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INSPECTION AND CONTROL UNDER AN INTERNATIONAL AGENCY

This paper was written for and at the request of the Division of International Affairs. It attempts to be responsive, in general, to the technical aspects of questions concerning methods of inspection and control by an International Agency of atomic energy operations carried out under an atoms for peace program. This paper is not concerned with questions of disarmament per se, and hence does not apply to the U.S., U.K., and USSR.

The statements and conclusions in this paper represent only the opinions of certain AEC staff members from several technical divisions. It should be emphasized that this discussion is not in any sense a thorough study of the very difficult and complex questions involved -- rather it is only a first appraisal of many of the problems. This is especially true of those questions involving inspection of a nation to ascertain whether non-permitted activities are being conducted clandestinely. It may require modification after further investigation.

The problem has two major divisions: (a) feasibility of inspection and control by the Agency of operations for which the Agency or another country has provided materials, technology, or other substantial assistance, and of any other "declared" operations for which the Agency has responsibility for inspection and control, and (b) feasibility of inspecting the country involved to determine whether prohibited production or preparations for production of special nuclear material are going on clandestinely within its territory. It is assumed that an Agency corps can be established which will be able to carry out reliably and honestly the activities with which it is charged.

INSPECTION AND CONTROL OF PLANTS AND FACILITIES UNDER THE AGENCY

Several possibilities are apparent. The facilities could be operated by the country involved, with inspection and control performed by the Agency or, in certain cases, the actual operation could be performed by Agency personnel. In the latter case, control of the operations would be facilitated and the requirement for an inspection and control force, in addition to normal operating and accounting personnel, would be consequently reduced.

If isotope separation plants were included in the permitted operations of recipient countries, it would obviously add to the Agency responsibilities. No consideration, for purposes of this discussion, has been given to this question of Agency inspection of such plants, under an assumption that operation of them by individual recipient countries would not be

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allowed. On this assumption, there would be no need for an inspection corps for such plants. The problem of detecting clandestine operations of this sort would be alleviated in some degree, since the discovery of the production of equipment for such plants could be taken as evidence of intent to engage clandestinely in isotope separation operations. With the above limitation, the types of operations which would be subject to inspection and control by the Agency could involve fuel element fabrication, reactor operation, chemical reprocessing plant operation, certain other auxiliary production operations, storage and transportation of fissionable materials, and certain research and development activities.

With respect to sensitivity, or greatest possibility of diversion, the chemical reprocessing and the fuel element fabricating plants are the most important. This is true because in these operations special nuclear materials are handled in bulk quantities - either in concentrated solutions, in the form of solid salts, or as metals. In such cases scraps, waste solutions and side streams for reprocessing are inherent and the problem of accountability rests in visual inspection, physical safeguards, and analytical methods (chemical analysis, weighing, etc.).

In the case of reactors themselves, accountability for fabricated fuel elements is relatively more simple, since they are, in most instances, discrete units. Control and inspection of reactors is important, however, because they can produce, as well as burn, fissionable material (Pu-239 or U-233) and it is necessary to know the magnitude of this production in order to account for the material later in the chemical processing of fuel and blanket materials. Certain types of reactors - e.g. those which might employ fluid fuels with continuous reprocessing in situ - would represent a more complicated situation in which fuel fabrication, reactor operation and chemical processing are combined in one plant.

A control and inspection system for a fuel element fabrication plant, a reactor installation or a chemical plant would depend primarily on accountability procedures and physical security measures applied to the special nuclear material to prevent undetected diversion. Such a scheme was outlined by Dr. I. I. Rabi, the U.S. representative to the six nation conference on safeguards under an International Agency. This conference was held in Geneva from August 22 to August 27, 1955.

Listed below are some of the technical suggestions, selected for greatest relevance to the present discussion, which were made by the U.S. representative at the above mentioned meeting as a basis for the kind of control and inspection envisioned:

1. The Agency will inspect and control the agreed-upon atomic energy operations of the receiving country.

2. The purpose of the inspection and control is to prevent diversion of sufficient amounts of nuclear material to constitute a hazard to world peace within a reasonable time, such as ten years.

3. The inspection and control system is to be so designed and

operated that it will be as economical as possible and will interfere with the operation as little as possible consistent with the objectives of the inspection and control.

4. The atomic energy operations of the country which is receiving this aid are fully disclosed to the Agency. These include:

(a) the reactor design, construction and operating experience;
(b) the fuel fabricating plants;
(c) the chemical processing plants;
(d) the transfer operations between the different plants or sites.

5. The design of these plants is to be such as to facilitate inspection and control and to minimize the number and size of areas which require control.

6. Measures of inspection and control need not be identical for all operations since the potential danger of diverted material will vary from operation to operation.

7. The inspection and control procedures of the Agency are to include physical security measures and material accountability measures.

8. Physical security measures are to be restricted to areas closely associated with any or all of the following:

(a) Storage of nuclear materials in either unirradiated or irradiated form;
(b) Reactor operations;
(c) Fuel fabrication;
(d) Chemical operations;
(e) Transport.

9. The purpose of the physical security measures in each of these areas is to permit the ingress and egress of nuclear materials only if properly recorded on accountability records maintained by the Agency or subject to inspection by the Agency.

10. Accountability records are to be such as would normally be used by the receiving country since the nuclear materials will have a high monetary value.

11. At periodic intervals or continuously the Agency will audit the accountability records and will make or supervise physical inventories, employing such analytical procedures as may be appropriate. Except in cases of suspected diversion or at reasonably long intervals such inventory-taking should not require the interruption of reactor or other operations. The Agency may, however, inspect any or all parts of the operation at any time which it deems necessary or appropriate and without prior notification.

12. In order that the Agency may properly assess the accuracy of quantities of nuclear materials entered on the accountability records, all phases of the technical operations involved must be made known to authorized competent Agency personnel. Pertinent trade or other types of secrets should not be withheld from the Agency personnel.

13. The degree and kind of inspection and control instituted by the Agency may vary depending on whether all or only a part of a fuel cycle lies within the boundaries of a country, and may vary depending on whether ownership of a particular facility is by the receiving country or otherwise.

14. The transport of nuclear material is to be controlled in a manner dictated by the quantity and condition of the materials. Transport may be entirely under the supervision of Agency personnel. It may be possible in some cases to use common carriers, with Agency personnel responsible only for the inspection of seals, containers, etc. at appropriate points.

15. Wastes containing nuclear materials or fission products may be removed from the control system, provided they are disposed of in some irreversible manner under the supervision of the Agency.

16. It should be noted that reactors other than those operating on enriched fuels can also produce fissile material. These are reactors employing normal uranium as a fuel. The control and inspection system outlined above is also adequate for these types of reactors.

In addition, certain techniques for more readily tracing the flow of special nuclear materials were suggested and discussed. These methods may prove to be practical and feasible and may assist the control and inspection system but they cannot be thought of as relieving the requirements for close accountability and physical security mentioned above.

In essence, the control and inspection procedures proposed are based on the operation of a corps of competent and trained personnel, including the necessary number of technical people, permanently located at the plants to be controlled. The procedures would involve intimate knowledge, on the part of the inspectors, of the operations and of the design and operating characteristics of the plants themselves. Critical and sensitive operations would be visually observed and records continuously monitored and audited. In addition, duplicate measurements by the inspecting force would be made where considered necessary. Ingress and egress of materials and personnel would be monitored. The degree and extensiveness of control would obviously vary with the type of installation. Low power research reactors would call for very little inspection, with increasing degrees of thoroughness called for in the cases of power reactors, fuel fabricating plants, and chemical processing plants.

It should be realized that absolute assurance against the possibility of diversion of materials is exceedingly difficult and probably impossible

to attain. The measures adopted would be designed to achieve some kind of balance between minimizing the risk of undetected diversion while at the same time not imposing a too burdensome and irritating superstructure on the normal operations.

In cases where the operating characteristics (nuclear parameters) of a power reactor are well known and performance characteristics for a chemical plant are established, material accountability in such a system can probably be maintained to within a few percent over an extended period such as one year. (Accountability will be poorer over a shorter period.) Obviously, for systems where performance characteristics are less well known (e.g. breeder reactors, certain of whose nuclear constants may be initially uncertain by as much as 10%-20%) the accuracy of accountability will be poorer. The above figures would represent limits of undetected divertability, but as a practical matter, with adequate physical security, it could be made very difficult to divert this much material consistently.

With respect to Agency personnel required for inspection and control at a plant under their jurisdiction, an estimate may be made in an illustrative case. A moderately sized chemical plant, such as would be required to process irradiated fuel elements from a reactor, or reactors, producing around 1000 megawatts of heat, requires of the order of 200 people (exclusive of guards) for full time operation (24 hours per day, seven days per week). It is estimated that an inspection force of about 40 people (exclusive of guards) might be adequate to inspect and control such an operation. The number of people required for operation or inspection of such a plant does not increase proportionately to capacity. Of these 40 people, between one-third and one-half would be technical personnel. On this basis the additional expense required for inspection and control would be represented primarily by the salaries of this force, in this case amounting to approximately 20% of the normally required operating and maintenance staff. Similar ratios would appear to be reasonable in the case of larger operations, or in the case of reactor or fuel fabrication plant operation, although a reactor might require a somewhat smaller ratio, and a fuel element fabricating plant a somewhat larger ratio. Some guard force personnel would also be required to monitor ingress and egress of personnel and materials. These requirements (not included in the above figures) might involve 12 - 16 people.

It may be pointed out that the strictly technical aspects of the inspection and control function, involving the services of trained chemists, physicists and engineers, need not necessarily be entirely of a negative nature. Some proportion of their time may be devoted to more positive aspects of technical assistance. The fraction of the time which could be devoted to this for the numbers of people listed above would be only nominal since the estimate is based on their being engaged in inspection and control essentially full time. However, the resulting advantages in communication with technical personnel of the plant would make such functions worthwhile.

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It should be noted that it is not mandatory that every power reactor have its own fuel fabrication and chemical reprocessing plants, in the sense that it is possible for one each of the latter plants to serve a number of reactors, depending on their size and type. To the extent that it proves practicable and acceptable to adopt centralized fuel fabricating and reprocessing facilities the problem of inspection and control will be simplified in the following ways: (a) the total number of inspectors and operators would be reduced over that required for a larger number of smaller plants, both reducing the cost and making control simpler, and (b) many countries would, in this case, not legally acquire facilities usable for converting reactor products to weapons materials.

INSPECTION FOR CLANDESTINE FISSIONABLE MATERIAL PRODUCTION

In addition to potential fissionable material diversion from disclosed and inspected facilities, there is the possibility that a country can set up or operate an entirely unknown facility while the inspection plan is in operation. Here the pertinent question is not margin of error in accountability and physical plant surveillance, but the probability that an operation of significant size could long go undetected and unsuspected. Although effective methods can probably be devised to preclude substantial efforts of this nature, if it is desired to attain maximum and continuing assurance that such entirely clandestine operations are not carried on, unimpeded access would be required.

The operational methods for preventing secret operations would fall into the general areas of continuing surveillance of the resources that would be required to support a secret activity and extensive searching for unexplained activity, for effluents from processes, and for the fate of materials and power not clearly accounted for. The complexity of an atomic energy operation makes substantial efforts most difficult unless they are tied into the general economy, and requirements would be expected for construction, for materials peculiar to processes involved, for scientific and engineering equipment, for power, for financing and for uniquely trained people. A substantial surveillance effort on all these matters, with accompanying physical inspection capabilities, would give maximum assurance that clandestine operations are not set up. The potential capabilities of various countries in this field differ very greatly and the actual inspection system would be varied accordingly, with a concentration on those aspects of an atomic energy operation where the resources of the particular country are weakest (i.e. where the chance of concealing an unusual activity is poor) or maximum detection probability is otherwise indicated. The problems and techniques of a complete intensive system will first be described and then the nature of more limited inspection will be considered.

Nature of Required Clandestine Effort. To produce militarily useful amounts of fissionable material independently, a country would have to provide itself with materials and facilities modest in amount and size, but in some cases uniquely characteristic of an atomic energy effort.

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A supply of uranium is needed, possibly supplemented by thorium. Quite a few tons will be required and it will be necessary to mine or import the material. Ore concentration facilities will be required followed by fuel element or chemical processing plants depending on whether the reactor or isotope separation approach is used.

In the reactor alternative a concealed production reactor would be required, followed by a separation plant in which highly radioactive materials can be processed without extensive contamination of the environment. Isotope separation requires a substantial plant - by gaseous diffusion or other feasible methods - and facilities for producing metal from the enriched product. Establishment of the atomic energy capability will also require production or acquisition of other characteristic materials such as graphite or heavy water moderators in the reactor approach or barriers and fluorine gas in the isotope separation approach. The problem posed to an inspection system is to detect any or all such operations.

Available Inspection Methods - Complete System. A complete inspection system would require intensive use of several different approaches; of these the first to be used on a large scale would be direct searching. This would be particularly important in the initial survey and would have to be used continuously thereafter in a permanent attempt to preclude establishment of new facilities. An aerial inspection, repeated at intervals and carefully evaluated, may reasonably indicate the presence of mining operations and the location of individual industrial facilities. Assays of samples of environmental materials may give indication of radioactive releases in an area under investigation.

These methods would probably be chiefly functional in providing a guide for on-the-ground inspection. For reasonable assurance each mine and chemical plant disclosed or found by inspection would have to be examined periodically for the nature and extent of its operations. In addition, the possibility that industrial operations of reasonable magnitude could be carried on in buildings of residential appearance cannot be entirely disregarded.

This physical searching is the aspect of inspection that would probably vary most with the country to be inspected. Small size of an inspected country is advantageous; industrialization would make the problem more difficult. The problems of inspecting India would be very much different from those encountered in a small Western European nation.

The complexity of the necessary effort and the difficulties in concealing a complete installation in one place make probable the shipment of characteristic materials from site to site as opposed to concentrating all operations in one place. In the continuing phase of inspection, the examination of industrial and transportation systems for such shipments should become important.

The nature of required transport encompasses two types of shipment different in nature and in the means of detection. In one form of

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activity, the principal nuclear materials would be transported between installations: ore from mines to processing plants, natural uranium to the reactor or isotope plant, and the like. Such shipments would be entirely clandestine and direct surveillance of the transport system would be required for their detection. Monitoring of shipments for radioactivity at check points on railroads or at suitable road locations could give indication of shipments in the early stages of production where the natural uranium source material is present. Satisfactory monitoring for fissionable product could be set up only at cost of great effort and interference with the flow of commerce.

The second type of material movement involves the diversion of normal industrial materials to use in a clandestine atomic energy program. An intensive inspection effort would include an accounting of the movement and destination of such of these industrial materials as would be most characteristic of an atomic energy effort. The survey would be based upon records of production and destination and would be confirmed by physical checks of the actual flow of materials.

The monitoring of power consumption provides an inspection device similar in nature to the flow of materials. Electrical power production and distribution would be measured and audited by the inspection authority under circumstances where accurate instrumentation can be assured. The general effect of industrial materials and power monitoring will be to detect a clandestine operation that is tied into the industrial economy. Possibilities of successful evasion would then be confined to systems that are completely independent for important supplies and thus so large that they would be reasonably easy to detect directly.

The continuing search for facilities and the monitoring of materials flow would be combined in the field of construction so that any substantial new construction or renovation could be discovered and examined. An effort adequate to inspect all significant new construction is therefore required in a complete system. A successful atomic energy production operation depends on substantial concentrations of people highly trained in clearly definable areas. The tracing of technical experts can provide information on past sites and can make difficult the staffing of new undisclosed locations; it would thus be desirable in a complete system to provide facilities for keeping track of the professional activities of competent scientists and engineers.

Any serious evaluation of the specific staffing needed for a complete system, making use of all the approaches listed above, would require a detailed examination of the appropriate effort in each field for the particular country under consideration. It seems a reasonable judgment, however, that in a system of such completeness a permanent staff of several hundred people would be required for a small but industrialized country, such as Switzerland, and that several thousand would be required for a country like India. Perhaps ten to twenty percent of these would be professional scientists and engineers.

The system described would be primarily concerned with detection of

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the efforts necessary to secure a supply of fissionable material. It would be necessary for the country attempting to evade its agreement to design and fabricate weapons from the material it would secure. Detection of such a fabrication operation would probably be most difficult. In a complete inspection system attention would be directed to efforts of laboratories that might be performing experiments needed for the design or whose personnel might be working on design, but detection of operations of this sort is far less promising than detection of fissionable material production. A country attempting clandestine development and fabrication of weapons would undoubtedly try to do this without actual testing of the weapon, since such a test would be very likely to be detected.

The inspecting force required for an initial survey of a country as compared with that required for a continuing inspection, at any degree of allowed inspection rights, will be dependent primarily on the time in which it is desired to complete the survey. If the time is long (a year or more) the force might be not much larger than the permanent one. If it is desired to complete this phase rapidly, then the staff would have to be augmented considerably during this period.

Less-than-Complete Inspection Systems. Maximum assurance that no clandestine operations are being conducted could be obtained only with an intensive and complete inspection system containing the activities just described. This intensive system, which must include rights of complete access to all facilities, areas, and records of the country, and rights of unlimited aerial photography, obviously entails an unprecedented infringement upon governmental, industrial and personal privacy. It is therefore germane to consider the effectiveness of less rigorous inspection systems which would entail a lesser degree of trespassing.

A less than complete inspection system may have sufficient effectiveness to be well worth establishing where practical and political considerations preclude the full inspection, but it should be realized that any significant restriction in the rights of inspection will substantially increase the probability that clandestine production could be successful. A reasonable question is whether departures from the theoretical standard of complete inspection outlined in previous sections can be made of sufficient scope to leave a less-than-complete system that will promise enough effectiveness to be worth trying, and at the same time not be so costly in money and political concession as to be outside the range of practical acceptability.

Probably the most serious infringement introduced by the complete inspection system is that which would result from the right of the agency inspectors to enter and inspect any and all facilities and areas of the country. One can envision a system in which this right would be abridged by an agreement that certain areas, such as military bases, armament factories, etc., and records relating directly to these operations, would not be open for inspection. Although this modification would still allow unlimited aerial photography and access to all other (non-military) areas

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and facilities and records, as well as the right to take and analyze environmental samples from allowed areas, the establishment of such boundary lines would seriously curtail the effectiveness of the inspection system. The inspection effort would concentrate on the detection of inconsistencies in available records, of suspicious activities by air and ground surveys, and on analysis of environmental samples for traces of materials characteristic of atomic energy operations. A well organized and well concealed attempt to set up and operate an unauthorized facility would have a finite probability of succeeding, and it must be recognized that success in this attempt could result in the possesssion of one or more atomic weapons by the country. Obviously the probability of success will be highest in those countries where the state of technological development is greatest.

Inspection efforts which would be even less distasteful to the country being inspected can also be envisioned. For example, the system described in the preceding paragraph could be further abridged by removing the right of aerial survey and the obligation of the country to produce records for inspection. This system would then be dependent on the inspectors having only the rights which are normally given to tourists or visitors in the country, including the right to take environmental samples from non-restricted areas, plus the right to inspect normal, non-sensitive industrial operations. These rights appear to be the minimum that could be allotted to an effort that could still be considered to be worthwhile. In more advanced countries, this system would give a low degree of assurance that clandestine operations could be detected.

The limited systems just discussed are obviously only two hypothetical examples of the many types of less-than-complete systems that could be postulated. For example, one might envision a system in which access to certain otherwise restricted areas could be authorized by search warrants issued by some appropriately constituted international body on a showing by the international agency of probable or reasonable cause to suspect or believe that clandestine activities were being conducted in these areas.

The ease of detection (or difficulty of concealment) of a clandestine effort, by a limited inspection system, will also be a function of the type of clandestine activities being attempted. The operations required for the small-scale production of plutonium or uranium-233 may be more readily detectable than those necessary for the small-scale production of enriched uranium-235, due particularly to the byproduct radioactivity formed along with Pu or U-233.

The completeness or intensiveness of possible inspection systems has been varied in the preceding discussion by reducing the degree of infringement upon the privacy of the country. It should be emphasized again that, as soon as the inspected country is allowed to retain any privacy at all, the effectiveness of the system suffers a sizeable decrease, which is of a relatively greater magnitude than would occur with further concessions to national privacy. The intensiveness of inspection systems could also be affected by the size of the effort or

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number of people engaged in the inspection activity. For a system operating within a given degree of access, its effectiveness would appear to be roughly proportional to the number of people employed, up to the point of maximum efficiency. It is very difficult, without considerably more study, to estimate staffing requirements necessary for maximum efficiency in any one of the hypothetical systems mentioned above. In the preceding section, a guess was made for the case of the complete or intensive system. It would seem reasonable to assume that the more moderate systems would require a smaller staff. It also seems possible, however, that if one were denied access to certain areas and facilities, one could profitably place a larger effort on the permitted areas, facilities, and activities.

As implied several times in the preceding discusssion, the adequacy of each of the systems of different degrees of moderateness will vary greatly with the size, state of development, and natural resources of the country. A very moderate inspection system, requiring little invasion of the country's privacy, might give sufficient assurance when applied to a country such as Paraguay, but would be of very little value if applied to, for example, Switzerland.

The deterrent effect that the presence of an agreed-upon inspection effort in a country would have on the likelihood of the country attempting to set up a clandestine operation is difficult to evaluate. Such a deterrent effect undoubtedly would exist, and would certainly be stronger when the country is faced by a complete inspection system than by a very moderate and less effective system. Even though it would be possible to set up and carry out an undetected operation in the presence of a moderate inspection system, the pains which would have to be taken to conceal all pertinent activities and perhaps to falsify records, and the risk of detection by the international agency, would cause the country to consider the action and its implications very seriously before it decided to proceed. A quantitative evaluation of the deterrent effect for different inspection systems, and when applied to different countries, is not possible at this time.

If plants for fuel fabrication and chemical processing were operated on a regional basis by the Agency, as noted in a previous section, and not permitted to be operated by individual countries that do not presently have such plants, several factors favorable to effective inspection and control would accrue: (a) the opportunities for diversions from the processing plant or for seizure of the plant are diminished or removed; (b) a country attempting illegal plutonium or uranium-233 production would have to attempt to construct and operate a chemical processing plant, which is one of the more easily detectable links in an atomic energy chain.

In summary, it may be pointed out that for a complete and extensive system of inspection of an entire country, with rights of inspection unlimited, the effectiveness will vary approximately linearly with the

manpower assigned to the operation, up to some range of diminishing returns, or saturation, and the level may be set at any desired degree of assurance. This maximum level will vary from country to country depending on the state of technological development, degree of industrialization, population density and total area. It will also be a complex function of these factors. On the other hand, successive and progressive abridgment of the rights of inspection down to no rights of inspection at all except in Agency-controlled facilities will lead to sharp drop-off in effectiveness as complete rights of detailed physical examination are eliminated, followed by a less sharp, but progressive loss of effectiveness as other privileges are removed. Personnel requirements in this latter situation could be reduced more or less linearly unless it was desired to attempt to compensate for the loss of effectiveness in the abridged rights by a more intensive examination of other factors.

Finally, it is pointed out that any degree of inspection of a country for clandestine activities should produce some deterrent effect against the country engaging in them.