops differs greatly in type. Our Y-12 shop has always had to deal more with large forms and repetitive work simply because of the customers it serves. Ed Greeley and the others in our Y-12 shop have always shown an inventiveness and willingness helpful to our customers. They are expert in the fabrication of square and rectangular plate glass boxes, something any glassblower will tell you is tricky business. Their developments in swaging and die drawing techniques have been adopted in all of our shops. Biology tends to the smaller, more delicate jobs, and with constant revisions, since all of the work is experimental, although there may be some repetitive work when a design is finally tied down as applicable to a general type of experiment. Glassware conceived and fabricated in the Biology Division has, on occasion, found universal appeal. Biologist Jack von Borstel came up with two ideas—one for a wasp anesthetizer and another for a cover slip holder, both of which have been widely copied. In fact, the anesthetizer is now commercially available. Norman Anderson, an enormously prolific idea man, designed for his MAN Program the first centrifuge tube ever to have a wall taper parallel to the lines of centrifugence, resulting in very sharp and straight gradient lines within the tube. He and his group were later to come up with the beautifully simple liquid gradient device which sharply reduced costs for such equipment.

At ORNL itself we find subtle changes in work needs through the years. More and more of our fabrications are of fused silica now that ultraviolet and high temperature effects are coming under

E. J. Greeley, head of the Y-12 Glass Shop, in a planning session with W. G. Pollard, director of Oak Ridge Associated Universities, and Wendell Russell, director of Training and Technology program (l. to r.).

closer study. In fact, most of the time fused silica work constitutes about 30% of our work load. As they become available in constantly better qualities the porcelains, mullites and aluminas are being used more as integral parts of glassy fabrications. Techniques for these seals are now well established. Metal-to-glass seals are available as relatively cheap commercial items, but we still fabricate specially sized seals and also stainless steel-to-glass seals.

GLASSBLOWER AVAILABLE
FOR CONSULTATION 8:00 AM to 10:00 AM.
NO ADMITTANCE TO GLASS SHOP
AFTER 10:00 AM

Not too many years ago there were signs similar to this on many glass shop doors in the country. In fact, there is one well-known university where, although the sign is gone, the policy is still enforced. Ridiculous? Sure, but it was necessary when glassblowers were hard to find and even harder to get along with. Attitudes are considerably changed today. At all of the ORNL shops today you find the feeling that today's research customer may be tomorrow's leader in a new breakthrough. He needs, deserves, and gets wholehearted cooperation.

Priorities in the Laboratory do change, and we find that we must respond to these changes. It's distasteful to have to tell any customer that his job is being held up because of the priority placed on someone else's work, but it must occasionally be done. Usually our customers are very understanding.

Glassblowers are proud, talented, and sometimes fretful people. And they are usually men. Marie Howell, back in 1943, was the only lady glassblower to work in an ORNL shop until last month, 26 years and a score of glassblowers later, when Phyllis Hazzard joined our ranks.

Like the picture window, it's going to take some getting used to, but we'll probably wind up liking the results.

AMW COMMENTS

Clarence and Jane Larson and I were having dinner in the Herceg-Novi Yugoslavian Nuclear Center when the phone rang: Belgrade calling Dr. Larson. Five minutes later a slightly overwhelmed Dr. Larson returned to the table: "That was the Associated Press in Belgrade. President Nixon has just sent my name to the Senate for confirmation as a member of the Atomic Energy Commission". Dr. Moljk, President of the Organizing Committee of the Third International Conference on Science and Society, broke out a bottle of Serbian champagne and we all drank to the Larsons' success and happiness in their new life in Washington.

This was the most dramatic moment of the conference. But there were others. This, the third conference, is the product of a quite unlikely collaboration between Oak Ridge and the Yugoslavian Nuclear Energy Commission. In 1963, shortly after we had held the first of our Oak Ridge summer science and humanities conferences, W. W. Grigorieff of ORAU happened to meet Dr. Anton Moljk. The idea of a similar conference in Yugoslavia came up, was accepted–and, with official blessings both from our State Department and from the Yugoslavs, the first conference was held in Herceg-Novi in the summer of 1964. Seventy scientists and humanists, mostly Yugoslavs and Oak Ridgers, attended the first conference; 120 were at the second in 1966; and over two hundred came this time. Among the participants were many Western Europeans as well as delegates from Czechoslovakia, Romania, Poland, and East Germany. The Russians had accepted, but failed to show up. Drs. Larson and Grigorieff and I represented Oak Ridge; other North Americans there were Dr. N. Sackman of System Development Corporation in Santa Monica, Professor L. Zadeh of Berkeley, Professor J. H. Milsum of Montreal, and Mr. Leclerc of the U. S. Embassy in Belgrade. Dr. Zadeh was a little puzzled meeting Clarence Larson at this conference since he had just come from a conference in Czechoslovakia at which he had met Robert Larson, Clarence's son who is an expert on state-system computation.

This third conference was entitled "Forecasting the Future". To engage in this most human activity, Dr. Moljk had assembled representatives of almost all disciplines: administrators, engineers, natural scientists, social scientists, humanists, philosophers, writers, jurists, politicians. (The path just outside the center was newly paved because it had been rumored that Tito might appear at the conference, and the town of Herceg-Novi wanted to be prepared.) There were even people there who called themselves "futurologists", a word I hardly believed existed. The futurologists lately have been much in view what with the showing of the movie "2001–A Space Odyssey", and the publication last year of "The Year 2000". In this book, Herman Kahn and Anthony Wiener list 100 inventions they expect will be achieved by 2000 A.D., 10 less probable ones (like controlled fusion and direct input into human memory banks), and 10 highly unlikely ones (like antigravity). I figure that ORNL is working on 10 of Herman Kahn's likely inventions (desalting, genetic engineering, tunneling, transuranics, etc.), on one of his less probable ones (CTR), but on none of his highly unlikely ones (at least not on Laboratory time).

My job was to summarize the conference—in 25 minutes.

In my summary I stressed four "confrontations" at the conference: between natural scientists and social scientists, between analytic futurologists and dialectic futurologists, between East and West, and between scientists and humanists.

Since social scientists are no longer a rarity at ORNL, I was not surprised to find the same differences in style between natural and social scientists at Herceg-Novi that I think I detect at home: the natural scientists confident in their many pieces of working hardware; the social scientists still trying to devise workable models for the universally complex systems they deal with.

The dialecticians were mainly professors of philosophy from the Eastern universities; the analysts, designers of think tanks, both East and West. Both groups claim their mode to be the scientific key to predicting the future. This claim the Marxist dialecticians have been making for more than a hundred years; yet many of the analysts come from the East. Analysis is more likely to yield unique predictions than is dialectics. If both sides begin to adopt the analytic mode of viewing the future, we may begin to have the real possibility of both sides perceiving more or less similar futures. Insofar as strife between East and West is an outgrowth of the difference in perception of the future on the two sides, I see this adoption of a single analytic mode as an important step in the resolution of some of the world's gravest sources of strife.

The confrontation that transcended all the others was that between humanist and scientist. The basic differences were brought out eloquently by the passionate and imaginative Croation novelist Dobrica Ćosić. After reminding us in general of the inherent uncertainties of the future, Ćosić pointed to new troubles on the horizon that were not predicted by Karl Marx (Ćosić is a member of the Croatian Communist Party), nor for that matter, by euphoric technologists such as myself. He reminded us that no matter the social system, no matter the information system, no matter the degree of abundance, the dynamics of bureaucracy and man's desire for survival and then for power seem to be immutable forces that eventually transcend all else. Thus we finally come to the central question of human freedom: Can human freedom be maintained in the post-industrial society, in the face of hardened bureaucracies whose every instinct is to quench this spirit? All this struck a responsive chord, particularly among the Yugoslavs, who had partially mobilized their army at the time the Russians moved into Czechoslovakia.

Perhaps at another Herceg-Novi conference, tentatively scheduled for 1972, we shall come further to grips with these questions. By then, we are hopeful that the ORNL delegates will have had more practice at futurology and will be able to provide technological fixes for novelist Ćosić's very poignant concerns. I hope Commissioner Larson won't object if we at least think about this one in the interim—not on company time, of course!

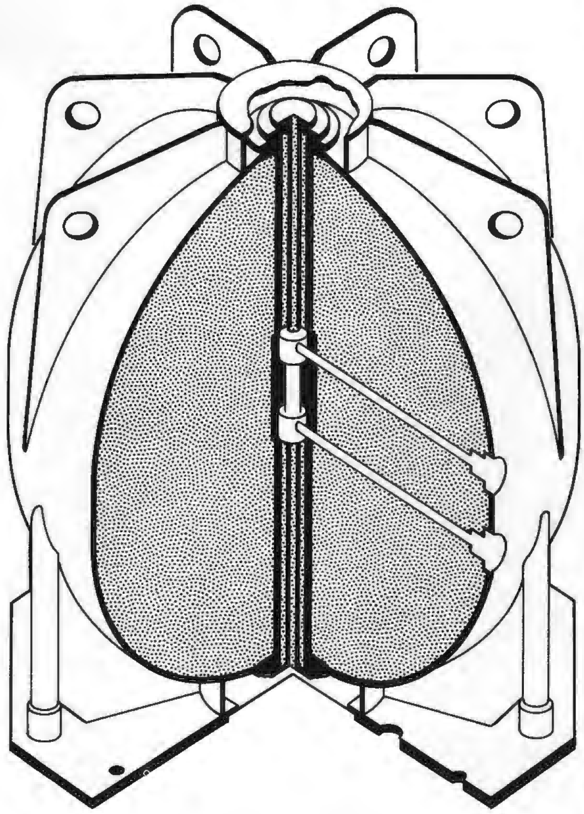
Alvin M. Weinberg

Larry Shappert got involved in the shipping cask business in the early sixties, and rapidly became ORNL's expert on the subject. He is a member of the committee (N 14.2) in the USA Standards Institute that is charged with the responsibility of writing standards for industry on the transportation and handling of radioactive material for industry. Last year he was general chairman of the Laboratory-hosted Second International Symposium on Packaging and Transportation of Radioactive Materials, a meeting that drew worldwide interest. He is currently editing a definitive guide manual on the subject covered in his article here.

Transporting Radioactive Material

By L. B. SHAPPERT

THE RAPID INCREASE in nuclear power plants around the U.S. will shortly have a pronounced effect on the quantities of radioactive materials that must be shipped in the near future. The spent fuel from these plants is predicted by some to reach 4,000 tons by 1980. At the same time, industrial use of radioisotopes is expected to increase in a similar manner. These isotopes, produced in reactors and cyclotrons, are utilized principally in the radiochemical and radiopharmaceutical industry, in radiographic, teletherapy and radioisotopic power units, and in the radiation processing industry.



Bill Barrett (W. G. Jr.), standing beside the ORNL californium shipping container, holds the capsule that is designed to contain the minute quantities of transuranium elements that travel inside the 10 tons of concrete. Left: cutaway sketch shows tiny cavity in center for holding capsule.

Radioactive material is often transported in interstate commerce, and packages carrying it are designed to prevent its release under accident conditions.

Safety in Transport

Economics is of great importance in shipping radioactive material but in the nuclear industry it is always considered within the framework of safety. Regulations have been established which govern the amount of material which can be shipped in one container and the type of container that must be used. These regulations are implemented by two U.S. agencies, the AEC and the Department of Transportation.

In broad terms, the container during normal transport conditions must not release any activity, permit excessive dose rates around the container, or sustain a nuclear chain reaction if fissile material is being transported. To ensure a reasonable and uniform degree of safety for all containers, the regulations describe a number of mechanical accidents that any container must successfully withstand before being approved.

Containers designed to carry large quantities of radioactive material must be able to withstand the most severe accidents. If a container is physically tested, the following assaults must be delivered to it in the order listed to determine their cumulative effect on the package:

First, *free drop:* A free drop through a distance of 30 feet onto a flat, essentially unyielding, horizontal target, in which the cask strikes the target in a position for which maximum damage is expected.

Second, *puncture:* A free drop through a distance of 40 inches, in which the cask strikes, in a position for which maximum damage is expected, the top end of a vertical, 6-inch-diameter cylindrical steel bar mounted on an essentially unyielding horizontal surface.

Third, *thermal:* Exposure to a thermal test in which the heat input to the package is no less than that which would result from exposure of the whole package to a radiation environment at 1475°F for 30 minutes with an emissivity coefficient of 0.9. The surfaces of the package are assumed to have an absorption coefficient of 0.8. The package shall not be cooled artificially until three hours after the test period unless it can be shown that the temperature on the inside of the package has begun to decrease in less than three hours.

Fourth, *water immersion* (for packages containing fissile materials): Immersion in water to the extent that all portions of the package to be tested are submerged under at least three feet of water for a period of at least eight hours.

It is not necessary to conduct the actual tests if engineering evaluations or comparative experimental data can clearly show that the container would be capable of performing satisfactorily under the prescribed test conditions.

To put safety in the proper perspective one should note that the shipping rate for all shipments of radioactive material is currently estimated to be 300,000 packages per year in the U.S. and that statistically one out of every 10,000 shipments will be affected by an accident of some kind. While it is impossible to design a container to survive all types of postulated accidents, it is encouraging to note that in no case over the past 20 years has a container carrying a large quantity of radioactive material been breached or involved in a major fire. Such a record attests to the care used in the packaging and transportation of radioactive materials so far.

Types of Sources Shipped

Radioisotopes shipped in normal commerce emit either alpha, beta or gamma radiation, neutrons, or combinations thereof. The activity shipped can vary from microcuries to megacuries and the packages used to contain it can weigh a few ounces or many tons. Such variations make standardization very difficult.

In addition to isotopes, both unirradiated and irradiated fuel elements are shipped; the former category has only a criticality problem, whereas the latter has both a shielding and criticality problem.

As the sources and packages get larger, the heat load produced as a result of the radioactive decay becomes greater. Heat loads can produce undesirably high internal temperatures if the package does not permit reasonably efficient transfer of heat from the source to the environment. Although there are some notable exceptions, the heat load is generally not a problem until it gets into the kilowatt range.

Casks for spent fuel are often large and heavy and are capable of dissipating tens of kilowatts of heat to the environment without incurring excessive temperatures in the fuel elements themselves.

The sources most often shipped are in solid form, although it is not unusual to ship either radioactive gases or liquids. These latter forms present more of a problem because of their inherent mobility in the event of a break in their protective container.

Transuranium sources are interesting in that they offer a wide spectrum of emissions from a relatively small group of isotopes. In addition to the alpha, beta and gamma emitters, some are fissionable and others fission spontaneously. Several have high specific heat releases. As might be expected, many transuranium elements present a variety of challenges to the shipping cask designer.

A potentially significant problem is the buildup of transuranium elements in light water reactor fuel. Specifically, curium-242 and 244 will be produced in excess of 10 grams per ton of fuel each if the fuel has received greater than about 25,000 Mwd/ton burnup. (Production of these isotopes in plutonium recycle fuel will be considerably greater than the value noted here for the same burnup.) Since these two isotopes fission spontaneously with a yield of between 1 and 2×10^7 n/sec-gram, and the neutrons are emitted at energies in the MeV range, significant dose rates from neutrons may be measurable outside the cask.

External dose rates are limited, of course, to those values specified in the regulations. Whatever contribution the neutrons add must be matched by a decrease in the gamma dose rate. The problem is one of moderating and capturing the neutrons before they can leave the cask. Since light water fuels are now being designed for burnups in excess of 30,000 Mwd/ton, the neutron problem could exert significant influence on the cask design and thus affect safety and economy.

Types of Containers Used

Lead-shielded containers are the most widely used today when dense material is required for shielding. Lead is inexpensive and easily fabricated in odd shapes. However, both steel and depleted uranium show promise in replacing lead for specific jobs.

Steel and depleted uranium have the advantage of high melting temperatures, a point of importance when considering accidents involving fire. Although comparable in cost to lead, an all steel cask of identical cavity size will weigh considerably more, thus decreasing the payload per unit of cask weight. The material cost of depleted uranium is considerably greater than lead, but because of its density, a uranium cask will weigh less than a lead one of identical cavity size. Thus economics and safety can both affect the choice of shielding materials used.

Other materials have found use as shielding materials for shipping containers. Dense concrete, for example, is sometimes used to shield neutron sources. An 11-ton concrete cask is used for transporting milligram quantities of californium-252 or up to ten grams of americium-243 or curium-244. It is limited to sources producing 50 watts of heat or less.

Safety requirements have had a substantial effect on container design. The two most difficult accident conditions that containers must survive are a 30-foot free fall and a 30-minute fire.

At first glance the solution appears to be to encase all containers in a shock absorbing insulation material. Such materials are not difficult to find, but the solution is seldom this simple.

Since radioactive materials continuously emit energy which shows up in the form of heat, insulating a shipping container will cause the temperature of the heat-emitting source to rise. Presumably, with a good insulation, a source could get hot enough to melt—a most undesirable effect.

Certainly small isotopic sources can be handled with relative ease, particularly if the internal temperatures produced by an external fire constitute a greater threat than the internal temperatures produced by insulating the container (a circumstance that is often the case). Larger heat sources are not so easy to handle.

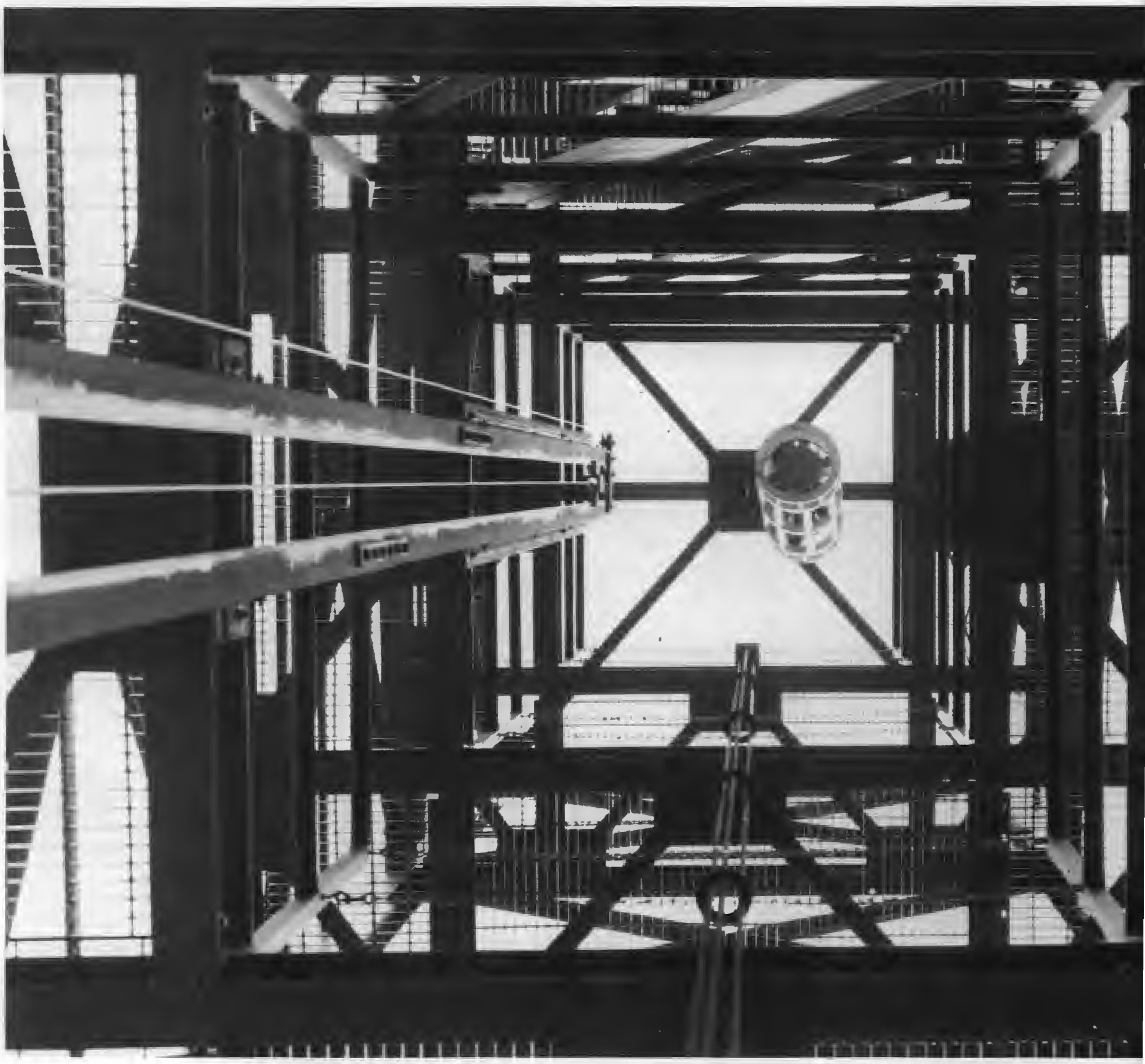
In order to transfer and dissipate heat with relative ease under normal conditions and yet protect the source against fire, the French have suggested placing a third steel shell an inch or so outside the two that normally contain the lead shielding. The annulus would be filled with wet plaster containing an excess of water. Under normal conditions the water provides an excellent heat transfer path between the two outer steel shells. If the container becomes involved in a fire, the outer shell is designed to rupture, whereupon the excess water is boiled away. An air gap is thus produced with the now dried plaster, forming a porous layer which resists the flow of heat from the cask exterior to interior.

The British prefer to buy their fire protection by using all steel casks. Even though the payload is less than for a lead-shielded cask of the same weight, there are other advantages to steel: it will not melt in a normal fire, and deformation on impact is reduced.

ORNL's Role in Container Research

The Laboratory has for a number of years been evaluating models of irradiated-fuel shipping casks in anticipation of the need for design guidance to ensure the continuation of the excellent safety record established by both government and industrial concerns. Structural integrity and heat transfer have received most of the attention since results of impact and fire are the most difficult to determine analytically. Ironically, because of the excellent safety record of the nuclear industry, little practical experience has been gained over the past 20 years regarding the actual effect of major accidents on radioactive materials containers.

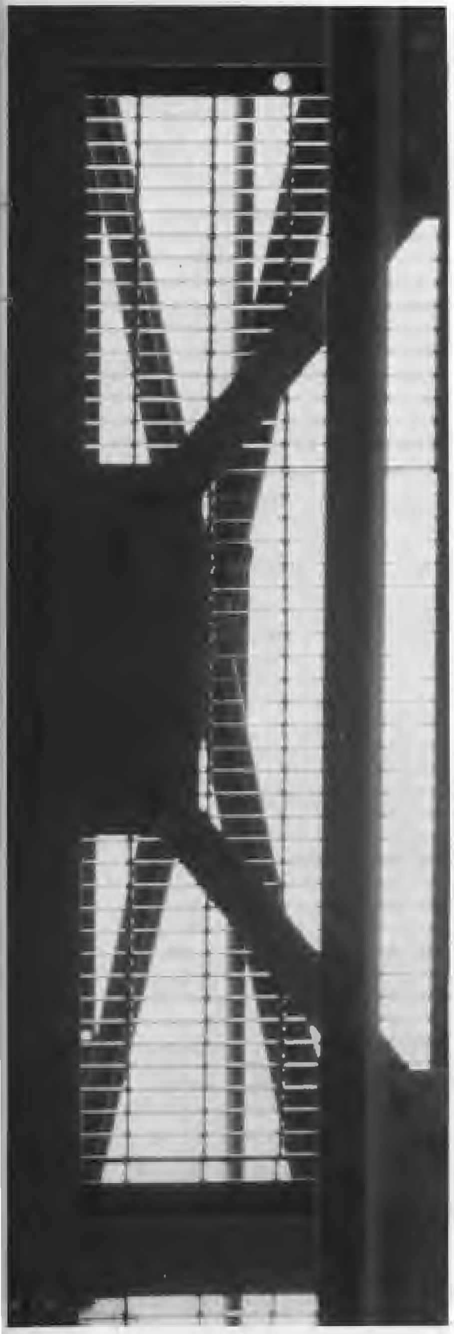
The Chemical Technology Division began testing containers over seven years ago by dropping them on a pad of concrete and steel armor plate constructed for the purpose behind the steam plant in the 2500 area. The first containers so tested were birdcage types, used to ship fissile material. Later K. W. Haff of Isotopes Division initiated a program of testing and redesigning isotope containers. The result was several new container concepts, notably

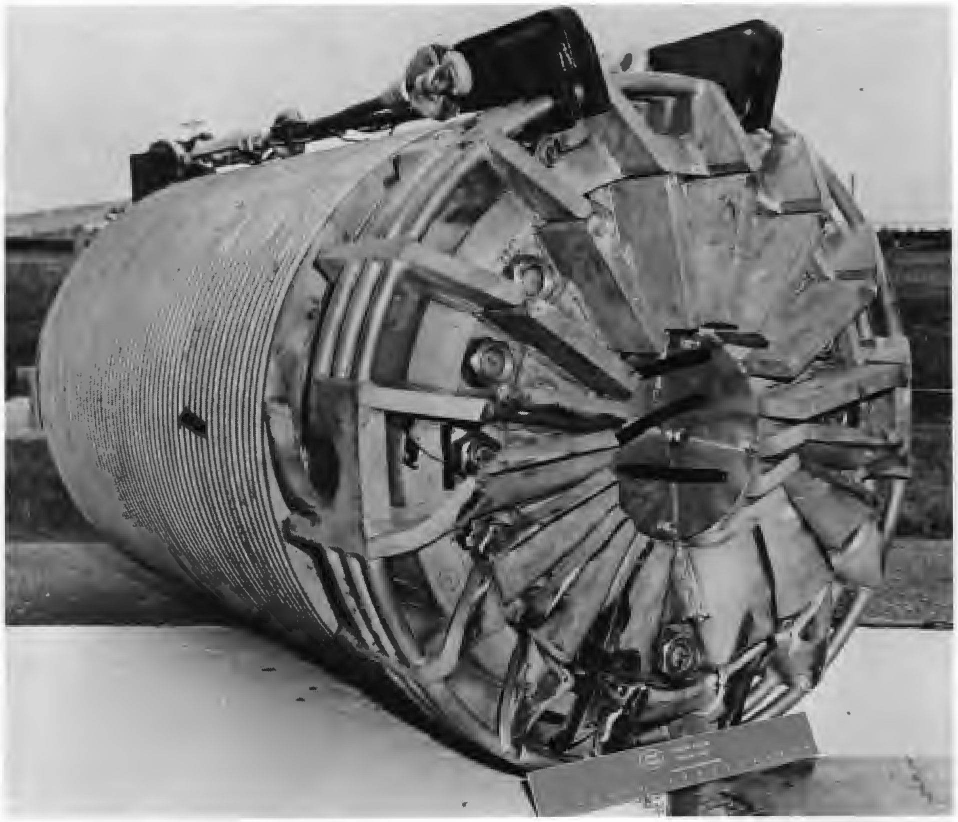


the multiple-shell cask and the gun barrel cask, the latter having been fabricated from the breech end of a surplus naval gun barrel.

More recently, W. C. Stoddart, H. A. Nelms, J. H. Evans and others in the General Engineering Division have been studying the structural aspects of shipping containers. Their work can be categorized broadly as "proof" and "research." Proof work involves the analysis and occasional proof testing of existing or proposed shipping containers; research is aimed at generalizing methods of analysis to achieve a broad framework wherein all casks can be evaluated.

Recently, for example, Atomics International designed, for AEC's Chicago Operation Office, a lead-shielded cask for shipping irradiated fuel. ORNL was asked to conduct an analysis and review of the design. Here the design was scaled down for the construction of a model, which was then drop tested from a small tower at the University of Ten-





A 14-ton cask, shielded with depleted uranium, after having been dropped from 30 ft onto its closure end. Steel fins absorbed most of the impact energy, leaving the cask seal intact even though there was initially 165 psi pressure in the internal cask cavity, which would normally contain spent fuel elements. Tests like these indicate the amount of protection necessary to maintain seals under conditions of severe impact. Left, the ORNL drop tower, from the point of view of the pad. Hanging 30 feet aloft is a crash-shielded model of the LMFBR shipping cask, ready to drop.

nessee. The tower offered the necessary control for such vertical impact experiments. Back at ORNL, the cask was x-rayed to determine whether there had been any movement of the lead inside the steel supporting shells. The lead had moved a significant amount from the end of the cask opposite the point of impact, permitting the development of a predictive equation regarding the maximum amount of lead movement under such circumstances. Armed with this equation, designers can now develop casks in which shielding loss from lead movement is at a minimum.

Performed in ORNL's General Engineering Division, this useful research involved a team made up of Dave Watkin, J. R. McGuffey and Stoddart.

Dispersal of radioactive materials from the cask as a result of impact or fire must be avoided; thus the design and security of cask closures has been extensively studied. Union Carbide's Paducah facility designed, built and tested a depleted uranium cask to determine its sealing characteristics under specific abnormal conditions. Although the 14-ton container was dropped 30 feet onto its closure end, the seal remained intact because of the presence of steel fins surrounding it which absorbed most of the impact. Such tests form the basis for future designs.

Resistance to puncture of steel shells backed by lead shielding has been under investigation for several years. H. Nelms and A. E. Spaller have investigated the punching action of 6″-diameter steel pistons on both flat and curved steel plates backed with lead. The drop specimens, ranging in weight from 25 to 85,000 pounds, were fabricated from both carbon and stainless steel. Their studies led to the widely accepted equation for the required thickness for resisting such assaults:

$$t = (W/S)^{0.71}$$

in which t is the thickness required to resist complete penetration, W is the cask weight in pounds, and S is the ultimate tensile strength of the outer shell material in psi.

G. E. Edison and A. M. Perry in the Reactor Division have contributed work toward criticality control on casks in which the effective multiplication factor is predicted, and Clyde Claiborne and Milo Solomito of Neutron Physics have performed extensive shielding studies.

The bulk of this information has been organized into a preliminary ORNL report entitled "Irradiated Fuel Shipping Cask Design Guide," which not only provides a considerable amount of new information, but also draws upon extensive past experience of tests and accepted engineering practice in cask design and fabrication. Casks made from designs based on the Guide can be expected to meet all U.S. regulations and provide safe transport for large quantities of radioactive materials.

With the Laboratory's involvement now in the Liquid Metal Fast Breeder Reactor program, research is underway to develop an acceptable shipping system for the fast reactor fuels that will be used. Inherent differences between the LMFBR fuels and the light water reactor fuels lead to new packaging problems now being tackled by A. R. Irvine and others of Chem Tech. They see the main problem stemming from the large amount of decay heat present, caused in part by the short cooling times of the fuel prior to shipment and the large numbers of elements to be transported in the cask. Both of these factors are dictated by economic considerations.

The theoretical aspects of the LMFBR cask heat transfer are being handled by the General Engineering and Chemical Technology Divisions while personnel in the Reactor Division are mocking up a model of the cask cavity which will include a number of electrically heated, simulated fuel elements and involve sodium as a primary heat transfer medium. Information from this work will be used to pinpoint problem areas in the cask design and to substantiate temperature predictions on the finished design.

LMFBR fuel fission product inventory will be large. Isotopes like iodine that could be neglected in longer-cooled fuel will be present in significant quantities. The cask must be designed to contain all fission products in the event of an accident. Although it is true that the regulations permit a specified amount of leakage under such conditions, it would be almost impossible to determine, either analytically or experimentally, the quantity of fission products that could escape, in the event that the cask containment were breached. The effect of fire on the cask may not be considered untenable as long as the contents of the cask remain intact. Emergencies, such as rupture of the fuel cladding or discharge of fission products from the fuel to the cask cavity, might occur; however, they can be handled under controlled conditions at the receiving site if the containment is not lost. The containment problem is thus of paramount importance, and it can almost assuredly be solved by present-day technology; Dave Watkin has several proposed closure designs that are being fabricated preparatory to testing under accident conditions.

No Turning Back

Radioactivity is here to stay; we must learn to live with it. We have made great strides in learning how to control it.

It may seem to people who work with such material daily that radioactivity is simply another hazard and once you have learned how to handle it, you can forget it. Occasionally such people accuse us of falling over backwards in our efforts to keep from falling on our faces.

Whichever side of the question you are on, there is no doubt that the number of packages shipped per year is rapidly increasing. While we are all proud of the results of our safety efforts so far, there is the possibility that the frequency of accidents is going to keep pace with the rate of shipments, and increased vigilance is prudent.

Certainly a continuing educational program for the public is needed, one that will put the true hazards of radioactivity in perspective. And in addition, the industry must be fully prepared to justify the containers used in transporting radioactive material in interstate commerce in terms of the designs required by law for protection of the public.

Earl Shank came to Oak Ridge National Laboratory in 1945 from Alcoa with his degree in Chemical Engineering from the Missouri School of Mines, now called The University of Missouri at Rolla. As a member of the Chemical Technology Division here, he was involved with most of the Laboratory's fuel processing programs before becoming U. S. technical advisor in the Eurochemic Assistance Program in 1962. He and his wife Ruth and their two daughters lived in Mol, Belgium, from August of '62 until January of this year, when Shank returned to the States. He changed employment at that time by joining Allied Chemical Corporation in Morristown, N. J., where he is now director of nuclear project engineering in the Nuclear Fuels Department. Although he has since been joined here by his wife and younger daughter, now 17, his 19-year-old daughter has chosen to remain in Europe for the continuation of her education at the American College of Paris. The accompanying article is an account of some of their experiences while living in Europe, with a few reflections on the problems of transplanted families. Here he points out Mol to his secretary, Ruby Miller.

The Tennesseeans of Mol

A personal account by one of Eurochemic's U.S. resident advisors

By Earl M. Shank

Have you ever wondered what it is like to work with a group comprising 16 other nationalities on a job as complex as designing, constructing and operating a radiochemical reprocessing plant? Many Americans probably have been aware of such projects, but few have had the opportunity to participate firsthand. Other international institutions may be more complex, like NATO, or more international, like IAEA, but these are either shrouded in secrecy or are limited to activities that are directive and/or observational. Eurochemic has had, and will continue to have, several unique aspects.

Eurochemic Is Born

Eurochemic, "the European company for the chemical processing of irradiated fuel," was established under the auspices of the European Nu-

T. Iltis of Brussels AEC (l.) conducting Glenn Seaborg of USAEC through Eurochemic control room.

clear Energy Agency of the Organization for Economic Cooperation and Development (ENEA of OECD, formerly OEEC, or Organization for European Economic Cooperation). A permanent steering committee of the OEEC established a study group in 1956 to determine the feasibility and desirability of such a processing plant.

The idea for such an undertaking was conceived in the minds and spirit of several European scientists before 1956; in fact, the idea was given impetus during the 1955 Atoms for Peace Conference in Geneva when they discussed with several U.S. participants the possibility of USAEC assistance in such a venture.

When the study group visited the United States during the summer of 1958, the USAEC-Eurochemic Assistance Program was formulated and plans were made for a resident U.S. advisor. The original concept called for such an advisor to remain at the site for no longer than a year, and the coordination of information, in response to requests, was assigned to ORNL. It was felt mandatory that the technology developed by all the USAEC sites be made fully available.

The assistance program initially was to have covered only the preproject stage. In fact, however, it has now lasted better than 10 years, with the participation of three resident advisors.

It became evident early in the game that continued participation of a resident advisor and a central coordinator greatly facilitated information transmittal. Consequently the on-site Eurochemic staff continually requested extensions to the program.

The first resident advisor, ORNL's Ed Nicholson, had arranged his affairs for a relatively short absence, and at his request his assignment was terminated after 20 months. The second advisor, Bob Sloat of Hanford, also anticipated a relatively short assignment to cover project design. Bob also terminated his assignment after 18 months. I was the third advisor, and armed with the experience of the other two I arranged my U.S. affairs to permit a two-year-plus assignment. Fortunately for the Shanks, living in Belgium became increasingly enjoyable (tolerable for my wife), and the six and one-half years we spent there will always remain a memorable period for the whole family.

One of the problems created by the extended assistance coverage was that of program cost funding at the various sites. Since the original program had been expected to last only six to 12 months, the Division of International Affairs (DIA) had budgeted only for one man-year. Moreover, the deluge of requests from the advisor was not expected.

Somehow the money was found, not only to cover the resident advisor's time, but also to keep him informed by the various sites and to coordinate the program. This was most fortunate, and has paid off richly, both by improving European-U.S. relations, and in filling a gap in our radio-chemical technology.

The establishment of the coordination procedure required about a year to complete. It involved the complete coverage of U.S. technology, the handling of U.S. documents, and the handling of Eurochemic documents. Since the first advisor was from ORNL and the program coordination was being handled also by the Laboratory, there was extensive concern that the transmitted technology would be only ORNL's. To alleviate these concerns, several discussions were held in Washington among the AEC and representatives from five other sites. A representative was appointed at each site who was kept informed on all matters.

The handling of the documents presented several unique problems. For the U.S.-originated material, it was a matter of fast release, both for declassification and for patent. To expedite the release, special procedures and priorities were established which functioned exceptionally well. Information specifically generated for Eurochemic in answer to specific questions from the resident advisor was prepared in the form of reports, which were sent to the USAEC-DIA for retransmittal to Belgium.

The Eurochemic-originated documents, issued in four categories of classification and supposedly in either English or French, turned out in the early stages to be almost all in French, requiring translation prior to review or distribution. Translation services did not then exist at Eurochemic, nor were they as efficiently established in the U.S. as they have since become. Except for Category 4 reports, all Eurochemic-originated documents were stamped RESTRICTED or CONFIDENTIAL. In addition, many of these reports were "internal" and were not available to member countries or Eurochemic board members but were available to the U.S. as part of the exchange program agreement. One unfortunate slip-up occurred when limited-distribution, Eurochemic-originated reports were listed in *Nuclear Science Abstracts* as being available from the U.S.! These reports were not available in Europe from Eurochemic. Eventually the problem was resolved by restricting such reports to the USAEC and its Prime Contractor personnel, and confining the external distribution of such reports to the Division of Technical Information Extension alone; additional distribution was made only after written release from Eurochemic.

Living in Belgium

From the other side of the ocean, the first resident advisor also had his problems. Being a young organization, and not officially a company, Eurochemic was not yet equipped in experience and people to help an American get situated in Belgium. Housing and schooling, *á la américain*, were not available. Clubhouse living for several months, with three young and active boys, can be a nerve wracking experience in itself. Add to this the differences in languages, eating habits, climate, and driving (which alone can age a man years in days), and a picture of the adjustment problems begins to emerge.

Professionally it was also trying: have you ever attended a meeting where six to eight languages were spoken, many simultaneously? The Europeans are fine, courteous people, and it is always a pleasure to work with them, but differences in habits and attitudes do pose problems.

After the first advisor's experiences, the two subsequent advisors found it successively easier to obtain housing and other physical arrangements. Owing however to the increasing number of people in the project, the other problems became, if anything, more pronounced. At first, essentially all employees at Eurochemic could speak English; as the number increased from about 30 in 1958 to close to 600 in 1964, the language problems proliferated accordingly.

Reactions

During the years we lived in Belgium, numerous American families came to Mol and left. These families stayed for periods ranging from one year to over three years. It has been interesting to observe the adaptability and fluctuation of family spirit with time. It has also been interesting to observe similar aspects for European foreigners in terms of individual background, distance from home, and marital status. Obviously the trends have exceptions, but some generalized comments can be made.

For the Americans, adaptability seems to be a function of children's age (because of schooling requirements), the family's overall health, and the expected assignment length upon arrival. For those families with children in the primary grades or with older children who remained in the States, adaptability was more difficult than for those with teenage children. It has appeared that the teenagers become quickly accustomed to and integrated into the stream of life; this in turn is a big factor in the total family's ability to adapt. Nor is this observation unique with Americans, or with only the Mol area. Similar reactions have been observed for the Europeans and for Americans living in Antwerp and Brussels. Family health, both at the start and later,

*A typical Belgian farm:
the two doors on the right open
into the living quarters, adjacent to them
is the barn, and on the left is
the hay and equipment storage.*

plays a very important role. If the family is fortunate, as we were, to be healthy at the start and not to have experienced any serious illnesses, its entire outlook remains bright. Also, if one knows he will be here for one or two years, or if one assumes an extended assignment, the family plans accordingly. Difficulties arise when a short assignment is anticipated, but is then extended in repeated short-term increments.

Regardless of these aspects, however, family spirit appears to pass through distinct cycles, varying in magnitude and frequency, but distinct cycles nevertheless. At first, the new adventure is enough to keep the spirit high. This period may last from one year through two or three years (as in our case). At the beginning, short and long trips are taken whenever possible. During this period of total family activity, there is just not enough time to become despondent. Consequently, for those families with a one year or less definite assignment, there is generally no slump period and everyone leaves Europe with a desire to return. For those families of longer assignments, the curve can reverse itself and will reverse itself if the assignment extends much over three years. After the initial excitement has passed and the major tourist attractions have been visited, life settles into a routine where the undesirable aspects become important. If a family should return home during this period, the desire to revisit Europe is at a minimum.

This slump period may last from several weeks to as long as six months or a year. Our slump started—and this does not include the children, who never passed through this part of the cycle—after about three and a half years, and lifted only after our 1966 home leave. Because our children were in their early teens when we arrived, most of their friends in 1966 were Europeans. Consequently, they have not wanted to take home leave since 1964, and have expressed a desire to remain in Europe. Following the slump, the spirit curve rises again to its previous level, if not higher. I'm not sure why this is so. One explanation is that, if it doesn't rise, the family will leave. There are positive reasons, however. First, the family will have changed its habits to a degree that is more acceptable to the Europeans; the Americans will also find themselves accepting more the Europeans' way of life. Deeper

Barge going through the locks in Mol's canal

friendships are made, language barriers diminish, and Europe becomes home. Secondly, lesser-known tourist areas are discovered and these show the real charm of Europe. Thirdly, the instilled European reserve and formality largely disappear and the result is communion on a more friendly basis.

The cycle apparently repeats itself, although with what frequency depends on the family. For one family, the slump recurred after about ten years. This family had raised four children in Europe. Suddenly, within two years, two were back in California in college. This was difficult for the parents to adjust to. After four years, this family has not completely risen from the slump. After six and a half years, the slump has still not recurred for us. This is partly because our girls are still in Europe with us, and both are still very content. Also, our projected assignment is nearing an end. This, in fact, has produced a slight reverse action, since our oldest daughter has expressed a desire to remain in Europe.

What about the German, the Italian, the Dutchman, Spaniard or Scandinavian in Belgium? Do they encounter the same cycle as the American? I think so, but with a lesser magnitude. After all, it is easier and cheaper to revisit one's country if it is in Europe. The effect on the housewife is almost the same, whether American or European. Housewives find the most difficulty in adjusting owing to their more limited activity, their need to do the daily shopping, etc. Distance from home is an important factor because this distance determines the extent to which customs differ. People from Holland have essentially no problems (Mol is only five miles from Holland) whereas Scandinavians find adjustment almost as difficult as the Americans do. Many Belgian habits are similar to the French or the Dutch; as a consequence, adjustment is easier for them. Single people generally find it more difficult to stay a long time than do families. Family members can be mutually helpful, but for the poor single young adult, life in a foreign country can mean being very alone. Also, most young people, while friendly to all nationalities, generally look to their own countrymen when choosing a mate. The selection from compatriots in a foreign country is, to say the least, limited.

City Life: Mol

The personal experiences of the Shank family have varied extensively. Having lived in a house all of our lives, moving to an apartment in the center of town was quite a change. Our apartment was on a principal bus route and across the street from Mol's central market place. A heavy bus rolling along a cobblestone street can really shake a building up, particularly when the terrain is essentially sand. And when its schedule extends from 5 AM to 1 or 2 AM, it takes its toll on the nervous system. What's more, there was also a stop light at our corner, affording us the music of bus brakes in the night.

The central market place naturally was an active area. Generally, the activities were very interesting and not obnoxious. Every Sunday morning we had the pet market, to which animals of all types were brought for trading and selling. On Tuesdays we

"Our apartment in Mol was on a main bus route . . .

had open market, where merchants of all varieties of goods set up their booths. Tuesday, then, became principal shopping day for all Mol housewives, including my wife. She soon picked out her preferred booths, and after a few months she became known to the owners. There were booths for butter, eggs, cheese, meats, handwear, footwear, coats, etc. Market day varied in each city since most of these merchants participated in such seven days of the week.

In addition, special city events were held on the market place: bicycle races would start and finish there, and various displays would be set up. All of these were interesting, and we had ringside seats for the year-round show. An exception to these enjoyable things were the frequent carnivals. Now the carnival in Belgium is something special. Schools are closed for one day, people just take off from work, and everyone has a good time. Everyone, that is, except the Shanks. How would you like to listen to the same record three or four days in succession from a loud speaker directed at your windows, played in constant repetition from noon until 2:00 AM? This can really become annoying, particularly when the children are trying to study for examinations.

European Schools

Which leads me automatically to the school system. Two schools are available in Mol, one the local Belgium system and one the European school. The European school is Common Market sponsored, which means that it has four principal sections corresponding to the four languages spoken in the Common Market countries: German, French, Italian and Dutch. Of course, American grade and high schools exist in Brussels, but who wants to go to an American school in Belgium?

Admission to the European school is open to all families associated with a Western European, multinational activity (and to some other non-Belgian families living in the area). While Eurochemic is not restricted to the Common Market, it certainly is multi-national, and five of the six Common

. . . from our window we could see . . .

Market countries are actively engaged. Hence, my daughters were eligible for admission to the European school. This system has 12 years in all, of which five are "primary" level and seven are "secondary." After the full 12 years, the student receives a "baccalaureate," which is equivalent to the U.S. high school diploma. The European degree is actually more than equivalent, in that the level of subjects is one to two years advanced over the U.S. system. This is particularly true of languages and scientific subjects.

. . . every Sunday morning a pet market . . .

Initially, my daughters entered the French section. Owing to several factors, such as the attitude of the French teachers, and their almost universal inability to speak English, the girls changed to the German section after the first trimester. For two years my daughters found the going rough but were able to hang on sufficiently to pass. After this initial period of language learning, the various courses became more enjoyable. With German as their mother tongue, they received all the scientific courses in German. Automatically French was the second language for those in the German section, and they received the non-scientific courses in French. Italian became their third language and, eventually, English their fourth.

When reviewing the results of the five and seven years, respectively, that my daughters spent in the European school system, I can only say the net results are definitely positive.

Social Habits

Our first six months in the apartment were very difficult, especially for my wife. As we later learned, we made a social goof during the first few weeks. We could not understand the coldness of the other residents of the building. Coming from friendly East Tennessee, where new neighbors are helped to the extent needed or desired, we were unprepared for this reception, particularly since the husbands of four of the other five families worked at Eurochemic. I finally found out that the difficulty arose from our improper use of protocol. In Europe, so I've been told, the new neighbor must present himself to the others, at very discreet times, for the first introduction. Without this, the others cannot make a move to be friendly. Unfortunately, by the time we learned of our mistake, we were no longer new inhabitants. Time, however, changes many things, and eventually our neighbors forgot and forgave us our *faux pas*.

Social customs can be embarrassing. Not fully realizing the magnitude of differences, we followed our normal habits at first. Two customs which we learned the hard way are the arrival time for dinner and the charming gesture of bringing a small gift to one's hostess. In the Latin countries (Belgium, France, Italy and Spain) not only is the dinner hour later than in other countries, but it is also customary to arrive one-half to three-quarters of an hour after the time specified in the invitation.

Although our first dinner invitation was from a Swedish couple, they knew and observed the local custom. The invitation actually was for a party,

. . . on Tuesdays open market . . .

. . . and special events . . .

which still required a gift and a late arrival, but which did not imply dinner to us, set as it was for 8:00 PM. Since we normally ate at 6:00, we finished our dinner as usual and then timed our departure from our apartment carefully so as to make our appearance at the home of our hosts promptly at 8:00. Needless to say, this was a shock to them. The host, only partly finished in his dressing, entertained us while his wife quickly dressed. Then, while the hostess talked with us, the host completed his toilet. We, too, had a shock when we saw, on entering the house, a table set for a formal dinner! As all good stories should, this one has a pleasant ending. Two more couples had been invited, a French and a Danish couple. True to good old European form, they arrived at 8:30 and 8:45, each carrying flowers. After drinks, small talk, etc., we all sat down to dinner at 10:00. Since we had eaten at 6:00, we were ready for another meal.

Shopping

Shopping was one thing that we had to relearn. We were fortunate in having a large (for Belgium) refrigerator, which was about 6 cu. ft. Having been used to a freezer and a larger refrigerator, we found daily shopping to be a chore at first. This eventually, however, became a way of life. European bread is almost universally excellent, but only for a day or two after its purchase; after that time it is good only for crumbs or bird feed. Meat was another problem. Since meat is cut differently, preparation must also be relearned. Roasts, of good quality meat but cooked in American ways, sometimes

. . . *would start and finish there.*"

turned out to be disastrously inedible. Frozen foods hardly existed except at import stores, where prices were double. The result was that we ate fresh vegetables in season. After several weeks of cauliflower, for example, the appetite craves a change. During the last six years, of course, these aspects have changed extensively.

I remember our first attempt to buy spareribs for barbecueing. Such a cut of meat was unheard of even at Eurochemic. Belgian bacon is prepared by removing the individual ribs, thus there are no ribs as we think of them. I explained carefully to a Flemish employee at Eurochemic exactly what I wanted. Now, she understands English (although come to think of it this may have been my problem: she didn't understand American!) because her husband is an Englishman. She explained my wants to the butcher in a way designed to enable me to go directly to the shop and pick up my order. Upon our arrival, the butcher proudly held up an entire pork loin. After much discussion, using hands, etc., we convinced him that we didn't want the loin. What we did want, however, didn't get across. He disappeared into his storage locker and returned with an entire side of pork. We took it. Our first barbecue was expensive, but we did end-up with a generous supply of good, fresh side meat. After that we confined our barbecueing to chickens.

Experience with T-bone steaks was almost as bad. All bones and fat are removed by the European butcher prior to selling, with corresponding adjustment in price. By chance we happened to be in the shop one day when the butcher was removing the T-bone. We couldn't resist the temptation, even at $2.00 a pound. After much sign language, we convinced him to cut four steaks with bone and fat left on. This really hurt him: how could we possibly be stupid enough to pay $2.00 a pound for bone and fat? He solved this by charging only $1.80 a pound.

Frontiers

Crossing the border is always a game, particularly if you live in Europe. If you are only traveling in Europe on vacation, there is really no trouble to be expected until you return to the U.S. If, like us, you have taken up residence in a European country, the import laws are as restrictive officially as they are for the natives. Fortunately, most European countries still like the American dollar and the American passport; these, along with the ability to speak only American, are a big help at the border. One aspect of the customs official in Europe is his humane attitude toward the traveler. I have frequently thought how unfortunate it is that, for many Europeans, their first impression of the U.S. and the Americans is offered at JFK airport.

Some of the Problems

Probably the biggest problem, the one that hit us initially and that continues to plague us today, is that of communicating. Communicating between countries, between board and management, between management and personnel, and among co-workers. Although most Europeans are at least bilingual and often multilingual, real understanding of written or spoken phrases is usually limited except in the mother tongue. A glance through any bilingual dictionary will reveal this: for each word there is a

First Communion procession.

multiple meaning or use potential. Add to this the fact that most of the conversations and written material are done in a language native to neither of the communicants. French and English are the official languages for Eurochemic; they are not the mother tongue for most of the personnel. It is not unusual for an Italian and a German to discuss in English.

An experience of mine illustrates this problem. At the beginning of my assignment, the technical manager had a group meeting of his division heads. Since this was an administrative meeting, I was not invited, nor should I have gone if I had been invited. Following the meeting, which was conducted in English, two participants of different nationalities, but with comparable proficiency in the English language, reviewed the meeting with me. To this day I don't know what transpired at that meeting. The two reports were diametrically opposite, and I never got a third version from the technical manager to judge which one was accurate.

Personalities

Another early problem which still exists is the difference in attitudes and personalities characteristic of the various nationalities. By this I mean work habits, viewpoints, receptivity, discipline, etc. Many examples come to mind. One I've already mentioned is the timing factor in social occasions.

Try taking a Spaniard, who is more or less flexible in his work habits, and putting him under the supervision of a German, who is more or less inflexible. Sparks can begin to fly. The upshot of this conflict was that many of the groups became nationally centered. This helped cooperation within the group, but made for limited cooperation between groups. The main process people, mostly Latins, were essentially excluded from the plant during construction, since construction was the responsibility of the engineering section, which was made up mostly of Germans. Because I was not assigned to any particular group, I could float among all the groups, a privilege that had its advantages and its disadvantages.

Legal Problems

With any international organization, special legal problems can be expected, and Eurochemic was no exception. As I mentioned earlier, Eurochemic is governed by the laws of Belgium except in matters specifically covered by the International Convention. This invariably leads to interpretation differences. Such items as social security, special tax-free import privileges, and work permits must be administered within the proper boundaries. Some of these items differ for employees from different countries. Mutual exchange agreements may exist between countries within the Common Market, but may not exist with countries outside. At the same time, equal treatment must be given to all employees.

Drivers' licenses have been an interesting problem, and one that has only recently been solved. Prior to 1968, Belgium did not require individual drivers' licenses. This was not too bad, since the work permit established one's residency, and one could therefore drive a Belgian licensed car throughout Europe. In fact this was a frequent help to those employees who had been unable to pass the driver's test in their own countries.

The problem became complicated in 1968 when the new driver's license law was put into effect. It was so written that no provisions were made for licensing foreigners. Moreover, now that Belgium had a license law, no Belgian resident could drive a Belgian-registered car in another country without a license. And on top of this, a foreign resident of Belgium could not obtain a license from his own country. As the full implication of this dilemma became gradually apparent, a temporary solution was sought in the international driver's license, which is relatively easy to obtain. The final solution has just been reached in the modification of the law to permit foreign drivers to be licensed.

Inauguration ceremonies were attended by Belgium's King Baudouin I, shown here, fifth from the left on the front row, in the spent-fuel reception and storage building. At the microphone is Chairman of the Board Schulte-Mermann, and in the foreground is the reception pond.

Eurochemic Chemical Processing Plant as it looks today. It has been in full operation since 1966.

Eurochemic Comes of Age

The big day for Eurochemic was July 7, 1966, the day King Baudouin officially inaugurated Eurochemic by operating the dissolver loading cask for the introduction of the first radioactive fuels. The date was chosen because it was the same as that on which Prince Albert of Belgium, brother of the King, laid the cornerstone in 1959 for the first Eurochemic construction. In the intervening seven years, the site was transformed from scrub pines to a completed reprocessing facility. When I arrived in 1962, the scene was a miniature of the early Oak Ridge days.

Design and Construction Coordination

To fulfil one of the goals of Eurochemic, contracts were made with firms from all the participating countries. Architect engineering contracts, for example, were made with nine principal firms, one of which had the responsibility for coordinating. Throughout all the design, fabrication and construction phases, a recurring problem was contract conditions and specification preparation and interpretation. All such details were prepared in the two official languages, and one or the other version, depending on the contractor's preference, became an official part of the contract. A major problem was the correct translation of these details from the original language to the second language.

Three types of conditions or specifications were prepared. Eurochemic general contract conditions, Eurochemic general specifications (prepared by Eurochemic), and detailed specifications (prepared by the architect. The general contract conditions were prepared in French and translated into English. The general Eurochemic specifications were prepared either in French or English, depending on the originator, then translated into the other. The detailed specifications were likewise in one of the two languages, depending on the architect, and translated. Unfortunately, something is always lost in a translation. In some cases we had two versions of the same document that were substantially different. This gave rise to some lively and extended discussions between architects using the French version and contractors using the English version in cases where the two versions said different things. The time required to resolve these difficulties is almost beyond comprehension to an American.

The European participants in the Eurochemic project showed extraordinary tenacity and forbearance in overcoming this particular problem. Add to this all the other problems normally encountered in a large project, and they must really be congratulated for a job well done.

Once construction was completed, old problems were traded for new. Eurochemic had decided early on that only one language would be official in plant operation. Fortunately for me, the choice was English, but the job of preparing safety analysis reports, operating manuals, run sheets and daily instructions in a foreign language to be read and understood by others to whom it is also foreign fell to a large proportion of the workers. One of the early instruction programs was a series of English courses. The progress of the Europeans in learning a new language is phenomenal.

Test Operations

Inactive tests were initially contracted under the architect engineers. Owing to delays and other problems the contracts were modified. Plant startup operation, starting with the cold tests, was put under the direct operating responsibility of the Eurochemic staff. Several of the architects were integrated into the staff at this time.

Active test operation started in July 1966 and continued for two and a half years. With the signing of the license application at the end of 1968, we could finally say that Eurochemic had come of age.

Nor does this act in itself remove all problems. There still remain fuel contract negotiations, operation planning, deficit financing and information distribution to the participating countries.

It is clear, however, that a new era is dawning for Eurochemic.

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