INMM

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1975 ANNUAL MEETING — NEW ORLEANS, LA.

NUCLEAR MATERIALS MANAGEMENT

VOL. III, NO. I

SPRING 1974

JOURNAL OF THE INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

FAREWELL EDITORIAL

Curtis G. Chezem
Past Executive Editor
INMM Journal

CHEZEM COMMENTS

Some months ago, after informing the INMM Executive Committee of my desire to resign as Executive Editor of the Journal, Tom Gerdis asked me to jot down my thoughts upon taking such a step. This is a difficult task which is somewhat comparable to a request to me from "Who's Who in America" to express "thoughts on my life" in one or two paragraphs. Such thoughts defy simplistic statements since I have served nuclear energy in the government laboratories, in the Atomic Energy Commission, colleges of engineering and now in the hard core of industry. In discussing the conditions which make my resignation necessary to pursue what I will choose to call the highest priority activities, I will answer many questions that I had about the relations between the electric utilities and the balance of the industry.

It has been my good fortune to become personally acquainted with most of the leaders in the nuclear industry and the engineering education field. The nuclear engineering educators join their colleagues in electrical and mechanical engineering in condemning the utilities for neglecting the needs of the colleges of engineering.

Looking at the matter from both sides, I have seen excellent rapport between individuals in the utilities and selected individuals in the educational field. Why then, as institutions, are the utilities and the colleges of engineering so far apart? I believe it is because of what seems to be an inherent inability of the university system to respond at the academic level to project oriented tasks in a timely fashion in return for such support. Some of this is ivory-towerism toward being dictated to as to what projects to accomplish, some is due to the difficulty in managing a university unit in a business-like fashion because of various forces of tenure, individualism, etc. These are most often cited to me by educators across the country. The generalized result is that only small groups of professors or individuals can be brought together to put their own reputations on the line to accomplish given tasks by a specified deadline. The reward for accomplishment is theirs alone and not used to support less productive individuals. This could go on and on as the evidence piles up to me on both sides of the question. Simply, the utility must go to an individual or a profit making research institution to obtain special assistance in a timely fashion especially in situations where delays can be measured in terms of hundreds of thousands of dollars per day or in the case of 1000 MWe nuclear units, delays which can be measured in terms of approximately a million barrels of oil-equivalent per month per unit.

But should not the utilities support engineering departments simply because that's where they get all their employees? Experience has shown that such support is good for students who promptly scoot off into other more glamorous pursuits or in some cases into the more

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NUCLEAR MATERIALS MANAGEMENT is published four times a year, three regular issues and a proceedings of the annual meeting of the Institute of Nuclear Materials Management, Inc. Official headquarters of INMM: Mr. V. J. DeVito, INMM Secretary, Goodyear Atomic Corp., P.O. Box 628, Piketon OH 45661.

Subscription rates: annual (domestic), $20; annual (foreign), $30; single copy of regular issues published in spring, summer and winter (domestic), $4; single copy of regular issue (foreign), $6; single copy of fall proceedings (domestic), $10; and single copy of proceedings (foreign), $18. Mail subscription requests to NUCLEAR MATERIALS MANAGEMENT, Journal of INMM, Seaton Hall (EES), Kansas State University, Manhattan, KS 66506. Make checks payable to INMM, Inc.

Inquiries about distribution and delivery of **NUCLEAR MATERIALS MANAGEMENT** and requests for changes of address should be directed to the above address in Manhattan, Kan. Allow six weeks for a change of address to be implemented. Phone number of the I.N.M.M. Publications and Editorial Office: Area Code 913 532-5844.

Inquiries regarding INMM membership should be directed to Mr. V. J. DeVito, INMM Secretary, Goodyear Atomic Corp., P.O. Box 628, Piketon OH 45661.

Third-class postage paid at Manhattan, Kansas 66506.

TWO MORE N15's APPROVED . . .

Delnay

STANDARDS REPORT

By R. L. Delnay

Since our last annual meeting, the Board of Standards Review has approved two more N15 standards, bringing the total of N15 American National Standards to 11. The Board approved N15.15, "Assessment of the Assumption of Normality" on October 3, 1973 and N15.13, "Nuclear Material Control Systems for Fuel Reprocessing Facilities" on November 15, 1973.

N15's letter ballot and ANSI's public review have closed on proposed American National Standard N15.16, "Limit of Error Concepts and Principles of Calculation in Nuclear Materials Control." The one negative ballot has been resolved. The subcommittee is now resolving comments received on affirmative ballots plus one comment from ANSI's public review. The one negative ballot has been resolved. The subcommittee is now resolving comments received on affirmative ballots plus one comment from ANSI's public review. John Jaech and his subcommittee are to be congratulated for their efforts as N15.16 represents their third standard and they have a fourth standard well underway.

Currently, there are two more proposed standards in N15 letter ballot. We sent proposed standard N15.9, "Nuclear Material Control Systems in Fuel Fabrication Plants" to letter ballot in January. In February, we authorized the letter ballot from N15.8, "Nuclear Material Control Systems for Nuclear Power Reactors." Our thanks to Gene Miles and Armand Soucy as chairmen of the respective task groups that produced the two standards.

Lou Doher expects to submit the four standards covering calibration techniques to N15 for letter ballot this year. The first of the four, N15.22, "Calibration Technique for Calorimetric Measurement of Plutonium for Nuclear Material Control," will go to letter ballot in April.

Dan Wilkins predicts that his subcommittee will complete their work on N15.26 so that it can be submitted for letter ballot before our Atlanta meeting. This standard covers physical protection of special nuclear materials within a facility. Dan and his subcommittee have really stayed with it since their assignment in November, 1972.

If our hopes are not too high and the proposed standards described above stay on schedule, then the INMM can boast of having prepared 19 American National Standards by the end of 1974. That is the good news. The bad news consists of the knowledge that there remain five potential standards that may never become American National Standards because of the failure of some INMM members to work.

BOOK REVIEW

J. L. Jaech

STATISTICAL METHODS IN NUCLEAR MATERIAL CONTROL

The U.S. Atomic Energy Commission has just released the book **Statistical Methods in Nuclear Material Control** by John L. Jaech, Exxon Nuclear Company. Useful as backup material in implementing various standards and applying regulatory guides, the book should be of considerable value to those responsible for nuclear accountability.

Intended as a personal reference book to be studied by the individual reader, the text puts heavy emphasis on worked examples, usually with sufficient calculational details to enable the reader to follow the solution step by step. The material is organized for ease in locating topics of interest. The reader interested in a particular application can choose only problems in his sphere of interest, and the reader interested only in applications can omit sections dealing with the statistical bases for the solutions. This is a volume which should provide increased industry-wide understanding and guidance in improving material-unaccounted-for control and evaluation.

Statistical Methods in Nuclear Material Control contains ten chapters: Introduction; Probability and Statistics; Sources of Uncertainty in Nuclear Materials Control; Mean and Variance of Functions of Random Variables; Limits of Error on Individual Items; Limits of Error for General Algebraic Sums; Interpretation of MUF and LE-MUF; Analysis of Paired Data; Inventory Verification; Integrated Applications. Also included are seven appendixes, consisting of statistical tables, and an index. (402 pages, 6 by 9 inches, paperbound; Library of Congress Catalog Card Number: 73-600241.) This book is available as TID-26298 for $10.60 from National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22151.

GUARD VESSELS

RICHLAND, Wash., — The first of three sets of primary sodium pump and intermediate heat exchanger guard vessels was recently installed beneath what will be the reactor operating floor of the Fast Flux Test Facility (FFTF).

These guard vessels are located beneath the floor in a concrete cell where they serve as a backup to the primary system boundary in the unlikely event of leakage from the primary sodium system. Sodium, the liquid metal coolant for fast breeder reactors, extracts heat generated during fission from the reactor core and uses it to produce steam for electricity.

Personnel at the FFTF site installed the vessels, following carefully planned procedures, in less than six hours. The pump guard vessel weighs almost 23 tons and measures about 14 feet wide by 25½ feet long.

The three sets of pump and intermediate heat exchanger guard vessels were fabricated by Stearns-Roger, Denver. The second set of vessels arrived last month at the Hanford Engineering Development Laboratory (HEDL) and will be installed over another weekend to prevent impact on the beehive of activity in the containment building. The third vessels already have been fabricated and are due to be shipped from Denver soon. By March 1, all three sets of guard vessels will be installed.

Westinghouse Hanford Company manages HEDL for the U.S. Atomic Energy Commission. A major AEC contractor at Hanford, Westinghouse has responsibility for the construction and operation of the FFTF.

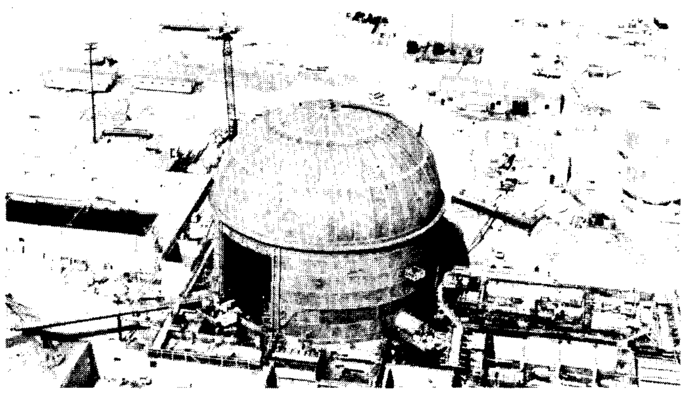
ADVERTISING INDEX

RAY MULKIN TO LOS ALAMOS

LOS ALAMOS, N.M. — Ray Mulkin has recently joined the staff of the Los Alamos Scientific Laboratory to work with the Chemistry-Materials Science Division.

Mulkin received a B.S. degree in chemistry from the Oklahoma State University, Stillwater. He is a member of the American Chemical Society and the Institute of Nuclear Materials Management.

The new staff member and his wife, Barbara, have a daughter, Christine Fitzrandolph of Ft. Collins, Colorado.



This aerial of the FFTF, Richland, Wash., shows construction progress of the reactor service building (right) and two of the three heat exchanger buildings on the left adjoining the containment vessel. Two silver-colored tanks in the upper right store 300,000 gallons of water each for sanitation and fire protection. Buildings at the extreme left are temporary construction service buildings and will be removed when construction is completed in 1975.

Wm. J. Gallagher

THE USAEC— MODERN VENDUE MASTERS

Editor's Note: We welcome this guest editorial, the second written by Bill Gallagher of Intelcom Rad Tech, San Diego, Calif. In the Winter 1974 issue we published, "Dollar Above Everything Else?" Mr. Gallagher is an active supporter of INMM activities and most recently coordinated the nominations of officers for the 1974 annual meeting of INMM set for Atlanta, Ga., June 19-21.

Near the tip of Long Island, New York, reaching out into the Atlantic Ocean, are a series of beach-front communities whose beautiful colonial homes date back to the founding of the United States. Walking through these historic little towns and villages, it is easy to imagine what life was like 200 years ago, particularly for the early American aristocracy. One of these quaint villages has a town square, in the middle of which is a wooden flagpole made from a ship's mast, and therein lies a tale that receives little publicity.

The mast was taken from a shipwreck on the Long Island shores during the days of the early American colonies. During this time period, the local residents also salvaged various commercial goods that floated ashore from ships wrecked on offshore rocks and shoals. The salvagers enjoyed this bounty, but there was one disadvantage — they had no control over the type of merchandise that floated ashore. For example, the villagers may have been short of tobacco one month, but perhaps all that floated their way that month were barrels of rum. The village salvagers hit upon a scheme to increase the supply and variety of the bounty. During storms, or on overcast nights, they erected false navigational lights on the beaches to lure the passing merchant ships onto the offshore rocks and shoals. This situation continued for some time, reaching a climax when the village salvagers began cutting rings from the fingers of unconscious merchant sailors washed ashore from the wrecks. At this point a group of men, referred to as Vendue Masters, came into being along the Long Island shores. The Vendue Masters maintained surveillance of the beaches during storms or overcast weather to assure that false navigational lights were not in operation. When shipwrecks did occur, the Vendue Masters gathered and collected the cargo and half-drowned sailors washed ashore, protecting both from the eager salvagers. They posted guards over the remains of the wrecked ships to protect the interests of the ship owners and the public. Needless to say, the courageous Vendue Masters did not meet with universal approval. Looking back at this little publicized bit of Americana, one wonders how such atrocities could have occurred. In the final

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ADDRESS CHANGES OF I.N.M.M. MEMBERS

The following are new addresses for members of the Institute of Nuclear Materials Management, Inc.:

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Ira Cohen, U.S. Atomic Energy Commission, 631 Park Ave., King of Prussia PA 19406.

John M. Crawford, 446 Love St., Erwin TN 37650.

Delmar L. Crowson, Middle South Services, Inc., P.O. Box 61000, New Orleans LA 70161.

William E. Gilbert, Inspection Branch, U.S. Atomic Energy Commission, Division of Nuclear Materials Security, Century XXI Bldg., A2-1303, Washington DC 20545.

F. C. Hanny, 80 Brookview Rd., Windsor CT 06095.

C. Gordon Hough, Arbesbachgasse 4/4/15, A-1190, Vienna, Austria, Europe.

Dr. **Herbert J. C. Kouts,** U.S. Atomic Energy Commission, Washington, D.C.

Walter G. Martin, U.S. Atomic Energy Commission, 631 Park Ave., King of Prussia PA 19406.

Charles H. Mayer, Tri-State Motor Transit Co., P.O. Box 113, Joplin MO 64801.

Ray Mulkin, 134 Aztec Ave., Los Alamos NM 87544.

S. G. Nordlinger, 1620 S. Ocean Blvd., No. 4A, Pompano Beach FL 33062.

Frederick J. Perella, 8400 Charlesgate Apts., Charles Valley Ct., Towson MD 21204.

Dean D. Scott, NUMEC, 609 Warren Ave., Apolla PA 15613.

Joseph W. Shaver, MC/179, General Electric Co., 175 Curtner Ave., San Jose CA 95114.

L. C. Solem, U.S. Atomic Energy Commission, Directorate of Regulatory Operations, Regulation, Washington, DC 20545.

Clifford G. Steele, 243 Buttonwood Dr., Paramus NJ 07652.

H. F. Stringfield, 2000 Fenwood Dr., Knoxville TN 37918.

1975 ANNUAL MEETING—INMM New Orleans, La.

SAFEGUARDS

The following was supplied to us by Dr. Fred Forscher, a member of the INMM Executive Committee who operates his own consulting firm in Pittsburgh, Pa. This excerpt from an article, "Ultimate Blackmail," appeared in the **New York Times Magazine Magazine** on February 4, 1973:

Safeguards programs should also be designed in recognition of the problem of terrorist or criminal groups clandestinely acquiring nuclear weapons or material useful therein . . . It should be recognized that political and social restraints would not influence terrorist, insurrectionist or criminal groups.

Some of the worries of the advisory group that prepared the document came to light in a more recent study by the Institute of Nuclear Materials Management, a professional society of nuclear experts who became concerned about the adequacy of the A.E.C.'s safeguards. In a candid manner, untypical of professional societies, a May 15, 1970 report singled out transportation as the weakest link in the chain of security enveloping nuclear materials. "Potential mechanisms for diversion include the hijacking of trucks and aircraft and thefts from traffic terminals," the report maintains, and concludes: "To these cogent concerns there has been no statement or assurance by our Government that preplanned and debugged mechanisms exist that would provide an adequate response to these threats."

The institute made it clear that United States trucking routes were an utterly unsafe way to ship nuclear material. An appendix to its report cites facts on truck hijacking to the effect that total losses from theft amount to well over $1-billion per year. Reference to the Mafia is made. "The transportation industry is infiltrated by organized crime and must be adjudged incapable of providing reasonable protection for valuable or strategic cargo." (A still-secret A.E.C. study that investigated a total of 735 Mafia members showed that significant numbers were associated with trucking either as union officials or as owners of trucking firms.)

Summing up its analysis of nuclear risks, the institute report concluded:

"As a professional society, the Institute of Nuclear Materials Management can do no less than follow objectively where professional responsibility and logic lead. When logic applied by calm and reasonable men leads to alarm, as in the matter of safeguards for nuclear materials in transportation, then the institute must be alarmist. Further, professionalism demands that the institute report facts, logically and systematically arrived at, without regard to the palatability to all groups concerned. The situation with regard to safeguarding nuclear materials in transportation is itself unpalatable."

17 NEW MEMBERS

The following individuals have been accepted for INMM membership as of May 20, 1974. To each, the INMM Executive Committee extends congratulations.

New members not mentioned in this issue of the Journal will be listed in the Summer 1974 (Volume III, No. 2) issue to be mailed in late July or August.

Leonard A. Abrams, NUS Corp., 4 Research Pl., Rockville MD 20850.

John E. Bergman, General Electric Co., P.O. Box 780, Wilmington NC 28401.

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Yvonne M. Ferris, Dow Chemical USA, Rocky Flats Division, P.O. Box 888, Golden CO 80401.

Lewis W. Fields, U.S. Atomic Energy Commission, P.O. Box E, Oak Ridge TN 37830.

Dr. **Tsahi Gozani,** Intelcom Rad Tech, 7650 Convoy Ct., San Diego CA 92122.

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Claes Kallbom Esq., Box 13017, 58320 Linkoping 13., Sweden.

Silve Kallman, Ledoux & Co., 359 Alfred Ave., Teaneck NJ 07666.

Willis T. King Jr., Johnson & Higgins, 95 Wall St., New York NY 10005.

Raymond J. Kofoed, Atlantic Richfield Hanford Co., 2713-E Bldg., 200 East Area, Richland WA 99352.

Robert P. Olding, 350 Nimitz Ave., Redwood City CA 94061.

Marshall L. Pendergrass, Arkansas Power & Light Co., P.O. Box 551, Little Rock AK 72203.

Richard D. Seagren, Union Carbide Corp., Nuclear Div., ORNL, P.O. Box X, Oak Ridge TN 37830.

Waldemar B. Seefeldt, Argonne National Laboratory, 9700 South Cass Avenue, Argonne IL 60439.

Samuel Untermyer, National Nuclear Corp., 3150 Spring St., Redwood City CA 94025.

Joseph L. Womack, 793 Boardman Rd., Aiken SC 29801.

Dale

15 YEARS! HAS IT BEEN WORTHWHILE?

By Larry F. Dale

The Institute of Nuclear Materials Management is approaching its 15th Annual Meeting, scheduled for June. What has the INMM accomplished during its 15 years of existence? Has it been worthwhile? Let's examine some facts!

Membership! In 15 years the Institute has grown from only a handful of members to almost 400 people representing every discipline of nuclear materials management. In spite of this rapid expansion, the high professional caliber that has always been characteristic of the INMM's membership has been maintained. All of these people and their employers evidently feel it's worthwhile.

Standards! The Institute has been singularly responsible for the development of eleven American National Standards, of which seven have received AEC endorsement as Regulatory Guides. There are presently fourteen more in various stages of development and review. This is certainly a worthwhile effort.

Certification! By conferring upon them the distinction of Certified Nuclear Materials Manager, the Institute has recognized 74 persons whose efforts in the area of nuclear materials management have reflected the highest in professional competence. Others seeking this honor will strive to attain the professionalism exhibited by these CNMM's, thus contributing to the accomplishment of the Institute's objectives.

Information Exchange! It is impossible to quantify the value gained by each attendee from formal presentations, panel discussions, and even social hour bull sessions at the annual meetings. However, I have always felt that I received my money's worth. How about you?

Industry-Government Relations! The INMM, with its broad based membership, provides an informal atmosphere where industry and government representatives can discuss problems relating to nuclear materials management. This factor has certainly contributed to our ability to work toward rapid and efficient resolution of many of these difficulties.

Has it been worthwhile? Judge for yourself!

Now we must inform others in the industry. You, the individual INMM member, are the most powerful public relations tool we have. Your daily contacts with potential members and advertisers can do more toward telling of the Institute's worth than dozens of letters or brochures. And speaking of advertising, let's not forget the Journal you are reading — another INMM accomplishment.

As we pass the 15 year mark, confident that our efforts are worthwhile, let us each resolve to devote of our time and efforts toward assuring the Institute's continued success.

NEW A.E.C. PACKAGING DIRECTORY

The Atomic Energy Commission (AEC) has announced the publication of its new packaging directory. It is WASH-1279, "Directory of Packagings for Transportation of Radioactive Materials." It is being offered for sale by the U.S. Government Printing Office, Washington, D. C. 20402, at $2.60. This Directory updates its 1969 predecessor. The new listings cover only AEC-owned and approved casks, birdcages, and other packagings. AEC is asking for additional listings for nuclear industry packagings, to be published later this year in the next revision.

The Directory was put together by the AEC's Transportation Branch (Division of Waste Management and Transportation). Its purpose is to offer shippers a chance to avail themselves of existing packagings, rather than to have to go through expensive design, approval, and construction of new packagings. The Directory is indexed by AEC approval number (old DOT Special Permit number), shield thickness, cavity size, and common name.

This is the lobby of the Riviera Hyatt House in Atlanta, Ga. This fine hotel is the site of the 15th annual Institute of Nuclear Materials Management.

An outside view of the Riviera Hyatt House in Atlanta, Ga. More than 200 registrants are expected to be in Atlanta for the June 19-21 annual meeting of INMM for 1974. Jim Joyner of Atlanta is the local chairman for the annual meeting where an excellent slate of papers is to be presented.

VERIFICATION SAMPLING TECHNIQUES IN A SAFEGUARDS SITUATION

By K. B. Stewart and R. A. Schneider

INTRODUCTION

Verification sampling techniques in a safeguards situation are used to detect whether the assigned amount values on materials of strategic importance are, within the limits of statistical measurement variation, correctly stated. If they are not, the statistical evidence of verification is used to signal an investigation into the causes of the anomalies and discrepancies. Such an investigation is designed to see if there is prima facie or highly corroborative evidence of diversion and/or of attempts to conceal diversion. The main characteristics which the verification techniques should have is that they be adequate, robust and efficient against those diversion techniques which may be used to accomplish and/or to conceal diversion. A terminology which has gained currency here is to call the inspection agency the inspectorate.

In the context used here, the inspectorate could be any group interested in verifying material quantities. This could include plant management, an independent audit group, or a national or international inspection team. The diverter is defined as an individual or group of individuals with access to the material and the capability of exercising various diversion strategies. In practice, of course, the diverter capabilities may be extremely limited. However, to illustrate a rigorous proof of the mathematical relationships involved, the diverter is assumed to have a broad range of capabilities in terms of ways of removing either small or gross amounts of material or in terms of data falsification.

Traditional sampling plans are not designed to guard against a multiplicity of alternatives, and their users are prepared to assume, for economic reasons, that there is a gradation from good to bad which is possible in lots. In safeguards there is no slightly bad lot, inventory or population that is acceptable because it has been subjected on only a "slight" amount of diversion. There are, however, constraints on just how much the inspectorate can accomplish in investigating for evidence of diversion and/or concealment due to limitations of time, costs, measurement limitations and sometimes even intrusiveness.

In this safeguards situation it is better to structure a verification sampling procedure in the direction of an exactly stated problem and to get an adequate, though approximate, solution than to restate the verification problem in an artificial way so that the traditional sampling plans could be used.

Following are some of the characteristics which distinguish sampling in a safeguards situation from the usual acceptance sampling.

THE USUAL ACCEPTANCE SAMPLING SITUATION

- The sampling tends to be done against a background of objectivity. The sources of variation are generally due to mechanical, chemical, measurement and natural mechanisms.
- Some defectives are expected and tolerated so long as the sample does not indicate that the lot has an excessive percent defective.
- The null and alternative hypotheses (AQL and LTPD) are determined from economic considerations.

  The alternative hypothesis is easily stated. Under either the attribute or the variable sampling it is generally defined as a percent defective.
- Process variation and measurement errors are controlled in order to assure that produce specifications are met.
- For large lots where the AQL and LTPD's are expressed in % defectives the sample size does not tend to depend upon lot size primarily.

SAMPLING IN A SAFEGUARDS INSPECTION SITUATION

- Natural sources of variation are present. However, the main concern is with those anomalies and discrepancies induced by a diverter in order to accomplish and/or disguise diversion.
- No attribute gross defectives are tolerated. Attribute defectives must be explainable by a cause which is not connected with diversion. Thus the null hypothesis for the attribute test is that AQL...H_0:p_0 = 0.
- The null and alternative hypotheses are determined from strategic considerations primarily, although inspection costs can be a limiting factor.
- The alternative hypothesis is composite. The inspectorate wants assurance that under any likely set of true conditions the verification sampling plans are adequate. This usually requires a combination of instruments and a combination of attribute and variable plan characteristics.
- Measurement variation needs to be controlled in order to induce sensitivity in detecting diversion and to assure that diversions are not camouflaged under a cover of large measurement error.
- Since the inspectorate is guarding against the same amount of diversion in a large or small lot, the sample size depends on the lot size, when inspecting for gross defectives.

The Problem Setting

There are N items in a lot. The inspectorate wishes to guard against a discrepancy of A = SGQ (strategic goal quantity) units of material. There are an unlimited number of ways that the SGQ amount can be divided among the N items in the lot but there are constraints induced by the inspectorate's verification instruments and techniques and this broad continuum of diverter "strategies" can effectively be reduced to a few plausible diverter strategies.

The inspectorate has two types of instruments (or equivalently two types of procedures) which are as follows.

Instrument A. This is a go/no-go type instrument which can detect the removal of 100% of the material and replacement by a dummy and is sensitive to a removal of as little as 100p% of the material and replacement by degraded material. For example, the instrument may be able to detect when 30% or more of the material has been taken and replaced by degraded material. The instrument is characterized by an ease and relative speed of application and is used in detecting the removal of gross amounts of material, i.e., in detecting a gross defective.

Instrument V. This instrument measures, in some manner, the amount of material which is present in an item. The instrument may count, measure heat or an equivalent procedure may be to make an analytical determination. If instrument V is a counting instrument its precision is affected by counting time, geometry and dead time. For a fixed counting time, in this example and as used in verification sampling, the precision and sensitivity of instrument V will far exceed that of instrument A. Any gross defect which occurs in the

*This paper is based on work performed under United States Atomic Energy Commission Contract AT(45-1)-1830.

sample and which is tested by instrument V will be detected as such. This instrument is used to detect the situation where the stated item amounts in some or many items are in excess of the actual amounts. These amount biases may be due to shaving or to inflating the stated inventory amounts to conceal diversion elsewhere. A criterion here for a gross defective is that the stated item amount exceed the estimated amount as gauged by the inspectorate by some multiple of the standard deviation of the difference due to measurement. Thus for item i if d_i, the difference is such that

$$d_i = x_{0i} - x_{Ii} > k_1\sigma_d$$

the difference is deemed to be significant. Here x_{Ii} and x_{0i} denote, respectively, the inspectorate's estimated amount value and the operator's stated amount value for the *ith* item, and $\sigma_d = \sqrt{\sigma_1^2 + \sigma_2^2}$ = the standard deviation of the difference due to measurement error. k_1 is generally taken as a relatively large value, $k_1 = 4$ say. In addition to this the average of the n_v such variable samples are deemed to indicate a significant bias if

$$\bar{d} = \bar{x}_0 - \bar{x}_I > k_2\sigma_{\bar{d}} = k_2\sigma_d/\sqrt{n} \ .$$

where k_2 is determined by the level of control of the type 1 error, i.e., $k_2 = T_{1-\alpha}$. This instrument V fulfills a dual role. It guards against (a) gross outliers like the attribute test does and (b) biasing by the diverter. Biasing may be due to shaving of the individual items by taking small amounts or by simply overstating amounts by a small percentage in order to conceal diversion elsewhere. In guarding against gross defective using instrument V results when a difference exceeds $4\sigma_d$, say.

Different Ways of Obtaining an AGQ

The diverter wants to obtain the amount of material A = SGQ by taking material from the N items in a lot. If he is going to take something between 100p% and 100% of the item, when the attribute instrument can detect a removal of 100p% or more material, the diverter might as well take 100% of the item with a suitable dummy replacement since the attribute instrument will detect the removal of any amount of material above 100p%. Taking 100% of an item, with replacement by a degraded material, will require fewer items to reach an SGQ and thus a defective item will have a smaller probability of being included in an attribute sampling plan.

The diverter may also take amounts from some of the items which are below the threshold of the attribute instrument. Amounts below 100p% and above $4\sigma_d$ will be detected on an individual basis by the variable instrument. Amounts below $4\sigma_d$ will tend to be detected on an average basis if there are enough such amounts taken. If the diverter wishes to obtain an average amount δ for item amounts taken which are below $4\sigma_d$ it can be shown that the operator has less chance of being detected where the average value of the discrepancy δ is used as a criterion if he concentrates his diversions as near as possible to $4\sigma_d$. The reasons for this will be shown in the section on the probability of detection.

Thus there tends to be three regions where the diverter can divert from in order to minimize the inspectorate's probability of diversion.

REGION 1. Nearly 100% of the amounts are taken from some items.

REGION 2. Amounts per item are taken above $4\sigma_d$, but below 100p% of the item amount and as close as possible to 100p% without detection by instrument A.

REGION 3. The item amounts taken are below $4\sigma_d$, but are close as possible to $4\sigma_d$, where the purpose here is that the total amount of discrepancy will add to a given value.

The total amount of material taken is to sum to A = SGQ. If the diverter chooses amounts which are outside these regions his chances of detection are increased. The task of the inspectorate is to obtain a plan which is adequate against the best diverter techniques and which improves the probability of detection if the diverter uses inferior techniques.

The operator wishes to obtain an amount A based on the relationship

$$A = n_1g + n_2h + n_3k$$

where g, h, and k units are taken from n_1, n_2, n_3 units in regions 1, 2, and 3 respectively, where $h = pg$ and $k = 4\sigma_d$. The inspectorate can evaluate his chances of detection against the material amounts being g, pg, and $4\sigma_d$ units per item from the regions 1, 2, and 3, respectively, where g is the amount per item and it is assumed that none of the defective items in region 2 will be detected by the attribute instrument. The reason the inspectorate considers the diverter's activities as being concentrated in these three regions is that it leads to a conservative estimate of detection probability since diversions outside these regions increase the probability of detection. The diverter would generally not know exactly where these regions are so the inspectorate's assessment of the probability of detection tends to be understated. This is preferable to creating an overstatement of the probability of detection.

The Probability of Detection

The inspectorate uses sampling plans to test whether there is any evidence of operator misbehavior. A signal is given for extensive investigation if

- a grossly defective item is detected by either instrument A or instrument V and/or
- a significant bias in the direction of an operator's overstatement.

Let p(N,n,k,x) denote the probability that x defectives are detected in a random sample of size n from a lot is size N which has k defectives, where p(N,n,k,x) is the hypergeometric density.[4,5] The probability of an investigation is P = 1 - Q, where Q is the probability that the attribute and/or the variable tests will not find a bias and/or one or more gross defects.

The probability that no defectives from region 1 and region 2 will be found in the variable sample is $p(N,n_v,n_1+n_2,0)$. The variable and attribute samples use different lot items. The probability that no defectives will be found in the attribute sample given that none has been found in the variable sample is $p(N-n_v,n_a,n_1,0)$. The probability that no gross defectives will be found then is $p(N,n_v,n_1,n_2,0) \times p(N-n_v,n_a,n_1,0)$.

The number of items available for biasing is $N-n_1-n_2$. Suppose that the average bias here is δ so that $(N-n_1-n_2)\delta$ is the total amount which is taken from region 3 by biasing stated amounts within the limit $4\sigma_d$. The diverter would like to induce the largest possible variance in the $\bar{d}$ values to increase the probability that $\bar{d}$ will fall within the acceptance region and he does this by inducing the maximum process variance of the biases in the items.

Let $M = N-n_1-n_2$. There are many ways the diverter can accomplish his biasing goal. Consider, for example, the following three cases. Case 1: n_3 items are biased by the amount $4\sigma_d$ with a resulting process variance of $(4\sigma_d)^2 \times pq = (4\sigma_d)^2 \cdot (p - p^2)$ where $p = n_3/M$, $q = 1 - p$. Case 2: $n_3 > M/2$, M/2 items are biased by $4\sigma_d$, $M/2 - n_3$ items are biased by $-4\sigma_d$ with a resulting process variance of $(4\sigma_d)^2\ (q - p^2)$. Case 3: $M/2 + n_3/2$ items are biased by $4\sigma_d$ and $M/2 - n_3/2$ items are biased by $-4\sigma_d$ with a resulting process variance of $(4\sigma_d)^2\ (1 - p^2)$. The difficulty with case 3 is that the diverter would easily give the game away by dividing the population into two subpopulations whose means are $8\sigma_d$ units apart. For this reason case 3, which induces the maximum process variance, is not considered in this paper but the case is not difficult to treat if the inspectorate wishes to be very conservative. If $n_3 > M/2$, case 2 is not possible and case 1 is used. If $n_3 < M/2$, case 2 is used since it induces a larger process variance than under case 1. Then cases 1 or 2 are used in the analysis according as n_3 is greater or less than M/2. Cases 1 and 2 also divide the population into subpopulations but they are used as compromises between the extreme situations where all items are biased the same amount and in the same direction resulting in a small sample size requirement and case 3 which can be faulted on the grounds that it obviously dichotomizes the total population into such widely disparate subpopulations.

Case 1: ($n_3 > M/2$, no negative biases)

To obtain the variance for the average of the observed differences from a sample of size n_v, the measurement variance of the differences σ_d^2 must be added and the variance of the process must be adjusted by the finite population correction and then divided by the sample size. Thus,

$$\sigma_{\bar{d}}^2 = \frac{1}{n_v}\left\{\sigma_d^2 + (4\sigma_d)^2\left[pq\,\frac{M - n_v}{M - 1}\right]\right\}.$$

$$\simeq \frac{1}{n_v}\left\{\sigma_d^2 + (4\sigma_d)^2\ pq\ \left[1 - \frac{n_v}{M}\right]\right\}$$

The approximate probability that the average difference will not prove to be statistically significant given that no gross defectives are detected is

$$\Phi\left\{\frac{T_{1-\alpha}\ \sigma_d/\sqrt{n_v} - \delta}{\frac{1}{\sqrt{n_v}}\sqrt{\sigma_d^2 + (4\sigma_d)^2\ pq\left(\frac{M - n_v}{M - 1}\right)}}\right\} = \Phi(Z)$$

where

$$\Phi(Z) = \int_{-\infty}^{Z} \frac{\exp(-\ x^2/2)}{\sqrt{2\pi}}\ dx.$$

Then the probability that at least one of the tests will give a signal that there are grounds for investigating for possible diversion is

$$P = 1 - p(N,n_v,n_1+n_2,0)\ p(N-n_v,n_a,n_1,0)\Phi(Z) = 1 - Q_bQ_aQ_c$$

Case 2: ($n_3 < (N-n_1-n_2)/2$, with some negative biases)

If n_3, the required amount from biasing is such that $n_3k = M\delta$ and $n_3 < M/2$, the diverter induces the desired process variance by biasing M/2 values by $4\sigma_d$ and $M/2 - n_3$ values by $-4\sigma_d$. The expected bias per item is δ. The approximate probability of not detecting a bias given that no gross defectives are detected is

$$\Phi\left\{\frac{T_{1-\alpha}\ \sigma_d/\sqrt{n_v} - \delta}{\frac{\sigma_d}{\sqrt{n_v}}\sqrt{1 + 16\left[1 - \frac{n_3}{M} - \left(\frac{n_3}{M}\right)^2\right]\left(1 - \frac{n_v}{M}\right)}}\right\}$$

This should be a fairly accurate approximation since the process variance is related to a compound hypergeometric distribution and measurements tend to be normally distributed. The hypergeometric tends to normality so that a variable such as $\bar{d}$ which has two independent and normal contributions to its variation will tend to be normally distributed. This approximation may be used to estimate the sample size n_v by setting the argument Z in $\Phi(Z)$ equal to $-T_{1-\beta} = T_\beta$ in order to induce the desired power into the bias test.

One may argue that this is a very conservative approach in the sense that such a large process variance would lead to individual gross defectives or to such evidence that the data would be rejected on this basis. However, the inspectorate wishes to be conservative in the approach to sample sizes and to guard against the worst plausible cases. Formulae for the exact probabilities have been worked out and are available from the authors. Data processing programs have indicated good agreement between the results obtained by the exact formulae and the normal approximations for various situations.

There is an additional element of converatism in regard to the probability of detection which should be noted. This concerns the concept employed for the attribute instrument. To simplify the mathematics, the attribute instrument is portrayed as having a finite detection range with a cutoff or crossover point where the probability of detection drops instantly from 100% to zero. (An excellent discussion of this concept is given by workers in the United Kingdom and the IAEA in reference 1.) For the actual instruments used for such purposes, the change in detection capability is much more gradual. Consequently, the actual detection range of the attribute instrument will extend well below the crossover point. As a result the actual probability of detection will be larger than the computed probability. For purposes of determining the samples size for the crossover point, that point is usually taken as six times the measurement error (σ) of the attribute instrument. By contrast, the critical value for detection of a gross defect is taken at 2 to 3 times the measurement error. Items found defective by the attribute instrument using a critical value of 2 to 3 times σ are then designated for measurement by the quantitative (variables) instrument.

Different Inspectorate Solutions to the Attribute-Variable Problem

Three different approaches to obtaining sampling plans for the attribute-variable problem are shown; (1) the crossover, (2) the maxi-min and (3) the game-theory plans. The crossover plan is a somewhat intuitive approach in the sense that sample sizes are chosen which guard against the different adversary situations. The crossover plan, in many cases studied, has shown good agreement with the two other plans. The maxi-min plan is also a conservative approach which examines all the diverter probabilities of success for each inspectorate possibility and selects the inspectorate plan whose minimum probability of detecting a diversion attempt has the maximum value. The game theory approach improves on the maxi-min plan by applying the different inspectorate possibilities in a random manner with different relative frequencies and maximizes the average probability of detection.

The maxi-min and game theory approaches can be used to derive actual attribute-variable sampling plans. They may be of most value, however, in parameter studies and for comparison purposes.

The Crossover Plan

The crossover plan is a direct but approximate approach to selecting the sample sizes necessary to guard against a diverter's best strategies. The plan has been termed the crossover plan since the role of the variable instrument changes at the crossover point to that of an attribute instrument. Three sample sizes are estimated to protect the three regions where removals would have the least chance of being detected. Sample sizes are estimated for (1) the region of complete removal from an item, (2) the region just below the crossover point (partial removals of 100p%) and (3) the region from just below the crossover point to zero removals. From the three estimations, two sample sizes are chosen --one for each instrument. The plan has the advantage of being easily visualized and evaluated. The probability of detection can be computed for each region versus an assumed removal as well as the overall probability when the removals are assumed to take place in one or more regions.

The following steps are used to create this plan.

Step 1

The diverter may decide to divert from containers by amounts which are just outside the limit of the inspectorate to detect with his attribute instrument. Let gp denote the minimum removal per item which can be detected by instrument A. The diverter must then take something less than units of size gp from something more than $n_2 = A/gp$ items in order to attain his SGQ. The inspectorate finds a sample size n_b[3] such that

$$p(N,\ n_b,\ n_2,\ 0) \leq \beta$$

which assures that the number of random samples taken by the inspectorate and measured by instrument V is such that the inspectorate has at least a $100(1-\beta)\%$ chance of detecting at least one gross defective here. The approximation $n_b = N(1-\beta^{1/n_2})$ may be used.

Step 2

Suppose the diverter attempts, where this is possible, to divert within the measurement capability of instrument V on each item in order to attain the amount A units of material. Then one writes $A = \delta N$ where δ is the amount per item which is needed per item to attain the SGQ. A better strategy for the diverter is to maximize the process variance of differences. The process variance estimate of the biases under the adversary strategy which induces maximum variance depends on whether negative biases are introduced or not. For no negative biases, the sample size is determined from:

$$\Phi(T_\beta) = \Phi(-T_{1-\beta}) = \Phi\ \frac{T_{1-\alpha}\ \sigma_d/\sqrt{n_c} - \delta}{\frac{1}{\sqrt{n_c}}\sqrt{\sigma_d^2 + (4\sigma_d)^2\ pq\ (1 - \frac{n_c}{N})}}$$

where

$$\Phi(Z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Z} \exp(-x^2/2)\ dx\ .$$

The inspectorate finds the random sample size n_c such that z has the desired value. This is tantamount to finding the n_c value which induces the desired β risk under the optimum operator conditions. The algebra is involved unless the close but approximate finite population correction $(N - n_c)/N$ is used instead of $(N - n_c)/(N - 1)$. Set

$$A = \frac{\delta^2}{\sigma_d^2} + \frac{16\ pqz^2}{N}\ ,\ B = \frac{\delta T_{1-\alpha}}{\sigma_d}\ ,\ C = -z^2(1 + 16\ pq) + T_{1-\alpha}^2$$

and then

$$n_c = (\sqrt{n_c})^2 = \left[\frac{B + \sqrt{B^2 - AC}}{A}\right]^2 .$$

If $n_3 < M/2$, and $M/2$ and $M/2 - n_3$ items, respectively, are biased by the amounts $4\sigma_d$ and $-4\sigma_d$ the equation

$$\Phi\left(\frac{T_{1-\alpha}\ \sigma_d/\sqrt{n_c} - \delta}{\frac{\sigma_d}{\sqrt{n_c}}\sqrt{1 + 16\left[1 - \frac{n_3}{N} - (\frac{n_3}{N})^2\right]\left[1 - \frac{n_c}{N}\right]}} = T_\beta = -T_{1-\beta}\right) = \beta$$

is solved for n_c. The same equations can be used as in the previous formulation if 16 pq in the relationships is replaced by $16[1 - n_3/N - (n_3/N)^2] = 16(q - p^2)$.

Then the inspectorate chooses n_v, the maximum of n_b and n_c as the random sample size to use with the variable instrument. If the variable measurement is very precise compared to the lowest attribute detection level then n_b will be considerably larger than n_c. Conversely, it is possible for n_c to be larger than n_b if the variable measurement's precision is relatively poor compared to the lowest attribute detection level.

Step 3

Let g denote the maximum amount of material that can be taken per item. A value n_1 is determined such that $gn_1 = A =$ SGQ. Then n_a', the number of inspectorate attribute samples, is determined such that

$$p(N,n_a',n_1,0) \leq \beta\ ,$$

where $p(N,n_a',n_1,x)$ is the hypergeometric density.

Tables may be used which have been prepared specifically for this purpose.[3] However, the formula $n_a' = N(1 - \beta^{1/n_1})$ provides an excellent approximation.

Now since the samples used in n_v will detect gross defectives from region 1 it is necessary to take $n_a = n_a' - n_v$ random samples for the attribute tester in order to detect with $100(1 - \beta)\%$ or greater probability at least one gross defective if the diverter chooses to obtain the amount A in this manner.

Example

The lot of concern has the following characteristics

$N = 200$, the lot size

$A = 20$, the strategic goal quantity

$\sigma_d = 0.05$, the standard deviation of the difference due to measurement error

$g = 4$, the maximum amount attainable per item

$A/g = 5$, the minimum number of items needed in order to obtain a strategic goal quantity when g units are taken per item

$\beta = 0.05$, the probability of not detecting evidence of the diversion of the amount A.

a. The attribute tester can detect the removal of 20% or more of the material from a unit and replacement by a dummy. Then $p = 0.2$, $pg = 0.8$ is the amount which is the limit detectable by instrument A. $20/0.8 = A/(pg) = 25$, the number of items needed by the operator to attain his SGQ when material is taken just below the attribute threshold value. From [3] $n_b = 22$, is the sample size needed to be 95% sure of detecting a gross defective by the variable instrument in this case when items are taken just below the threshold value of the attribute instrument. Note that $N(1 - \beta^{1/n_2}) = 22.6$.

b. The measurement standard deviation of a difference is that $4\sigma_d = 0.2$. Thus $20/0.2 = A/(4\sigma_d) = 100$, is the number of items which need to be biased or "shaved", which in essence is the same as a bias, in order to attain a SGQ of 20. We wish to solve for the sample size n_c. $T_{1-\alpha} = 1.645$ is the 95% tile point of the N(0,1) distribution. The inspectorate wishes to be 95% sure of detecting a diversion with $E(d) = E(\bar{d}) = 0.1$, where the diverter induces the desired process variance. Since the diverter needs $n_3 = 20/4(0.05) = 100$ items to be biased by the amount $4\sigma_d$, either of the two process variance formulae apply. Let σ_p^2 denote the process variance. Then

$$\sigma_p^2 = (4\sigma_d)^2\ pq = (4\ \sigma_d)^2(1 - n_3/N - (n_3/N)^2) = 0.01.$$

The sample size n_c is determined as follows.

$$\delta = 0.10$$

$$A = \left(\frac{0.10}{0.05}\right)^2 + \frac{16(1/2)(1/2)(1.645)^2}{200} = 4.05412$$

$$B = \frac{0.10}{0.05}\ (1.645) = 3.290$$

$$C = -1.645^2\ (16)(1/2)(1/2) = -10.8241$$

$$\sqrt{n_c} = \frac{3.290 + \sqrt{3.290^2 - 4.05412(-10.8241)}}{4.0541} = 2.64$$

$$n_c = 2.64^2 = \approx 7.$$

Checking one has

$$z = \left[\frac{1.645\ (0.05)/\sqrt{7} - 0.10}{(0.05/\sqrt{7})\ \sqrt{1 + 16(1/2)(1/2)(1 - 7/200)}}\right] = -1.65$$

which yields a z value adequate to induce the required power in the bias test. Since $n_b = 22$, the number of variable samples is taken as $n_v = \max(n_b, n_c) = 22$, and 22 random samples are inspected by instrument V. Note here that the crossover point is relatively large compared to the measurement standard deviation and is thus the determining aspect in the variable sample size.

c. Then from reference [3], $n_a' = 90$, the minimum sample size needed in order to obtain evidence that at least one unit has been replaced by a dummy. That is

$$p(200,89,5,0) > \beta$$

$$p(200,90,5,0) \leq \beta$$

where p(N,n,k,x) is the hypergeometric density. Note that $n(1 - \beta^{1/n_1}) = 90.1$. Then $n_a = n_a' - n_v = 90 - 22 = 68$.

The crossover plan has provided assurance that the inspectorate will detect with at least 100 (1 - β)% assurance the removal of the amount of material A if the material is taken from any one of the three regions. The question remains as to the effectiveness when the operator apportions out the amount over the three regions in the form $A = n_1 g + n_2 h + n_3 k$ where at least two of the n values are not zero. This is best understood by studying the power of the sampling plan.

The following table gives the power of the crossover plan for various diverter strategies. The probability of detection is the power of the test, i.e., it is the probability that the attribute and/or the variable sampling plan(s) will detect a gross defective and/or a bias.

TABLE I

THE POWER OF THE CROSSOVER PLAN

n_1	n_2	n_3	Q_a	Q_b	Q_c	P
0	0	100	1.00000	1.00000	.00011	.99989
0	5	80	1.00000	.55491	.01100	.99390
0	10	60	1.00000	.30297	.07990	.97579
0	15	40	1.00000	.16261	.23744	.96139
0	20	20	1.00000	.08570	.45204	.96126
0	25	0	1.00000	.04431	.66454	.97055
1	0	80	.61798	.89000	.01404	.99228
1	5	60	.61798	.49230	.08802	.97322
1	10	40	.61798	.26789	.24653	.95919
1	15	20	.61798	.14327	.45709	.95953
1	20	0	.61798	.07523	.66431	.96912
2	0	60	.38056	.79161	.09619	.97102
2	5	40	.38056	.43648	.25531	.95759
2	10	20	.38056	.23671	.46191	.95839
2	15	0	.38056	.12614	.66409	.96812
3	0	40	.23353	.70365	.26380	.95665
3	5	20	.23353	.38672	.46650	.95787
3	10	0	.23353	.20901	.66388	.96760
4	0	20	.14279	.62507	.47088	.95797
4	5	0	.14279	.34241	.66368	.95797
5	0	0	.08698	.55491	.66349	.96797

Here Q_c was calculated by the normal approximation assuming the diverter maximized the process variance for the desired bias. Under the given diverter and inspectorate constraints it is apparent that the best the diverter can do if the inspectorate uses the crossover plan is a 1-0.95665 = 0.04335 probability of nondetection by taking three samples from region 1 and biasing by using a net 40 biased items from region 3. If, however, the diverter were to go to such extreme measures to divert by biasing in this manner, the general unacceptability of his measurement control would become apparent. Since this approach is conceptually possible by the diverter in order to minimize the inspectorate's ability to detect it must, as a conservative measure, be guarded against. If the total time to take samples is given by $T = T_a n_a + T_v n_v$, where $T_a = 1$, $T_v = 10$, the total time under the crossover plan is 288 minutes.

The Maxi-Min Plan

Suppose T, the total time used by the inspectorate is

$$T = T_a n_a + T_v n_v \qquad (3)$$

where T_a and T_v are, respectively, the times needed to take and measure an attribute and a variable sample. If T is fixed and n_a is given, then n_v is determined. Thus under a total time constraint as given by (3), the inspectorate strategies can be expressed as a function of n_a, (or n_v).

The equation for material obtained by the diverter is

$$A = n_1 g + n_2 pg + n_3 k \qquad (4)$$

where generally $k = 4\sigma_d$. Thus, if the diverter is to attain a SGQ of A units of material from the lot his strategies will consist of the different values he assigns to n_1, n_2 and n_3, and the value of n_3 follows from the values assigned to n_1 and n_2. Thus the diverter strategies can be defined as a function of n_1 and n_2, subject to the constraint (4).

Let $P(n_a, n_1, n_2)$ denote the probability that at least one gross defective and/or a bias will be found. Let $P_{min}(n_a)$ denote the minimum value that $P(n_a, n_1, n_2)$ has over all allowable diverter strategies, i.e., over all n_1, n_2 subject to (4), with n_a value, n_a' say, which gives $P_{min}(n_a)$ the maximum value. *Write* $P_{mm} = P_{min}(n_a') = \max P_{min}(n_a)$. *If the inspectorate then* uses n_a' and $n_v' = (T - n_a' T_a)/T_v$, he will be assured that no matter what strategy the diverter uses his probability of detection will be at least P_{mm}. The maxi-min plan then provides an upper bound on how good the diverter can do and a lower bound on how good the inspectorate can do expressed in terms of the probability of detection. It would be possible for the inspectorate to increase the total time until P_{mm} assumes a sufficiently high value.

Example

The parameters here are the same as in the example for the crossover plan, except that the constraint

$$T = T_a n_a + T_v n_v$$

is employed where

T = 288 minutes, the total time to be used in inventory verification,

T_a = 1 minute, the time per attribute sample,

T_v = 10 minutes, the time per variable sample.

The set of diverter possibilities is as follows.

Condition	n_1	n_2	n_3
1	0	0	100
2	0	5	80
3	0	10	60
4	0	15	40
5	0	20	20
6	0	25	0
7	1	0	80
8	1	5	60
9	1	10	40
10	1	15	20
11	1	20	0
12	2	0	60
13	2	5	40
14	2	10	20
15	2	15	0
16	3	0	40
17	3	5	20
18	3	10	0
19	4	0	20
20	4	5	0
21	5	0	0

Note that

$$A = 20 = gn_1 + (gp)n_2 + (4\sigma_d)\, n$$

$$= 4n_1 + 4(.2)\, n_2 + 4(0.05)\, n_3 \;.$$

The following table gives the probability of detection as a function of the 21 diverter strategies are given in the first two columns of the table.

TABLE II

THE PROBABILITIES OF DETECTION FOR ALL DIVERTER AND INSPECTORATE STRATEGIES

Inspectorate Strategies / DIVERTER STRATEGIES

i	n_v	n_a	1	2	3	4	5	6	7
1	10	188	.984	.926	.866	.830	.822	.832	.999
2	11	178	.989	.939	.883	.850	.842	.854	.995
3	12	168	.993	.950	.899	.867	.861	.873	.992
4	13	158	.995	.960	.912	.882	.877	.890	.991
5	14	148	.997	.967	.924	.896	.892	.905	.990
6	15	138	.998	.973	.934	.908	.905	.918	.989
7	16	128	.999	.978	.942	.919	.916	.929	.989
8	17	118	.999	.982	.950	.928	.926	.938	.989
9	18	108	.999	.986	.957	.936	.935	.947	.990
10	19	98	1.000	.988	.963	.944	.943	.954	.990
11	20	88	1.000	.991	.968	.950	.950	.960	.991
12	21	78	1.000	.992	.972	.956	.956	.966	.992
13	22	68	1.000	.994	.976	.961	.961	.971	.992
14	23	58	1.000	.995	.979	.966	.966	.975	.993
15	24	48	1.000	.996	.982	.970	.970	.978	.994
16	25	38	1.000	.997	.984	.974	.974	.981	.994
17	26	28	1.000	.997	.987	.977	.977	.984	.995
18	27	18	1.000	.998	.989	.980	.980	.986	.996
19	28	8	1.000	.998	.990	.982	.983	.988	.996

i	n_v	n_a	8	9	10	11	12	13	14
1	10	188	.998	.998	.998	.998	1.000	1.000	1.000
2	11	178	.991	.989	.988	.989	.999	.999	.999
3	12	168	.985	.981	.980	.982	.998	.997	.997
4	13	158	.981	.975	.974	.977	.996	.995	.995
5	14	148	.978	.970	.969	.973	.994	.992	.992
6	15	138	.975	.966	.966	.970	.991	.988	.988
7	16	128	.973	.964	.963	.968	.998	.984	.984
8	17	118	.972	.961	.961	.967	.985	.980	.980
9	18	108	.972	.960	.960	.967	.982	.975	.975
10	19	98	.972	.959	.959	.967	.979	.971	.971
11	20	88	.972	.959	.959	.967	.976	.966	.967
12	21	78	.972	.959	.959	.968	.974	.962	.962
13	22	68	.973	.959	.960	.969	.971	.958	.958
14	23	58	.974	.960	.960	.970	.969	.953	.955
15	24	48	.975	.961	.961	.972	.967	.949	.951
16	25	38	.976	.962	.963	.973	.965	.946	.948
17	26	28	.977	.963	.964	.975	.963	.942	.944
18	27	18	.979	.964	.966	.976	.962	.939	.942
19	28	8	.980	.966	.967	.978	.960	.936	.939

i	n_v	n_a	15	16	17	18	19	20	21
1	10	188	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	11	178	.999	1.000	1.000	1.000	1.000	1.000	1.000
3	12	168	.998	1.000	1.000	1.000	1.000	1.000	1.000
4	13	158	.995	.999	.999	.999	1.000	1.000	1.000
5	14	148	.993	.998	.998	.998	.999	.999	1.000
6	15	138	.989	.996	.996	.996	.999	.999	1.000
7	16	128	.986	.993	.993	.994	.987	.998	.999
8	17	118	.983	.990	.990	.991	.995	.996	.998
9	18	108	.980	.985	.985	.988	.991	.993	.996
10	19	98	.976	.980	.980	.984	.986	.989	.992
11	20	88	.973	.973	.973	.979	.979	.983	.987
12	21	78	.971	.965	.966	.973	.970	.976	.979
13	22	68	.968	.957	.958	.968	.958	.968	.968
14	23	58	.966	.947	.949	.961	.943	.957	.952
15	24	48	.964	.936	.938	.954	.924	.943	.931
16	25	38	.962	.924	.927	.947	.901	.928	.902
17	26	28	.961	.911	.915	.940	.873	.909	.865
18	27	18	.959	.897	.903	.932	.840	.887	.817
19	28	8	.959	.881	.889	.924	.801	.863	.756

The minimum probabilities of detection for the different inspectorate strategies are as follows

Inspectorate Strategy	Minimum Probability
1	.82152
2	.84249
3	.86104
4	.87744
5	.89195
6	.90478
7	.91612
8	.92615
9	.93502
10	.94285
11	.94977
12	.95587
13	.95665
14	.94277
15	.92389
16	.90080
17	.86468
18	.81664
19	.75581

Thus the maximum of all the minimum probabilities is 0.95665 under inspectorage strategy 13. For the given conditions of time to obtain the attribute and variable samples the maxi-min and the crossover plans are the same.

The Game-Theory Solution

Under the maxi-min solution the inspectorate guards against the diverter's strategies by taking a conservative approach. The approach is reassuring to the inspectorate if P_{mm}, the maxi-min probability, is large enough. Let the diverter's strategy which yields this minimum $P(n_a', n_1', n_2')$ value be denoted as $D(n_1', n_2')$. If the diverter knows the inspectorate strategy to be $I(n_a')$, then he will surely play $D(n_1', n_2')$. If the inspectorate knows that the diverter will play strategy $D(n_1', n_2')$, however, there may be other inspectorate strategies which will yield a higher probability such that $P(n_a'', n_1', n_2') > P(n_a', n_1', n_2')$. The inspectorate may be averse to playing another strategy, however, in case the operator is in fact playing a strategy other than $D(n_1', n_2')$. If, however, $P(n_a'', n_1', n_2') < P(n_a', n_1', n_2') < P(n_a', n_1'', n_2'')$, for $n_a'' \neq n_a', n_1'', n_2'' \neq n', n_2'$, the diverter should always play $D(n_1', n_2')$ and the inspectorate strategy $I(n_a')$. Let the inspectorate strategies be given as rows and the operator strategies as columns. If none of the row minima is a maximum of its column then one has an indeterminate game and if a solution is desired in the face of these conditions it is necessary to play a "mixed strategy" game in order to arrive at a conclusion.

If the inspectorate plays a mixed strategy, he employs the various strategies according to some density function, (i.e., he employs the different strategies in a random manner where a given strategy $I(n_a)$ will, on the average, have the relative frequency f_{n_a}). If, in turn, the diverter plays his strategies $D(n_1,n_2)$ in a random way with relative frequencies e_{n_1,n_2}, the average probability of detection is

$$P = \sum \sum P(n_a,n_1,n_2)\left(f_{n_a}\right)\left(e_{n_1,n_2}\right) \qquad (5)$$

summed over all allowable inspectorate and diverter strategies and subject to the constraints,

$$\sum\left(f_{n_a}\right)_i = 1,\ \sum\left(e_{n_1,n_2}\right)_j = 1,\ n_1 g \leq A,\ n_1 g + n_2 h \leq A,$$

$$T_a n_a \leq T,\ \left(f_{n_a}\right)_i \geq 0,\ \left(e_{n_1,n_2}\right)_j \geq 0,\ n_1,n_2,n_3 \geq 0.$$

A solution in terms of Lagrangian multipliers might be attempted but this approach is generally unsuitable here. It is possible to reduce the maximization of the probability to a problem in linear programming which always has a solution [2] pp. 291-301.

There are, however, some difficulties with this approach for philosophical and computational reasons. In the first place the inspectorate may not be content with the concept that "on the average" the probability of detection is P. The inspectorate may wish to be assured that on any particular inventory verification the probability is at least $1 - \beta$ that a diversion would be detected, given that the amount SGQ has been diverted. If the total "payoff matrix", which is the probability of detection for each possible situation, is written out it may have such a large number of entries that the sheer magnitude of the numbers induces computational difficulties.

The solution to the game is of the form

$$\left(f_{n_a}\right)_1,\ \left(f_{n_a}\right)_2,\ \ldots;\ \left(e_{n_1,n_2}\right)_1,\ \left(e_{n_1,n_2}\right)_2,\ \ldots;$$

where the sums of the f's and the e's are each equal to one. The value of the game is given by substituting these f and e values into formula (5). A solution in the form of a set of many relative frequencies for the inspectorate would present a less than inviting practical solution to the problem.

However, this approach can be used for "parameter" studies, as an aid in understanding the problem, and in seeing how well the other results compare with the game theory solution. If the number of inspectorate strategies can be limited one can compare results with the maxi-min approach.

The computational difficulties can also be reduced by several techniques. With the help of these techniques the solution is obtained that the inspectorate should employ strategies 12 and 13, respectively, with relative frequencies of 1/3 and 2/3.

The value of the game is 0.95933. This means that if the inspectorate employs strategies 12 and 13 in a random manner with the relative frequencies 1/3 and 2/3, respectively, a probability of detection of 0.95933 can be assurred against the best diverter strategies. It is interesting that strategy 13, the crossover plan, is used the most frequently. To recapitulate, the power of the crossover plan has a minimum probability of 0.95665 which is the same as that of the maxi-min since they result in the same strategy. The game theory results for this problem are essentially the same as in the other two plans. In terms of application the crossover plan seems to be the easiest to develop and experience to date has shown that its characteristics compare very well with those of the other approaches. If there is some doubt about the probabilities of detection with the crossover plan one can always calculate the power of the plan under the different diverter strategies.

The maxi-min approach is also an aspect of game theory but a distinction is made here between the maxi-min and the mixed strategies for emphasis. The maxi-min approach has an immediate logical appeal without the game theory framework.

Added Remarks

The elements in a safeguards inventory verification scenario may vary considerably. These elements, as far as the inventory is concerned, depend upon such factors as the amount of containment, the relationship of inventory magnitude to flow volume, the location independence within the nuclear complex, the convertibility of material, the inventory's effect on the mass balance accounting of the material balance areas, the diverter's technical capability in using the material, the accessibility of the material, the number of personnel with some access to the material and the probability of being detected in the act of removal from the facility. Consider one of these conditions, the location independence. Independence of location is a sine qua non for inventory verification since the ability to camouflage diversion by floating material from one location to another within a nuclear complex would invalidate many of the interferences to be drawn from the inventory verification sampling.

This document takes as its starting point that inventory verification sampling is needed at a specified assurance level to guard against a strategic goal quantity of a specified amount. The purpose is to obtain a sampling procedure which is robust and adequate against all diverter strategies. There are aspects of the problem which still need additional work such as the effect of irregular amounts of material in the different items on the sampling procedures, the fact that no instrument such as instrument A always catches removals up to a certain point and never beyond that point, and the fact that standard deviations of measurements are not exactly known but are only estimated.

Acknowledgment and Previous Work

As mentioned earlier a previous work [1] sponsored by the IAEA and UKAEA was developed along similar lines. This work created sample size methods to use for bias and attribute testing which guard against possible "management" diversion strategies when the population of items are fuel plates with stated sizes, numbers and fissile and fertile material amounts. The resulting sample sizes provided adequate and robust procedures for the problem at hand.

The present article treats of a more general problem where (1) individual items have stated amounts and operator-inspectorate individual differences are used to eliminate process variance component between items, (2) three critical regions inherent in the use of a combined attribute and variable testers are taken into account, (3) it is assumed the falsifications are distributed by a diverter in a way which minimizes the probability of detection, (4) conservative approaches are taken by the inspectorate at every turn, and (5) maxi-min and game theory approaches are used for comparison with crossover plan results.

Game theory has been used in safeguards studies in different forms by several authors [6,7,8]. There are always certain limitations to the game theory approach on the grounds of the assumptions, practicality and applicability and even the desirability of the effected results as a solution. In addition, the solutions are not readily obtained. Nevertheless, game theory can provide a useful basis of comparison for results which are calculated by more immediate methods.

One of the results of these studies has been to recognize that the development of adequate sampling plans in safeguards is more complicated than in ordinary acceptance sampling situations and the amount of sampling required is generally more extensive.

The authors have had many contacts with coworkers in this developing field over the years and would like to acknowledge their help and contributions.

Glossary of Symbols

Symbol	Meaning
α	The probability of inferring a bias discrepancy when no true difference exists.
β	The probability of detecting a diversion situation at the A = SGQ diversion level.
$T_{1-\alpha}, T_{1-\beta}, T_{\beta}$	The $100(1-\alpha)$, $100(1-\beta)$, and 100β percentile points of the zero mean, unit variance normal distribution.
∂	The observed discrepancy whose variance under diversion is a combination of the measurement variance of the differences and the process variance of the induced discrepancies between stated and true values.
$p(N,n,k,x)$	The hypergeometric density $p(N,n,k,x) = \binom{k}{x}\binom{N-k}{n-x}/\binom{N}{n}$.
$\Phi(Z)$	The value of the zero mean, unit variance normal cumulative distribution function at z.
σ_d	The standard deviation of the difference between the operator's and inspector's results due to random measurement error.
Q_b	The probability of finding no gross defectives in the variable sample.
Q_a	The probability of finding no gross defectives in the attribute sample given that no gross defectives have been found in the variable sample.
Q_c	The probability that the bias test will not be significant given that no gross defectives are in the attribute and variable samples.

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TODAY'S NEED:

ENERGY MANAGERS

Editor's Note: The following article is reprinted from **The Pittsburgh Press**, page 22, Tuesday, February 5, 1974. The author is Dr. Fred Forscher, a consultant from Pittsburgh, Pa., who is a member of the INMM executive committee.

By FREDERICK FORSCHER

The survival of our society — indeed, of any society — depends on a sufficient supply of energy.

Our society, like each one of us, needs calories to sustain its life functions. This similarity of man and society is not just a convenient analogy, but a fact. Any living thing, be it amoeba, man or society, consumes energy in order to survive.

The processes by which society converts all forms of energy for its daily needs can be described as social metabolism.

The biologists have discovered that any organism has the capacity to use energy essentially in two ways: To build up (anabolism) or to break down (catabolism) constituents and functions of the body.

Similarly, society uses energy and raw materials to construct its institutions and keep them operative; as well as to reduce them and make room for change.

Only if we begin to think along such lines can be we hope to develop the interdisciplinary methodology that is necessary for survival.

After many decades of study, biologists have not yet unraveled all the secrets of our human metabolism, while sociologists have not even begun their study of social metabolism. But the sooner we start on this research and apply what we learn, the sooner will our ailing social body find a feasible treatment.

We are at the beginning of a phase in the history of the industrialized world in which the understanding of all aspects of social metabolism is crucial.

We are now entering a period in which energy supply (like food) will become increasingly more important while energy demand (like consumption) must tend toward conservation.

This condition is bound to prevail well into the '90s, or until such time as newly developed energy sources can be counted upon to fill the needs.

Unfortunately, the fact that energy cannot be recycled, an indisputable physical fact, has not even been mentioned. But it is this truth, known as the second law of thermodynamics, that will shape many of the hard choices to be made between the welfare of some and the environmental quality of others, between the risks to be taken by some for the benefits of others.

From a practical point, there are only four basic energy resources: coal, oil, gas and nuclear. (At present, solar energy provides the daily food that keeps our biological systems alive.)

Little attention is now paid to the question of how to manage these resources in the most advantageous manner because there is no agency, no institution and no methodology to bring these four industrial interests to focus jointly on our common problem.

What is needed is a new framework for joint action in the public interest — a new profession of energy management, embracing the fields of engineering, economics and ecology.

We need this new profession now because we need a new methodology that can regain the confidence of the public and can stand the technical scrutiny of engineers, economists and ecologists. We need this unique professional approach to arrest our march toward self-destruction.

It is well to point out that Western Pennsylvania occupies a special position in the ongoing search for an equitable solution to the energy crisis.

Of the four basic energy resources, this region gave birth to three: coal, oil and nuclear. In addition, this region has led the nation in pollution control since the pioneering days of the Pittsburgh Renaissance.

Western Pennsylvania has the people, the universities, the means and the motivation to become once more a leader — in the new field of energy management.

This historic region can again lead the U.S. in a vital effort toward the wise management of its energy resources, so that our nation and our children shall have enough energy — enough clean and cheap energy.

SOME ELECTRONIC SECURITY DEVICES

By Frank Costanzi

Electronic security devices can significantly enhance the capabilities of a plant security program. Intrusion detectors, door alarms and the like are not a means of replacing personnel with gadgetry, but rather extend the senses of the guards and watchmen protecting your plant. What we hope to accomplish in this article is to describe the operation and limitations of some of the security devices applicable to nuclear facilities.

Before proceeding, we would like to state that much of the information contained in this article has been gleaned from manufacturers' data, reports of tests conducted by various government agencies, and some personal observation. Unfortunately, such material is largely nonreferencable. Nonetheless, we can refer the reader who desires more information to the proceedings of the Cannahan Conference on Electric Crime Counter Measures, as a place to begin looking.

Exterior Intrusion Alarms

An exterior intrusion alarm detects intrusion into a given area of a plant site. What is actually detected by the alarm system is an individual, or vehicle, within or passing through a specified zone within the area to be protected. Commercially available exterior alarm systems generally can be classified by five categories — microwave, infrared, ferrous metal sensitive, pressure sensitive, and vibration sensitive.

Microwave Systems. An exterior microwave intrusion alarm system is comprised of a transmitter, receiver, power supply and alarm annunciator. The transmitter produces beam-shaped pattern of modulated microwave energy directed at the receiver which senses the modulation of the microwave and amplifies the modulation signal to a preestablished level. Any partial or total interruption of the beam-shaped pattern will cause a change in the received modulation signal level and result in an alarm condition.

The microwave transmitter-receiver link is a line of sight system with the transmitter and receiver usually spaced about 100 meters apart. Hills, tall grass, or other obstructions will interrupt the beam resulting in "blind zones" behind which an intruder may pass. Ditches may provide crawl space for an intruder. To prevent passage under the microwave beam in the shadow of an obstruction, hills should be leveled, ditches filled, and obstructions removed such that the area between transmitter and receiver is clear of obstructions and free of rises or depressions.

A clear area should be provided on either side of the microwave beam which is sufficiently wide to preclude moving objects (e.g., personnel walking or vehicle traffic) from generating false alarms. If the microwave link is installed parallel to a chain link fence, the transmitter and receiver should be positioned about six feet inside the fence to enable detection of someone jumping into the protected area from atop the fence.

Successive microwave links can be overlapped to eliminate the areas where movement is not detected below and immediately in front of transmitter and receivers. Birds, small animals, and blowing debris of small size will generally not create alarm.

Although microwave systems will generally continue to operate during heavy rain and snow, drifts of snow will obstruct the beam and thereby create "blind zones" in the coverage area.

Infrared System. Like the microwave system, the infrared system is comprised of a transmitter, receiver, power supply, and alarm annunciator. The transmitter directs a narrow beam to a reciever typically 100 meters away. When the infrared beam between the transmitter and receiver is interrupted, an alarm signal is generated. As with the microwave system, the infrared system is line of sight and the beam is usually modulated. However, unlike the microwave system, no coverage pattern exists, although multiple beams between transmitter and receiver tend to define a "wall." If this "wall" is penetrated by an individual an alarm will result. The "wall" is generally insensitive to birds and small animals as a short interruption of more than one beam is required to create an alarm. However, if a single beam is interrupted for a longer time an alarm will also be generated, thus precluding intrusion by crawling or rolling along the ground.

Like the microwave system the operation of an infrared alarm system requires level terrain. Ditches, gullies or dips will allow areas where movement cannot be detected where an intruder could pass under the beam. Vegetation such as bushes, trees, grass, etc., will also block the infrared beams. Snow and rain generally will not decrease the effectiveness of the infrared system, although drifts of snow may create "dead zones." Fog will attenuate the infrared beam; however, units can be supplied with circuitry to compensate for attenuation due to fog. Dust collection and condensation on the optics can cause alarms as can blowing sand and dirt.

Recent developments employing LASER transmitters in place of the usual infrared transmitters have promised a greater resistance to interference from dust, fog, blowing sand, and the like, but may suffer from atmospheric disturbances such as schlieren.

Ferrous Metal Detector System. A ferrous metal detector consists of an elongated loop of wire, amplifier, and inhibitor, all buried in the ground, and an alarm annunciation unit. The system can detect very small amounts of ferrous metal carried by an individual crossing the buried wire loop. A current passed through the buried wire produces a magnetic field. A ferrous object entering the magnetic field induces an electromagnetic force (EMF) in the buried wire which is amplified and sensed by the alarm unit.

The loop of wire is laid in a pattern prescribed by the manufacturer to reduce false alarms due to electromagnetic interference. In addition, an inhibitor can be included in the system which senses strong electromagnetic interference and disables the alarm unit to further reduce false alarms. This sytem cannot be used parallel to high-voltage transmission lines or in close proximity to other sources of electromagnetic "noise."

As the magnetic system detects only magnetic objects, it is free from the usual interferences of weather, and birds and animals will not generate alarms. However, severe electrical storms can effectively "shut-off" the system and close proximity of fences can create nuisance alarms.

Since sensor loop is buried, no ground leveling or clearing of vegetation is required. Sensor loops can be up to 500 meters in length.

Pressure Sensitive Systems. Buried pressure transducers detect minute variations in the mechanical stress in the surrounding soil. The signals produced by the transducers are amplified and compared with a preestablished threshold. If the signal exceeds the threshold, an alarm occurs. The system is comprised of the transducer, which can be a liquid filled hose or a line of several individual pressure sensitive transducers placed a few feet apart, a power supply, and an alarm unit connected to an alarm annunciator.

The pressure sensitive perimeter alarm system should be installed in soil relatively free of rock to avoid damage to the transducers during installation or during soil settlement after installation. The sensitive area ususally consists of a narrow corridor, typically one to three feet in width, hence some systems employ two such corridors to prevent an intruder jumping over the buried transducers.

High winds can produce pressure waves on the ground surface which can result in nuisance alarms; however, techniques for elimination of noise due to wind can be designed into the equipment. Pressure sensitive systems may lose sensitivity as a result of deep snow or frozen ground covering the buried sensors. Other natural phenomena such as hail and rain can also cause nuisance alarms. Small animals will generally not generate alarms.

Vibration Sensitive Systems. Fences can be protected by use of vibration sensors mounted directly on the fence. The simplest system is comprised of a series of mercury switches attached to the fence posts and arranged such that motion of the fence will trigger an alarm. The system is very prone to false alarms generated by strong winds and birds and small animals.

Another system employs a cable attached to the fence to detect motion. The cable is an electret and essentially acts as an extended low frequency microphone generating signals as a result of stress and pressure on the cable. The apparent advantage of this system is that wind and animal generated signals can be "tuned out" and the system set to respond only to attempted breach of the fence. A single cable can protect up to 300 meters of fence.

Interior Intrusion Alarms

The purpose of an interior intrusion alarm system is the detection of intrusion into a specified area within a building. The type of alarm system needed is dependent upon the size, location and construction of the area to be protected. In general, intrusion alarms can de divided into three categories: volumetric protection, surface protection, and point protection.

As the name implies, volumetric protection provides for the detection of movement within a specified volume, such as the interior of a room, vault, building, etc. Any penetration through openings (doors, windows), walls, ceiling, or floor of the room or movement within the room, such as that of a "stay behind" intruder, will be detected by the system. Volumetric systems compare "signals" from the motion of an intruder with ambient levels of sound, light, microwave energy, acoustic energy, or infrared energy to detect the presence of an intruder.

The protection of individual room surfaces such as doors, windows, walls, and floors can be accomplished in a variety of ways. For example, a door can be protected by using a balanced magnetic switch or infrared light beam. Opening of the door even slightly will imbalance the switch or break the beam. A wall, ceiling, or floor can be protected using a vibration detector. An intruder trying to break through the wall, ceiling, or floor surface would cause vibrations on the wall, floor, or ceiling surface and be detected.

Conductive foil is often used to protect glass surfaces of windows or doors. Breakage of the glass by an intruder is detected by monitoring a current through the conductive foil. However, conductive foil, trip wires, and similar systems which rely upon a simple making or breaking of an electrical connection are easily circumvented.

Point protection detects the presence of an intruder in close proximity to, or contact with, the item being protected; however, persons passing within a few feet of the protected item will generally not trigger an alarm. Example of items protected by an alarm system in this category are filing cabinets, safes, window or door grids, etc.

The following is a brief discussion of a number of interior intrusion alarm systems.

Acoustic (Passive). A passive acoustic intrusion alarm uses microphones to detect sound, usually between 1500 Hz and 5000 Hz. An accumulator circuit within the system is designed to compensate for random sounds within the area protected. The accumulator circuit essentially counts the occurrence of sound above a preset audio trigger level over a predetermined period of time. If the sounds received above the audio trigger level exceed the preset count, an alarm condition ensues. The accumulation of occurrences is bled-off at a predetermined rate, hence fairly regular occurrence of noise within the area will neither cause alarms nor reduce sensitivity. Nonetheless, in areas where equipment operation or outside vehicle traffic produces a high noise environment, a passive acoustic intrusion alarm system would be highly susceptible to nuisance alarms.

Acoustic (Active). Active Acoustic (ultrasonic) Motion Detectors utilize the Doppler principle to detect motion within the area protected. An ultrasonic signal is radiated into the area by transmitting transducers. Receiving transducers detect the signal and compare the received signal to the transmitted signal. Movement within the area will cause the received signal to vary in frequency. As the received signal changes in frequency (also amplitude in certain systems), an alarm signal is generated from the comparator. A filter network can be provided to discriminate between an intruder and air turbulence (low frequency signals centered around 5 Hz). Nonetheless as an active acoustic motion detector uses the air media to propagate the ultrasonic waves, the need for an environment having little air turbulence is essential. In addition transducers must be located on a vibration-free surface away from air ducts, fans, and loose-fitting doors and windows. Loud, high-pitched sound will also affect the system, requiring receiver transducers to be located at least 3 meters from telephone bells, steam pipes, radiator valves, and electric motors for effective operation.

The sound absorption and sound reflecting characteristics of the contents and interior surfaces within the area protected affect the motion detection capability of the detector. In areas having high sound absorbing materials the transducers should be placed closer together to compensate for the lower motion detection capability.

Light Threshold Detector. The light threshold detection system is a passive sensor designed to detect change of light levels caused by an intruder within an area, and operates in much the same manner as the passive acoustic detector. Light-sensing diodes detect the ambient lighting of the area protected and the associated electronics adjusts for the existing light level. If the light conditions in the area change beyond a predetermined range, an alarm is generated.

The light threshold detector is designed for use in closed areas where the light level is free from variation. To avoid false alarms the area protected should be sealed from outside light. Further, the detector should not "look" directly at mirrors or mirror-like surfaces.

Microwave Motion Detector. Microwave motion detectors, like the active acoustic system, utilize the Doppler shift to detect motion within the area to be protected. Movement results in a frequency shift of the received microwave signal. As with the acoustic systems, filter networks are used to distinguish persistent motion (noise) from the motion of an intruder.

Microwaves will penetrate common interior partitions such as sheetrock, wood paneling, acoustic tile, etc., as well as wooden doors and glass windows, hence care should be exercised in locating a microwave system to avoid alarms due to motion outside the area to be protected. Generally, exterior walls constructed of metal or reinforced concrete or masonry will block or attenuate the microwave energy sufficiently to not allow the system to "see" motion beyond the wall. An electrically grounded metal screen enclosing the area protected will also prevent motion outside the area from generating alarms. If a portion of the area walls is made of material which can be penetrated by the microwave radiation, the unit should be located pointing away from the wall where penetration will occur.

As the specific pattern of coverage is governed by the antenna system, appropriate antennas should be selected such that their patterns of radiation and reception just cover the area that is to be protected. In order to achieve the highest system reliability and freedom from false alarms, it is important to set the range control always at the minimum level which will just provide adequate coverage of the desired area.

Passive Infrared. A passive infrared detector senses movement within an area by the change in radiation pattern of energy falling upon a detector. Generally, infrared radiation is either focused through a reticle onto a ferroelectric bolometer or focused upon an array of thermal junctions. In the bolometer system, as an intruder moves the reticle "chops" the radiation emanating from the intruder as it falls upon the bolometer, resulting in variations in the dielectric constant of the bolometer. These variations are detected as modulation of a carrier frequency being passed through the bolometer. In the thermal junction array system, motion of an intruder causes a change in the heat pattern falling upon the array of detectors. The alternating thermal junctions provide the same function as the reticle; however, the junctions themselves can produce a small electromotive force which can be directly detected, hence not requiring a carrier frequency and associated electronics. Although passive infrared systems are generally free from the environmental limitations imposed upon other systems, care should be taken to avoid having the detector "look" at intermittent sources of heat such as radiators.

Balanced Magnetic Switch. The balanced magnetic switch consists of a switch mechanism and a magnet mounted on doors, windows or other movable objects. The contacts of the switch are connected to an alarm monitor. In the secured position, a magnet (e.g., positioned on the door) is aligned with the balanced magnetic switch (e.g., positioned above the door). Opening the door or window, or moving the protected object, separates the magnet from the switching circuit causing the pole to change to another set of contacts, thus creating an alarm condition. In addition, the pole of the switching circuit is balanced against the magnet in such a manner that attempts to "capture" the switch by extraneous magnetic fields will also result in an alarm.

Infrared Beam. Similar in operation to the infrared exterior intrusion alarm system a transmitter produces an infrared beam which is directed to a receiver across the surface to be protected. Interruption of the beam will create an alarm condition. In general the infrared beam is modulated to prevent "capture" of the receiver and subsequent defeat of the system.

Vibration Detector. A vibration detector utilizes a piezoelectric transducer designed for mounting on the surface of walls to detect attempted breaking through the wall. The transducer can be "tuned" such that it is sensitive to vibration caused by an intruder breaking through the walls. The detector amplifies and accumulates the received signals caused by structurally borne vibration such as an explosion, a short series of blows, a longer series of light blows, or similar phenomena. An alarm condition ensues if the strength and number of vibration exceeds some present level within a prescribed time interval.

Capacitance Detector. Safes, filing cabinets, protective wire screens over windows, vents, or doors, and other such metallic items can be protected by a capacitance detector. Although except in the case of the metal caged-in or screened-in areas the usual application of a capacitance detector is not as an intrusion alarm.

The item to be protected is electrically insulated from its surroundings and is connected to the detector unit, for which the item acts as an antenna. Approach within a short distance of the item protected (less than 1/3 meter) will suffieciently alter the capacitive coupling between the "antenna" and the surroundings to change the impedence of the antenna system. This change of impedence is detected by the unit and an alarm is triggered. The capacitance detector can be used to protect any metallic object; however, for proper operation the object protected must be well insulated and the detector must be connected to a low resistance ground (e.g., cold water pipe ground).

Detection of SNM, Weapons, Explosives

The preceding portions of this article discussed various devices which protect areas from intrusion — the objective being to isolate the areas protected from unauthorized access. A second aspect of security is protection of these areas from those who would be authorized access to them. Searching such individuals for concealed weapons and explosives provides that protection. Searching for concealed SNM acts to prevent clandestine diversion of SNM.

SNM Doorway Monitors. Use of SNM doorway monitors provides an efficient means for detecting SNM concealed upon an individual. Commercially available doorway monitors are capable of detecting gram quantities or less of SNM with high reliability. A typical SNM doorway monitor consists of detector units sensitive to the radiation emanating from SNM (usually rays), electronics to process the signals from the detector units, and alarm circuitry which responds to the presence of SNM with an alarm. Some form of automatic background updating to optimize sensitivity and reduce the false alarm rate is incorporated into some commercially available units. Doorway monitors should be positioned such that individuals and objects cannot pass around, above, or below the sensitive area of the device. Shielding may be needed to reduce background to a sufficiently low level to allow the detection of small amounts of SNM. Use of a single channel analyzer to provide an energy window can significantly decrease the sensitivity of the device to background radiation and, thereby, increase the SNM detection capability.

A treadle pad switch, door switch, or similar device can be used to "turn on" the doorway monitor such that background fluctuations occurring when the sensitive area is unoccupied will not generate alarms.

Metal Detectors. Commercially available metal detectors are generally capable of a wide range of detection sensitivities and can detect both magnetic and non-magnetic metals. Metal detectors can be used in conjunction with an SNM detector to search for shielded concealed SNM, as some metal detectors will detect metallic shielding.

A typical walk-through metal detector consists of a detector loop through which individuals pass, and an electronics unit which drives the detector loop and interprets changes of the electromagnetic field within the area of the detector loop due to the presence of metal. Commercially available metal detectors generally can be set to a wide range of sensitivities by adjustments of the control unit. A treadle pad is usually employed such that the device need not be on continuously thereby reducing nuisance alarms due to movement of metal exterior to the device.

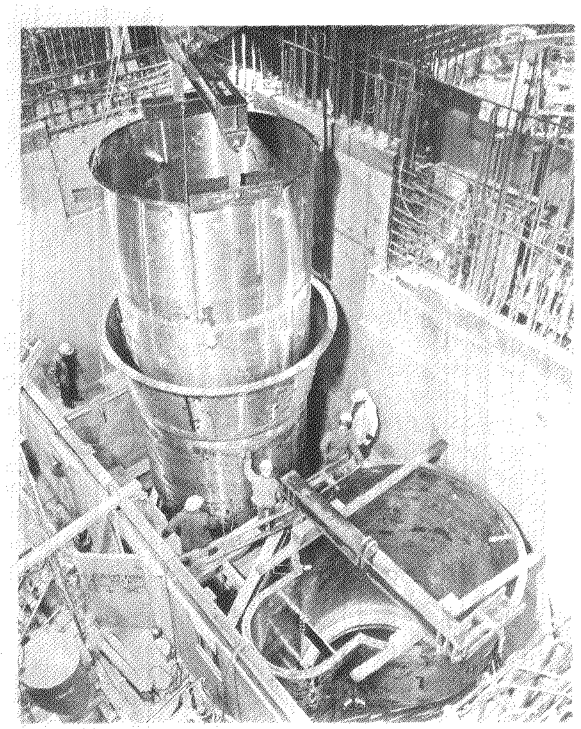
The frequency at which the coils are driven and whether the device detects eddy current loss determines the capability of the unit to detect non-magnetic conductors, such as lead. Generally the higher the driving frequency the greater the sensitivity to non-magnetic metals.

When installed, the metal detector sometimes requires "tuning" to the local environment (much the same problem as early color television sets). On some units metal in arch supports and safety shoes can be tuned out to suppress false alarms. Motion of large metallic objects (such as trucks, large metal doors, etc.) near the detector can generate nuisance alarms.

Explosive Detectors. Devices which detect explosives are sensitive to the vapors emitted from compounds contained in the explosive. For example, dynamite is detected by the detector responding to the nitroglycerin vapors. A number of methods have been used to detect explosives, but all are common in the respect that they each sample vapors to determine the presence of explosives. Of the variety of systems currently available the electron capture system seems most easily applicable to performing quick searches. Gas chromatographs and bio-luminescent devices offer greater specificity (lower false alarms). However, gas chromatographs require longer sampling time than electron capture devices, and the bio-lumninescent devices require daily preparation of fresh microorganisms. In addition, the microorganisms may be killed by some common industrial vapors. It should be noted that research is actively underway to improve the capabilities of all these systems and make them more useful for searching purposes. However, we will further discuss only the electron capture device.

The electron capture detector consists of a source, typically Tritium or ^{63}Ni, within a chamber through which is passed an inert carrier gas, typically helium or nitrogen. The electrons emanating from the source are quickly thermalized through inelastic collision with the gas molecules and are collected on an anode, providing a reference current. If the carrier gas contains compounds of high electron affinity, such as those contained in explosives, the reference current is suppressed, providing the mechanism of detection. Unfortunately, a number of common compounds other than explosive effluents will also capture the electrons and result in suppression of the reference current. However, sensitivity to many of these non-explosive compounds can be reduced by heating the gas passing through the chamber. Moreover, specificity can be further increased by noting the characteristic of the response of the device: non-explosives will tend to clear the detector quickly (order of seconds) whereas true explosives will register for long periods (order of a minute).

Obviously, much more can be written on the subject of electronic security than the brief description of the available systems which we have presented here. However, such is beyond the scope of this article. What we have attempted to do is to describe in very general terms various types of electronic security devices and to indicate the genre of considerations which should be incorporated in their use.



RICHLAND, Wash., — Construction site personnel at the Fast Flux Text Facility lowered an intermediate heat exchanger into its guard vessel after installing a sodium pump guard vessel in the same concrete cell. When completed, the FFTF will be the major test reactor for irradiation testing of Liquid Metal Fast Breeder Reactor (LMF-BR) materials.

N15
AMERICAN NATIONAL STANDARDS

By R. L. Delnay

The American National Standards Institute, ANSI, approached the Institute of Nuclear Materials Management, INMM, in 1966 to sponsor a newly-created Standards Committee in the nuclear field. The new committee was designated N15 "Methods of Nuclear Materials Control." An INMM Steering Committee met in 1967 to write a scope to cover the types of standards to be developed under N15. After ANSI approved the scope, the INMM was officially involved in the development of American National Standards. The balance of 1967 and part of 1968 was devoted to: (1) the organization of subcommittees, (2) the staffing of the subcommittees, and (3) the conducting of a canvass of professional organizations for representation on N15. By the end of 1968 there were 7 subcommittees under N15 to write standards and 13 organizations represented on N15. Currently, there are 9 subcommittees, 15 organizations on N15, and 74 INMM members involved in standard related activities.

To date, ANSI has approved the 9 standards that N15 has submitted for review and approval. The first N15 standard was approved in 1970. There were 2 approved in 1971, 5 in 1972, and 1 so far in 1973. The USAEC Directorate of Regulatory Standards has adopted 5 of the N15 standards as the basis for 3 Division 5 Regulatory Guides. Table 1 lists the 9 approved N15 standards and the corresponding regulatory guides.

In addition to N15 there are 15 more American National Standards Committees working on nuclear standards. Each one of these standards committees operates under its own scope which has been approved by ANSI. These committees are active in such fields as radiation protection, nuclear criticality safety, nuclear instruments, etc. All of the "N" Committees, with their respective titles and sponsoring organizations, are tabulated in Table 2.

TABLE I
N15 American National Standards

Number	Title	Reg. Guide No.
N15.1 - 1970	Classification of Unirradiated Uranium Scrap	5.2
N15.2 - 1971	Record and Reporting Units for Nuclear Materials Control	
N15.3 - 1972	Physical Inventories for Nuclear Materials	
N15.4 - 1971	Nuclear Material Control Systems for Conversion Facilities, A Guide to Practice	
N15.5 - 1972	Statistical Terminology and Notation	5.3
N15.4 - 1972	Analytical Procedures for Accountability of Uranium Tetrafluoride	5.4
N15.7 - 1972	Analytical Procedures for Accountability of Uranium Hexafluoride	5.4
N15.10 - 1972	Classification of Unirradiated Plutonium Scrap	5.2
N15.11 - 1973	Auditing Nuclear Materials Statements	

Need or Request for a Standard

The need or request for a standard may originate in any of four ways. The INMM Subcommittees have originated the majority of the N15 standards. In fact, the subcommittees have initiated 18 of the 24 standards currently under N15. These 18 standards are the result of each of the original 7 subcommittees reviewing their respective assignments and after much debate agreeing as to the number of standards needed to cover the assignment. In two cases the subcommittees, Inventory Techniques and Audit Techniques, have each covered their initial assignments with a single standard, N15.3-1972 and N15.11-1973, respectively.

A second means of initiating a standard is a request by standards committee. The standards committee may ask a subcommittee to write a specific standard. For example, the N15 Standards Committee identified the need for a plutonium scrap classification guide. An existing committee was asked to prepare the classification guide. In this case it was necessary to add people to the group that had written N15.1-1970. The enlarged group produced N15.10-1972 "Classification of Unirradiated Plutonium Scrap."

A third way involves organizations in the nuclear field. The organization may request or show the need for a specific standard. The request is sent to either ANSI or an "N" Committee Chairman. In either case, both ANSI and the appropriate "N" Committee Chairman review the request to determine which "N" Committee the request is to be assigned. In October, 1972, the Directorate of Regulatory Standards sent ANSI and the N15 Chairman requests for ten specific standards. After a review, 6 of the 10 requests were assigned to the N15 Standards Committee, 3 were assigned to other "N" Standards Committees, and the tenth request is still unassigned

STEPS IN PREPARING AN N15 STANDARD

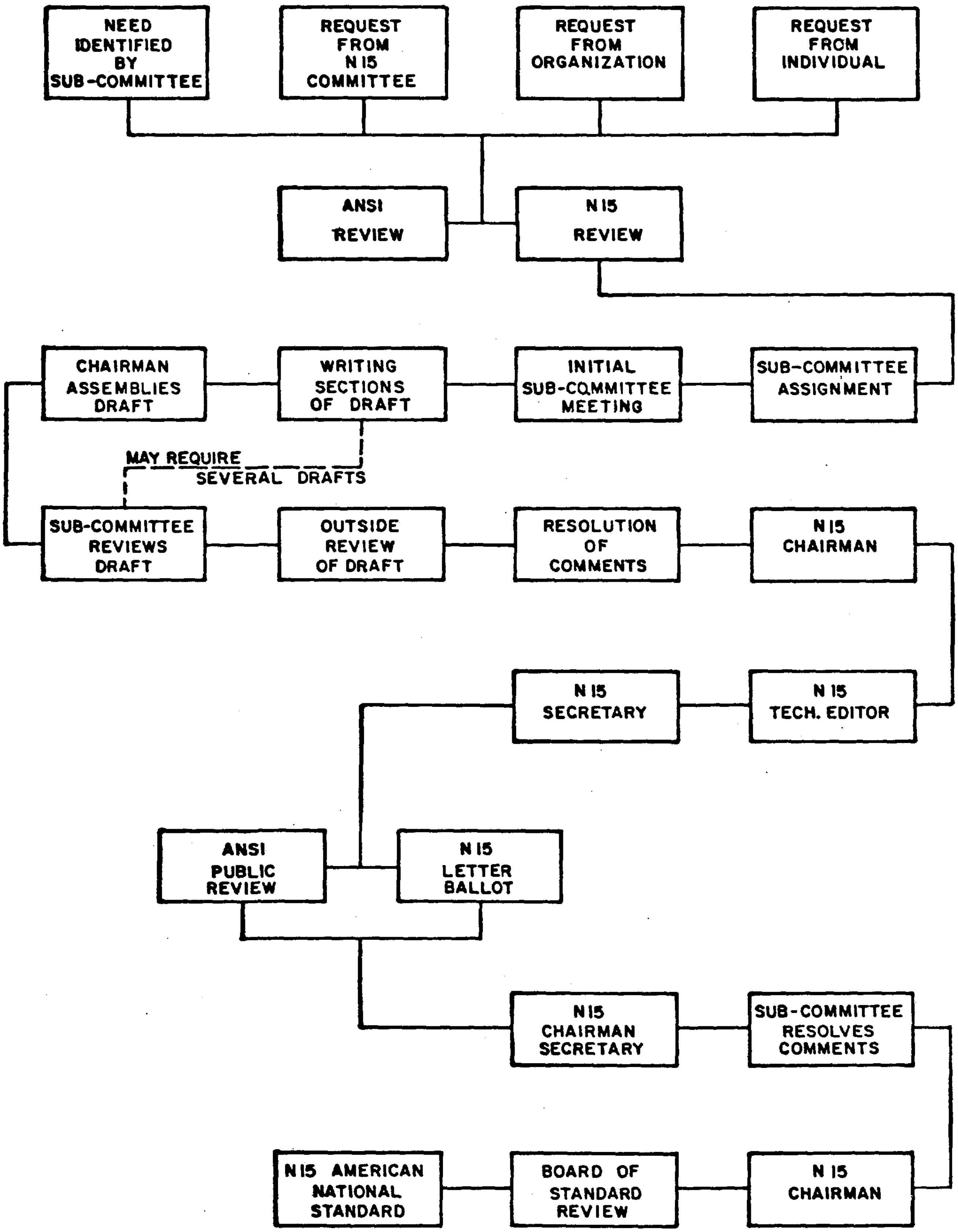


FIGURE 1.

as it does not pertain to any of the existing 16 "N" Standards Committees.

The fourth way by which a standard may be requested is a request by an individual in the nuclear field. Such a request follows the same review prior to assignment to an "N" Committee as explained above for request from organizations.

TABLE II
American National Standards Committees — Nuclear

Committee	Title	Organization
N11	Basic Material and Materials Testing for Nuclear Application	ASTM
N12	Nuclear Terminology, Units, Symbols, Identifications and Signals	AIF
N13	Radiation Protection	AIF
N14	Transportation of Fissile and Radioactive Materials	AIA
N15	Methods of Nuclear Material Control	INMM
N16	Nuclear Criticality Safety	ANS
N17	Research Reactors, Reactor Physics, and Radiation Shielding	ANS
N18	Nuclear Design Criteria	ANS
N19	Non-radiological Environmental Effects	ANS
N41	Controls, Instrumentation and Electrical Systems for Nuclear Power Generating Stations	IEEE
N42	Nuclear Instruments	IEEE
N43	Equipment for Non-medical Radiation Applications	NBS
N44	Equipment and Materials for Medical Radiation Applications	USPHS
N45	Reactor Plants and Their Maintenance	ASME
N46	Nuclear Reactor Fuel Cycle	AICE
N48	Radioactive Waste Management	ANS

Among these 16 standards committees there are approximately 500 standards either approved or being prepared.

INMM Subcommittees

As mentioned in the introduction, the original subcommittees under N15 were established by the INMM's Steering Committee. After the initial organizational work had been accomplished it became evident that a need to standardize calibration techniques existed. Once the need was established the Chairman of N15 formed a new subcommittee, Calibrations Techniques. It then became the responsibility of the new subcommittee to review the analytical laboratory procedures which require standardized calibration techniques. The result of said review was the development of four scopes: mass calibration, volumetric calibration, radiometric calibration, and calibration for calorimeters. The chairman of the subcommittee then formed four task groups, one for each of the scopes.

The other two subcommittees that have been organized, since the original group was formed, are the result of the request from Directorate of Regulatory Standards to prepare specific standards. A new subcommittee was formed to write a specific standard on the non-destructive assay of the fissile content of low-enriched uranium fuel rods.

TABLE III
INMM's Subcommittees Under N15 Jurisdiction

Number	Title	Chairman
INMM-1	Methods of Nuclear Materials Control	E. R. Johnson
-2	Measurements	J. C. Barton
-3	Statistics	J. L. Jaech
-4	Records	R. E. Weber
-6	Inventory Techniques	D. E. George
-7	Audit Techniques	B. F. Smith
-8	Calibration Techniques	L. W. Doher
-9	Non-Destructive Assay	L. K. Hurst
-10	Physical Protection in Plant	D. R. Wilkins

The second subcommittee formed became responsible for two very similar requested standards on material protection in uranium and plutonium scrap recovery operations. This subcommittee's responsibilities were expanded when N15's scope was expanded to include physical protection of special nuclear materials. As a result, the material to be covered by the two requested standards became part of a much larger-scoped standard on the physical protection of special nuclear materials in a plant.

Table 3 shows the INMM's subcommittees under the jurisdiction of N15. The table lists only the subcommittees and not the task groups that were created under Subcommittees 1 and 8.

It must be emphasized that the subcommittee chairman staffs the respective subcommittees, assigns the tasks of writing, expedites the writing of the drafts, assembles the drafts into a smooth and easily understood document, umpires disagreements within the subcommittee, and decides when the proposed standard is ready for N15 letter ballot.

N15 Standard

There are many ways in which a standard may be written. However, there are only two which have worked effectively for N15 standards. Both approaches require that the subcommittee chairman distribute to the members on his committee a copy of the request for the standard and ask them to form their own opinions as to the content of the standard. At the initial subcommittee meeting the subcommittee chairman shall have a clearly worded title, scope, and table of contents for discussion. Said items give direction to the initial meeting. The discussion can then concentrate on the task at hand and not a lot of rambling. The title, scope, or table of contents may or may not change during the discussion. Near the end of the meeting all members of the subcommittee will have an idea as to material that will be covered in the proposed standard. It is at this point when the subcommittee chairman decides "who," and "how," and "when" for the first draft. One of the two alternatives that has worked successfully requires that the chairman make assignments so that each member of his subcommittee has a section of the standard to write. Once all the sections are assigned, set a deadline by which the sections are due to the chairman. The chairman reviews the sections and assembles a smooth document, Draft 1. This draft is returned to the individual members for review and comment with a deadline for comments back to the chairman. If the comments are not extensive, the chairman prepares a second draft for review and comment for the subcommittee. If the comments are extensive, the chairman calls a second meeting in which the individual is asked to rewrite his section. This process is repeated until the subcommittee is satisfied with their work.

The second approach centers around the subcommittee chairman selecting himself, or an individual of his committee, at the initial meeting to write the first draft. This draft is sent to the subcommittee members for review and comment. All comments are returned to the author by a due date. The author incorporates the comments into the second draft, or explains why he did not in the cover letter for the second draft. This process is repeated until the subcommittee is satisfied with the proposed standard. Once the subcommittee is satisfied, the subcommittee chairman sends the draft standard to knowledgeable individuals for review and comment. Any comments received are incorporated into the proposed standard and/or resolved with the originator of the comment.

The subcommittee chairman officially transmits the proposed standard to the N15 Standards Committee Chairman along with an explanation of the "who" and "how." The N15 Chairman reviews the work and if satisfied forwards the proposed standard to the N15 Technical Editor. The editor puts the standard into ANSI format and makes sure that references, trade names, trademarks, etc. all comply with ANSI rules and regulations. The editor checks with the chairman of the subcommittee to assure there has been no change in the intent or meaning of the standard after it is in the ANSI format. The document is sent to the N15 Secretary for formal submission to the N15 Committee members for letter ballot, and to ANSI for public review.

Once again, any comments or negative ballots are resolved by the subcommittee which prepared the standard. The chairman of N15 formally submits the proposed standard and its background information to the Board of Standards Review (BSR) for final approval. The American National Standards Institute publishes the approved standard about 2 to 6 months after BSR has approved it. Figure 1 represents a block diagram of the essential steps in the preparation of an initial N15 American National Standard.

The life of an American National Standard is five years. This means that a standard must be reviewed, updated if required, and reballoted by the "N" Committee by the fifth anniversary date. It is highly likely that standards in the nuclear field will be updated prior to the 5-year requirement because the field is relatively new and growing rapidly.

THE USAEC—MODERN VENDUE MASTERS

(Continued from Page 8)

analysis, only one explanation is possible, and that is: society has always contained a small percentage of parasitic human "sharks" who live at the expense of other men and believe that the end does justify the means. Patriotism is a meaningless concept to such individuals.

An analogy can be made with our present Safeguards situation. There are radical groups within our society who, for personal financial gain, or for political blackmail or embarrassment, would not be averse to unlawful diversion of fissile materials. Consider organized crime. If this group does not hesitate to destroy part of our society with mass importation of hard narcotics, then how can we believe that they would give the rest of society any more consideration if a black market develops for fissile material. Finally, the most frightening specter of all is the fanatical terrorist groups. Is there any doubt that a group capable of mass murder of innocents, such as recently occurred at the Rome, Italy Airport, would not welcome the opportunity to use the ultimate weapon.

Yet, even with these unnerving potentials for unlawful diversion of fissile materials, we have something in our favor. Modern Vendue Masters are already in place to prevent this diversion and they are calling upon the latest technology to assist them in their surveillance. These men, under various titles, are found within the U.S. Atomic Energy Commission. The latest promulgations from the AEC may not meet with universal approval, but one thing is very apparent — we have men of courage within the AEC who place Safeguards above personal popularity, and with such modern Vendue Masters already in place we may actually survive in this nuclear age. — **Wm. J. Gallagher.**

STATEMENT OF FREDERICK FORSCHER
ENERGY MANAGEMENT CONSULTANT
BEFORE THE
JOINT COMMITTEE ON ATOMIC ENERGY
HOLDING HEARINGS ON NUCLEAR REACTOR SAFETY

(January 22, 1974)

Mr. Chairman, I appreciate being invited to submit this written statement as an independent expert on nuclear fuel and fuel performance. I have been an active participant in almost every phase of the nuclear fuel cycle for the past twenty years. (I am attaching a short biography for your information). I was a co-founder of NUMEC, Apollo, Pennsylvania, and its Vice President for Operations from 1957 to 1967 during which time our industry evolved the now common fuel (for LWRs): UO_2 pellets in sealed Zircaloy-2 tubes, and arranged in bundles known as fuel-elements.

The sole purpose of this statement is to raise the question: Is nuclear fuel safety connected in the sense of 10 CFR 50?

It can be argued that fuel is not safety connected, because a poorly designed and badly manufactured fuel may perhaps shut down the reactor, causing a substantial loss to the utility, but need not have impact on the health and safety of the public. It should be noted that even where reliability and safety are not overlapping concepts, quality assurance program will not only minimize the risk in regards to public health and safety, but will also provide long-term reliability and mechanical integrity.

On the other hand it can be argued — particularly in the light of the new rules governing the ECCS — that fuel is "safety connected" in the context of Part 50. That means that there shall be criteria that establish the necessary design, fabrication, testing and performance requirements for structures, systems, and components (such as fuel elements) important to safety; that is, such fuel elements shall provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public and the environment.

Present regulations do not make it clear whether or not the fuel elements are to be considered as "safety connected" in the sense of the above paragraph. I urge the Committee and the AEC to clarify this matter.

It is conceivable that accidents involving fuel elements, either inside or outside of a reactor, can initiate events that endanger the health and safety of the public. It is therefore reasonable to expect that certain quality assurances shall be provided by the licensee to minimize this risk. In the case of safety connected components, Appendix B, 10 CFR 50, defines quality assurance as "all those planned and systematic actions necessary to provide adequate confidence that a structure, system or component will perform satisfactorily in service."

In the case of an accident involving fuel, either inside or outside a reactor, the question of "negligence," and the question of "assignable cause" will inevitably be raised. In the absence of a clear mandate that fuel is safety connected, and hence requires a formally accredited quality assurance program, negligence becomes a mute question.

At the last annual meeting of the Institute of Nuclear Materials Management (San Diego, June 1973) Mr. S.H. Smiley, Deputy Director for Fuels and Materials, Directorate of Licensing, U.S. AEC, presented a talk on "Nuclear Fuel Fabrication and Quality Assurance." It reflects a thorough understanding of the necessary QA program, including:

1. Design criteria and fuel performance analysis;

2. Manufacturing process control, including: cladding fabrication; pellet manufacture; rod-

loading and welding; fuel element assembly, identification, handling and storage; material traceability; rework and repair procedures;

3. Tests and inspections performed to assure product quality, including: sampling plans, acceptance criteria, sensitivity and accuracy of measurements, and disposition of statistical nonconformance.

His excellent program outline is introduced by an ambiguous reference to the applicability of Appendix B to fuels elements. I urge the committee and the AEC to eliminate such ambiguity by clearly stating whether Appendix B is or is not applicable to fuel elements.

With the present emphasis on standards and standardization it is deplorable to note the absence of any fuel element standards, and even more importantly the lack of interest on the part of the industry to generate such standards. My devotion to standards, that is voluntary consensus type technical standards, is reflected in the attached resume. I applaud all the efforts by the Nuclear Technical Advisory Board of ANSI. But at the same time I must alert you to the serious imbalance of effort devoted to standards pertaining to reactors, and standards pertaining to the fuel cycle.

We are now at the threshhold of a plutonium economy. Even before breeders will stretch this nation's energy supply, plutonium will be used to stretch our uranium and thorium fuels in LWRs and HTGRs. Fabrication of Plutonium recycle fuel is unthinkable without the strictest form of quality assurance and the highest degree of reliability. This nation need not learn that fuel is safety connected the hard way; e.g. from accidents with plutonium recycle fuel. Much can be done now while the industry is still at the toe of a steep growth curve, aiming for 1000 reactors by the year 2000. What we need now is a clear statement whether fuel, or what type of fuel, is or is not, safety connected in the sense of 10 CFR 50.

CHEZEM COMMENTS

(Continued from Page 2)

lucrative regulatory agencies. Further, how can we explain that many utility engineering executives hold degrees in physics, chemistry or business administration rather than engineering?

It is not my intent to pick upon my friends in academia, however I must make one more point. At a recent utility briefing by a specialized fusion group, the utility scientists were talked-down-to by the professorish bigwigs. By the end of the day, the fusionists were up against the wall from the onslaught of criticism by the utility people . . . . mostly holding high academic degrees themselves. Except in the halls of congress, fusion claims are more realistic today.

After the outbursts levelled at the utilities by members of the balance of the fuel cycle over cocktails during the INMM meeting in San Diego, I began asking discreet questions. I believe that the fuel cycle has long been pampered by the government, is faced with a survival of the fittest situation, and those fuel cyclists now in a put-up or shut-up economic situation are seeking a scapegoat. That is quite understandable. Interestingly, one can now count the number of independent utility fuel fabricators on one finger of one hand. Why?

With a few un-notable exceptions, I have found the AEC to deserve the least criticism of any group with which I have been associated. I am still puzzled, however, by why an organization made up of some of the most competent and dedicated people in the field comes out so badly in its end product. It is probably because it is the only organization in Washington where you can find the boss, therefore it comes in for more flak from the anti-everything groups and simply recoils in confusion.

While I shudder in agonizing disbelief at the economic and business theories and attitudes of my former colleagues and present friends in the government laboratories, as long as they are sufficiently isolated they contribute nothing to our problems. Therefore, we can cease our ramblings.

(Continued Inside Back Cover)

TESTIMONY OF L. M. MUNTZING, DIRECTOR OF REGULATION U. S. ATOMIC ENERGY COMMISSION TO THE SUBCOMMITTEE ON REORGANIZATION, RESEARCH, AND INTERNATIONAL ORGANIZATION SENATE COMMITTEE ON GOVERNMENT OPERATIONS

March 13, 1974

Mr. Chairman and members of the Committee:

I appreciate this opportunity to discuss the AEC Regulatory organization's programs for materials and plant protection. Public attention is being increasingly focused on the potential hazard resulting from sabotage of nuclear plants and the theft or diversion of certain nuclear materials. Our purpose today is to define for you the parameters of the problem as we see it and to outline the steps AEC has taken to minimize the risk.

The national security and public safety problems created by a rapid expansion of nuclear power plants and the accompanying fuel cycle are real; yet when placed in perspective they are manageable.

The nuclear industry's vulnerability to sabotage and theft or diversion is limited to only a few points. The vast majority of the power reactors today are light-water plants. The enriched material produced as fuel for these plants usually contains 5 percent or less uranium-235. A nuclear explosive device cannot be made with this material without the use of complex enrichment technology.

Fuel for the gas-cooled power reactors, a number of which are now on order, is of greater significance since highly enriched uranium-235 dispersed in a thorium matrix is used for the initial fuel loading. Because of chemical characteristics, uranium-235 can be easily separated from thorium. As a consequence, the fabrication of fuel for the gas cooled reactors and the shipment of such fuel from the fabrication plant to the power reactor represent potentially vulnerable points of the fuel cycle which are addressed by the regulations I will describe later.

Once fuel elements are inserted into a reactor, vulnerability is greatly reduced. Since loading and unloading of fuel routinely takes days and even weeks to complete, surreptitious removal is unlikely and overt theft would require a considerable force, trained, knowledgeable and properly equipped.

When it is discharged from a reactor for shipment to a reprocessing plant, nuclear material is in the form of pencil thick rods about 12 feet long clustered in assemblies of as many as 200 or more rods. Such material represents a radiation hazard and must, therefore, be shipped in large, heavily shielded casks. The hijack of such shipments by weapon-oriented thieves is not likely because they would require the use of a complicated, remote processing and heavily shielded chemical plant to extract the putonium from the rods.

At this time spent reactor fuel is essentially inaccessible. In the relatively near future it is planned to begin recovering the plutonium from the spent fuel and concentrating it in nitrate form. While plutonium is, of course, a weapon material, very complicated technology is required to make a weapon from plutonium nitrate. Plutonium in forms from which weapons can more readily be made is not found in the commercial nuclear power cycle.

Some hazard exists while highly enriched uranium and plutonium are in transit to and from fuel fabrication plants. There are currently about 400 shipments of highly enriched uranium and about 40 shipments of plutonium per year in quantities which require protection. Most of the highly enriched uranium involved in these shipments is for the naval reactor program.

In addition to the vulnerability of the fuel material to theft or diversion, the possibility of sabotage of plants cannot be dismissed. The plants where sabotage would represent the greatest threat to public safety are the plutonium fabrication and chemical reprocessing plants. Nuclear power plants are unattractive targets for sabotage. They are massive physical structures which are not easy to damage seriously. Even if one were seriously damaged, the consequences to public safety would probably be minimal because of the extremely conservative safety precautions taken to protect the plants against untoward events of all kinds, including acts of nature and malfunctions.

Recognizing the potential vulnerability of portions of the nuclear fuel cycle to sabotage and theft or diversion, the AEC requires materials accountability practices and physical protection, both at licensed facilities and in transportation, for strategic quantities of plutonium and of highly enriched uranium used in naval reactors and in gas-cooled reactors. It is to be noted that most measures designed to protect against sabotage also protect against theft of material, and vice versa. We attempt to prescribe a degree of protection for different materials and situations commensurate with their potential hazards.

Since 1967, we have required that each application for a license to operate a nuclear facility must include a plan for protecting that facility from acts of industrial sabotage. A Regulatory Guide issued by the AEC indicates that such plans should include lighted physical barriers, armed guards, controlling access of personnel and vehicles to the plant, liaison with law enforcement authorities and protecting vulnerable areas with locks, barriers, and alarms.

In 1970 the AEC issued regulations for the protection of strategic nuclear materials at facility sites and in transit. These requirements were adequate for the protection of the relatively small quantities in the fuel cycle at that time. Early in 1972 we started issuing strengthened license conditions for protection of fuel cycle facilities authorized to possess strategic quantities of material, defined as two kilograms of plutonium or uranium-233 or five kilograms of highly enriched uranium. In November 1973 we incorporated these license conditions into our regulations. These require licensees possessing such quantities to put into effect tight access controls and to assure fast responses by security forces. For example, no personal vehicles are permitted within the protected area, and no worker is permitted access to special nuclear material unless he is accompanied or kept under observation. Visitors entering the protected area are registered and must be escorted at all times. Packages entering an area where special nuclear material is handled are searched for devices that could aid in a theft. The boundary of the secure area must be well lighted, kept free of obstruction to vision, and inspected several times a day at random intervals. Persons, packages, and vehicles leaving an area where special nuclear material is used or stored must be checked for concealed material and the area must be equipped with intrusion alarms that are tested regularly. The security force must be specially trained and equipped, and capable of a quick response to any intrusion alarm. The capability of the security force must be augmented by liaison with local law enforcement agencies. A capability for communication with such agencies must be maintained by two independent communication links.

The regulations also strengthened protection of strategic quantities of material in transit. Truck shipments must be escorted by another vehicle carrying armed guards unless the truck is of special design having features resistant to penetration and enabling immobilization of the vehicle in the case of an attempted theft. Trucks must be equipped with a radio telephone and drivers are required to communicate periodically with predesignated contact points. Rail shipments must be escorted by armed guards who are required to report periodically on the safe transport of the shipment. Air shipments must be guarded by an armed individual to all scheduled stops to protect the shipments and assure against misrouting.

In addition to physical protection, a comprehensive system of internal material control and accounting is utilized in the protection of nuclear materials, including not only strategic materials but also uranium of lower enrichment. This program is designed to deter the theft or diversion of these materials and to detect any such event if it occurs so that timely recovery action can be taken.

The classical accounting and internal control procedures of a financial operation form the basic elements of the system. These include debit-credit accounting records, the recording of material transfers, periodic physical inventories, and system audits. Plutonium and highly enriched uranium must be inventoried at least every two months and specific requirements are set forth to assure that the inventories are of high quality.

We think that, properly implemented, the regulations which we now have in place are appropriate for today's needs. We will need to upgrade these requirements continually in the future as the industry expands. We will base that upgrading on our experience with the present regulations, on the results of research and development programs, on future decisions regarding the relative usage of alternative fissionable materials, and on future political and sociological trends that might bear on the likelihood of terrorist attacks. A separate regulatory agency such as a Nuclear Energy Commission must have the continuing responsibility for maintaining an effective safeguards effort.

STATEMENT BY WILLIAM O. DOUB

COMMISSIONER, U. S. ATOMIC ENERGY COMMISSION

BEFORE THE

SUBCOMMITTEE ON REORGANIZATION, RESEARCH, AND INTERNATIONAL ORGANIZATIONS

SENATE COMMITTEE ON GOVERNMENT OPERATIONS

March 13, 1974

I am pleased to have this opportunity to testify on the subject of nuclear power regulation. The nuclear power regulatory process which exists today is the product of nearly 20 years of development. Yet the process is not static. It is inevitable that a safety oriented regulatory process governing technology as complex as this, in order to be responsive to the public interest and reflective of the state of technology, must undergo continual refinement and development. Thus, the history of nuclear power regulation shows that technical reviews and regulatory requirements have evolved to reflect increasing reactor sizes and power levels, advancing numerical techniques and computers, improved technical understanding engendered by the operation of each new generation of power reactors, imposition of nonradiological environmental requirements, and antitrust considerations. These, in turn, have influenced the Regulatory procedural and adjudicatory areas which have seen many changes designed to keep the overall process viable and responsive to public concerns.

Viewing in retrospect for a moment all the technical, economic and social problems with which the nuclear industry and the AEC have had to contend — many of recent vintage — it is a mark of achievement that nuclear power has reached the maturity and progress that it has to date. Industry acceptance of the nuclear option as a viable commercial method of generating electricity with no Government economic assistance came less than 10 years ago with a proposal to build a plant in the 500-megawatt class. Shortly thereafter came a spate of applications, involving increases in power all the way to the 1300-megawatt range. In addition to regulatory attention to the new safety issues raised by design evolution and increasing power levels, there were increasing public interventions, equipment fabrication problems, shortages of technical and construction personnel, strikes, overly optimistic utility schedules, and the necessity to import some pressure vessels and other equipment. The AEC's Regulatory organization in the past always appeared to be a few steps behind in the technical manpower required to cope with its workload, and its casework backlog peaked with the **Calvert Cliffs** decision in 1971. As an aftermath of this episode, 17 months elapsed with no license issued, while a complete overhaul of the AEC Regulatory system was made, and the industry adjusted to new requirements of environmental protection.

Through these concerted efforts by the industry and the AEC, the licensing logjam created by the **Calvert Cliffs** decision was broken in May 1972. Since then, nuclear power capacity in the United States has tripled. The 42 plants now licensed to operate have an aggregate capacity in excess of 25,000 megawatts, representing more than 5 percent of total U.S. electrical capacity. There are 177 other nuclear plants under construction or planned. The tempo of construction and licensing is such that nuclear power capacity seems certain to accelerate and rise as a percent of the national total. It will be about 8 percent of total at the end of this year, about 10 percent at the end of next year, and perhaps 20 percent by 1980. The long-range forecast currently used by AEC as a basis for planning its materials production activities foresees that there will be about 1,000 large nuclear plants operating in the year 2000, furnishing about 60 percent of the nation's electrical energy and about 30 percent of its total energy.

With this number of plants in prospect, it is clear that a huge regulatory job looms ahead in the nuclear power field. Each nuclear plant must be closely scrutinized from the time that a utility applies for a construction permit until the final decommissioning of the reactor. Thus, in addition to the review required before licenses are approved, each reactor must be subject to close surveillance and compliance inspection throughout its operating life. Furthermore, various fuel cycle facilities are needed to support the power plants — including fuel fabrication plants, chemical reprocessing facilities, and waste disposal facilities. These also will increase in number as the power plants multiply, and they must be carefully regulated, as must the transportation of materials between facilities. Indeed, the most hazardous concentrations of radioactive materials are found in certain of the fuel cycle facilities. As nuclear power plants increase in number, there will be a commensurate increase in the amount of plutonium produced as a byproduct of the nuclear reactions. Increasing regulatory activity will be required to safeguard this material from diversion to unauthorized uses.

It is important to recognize, moreover, that the type of technological regulation required for the complete nuclear power cycle is far more demanding than is the primarily economic regulation performed by other agencies. It requires more of people, both in number and in depth of training in a wide variety of highly specialized technical disciplines. It requires also that a large amount of often costly research be performed in specific support of regulatory decisions.

The AEC's Regulatory staff is presently equipped to perform these technical tasks. A remarkable nationwide recruiting effort has succeeded in attracting technical and managerial specialists of the highest quality to the staff in the numbers required to keep pace with the increased workload. As of the end of 1973, the professional staff in Regulation numbered over 800. Of this number, more than 43 percent had graduate degrees and more than 12 percent had doctorates. The principal criterion of the AEC's regulatory philosophy is that the quality of the regulatory reviews and surveillance must be upheld, no matter what the increase in workload or the pressures for greater output. We are convinced that, responsibly regulated as it is today, nuclear power will provide a safe, reliable, and environmentally acceptable source of energy to meet the nation's growing needs. Any standard lower than this could involve risks unacceptable to the public.

In furtherance of this philosophy the Regulatory organization has, over the past two years, vigorously pursued solutions to the few remaining major safety-related questions for light water reactors in order to improve the quality of safety regulation and to reinforce public accpetance of nuclear power. One question in particular which was much in the public eye concerned the performance of emergency core cooling systems (ECCS). These are backup safety features provided in light water reactors to remove heat from the nuclear core in the unlikely event that the normal coolant is accidentally lost. Following protracted public hearings the Commission adopted a rule on this subject. It became effective last month. Utilities are moving rapidly to comply with the rule, and this safety issue is considered to be resolved.

An example of another technical issue whose resolution is well underway concerns the restrictions on the radioactivity permitted in effluents from nuclear power plants. The AEC's rules require that these be "as low as practicable." Public hearings have been held on numerical guidance which the AEC proposed to implement as a requirement for light water power reactors. While the guidance has not yet been formally adopted, it is already being applied through the licensing process by requiring that plants whose releases exceed the proposed limits modify their radioactive waste treatment systems so that they will be in compliance.

A final example concerns a safety issue under current review. The issue is the adequacy of backup systems which protect against the possibility that reactors might fail to shut down (that is, scram) if required during a reactor transient. The staff and the ACRS have been studying this "Anticipated Transients Without Scram" (ATWS) problem for several years. The conclusion has been reached that, although current scram systems are quite reliable and acceptable for the number of plants licensed today, the large expected increase in the number of nuclear power plants requires improvement in the reliability of protection systems for the future. Applicants and licensees have been requested to submit their plans for improvements in this regard by October 1, 1974.

One way to enhance public confidence in nuclear power is to strengthen quality assurance in design, construction, and operation. The AEC has been pounding home this message at every available opportunity for a long time. We have held many meetings with utilities, individually and in groups, to discuss quality assurance. We have endeavored through inspection of reactor construction sites to detect lapses in quality assurance; we have stiffened our requirements on quality assurance programs prerequisite to licensing actions. During the past year we have accordingly assembled utility executives in a series of regional seminars to make unmistakably clear our attitude on the importance of quality assurance and to introduce and discuss new regulations strengthening our requirements in this area.

A cardinal principle in AEC's regulatory philosophy is that the right of the public to participate in the decision-making process and to express its legitimate concerns must not be compromised in the face of rising demands for speedy approval of energy producing facilities. Public participation is an essential ingredient of regulation undertaken in the public interest. The AEC has restructured its rules to make such participation more meaningful while at the same time making sure that it does not cause undue delays. We are satisfied that we have struck a proper balance between the goals of openness and efficiency in our procedures for public participation and we hope to maintain that balance as nuclear power becomes the major U.S. source of electricity.

In urging that the quality of regulation and degree of public participation be left unimpaired in the new energy climate, we would not want it to appear that we are trying to hold to the status quo, to leave unchanged all our previous ways of doing business. Nothing could be further from the truth. We recognize fully that the magnitude of the impending task makes it imperative that we bend every effort to improve and streamline our processes. Even had we not reached this conclusion by ourselves, we have before us the President's request that we reduce the time required to get reactors online from 10 years to six years.

I will take a moment here to summarize the principal steps by which the AEC hopes to accomplish the objective established by the President.

There are essentially three phases involved in the period required to bring a nuclear power plant online. First of these is the utility planning phase, which currently requires approximately two years. During that time the utility selects an architect-engineer and a reactor manufacturer, performs preliminary plant design work, orders long lead-time equipment, identifies and evaluates alternative sites, collects and evaluates further information on the site selected, and prepares the voluminous safety analysis and environmental reports required by the AEC as parts of a construction permit application. This two-year process could be reduced to six months by a combination of two steps. The first would require legislation to make possible the use of sites selected and approved in advance of the utility's decision to add to its capacity. The second step would be to provide further incentives to the use of approved standardized plant designs. If the utility were thus to select a standardized design and plan to place it on a predesignated site, it would have very little else to do before submitting an application to the AEC. Legislation to achieve this was sent to the Congress on March 8, 1974.

The next phase of the process is given over to AEC safety and environmental reviews, currently requiring about 14 months, and to public hearings and the decision making process, requiring about 4 months additional. The AEC has proposed adminstrative changes that would reduce this 18-month review and hearing phase by 8 to 14 months. This would be accomplished by accelerating the environmental review, and by holding hearings on the environmental aspects at an early date. If findings are favorable, a limited work authorization could then be issued permitting site preparation and early plant construction to begin, at the economic risk of the utility. Under this plan, construction of nuclear portions of a plant would not be permitted until a construction permit is issued following review of all safety aspects.

We believe that further improvements are possible. Legislation implementing the designated site concept would make it possible to separate completely the site review and the plant review. It would then be possible to permit certain site activities to begin immediately upon filing an application, thus eliminating the entire 18-month AEC plant safety review and hearing time from the critical path for plant construction.

The final phase of getting a nuclear plant online is given over to site preparation, plant construction, and preoperational testing. This currently requires approximately six years. The AEC believes about six months of this period will be saved by careful evaluation of the need for and implementing period of changes in regulatory requirements being imposed on any plant once its construction has begun. We also believe that construction time could be reduced an additional six months by the widespread adoption of standardized designs.

In summary, we believe the time required to bring plants online can be reduced to about 5½ years through a combination of adminstrative and legislative changes, the most important of which would foster the use of predesignated sites and standardized plant designs.

I will now turn to the broad picture of the future for nuclear power regulation.

There is a strong measure of agreement that the best way to get on with the job of regulating nuclear energy activities is through the establishment of a strong, independent Nuclear Energy Commission. Separating out the regulatory function from the AEC's research and development functions has been under consideration for nearly 15 years. During most of that time there has been a consensus that the separation should take place when nuclear power reached maturity, so that there would be reduced potential for conflict between developmental and regulatory objectives. Nuclear power is now mature and that separation is at this time clearly in the public interest. It would lead to greater public confidence in the objectivity and impartiality of regulatory decisions. It would also free the Commissioners to devote their full effort to the demanding task of technological regulation, a task at which the AEC Regulatory organization is unexcelled.

The Regulatory organization is primed and ready to proceed as an independent agency without delay. Evolutionary changes preparing for eventual separation have been underway for some time, so that the Regulatory component is in most respects already independent. **Ex parte** rules and licensing appeals board procedures have been adopted to assure independence and objectivity. An independent adminstrative support capability has already been vested in Regulatory. Administrative studies on the steps necessary to proceed with separation have been underway and are to a large degree completed.

The most important attribute which Regulatory has for independent existence is its technical staff to which I have referred. It is a very strong staff, carefully selected from the best qualified and most experienced people in the Nation. All the necessary technical specialties related to reactor safety and environmental impact are adequately represented.

One of the reasons often put forth for not separating the regulatory and developmental functions has been a postulated decrease in access of the Regulatory staff to safety, safeguards, and environmental protection research programs managed by the reactor development segment of the AEC. On the other hand, critics have raised questions as to whether previous safety research programs were adequate and sufficiently responsive to Regulatory's information needs. This matter is addressed in the proposed legislation and it no longer constitutes an obstacle to separation.

Under the ERDA-NEC separation presently proposed, ERDA would be responsible for performing safety research on its development projects. This is appropriate since safety is an integral part of developmental research. In addition, the new NEC will have independent capability for research aimed at developing and analyzing technical information related to reactor safety, safeguards, and environmental protection that is required to assure effectiveness and objectivity in its standards, licensing, inspection, and enforcement activities. This has come to be known as confirmatory research. Under NEC direction, such technical information and analytical methods will be researched in an organizational medium outside of a developmental environment. These independent data would be in confirmation of and thus in addition to data supplied by the proponents of the system for which licenses are sought and other Regulatory action requested. We anticipate that some research programs undertaken by ERDA and NEC will be of mutual interest. To assure that each agency has adequate opportunity to provide input and follow the progress of the other agency's programs and to preclude duplication of efforts, a method will be devised to assure coordination of activities. It is thought that a general interagency agreement will provide for points of contact. The proposed legislation and legislative history is clear in its intent that NEC and ERDA work closely on matters of mutual interest. NEC would have the statutory authority to engage in contracting for confirmatory research which the Commission deems necessary for the discharge of its licensing and regulatory functions. For example, it will be responsible for the planning and funding of research programs at the ERDA managed facilities of LOFT (Loss of Fluids Test Facility) and PBF (Power Burst Facility). Furthermore, NEC would be able to obtain appropriate research and development data developed by ERDA and other federal agencies, and to examine and analyze the data. ERDA and other Federal agencies to the extent practicable, would be expected to: (a) furnish NEC, on a reimbursable basis, such research services as the Commission deems necessary for the conduct of its functions, and (b) cooperate with respect to the establishment of priorities for the furnishing of research services requested by NEC.

In conclusion, I urge that consideration be given now to legislative action which would establish an independent Nuclear Energy Commission. Such action would be in accord with all of the alternative proposals for organizing energy R&D functions. That is, all such legislative proposals agree that the nuclear regulatory function should be independent. Making the separation will hasten the strengthening of this vital regulatory activity.

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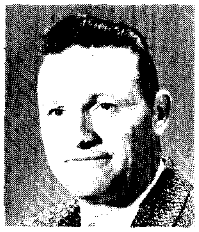

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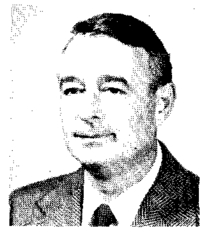

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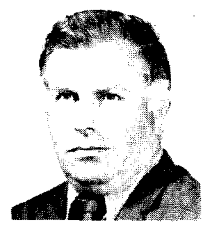

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CHEZEM COMMENTS

(Continued from Page 30)

Our **friends** in the nuclear arena take up all my time and more. Thank heaven we have no **enemies** (except among the radicals). Consequently, I bow out as Executive Editor of the Journal of the Institute of Nuclear Materials Management. The Institute will be seeing more of some of the bright young people in my oragnization.

Best wishes and good luck!

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