NUCLEAR SAFEGUARDS: 1. THE IAEA PROGRAM

Nations without nuclear weapons agree, if they sign the nonproliferation treaty, not to acquire them. The International Atomic Energy Agency is preparing to extend its existing procedures to verify compliance with the treaty.

BERNARD W. SHARPE

WITH THE SIGNING of the Treaty on the Nonproliferation of Nuclear Weapons (NPT), the International Atomic Energy Agency will become responsible for ensuring that nations without nuclear weapons do not acquire them. The IAEA Department of Safeguards and Inspection has for many years been making inspections to ensure that nuclear material being used for peaceful purposes is not diverted for weapons production.

Safeguards is the term used for a system of control to ensure that source or special fissionable materials are not diverted for use in nuclear-weapons manufacture. Because "safeguard" also refers to an antiballistic missile system let us use the expression "diversion safeguards" to avoid confusion. (The US has its own diversion-safeguards system under the AEC. See page 40.)

After studying physics at Liverpool University and serving in World War II, Bernard Sharpe joined the UK Ministry of Supply, where his work ranged from ammunition production to isotope separation. In 1958 he went to the UK Atomic Energy Authority, specializing in health and safety. He joined IAEA in 1964 and is now responsible for diversion safeguards in North, Central and South America and Africa.

Nonproliferation treaty

The general public might well ask many questions, if only because of any possible impact the treaty may have in terms of national security and cost:

- What has IAEA been doing so far regarding diversion safeguards?
- What is the difference between diversion safeguards under present conditions and under NPT?
- What is IAEA doing to enable it to cope effectively with its future (NPT) obligations?
- What is the time scale for the transition?

The nonproliferation treaty has been signed by 91 nations and ratified by 20, including one nuclear-weapons country, the UK. The Senate of the US has given the NPT its positive advice and consent, and it now awaits only the action of President Nixon for formal ratification. The USSR has urged the rapid entry into force of the treaty, and it is to be hoped she, too, will give it early ratification.

When the treaty has been ratified by all three nuclear-weapons nations acting as depositaries (UK, US, USSR) it is expected that non-nuclear weapons nations will also ratify it in increasing numbers. The treaty comes into effect when it has been ratified by 40 nonweapons nations and the three depositary weapons nations. Under the treaty, weapons nations agree not to transfer nuclear weapons or other nuclear explosive devices, and nonweapons nations agree not to receive them and to refrain from manufacturing them. The latter group also agrees to accept diversion safeguards as set forth in an agreement with IAEA to verify compliance with the treaty obligations.

IAEA was selected to apply diversion safeguards on the basis of its statutory responsibilities. Presumably the experience and reputation it has gained in applying its safeguards system throughout the world also influenced this decision favorably. The agency has expressed its readiness to accept these NPT safeguards responsibilities.

The time when diversion safeguards will be implemented under NPT conditions depends upon many things. The treaty must, of course, be ratified. The basic safeguards agreement must be found to be acceptable. The impact of the practical application of IAEA safeguards in each country must have been evaluated. A number of political considerations, unrelated to diversion safeguards, may play a role.

When the treaty has come into

effect, each nonweapons nation must enter into negotiations with IAEA within 180 days and conclude agreements for the application of safeguards that should enter into force within 18 months. The time needed for negotiation of agreements will depend, to some extent, upon the degree of sophistication and development of that nation's nuclear industry. Thus one might forecast that diversion safeguards could be in operation under NPT in countries that have been quick to ratify and where the nuclear industry is not highly developed within two years after the treaty has come into force.

Table 1. Nations Under IAEA Diversion Safeguards

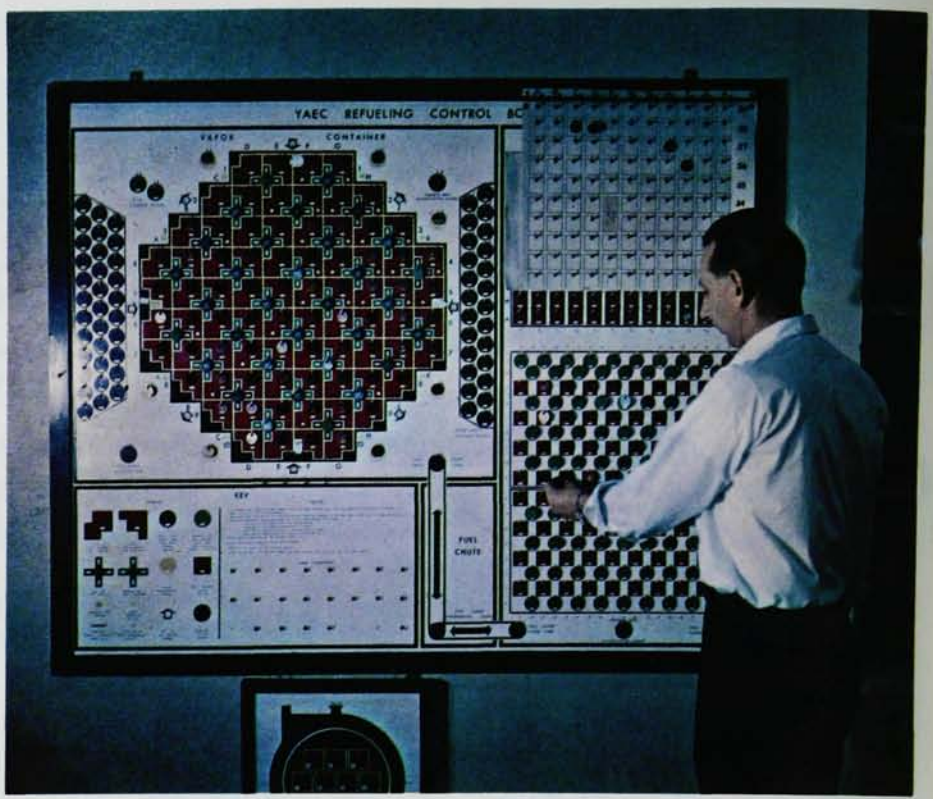
Nation	*Thermal power (Megawatts)*
Argentina	5.10
Australia	10.01
Austria	5.25
Brazil	5.00
Colombia*	0.10
China	206.00†
Congo, Democratic Republic of the	0.05
Denmark	15.00
Finland	0.25
Greece	1.00
Indonesia	0.25
Iran	5.00
Israel	5.00
Japan	704.18†
Korea, Republic of	0.10
Mexico	1.00
Pakistan	5.00
Philippines	1.00
Portugal	1.00
South Africa	20.00
Spain	513.02†
Thailand	1.00
Turkey	1.00
United Kingdom	1100.00†
United States	668.50†
Uruguay	0.10
Venezuela	3.00
Viet-Nam	0.25
Yugoslavia	0.25

* Agreement not in force yet

† Largest installations are: 205 MW at Lincou Hsian, China, 585 MW at Tokai-mura, Japan, 510 MW at Almonacid de Zorita, Spain, two reactors totaling 1100 MW at Bradwell, UK and 600 MW at Yankee Nuclear Power Station, Rowe, Mass.

Table 2. Growth of Department of Safeguards and Inspection

1964	*1969*
Professional and Managerial Staff	11 34
Budget (thousands of US dollars)	330 920



REFUELING CONTROL BOARD at Yankee Atomic Electric Co., Rowe, Mass. Each component (such as source, fuel assembly, control rod) is indicated by a tag. Each square corresponds to a fuel assembly, and each cross to a control rod. —FIG. 1

(Quite apart from the nonproliferation treaty, the Latin American countries are declaring themselves a nuclear-weapons-free zone under the Treaty of Tlateloco. The treaty prohibits introduction of nuclear weapons into the area and forbids diversion of nuclear material for weapons production; IAEA will operate the diversion control system. The implications of this treaty for both the agency and the countries are very similar to those under NPT. Even now IAEA is operating agreements with six Latin American countries.)

Today's situation

The IAEA diversion-safeguards system is designed to ascertain, by materials accounting and physical inspections, the quantity and use of nuclear material wherever it appears in the fuel cycle. The nuclear fuel cycle consists, essentially, of chemical conversion and fuel fabrication plants, reactors (figure 1 is a reactor control board), reprocessing plants, enrichment plants and storage facilities. Proper control of nuclear material based on prudent and economic management principles at any plant or installation goes a long way towards meeting diversion-safeguards requirements.

A significant amount of nuclear material exists outside the places listed above, for example, in transit. Adequate security measures are required for such material, but this type of assurance is not the responsibility at present of international diversion safeguards.

IAEA now undertakes safeguarding responsibilities in three circumstances:

- when a nation unilaterally submits facilities and nuclear material to diversion-safeguards control;
- when the diversion safeguards under a bilateral agreement between two nations are transferred to IAEA;
- when IAEA has supplied material, services, equipment or facilities to a nation.

The remarkable growth in IAEA safeguards over the last few years is illustrated in figure 2. The agency applies safeguards in 29 countries under 40 agreements, which cover material and facilities at more than 120 individual locations. Table 1 lists the thermal power in reactors currently under safeguards agreements. The total thermal capacity of the 70 reactors under agency safeguards in mid-1969 was approximately 3277 MW.

Over the last five years the IAEA Department of Safeguards and Inspec-

tion has grown as shown in table 2. For 1970, the number of professional staff is forecast to be 54 with a budget of $1.29 million.

The organizational structure of the department is given in the box on this page.

One can say that so far IAEA has been demonstrating, on a limited scale, how an international, credible and viable diversion-safeguards system, at a relatively low cost, can work.

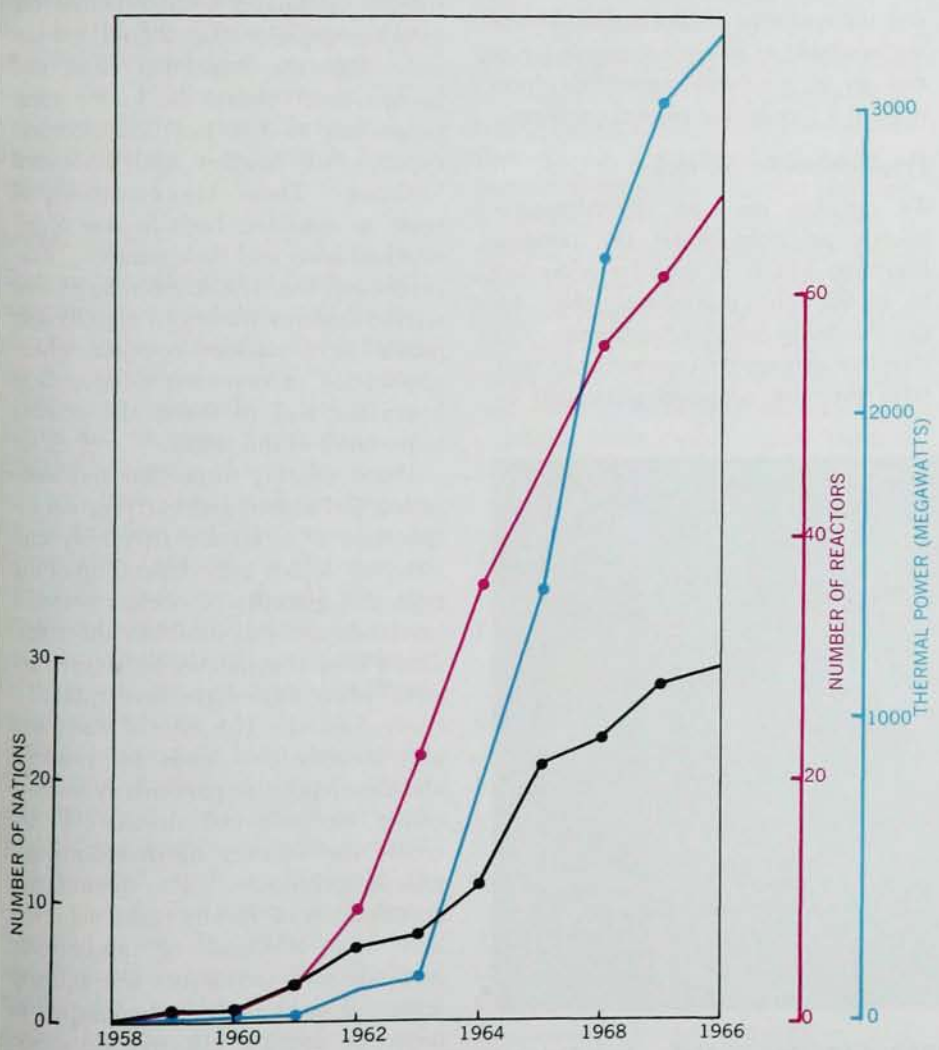
IAEA procedures

The agency safeguards system is described in an agency document known by the reference INFCIRC/66/Rev. 2; this contains the principles and procedures that enable nations to determine in advance the impact of agency diversion safeguards on their national nuclear organizations. The document contains some basic principles: The application of diversion safeguards is not to hamper the economic or technological development of a nation; the administration of safeguards is to be implemented in a manner consistent with prudent management practices; there is to be continuous consultation between the IAEA Secretariat and the nation being inspected; commercial and industrial information of a confidential nature is to be protected.

The document provides for a design review of the installations concerned so that the agency can decide whether or not effective diversion safeguards can be applied to them. Only the minimal amount of information and data consistent with carrying out this responsibility is required. Each installation must keep records of its activities and must keep accounting records of all safeguarded material. Reports must be sent to the agency, both to account for nuclear material and to describe the operation of the installations; this procedure enables assessments to be made at IAEA headquarters. The frequency of reports is a matter for agreement between the nation and the agency, special reports being necessary in extraordinary circumstances.

Inspections are also provided for. (Figure 3 shows an IAEA inspection.) The inspector may audit the records and reports, verify the material under diversion safeguards either by physical inspection, measurement or sampling, examine the installation to confirm design, review information (including checks of measuring instruments and operating characteristics), and check operations generally. The inspector may not operate any installation or direct the staff of any installation.

How does IAEA apply safeguards? Once the agency and the nation concerned have concluded an agreement for safeguards, they then negotiate "subsidiary arrangements" for the practical application of the relevant control measures. These arrangements identify the facilities concerned, describe the records to be kept by the nation so that materials may be safeguarded, and specify the reports that must be submitted to IAEA. The nation sends to the agency an "initial in-



GROWTH OF IAEA DIVERSION SAFEGUARDS. Nations with safeguards agreements are shown in black; number of reactors under safeguards agreements are shown in red; total thermal power under safeguards agreements are shown in blue. —FIG. 2

ORGANIZATION OF DEPARTMENT OF SAFEGUARDS AND INSPECTION

Rudolf Rometsch, Inspector General

DIVISION OF OPERATIONS

Slobodan Nakicenovic, Director
Bernard W. Sharpe, Chief, Americas and Africa Section
Carlos Büchler, Chief, Asia, Far East and Pacific Section
Frantisek Klik, Chief, Europe Section
Lewis Solem, Chief, Accounts and Reports Section

DIVISION OF DEVELOPMENT

Shigefumi Tamiya, Director
Vladimir Shmelev, Chief, Systems Studies, Technical Services, Training Section
Arthur Waligura, Chief, Methods and Techniques Development Section
Robert Skjoeldebrand, Chief, Field Operations Section

ADMINISTRATIVE SECTION

Ben Sanders, Chief

ventory" listing all the installations and material that are to be subject to the agreement. This inventory and the reports are fed into the agency accounting system. The reports and the accounts are themselves verified by inspections, carried out by "safeguards inspectors" from time to time.

Negotiating agreements with nations as well as making the necessary arrangements for implementation of diversion safeguards is already part of the agency's routine work. It has developed the expertise for the application of diversion safeguards suitable for the discharge of today's responsibilities.

Changing requirements

Recently the size and complexity of the task has been altering rapidly. There has been a change of scale and, with this, a change in the nature of the techniques required for the effective application of diversion safeguards.

In the past IAEA may not have inspected all of a nation's nuclear installations, only those it offered to put under diversion safeguards. But, under the nonproliferation treaty, complete national nuclear complexes will have to be covered; the problems to be overcome are qualitatively different. The problems will vary greatly from country to country, depending on the stage of development of the nuclear industry. Another aspect that must be considered is the inspector–operator relationship. National control authorities may have stringent legislation on which to base their actions, but the position of an international safeguarding organization is more delicate vis-a-vis the operators of installations. The experience gained by national authorities charged with the protection of nuclear material has been helpful to IAEA, but the techniques and methods developed to handle these national activities need some modification and adaptation for the application of diversion safeguards on a standardized international basis.

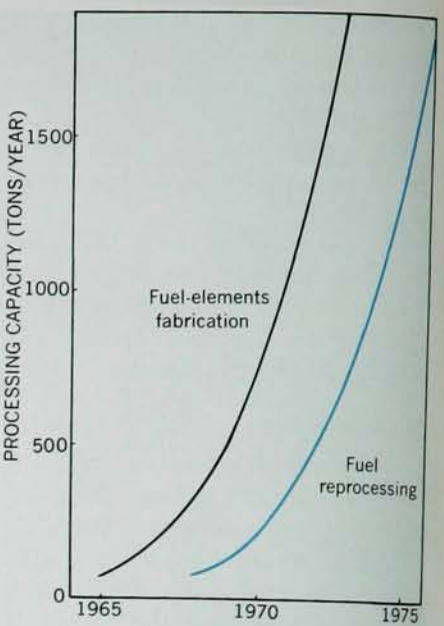
The problem is also a quantitative one. Considering only nonweapons nations, a forecast of installed electrical capacity up to 1975 is shown in the figure on page 42, and associated requirements for fuel-element fabrication (based on the use of slightly enriched uranium) and for reprocessing are shown in figure 4. The increase in the number of nuclear power plants over the next few years must be preceded by a growth in the number of fuel elements fabricated and followed, a few years later, by a similar growth in reprocessing of spent fuel elements. The amount of uranium in circulation and the quantity of plutonium becoming available at an ever increasing rate and in a relatively accessible form present a formidable control problem.

Preparations for the future

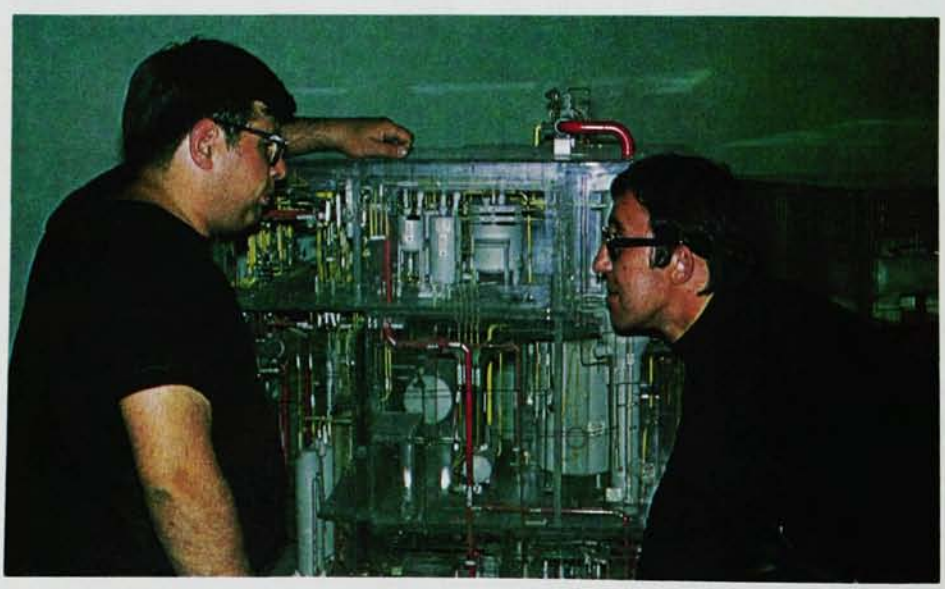
To develop effective diversion-safeguards practices under the nonproliferation treaty, it may be necessary to modify the procedures used under limited inspection conditions. The effective allocation of resources to cope with the new situation presented by the treaty can produce significant financial and manpower savings. Even though safeguards responsibilities are growing rapidly, one should not assume that the inspection effort and budget must always be in the same proportion to the installed electrical capacity of reactors and associated facilities. There are economies of scale to consider, both in size of individual units and their number. Furthermore, the IAEA Secretariat has started systems studies to identify key points in a nuclear complex where application of diversion safeguards is important and to assess the relative importance of the points.

Using existing inspection and measuring techniques and carrying out inspections at a certain frequency and intensity, which may depend upon the type and quantity of nuclear material involved, one can establish the confidence level of achieving the desired results, when these have been quantitatively defined. This type of study will also identify the needs for research and development (particularly in measuring methods and devices) to increase the efficacy of diversion-safeguards techniques. The quantitative specification of results to be achieved and the selection of appropriate methods and techniques are primary technical tasks to be accomplished in order to develop effective diversion-safeguards practices under the nonproliferation treaty.

It is clear that IAEA cannot "go it



PROCESSING CAPACITY forecast for nuclear power plants in non-nuclear weapon states. —FIG. 4



IAEA INSPECTOR WITH MODEL OF REPROCESSING PLANT. Jose Dolnicar (right) and plant employee examine model of the Nuclear Fuel Services plant in West Valley, NY. An 18-member IAEA team, headed by Bernard Sharpe, recently conducted a diversion-safeguards inspection of the installation. —FIG. 3

alone." A group of consultants, selected from various countries with experience in the application of safeguards, has been meeting to assist the agency in defining criteria and requirements that will be consistent with the task under NPT and with the agency's present system. The agency's long-term activities will be built on the foundation that is now being laid.

Because the IAEA budget for research and development is only a small fraction of the worldwide effort on diversion safeguards, we must depend on the results coming from national programs. The IAEA annual budget for research and development is about $200 000, whereas the USAEC spends about $3 million on diversion safeguards; and other countries, such as the Federal Republic of Germany, the Soviet Union, Japan and the UK also have such programs.

In some cases, IAEA will need to demonstrate to individual countries the relevance of its methods; the support of the consultants' advice will be most valuable for this purpose. The importance of this aspect of preparations for the future cannot be overemphasized, because it is reasonable to assume that some signatories of NPT may hesitate to ratify before they know the details of safeguards implementation.

Staffing

The question of staff is of fundamental importance for the future. It is complicated by the difficulty of recruiting suitable personnel. Few countries have national materials-control organizations that correspond to a diversion-safeguards system. Many developing countries have only small numbers of highly qualified and experienced staff. Nevertheless, inspectors for agency safeguards purposes should be recruited on a worldwide basis to maintain a real international corps, without bias towards any particular political or industrial group.

Many assessments have been made of the size of staff required. There are significant differences between them, depending upon the ground rules adopted, such as the rate of power growth, frequency of inspections, and so on. The effective allocation of agency resources will influence greatly the number of inspectors needed, but this will also be affected by: the possibility of agency inspectors working from control centers in different regions, utilization of effective national materials-accounting organizations, and the possible interrelationship with regional organizations.

However, one can make an estimate based upon experience to date and on the assumption that the methods in the near future will not differ significantly from those used at present. Because the NPT calls for diversion safeguards to be applied only in nonweapons nations, the estimate should be aimed at forecasting the staff needs for discharging this operational responsibility. A strong development effort is essential, as is sound administrative support. Finally, in an expanding organization, where most new recruits will need to be trained, a considerable lag occurs before they can be used in operation.

Based on considerations like these, the provisional estimate is that if full NPT conditions are achieved for nonweapons nations by 1973, the agency would need a professional staff of about 200 inspectors, with appropriate administrative and supporting staff. There will have to be a gradual build up of staff to meet that date.

National safeguards

Nuclear material has distinctive characteristics. First, it is accompanied by health hazards; the nation must ensure that special precautions are taken to protect its population against radiation exposure. Secondly, the material is extremely valuable, plutonium being valued at many times the price of gold. For this reason good control of material will be necessary. Thirdly, because of its potential use as an explosive device, nuclear material has a strategic value, which also requires special national control measures.

Basically, international diversion safeguards rely upon sound techniques for the management of nuclear materials and upon the existence of appropriate security precautions. The operator of a plant has a responsibility to control effectively the material he is handling. Application of international diversion safeguards gives him the benefit of the wider experience of IAEA and an independent assessment of his materials accountancy. Experience shows that there is only a negligible disturbance of plant routine. The security system against unauthorized removal of materials is in the interest of the national authorities and, if effective, it may strengthen and simplify international safeguards arrangements.

Industry can play a big part in development and implementation to make diversion safeguards effective, economic, efficient and nonintrusive. IAEA coöperates with all organizations that can contribute to the achievement of these objectives.

To improve control over nuclear materials, devices and instruments must be developed by industrial organizations. Features can be built into plants by designers and constructors to facilitate diversion safeguards and make them as little intrusive as possible. The use of better equipment and techniques for the measurement of materials should be encouraged by management. National authorities can coöperate in research and development; they can convince the public of the need for diversion safeguards; they can establish the national security measures that are required.

IAEA is making great efforts to prepare itself for its future role under NPT. Many nations are studying the effects of NPT and preparing themselves for the treaty. But in the long run, the actual application of diversion safeguards in a plant is the acid test of the diversion-safeguards system. The nuclear industry, too, must prepare itself for diversion safeguards. By doing this in a manner that facilitates the independent verification by the agency of the material control and accounting system, the nuclear industry certainly will be not only discharging obligations placed upon it by the nation, but also improving and helping itself.

It is crucial to the success of the nonproliferation treaty that IAEA exist and be capable of handling the necessary diversion safeguards. The agency has shown that safeguards under today's conditions are a practical and economical proposition, both in terms of manpower and economics. The extension to the worldwide scope of the nonproliferation treaty, whereby whole countries come under diversion safeguards, can be handled in the same way as a pilot plant is scaled up to full size, provided new conditions are taken into account.

We realize that to succeed the future program must: recruit and train a corps of inspectors with a wide range of technical skills and high integrity, perform systems analysis to identify key points in the fuel cycle for safeguards operations, and carry out research and development to provide the best and most efficient equipment and techniques. The agency has made a promising beginning. □