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MARTIN MARIETTA

Report of Foreign Travel

International Atomic Energy Agency's Advisory Group Meeting on Safeguards Related to the Final Disposal of Waste and Spent Fuel

Vienna, Austria

September 12-16, 1988

B. W. Moran
International Technology Programs Division

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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REPORT OF FOREIGN TRAVEL

INTERNATIONAL ATOMIC ENERGY AGENCY'S ADVISORY GROUP MEETING ON SAFEGUARDS RELATED TO THE FINAL DISPOSAL OF WASTE AND SPENT FUEL

VIENNA, AUSTRIA

SEPTEMBER 12-16, 1988

B. W. Moran
International Technology Programs Division

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Prepared by the
OAK RIDGE GASEOUS DIFFUSION PLANT
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CONTENTS

Page

SUMMARY v

1. INTRODUCTION 1

2. PARTICIPANTS 2

3. PROCEEDINGS 2

4. CONCLUSIONS 3

REFERENCES 3

APPENDIX A. ITINERARY 7

APPENDIX B. SECRETARIAT WORKING PAPER, STR-243 11

APPENDIX C. LIST OF PARTICIPANTS 73

APPENDIX D. ADVISORY GROUP MEETING AGENDA 81

APPENDIX E. U.S. POSITION PAPER 85

APPENDIX F. WEST GERMAN POSITION PAPER 105

APPENDIX G. FRENCH POSITION PAPER 115

APPENDIX H. EURATOM POSITION PAPER 133

APPENDIX I. IAEA REPORT ON MEASURED DISCARDS. 143

APPENDIX J. ADVISORY GROUP CONCLUSIONS AND RECOMMENDATIONS 157

SUMMARY

B. W. Moran, section head, OCRWM Safeguards, Safeguards Studies Department, International Technology Programs Division, at Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, traveled to Vienna, Austria, during the period of September 12-16, 1988, to serve as the technical advisor to the U.S. Department of Energy's (DOE's) Office of Civilian Radioactive Waste Management (OCRWM) representatives to the International Atomic Energy Agency's Advisory Group Meeting on "Safeguards Related to the Final Disposal of Nuclear Material in Waste and Spent Fuel." The goal of the U.S. representatives to this meeting was to ensure that the advisory group's recommendations established (1) an effective IAEA safeguards approach for all radioactive waste and spent fuel management facilities and (2) a safeguards approach that is appropriate for the U.S. Federal Waste Management System. In addition to Mr. Moran, the United States was represented at the meeting by W. Murphy, U.S. Department of State; D. Crawford, DOE Office of Safeguards and Security (OSS); T. Issacs, DOE/OCRWM; G. Saltzman, DOE/OCRWM; W. Higinbotham, Brookhaven National Laboratory (Advisor to DOE/OSS); and D. Mangan, Sandia National Laboratories (Advisor to DOE/OSS).

The principal concerns of the United States on entering the advisory group meeting were (1) criteria for the termination of safeguards on waste should not be established but should be referred for further study, (2) safeguards on spent fuel should not be terminated, and (3) safeguards studies are required before IAEA safeguards approaches for spent fuel are established. The U.S. representatives generally recommended that consultant meetings be convened to address the technical issues after the requisit safeguards related research and development tasks have been performed. These objectives of the U.S. representatives were achieved, and the recommendations of the advisory group generally coincided with and extended the recommendations presented in the U.S. position paper.

The total cost of this travel was $2005.44, which was charged to the DOE's budget category DB 04 02 16 F at the Oak Ridge Gaseous Diffusion Plant.

1. INTRODUCTION

During the period of September 9-23, 1988, B. W. Moran, Head, OCRWM Safeguards Section, Safeguards Studies Department, International Technology Programs Division at Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, traveled to Vienna, Austria, to attend an International Atomic Energy Agency (IAEA) Advisory Group Meeting (Itinerary attached as Appendix A). The goal of this advisory group meeting was to resolve selected safeguards issues related to the final disposal of nuclear material in waste and spent fuel. The IAEA had written and distributed to the member States a secretariat working paper on the subject containing questions that were to be addressed by the advisory group. The secretariat working paper is attached (Appendix B).

The United States and other participant countries prepared position papers that included answers to these questions. (The U.S. position paper was prepared with input from the U.S. Department of State, the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission, and the U.S. Arms Control and Disarmament Agency.) The intent of the U.S. position paper and of the U. S. presence at the meeting was to ensure that the Advisory Group's recommendations established (1) an effective IAEA safeguards approach for all radioactive waste and spent fuel management facilities and (2) a safeguards approach that is appropriate for the U.S. facilities. The United States was represented at the meeting by W. Murphy, U.S. Department of State (Spokesman); D. Crawford, Department of Energy (DOE) Office of Safeguards and Security (OSS); T. Issacs, DOE Office of Civilian Radioactive Waste Management (OCRWM); G. Saltzman, DOE/OCRWM; B. Moran (Advisor to DOE/OCRWM); W. Higinbotham, Brookhaven National Laboratory (Advisor to DOE/OSS); and D. Mangan, Sandia National Laboratories (Advisor to DOE/OSS).

The systems and facilities that will be part of the Federal Waste Management System (FWMS) — managed by the OCRWM — will be subject to the requirements of nuclear materials safeguards. The FWMS will include the acceptance of spent nuclear fuel (SNF) and high-level radioactive wastes (HLW) at the generator's site, the transportation of these materials to DOE facilities, the handling and packaging of SNF and HLW, the monitored retrievable storage of SNF, and the disposal of SNF and HLW in a mined geologic repository. The safeguards requirements that must be considered and planned for early in the design of the FWMS facilities and procedures are those specified in the DOE orders and U.S. Nuclear Regulatory Commission (NRC) regulations and in the U.S.-IAEA Safeguards Agreement. Early identification of technical and institutional issues can prevent possible delays in the licensing of the FWMS facilities and ensure more economical implementation of the required safeguards elements in the FWMS.

The United States has a direct national security interest in the effective application of international safeguards to repositories and SNF dry storage facilities in States without nuclear weapons. The potential application of IAEA safeguards to FWMS facilities provides the United States an opportunity to exercise leadership in shaping the development of the IAEA safeguards procedures that would be applicable not only to FWMS facilities but also to analogous facilities in States not possessing nuclear weapons. As a result, the application of IAEA safeguards to activities administered by OCRWM could be of considerable benefit to U.S. international interests. The U.S. international safeguards policy is jointly developed by the U.S. Department of State, the U.S. Arms Control and Disarmament Agency, the DOE, and the NRC.

2. PARTICIPANTS

The IAEA Advisory Group Meeting began on Monday, September 12, 1988, at the Vienna International Center, Vienna, Austria. A total of 43 participants (excluding IAEA personnel) from 17 countries and 2 international organizations (i.e., EURATOM and IAEA) attended and are listed in Appendix C. The IAEA attendees served as the recording secretary and as technical resources to and observers of the meeting.

3. PROCEEDINGS

The agenda of the Advisory Group Meeting is attached as Appendix D. Position papers (including answers to the IAEA Working Paper questions) were distributed by 3 countries (i.e., United States, Federal Republic of Germany and France) and by Euratom and the IAEA and are attached as Appendices E through I. The representative from Switzerland was selected as the chairman of the meeting. Each question from the draft IAEA Secretariat Working Paper was addressed and discussed in order. Questions for which an answer could not be agreed upon were referred to the appropriate subgroup for further discussions. The subgroups were also charged with drafting text stating the conclusions and recommendations of the advisory group on the appointed subject. These texts were reviewed and approved by the advisory group as a whole and are attached as Appendix J.

The U.S. position paper was predominantly developed by the U.S. Department of State and by DOE/OCRWM. The principal statements made in this position paper were (1) criteria for the termination of safeguards on waste should not be established but should be referred for further study, (2) safeguards on spent fuel should not be terminated, and (3) safeguards studies are required before IAEA safeguards approaches for spent fuel are established. The United States generally recommended that consultant meetings be convened to address the technical issues after the requisit safeguards related research and development tasks have been performed.

All countries were in agreement that a consultants group needs to be formed to establish conditions for the termination of safeguards on radioactive wastes. Agreement on the parameters to be considered was not achieved, and only a general recommendation was made. General disagreement with the majority position was taken by France and West Germany, whose goals appeared to be the minimization of the impact of safeguards on their facilities. These two countries pressed for the termination of safeguards as early in the waste process as possible and for the criteria for termination of safeguards to be facility specific.

Other areas of general agreement were as follows: (1) conditioning of waste (e.g., vitrification) is not a condition for termination of safeguards; (2) the use of the retained waste category should be reviewed (and possibly eliminated); (3) the placing of spent fuel in a repository does not make the spent fuel irrecoverable; (4) the design of waste management facilities must facilitate safeguards; and (5) the application of safeguards to spent fuel must rely on containment and surveillance, and other monitoring measures, instead of material accounting based on measurements.

The Advisory Group recommended that the following actions be initiated in the development of the IAEA's safeguards approach: (1) define criteria and threshold limits for the termination of safeguards on radioactive waste, (2) define verification methods for SNM quantity and termination threshold values, (3) define a safeguards approach for waste on which safeguards is not terminated, (4) review the safeguards approach for spent fuel storage facilities, (5) develop a safeguards approach for the conditioning of spent fuel, (6) develop a safeguards approach for

operating repositories, and (7) develop a safeguards approach for closed repositories. A consultants group is to be established in the near future to address the first issue (i.e., safeguards termination criteria). In addition, it was decided that the waste and spent fuel safeguards approaches should be considered in the future by separate advisory groups.

4. CONCLUSIONS

The objectives of the U.S. representatives to the IAEA Advisory Group Meeting on safeguards related to the final disposal of nuclear material in waste and spent fuel were achieved. The recommendations of the advisory group generally matched and extended the recommendations made within the U.S. position paper.

The U.S. position paper was separately developed by the Department of State and by DOE/OCRWM. The OCRWM position paper was based on the recommendations made in the Martin Marietta draft report Safeguards and Security Recommendations for the OCRWM Federal Waste Management System, K/ITP-192.[1,2] Although the recommendations of the report concern only spent fuel issues, the recommendations and philosophy were extended to the waste issues. The recommendations of the report applicable to international safeguards approaches are those recommending the performance of vulnerability assessments and the development and evaluation of measurement systems, containment and surveillance systems, and other monitoring systems. The development of criteria by the IAEA for the termination of safeguards on waste and for safeguards approaches for spent fuel must be based on a knowledge of the potential vulnerabilities of the nuclear materials and facilities and of the effectiveness of the safeguards procedures that might be applied to them. The Advisory Group recognized that (1) there are currently no measurement methods capable of providing accountability-grade measurements of spent fuel assemblies and conditioned waste; and (2) international safeguards must therefore rely on containment and surveillance, and other monitoring techniques, to maintain continuity of knowledge of the SNM. It was also recognized by them that accountability measurements are not required or are not possible during some stages of the disposal process. If containment and surveillance, and other monitoring techniques, are to become the principal tool for the safeguarding of waste and spent fuel, the reliability of the systems must be increased to the point that a failure of the monitoring system would be a direct indication of diversion. Although the use of measurements was not favored at the Advisory Group Meeting, measurement systems need to be evaluated (1) to determine if there are any new procedures that may be applicable to determine SNM quantities in those stages of the system in which monitoring systems may not provide adequate safeguards, and (2) to determine their potential for use in monitoring systems.

REFERENCES

[1]L. M. Brenner and B. W. Moran, Office of Civilian Radioactive Waste Management Policy Paper on International Safeguards for Geologic Repositories, ESP88-431, Draft, Martin Marietta Energy Systems, Oak Ridge Gaseous Diffusion Plant, August 15, 1988.

[2]B. W. Moran et al., Safeguards and Security Recommendations for the OCRWM Federal Waste Management System, K/ITP-192, Issued for Approval, Martin Marietta Energy Systems, Oak Ridge Gaseous Diffusion Plant, August 1988.

APPENDIX A
ITINERARY

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ITINERARY

September 9-10, 1988	Travel from Knoxville, Tenn., to Munich, West Germany, via air
September 10, 1988	Munich, West Germany
September 11, 1988	Travel from Munich, West Germany to Vienna, Austria via car
September 12-16, 1988	Vienna, Austria (IAEA Advisory Group Meeting)
September 17, 1988	Travel from Vienna, Austria to Saalbach, Austria via car
September 17-23, 1988	Personal Vacation
September 23, 1988	Travel from Saalbach, Austria to Munich, West Germany via car
September 23, 1988	Travel from Munich, West Germany to Knoxville, Tenn., via air

APPENDIX B
SECRETARIAT WORKING PAPER, STR-243

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SECRETARIAT WORKING PAPER, STR-243

International Atomic Energy Agency

Department of Safeguards STR-243

ADVISORY GROUP MEETING ON SAFEGUARDS RELATED TO

FINAL DISPOSAL OF NUCLEAR MATERIAL IN WASTE AND SPENT FUEL

Secretariat Working Paper

System Studies Section
International Atomic Energy Agency
Vienna, Austria

July 1988

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ADVISORY GROUP MEETING ON SAFEGUARDS RELATED TO
FINAL DISPOSAL OF NUCLEAR MATERIAL IN WASTE AND SPENT FUEL

Secretariat Working Paper

Table of Contents

topic	page
1. Introduction	1
1.1 Statement of Problem	1
1.2 Background Perspective	5
PART I: WASTE	
2. Waste	6
2.1 Waste Definitions and Descriptions	6
2.1.1 Definition of Waste	6
2.1.2 Some Typical Waste Categories	7
2.2 Safeguards Experience w/Retained Waste and Measured Discards	12
2.2.1 Measured Discards	12
2.2.2 Retained Waste	13
2.3 Waste Measurement Procedures	14
2.4 Waste Conditioning Processes	16
2.4.1 Vitrification of Fission Product Waste Materials	16
2.4.2 Conditioning in a Bituminous Matrix	19
2.4.3 Conditioning in a Cement Matrix	19
2.4.4 Other Waste Conditioning Processes	20
2.4.5 Recoverability of Conditioned Waste	20
2.5 Waste Repositories	21
3. Safeguards Questions with Regard to Waste	23
3.1 Safeguards Concerns	23
3.2 Measurement Requirements	24
3.3 Unconditioned Waste	26
3.3.1 Termination of Safeguards	26
3.3.2 Safeguards Prior to Termination	28
3.4 Conditioned Waste	29
3.4.1 Termination of Safeguards	29
3.4.2 Safeguards Prior to Conditioning	30
3.4.3 Safeguards After Conditioning	30

topic	page
PART II: SPENT FUEL	
4. Nuclear Material Safeguards for Spent Fuel	31
4.1 Spent Fuel Definitions and Descriptions	31
4.2 Spent Fuel Measurement Procedures	33
4.3 Spent Fuel Conditioning Processes	36
4.4 Spent Fuel Repositories	37
4.4.1 Canada	37
4.4.2 United States of America	38
4.4.3 Sweden	39
4.4.4 German Federal Republic	40
5. Safeguards Policy Issues for Spent Fuel	41
5.1 Measurement Requirements	43
5.1.1 LWR Fuel	43
5.1.2 On-Load Reactor Fuel	45
5.1.3 HTGR Reactor Fuels	45
5.2 Safeguards Measures Prior to Final Disposal	46
5.3 Safeguards for a Repository which is Open	49
5.3.1 Permanent Repository versus Long-Term Retrievable Storage	49
5.3.2 Determination of Practicably Irrecoverable	49
5.3.3 Continuation of Safeguards	51
5.4 Safeguards for a Repository Which is Closed	53
6. Problems Requiring Further Study	54
References	55

ADVISORY GROUP MEETING ON SAFEGUARDS RELATED TO
FINAL DISPOSAL OF NUCLEAR MATERIAL IN WASTE AND SPENT FUEL

Secretariat Working Paper

1. INTRODUCTION

1.1 Statement of Problem

INFCIRC/153, the basic model safeguards agreement for States party to the Non-Proliferation Treaty, provides three circumstances under which nuclear material safeguards may be terminated [1]. The versions given here paraphrase the actual text.

- Section 11 provides for termination upon a determination by the Agency that nuclear material subject to safeguards has been consumed, has been diluted in such a way that it is no longer usable for any relevant nuclear activity, or has become "practicably irrecoverable." Virtually identical provisions are contained in INFCIRC/66 rev 2, Section 26c [2].
- Section 12 provides for termination when nuclear material has been transferred out of State and the recipient State has assumed responsibility.
- Section 13 provides for termination, by mutual agreement, when nuclear material is used for non-nuclear purposes such as alloys or ceramics. INFCIRC/66 rev 2, Section 27, similarly provides for termination by reason of non-nuclear use, but expressly limits termination to source materials.

Two further terms are defined in INFCIRC/153. "Retained waste" is defined as "nuclear material generated from processing or from an operational accident, which is deemed to be unrecoverable for the time being but which is stored." "Measured discard" is defined as "nuclear material which has been measured, or estimated on the basis of measurements, and disposed of in such a way that it is not suitable for further nuclear use."

It is also useful to note Section 35 of INFCIRC/153. After first specifying that safeguards should terminate under the conditions defined in Section 11, Section 35 notes that "where the conditions of [Section 11] are not met, but the State considers that the recovery of safeguarded nuclear material from residues is not for the time being practicable or desirable, the Agency and the State shall consult on the appropriate safeguards measures to be applied." The Agency's Legal Division has ruled that Section 35 does not permit the Agency to terminate safeguards where the conditions of Section 11 are not met. However, the Agency may agree to alternative (and presumably reduced) safeguards measures for retained waste [3].

INFCIRC/66/rev. 2 makes no provision for retained waste. On the contrary, one may note Section 8 of Annex II to INFCIRC/66/rev. 2, which calls on the State to ensure that ...waste...is recovered...within a reasonable period of time. Where recovery is not considered practicable, Section 8 calls for the State and the Agency to cooperate in making arrangements to account for and dispose of the material.

This paper is primarily concerned with Section 11 of INFCIRC/153 (or Section 26c of INFCIRC/66), the possible termination of safeguards based on a determination that the nuclear material in question has been consumed, has been diluted, or has become practicably irrecoverable. Since the circumstances under which the Agency should determine that nuclear material has been consumed are clear, the paper further is primarily concerned with the circumstances under which safeguards may be terminated on the basis of an Agency determination that nuclear material has been diluted or has become practicably irrecoverable. Where nuclear materials are determined not to be practicably irrecoverable, (and therefore are to remain subject to safeguards) it is necessary to consider what safeguards measures should be applied pursuant to Section 35 of INFCIRC/153, or pursuant to applicable Sections of INFCIRC/66/rev. 2.

Two distinctly different categories of nuclear material have been suggested for possible termination of safeguards based on a determination that the nuclear material has become practicably irrecoverable. One relates to a variety of low concentration waste materials, meaning thereby materials which the State or plant operator considers to be of questionable economic recoverability. (See Section 2.1.1 for a more precise definition.)

The discussions leading to inclusion of Section 26c in INFCIRC/66 rev 2 (and later, Section 11 in INFCIRC/153) concerned only these low concentration residues In more recent years, however, it has been recognized that some spent fuel may be placed in permanent storage, either in geological formations or in some form of engineered containment structure. INFCE WG/6 recognized four conceptual options with regard to spent fuel, as follows [4].

concept 1: decision to reprocess
concept 2: deferred decision
concept 3: fuel transfer decision
concept 4: no-reprocessing decision

Spent fuel in the form removed from nuclear power reactors is generally described as not meeting the requirements for a determination of practicably irrecoverable, which is a reverse way of stating that the nuclear material content of freshly discharged spent fuel is, in an engineering sense, recoverable. Spent fuel placed in any of a variety of away-from-reactor storage facilities, specifically including those described as "long-term retrievable storage" facilities, remains accessible with at most modest difficulty and therefore must be assumed to remain recoverable. Spent fuel placed in facilities described as "permanent repositories," generally (or necessarily) located on the order of 100 meters underground in geologically defined formations are at least claimed to represent "final disposal" facilities, and are candidates for a possible determination of practicably irrecoverable.

Thus in broad terms one may define the subject under discussion in terms of two sets of closely related questions, one set for waste and one set for spent fuel.

Questions Primarily Related to Nuclear Material in Waste

Question 1: Under what circumstances should the Agency determine that nuclear material in waste has been diluted or has become practicably irrecoverable, such that safeguards may be terminated?

Question 2: Where waste materials are "conditioned" in anticipation of placing them in a permanent storage repository, is the act of conditioning itself sufficient to qualify the waste as practicably irrecoverable, or is it necessary that the Agency verify that the conditioned waste is in fact transferred to a geological formation?

Question 3: To what extent should the Agency insist that the nuclear material content of waste be measured prior to its being placed in a permanent repository?

Question 4: What measurement verification procedures should the Agency implement (and at what stage) prior to agreeing to the termination of safeguards for waste?

Question 5: Where nuclear material is transferred to the retained waste category pursuant to INFCIRC/153, what safeguards measures should the Agency implement?

Questions Primarily Related to Spent Fuel.

Question 6: Under some circumstances a State may wish to place in permanent storage nuclear material of a form which in itself the Agency cannot agree has been diluted or has become practicably irrecoverable. Does the act of placing nuclear material (e.g., spent fuel) in permanent storage constitute making that material "practicably irrecoverable"?

Question 7: Both "permanent storage facilities" and "long-term retrievable storage facilities" are being developed. What specific characteristics should a storage facility possess in order for the Agency to agree that nuclear material placed therein has been rendered practicably irrecoverable?

Question 8: To what extent should the Agency insist that spent fuel be measured prior to being placed in a permanent repository?

Question 9: What measurement verification procedures, and at what stage, should the Agency implement prior to agreeing to the termination of safeguards, or prior to the placing of spent fuel in permanent storage?

Question 10: To the extent that spent fuel placed in permanent storage facilities or long-term retrievable storage is not determined to be practicably irrecoverable, what safeguards measures should the Agency implement?

The Sections that follow discuss possible answers to these and other questions. Separate consideration is given to "waste" in the sense of low level materials having no particular economic value, and to "spent fuel," a nuclear material form which in itself is not practicably irrecoverable.

1.2 Background Perspective

Historically, the safeguards community has given relatively little attention either to actual safeguards measures to be applied to low concentration residues from fuel cycle manufacturing facilities or to the circumstances under which INFCIRC/153 Section 11 should be invoked and safeguards should be terminated. SAGSI, the Standing Advisory Group on Safeguards Implementation, has referred secondarily to the question of the termination of safeguards [5], but has not specifically addressed the questions posed above. Internally, the departmental Technical Review Committee (TRC, previously Technical Review Group or TRG) originally scheduled the subject for discussion during 1988, but has deferred those discussions in view of this Advisory Group Meeting.

Section 2.2 reviews current inspection practice with regard to retained waste and measured discards, and summarizes the types and quantities of waste materials which have been placed in those categories.

2. WASTE

2.1 Waste Definitions and Descriptions

2.1.1 Definition of Waste. It is not easy to define waste. Plant operators typically classify any nuclear material as waste if it is no longer usable in the processes for which the plant was constructed, but this definition avoids the question of whether recovery and reuse would be feasible, given the existence of a separate waste recovery process. Definitions which refer to the economics of recovery and reuse have similar problems; what is economic in one State may not be economic in another (for example, because the first State has a sufficient quantity of waste to justify a reasonable plant size). A complete economic analysis should also consider all the alternatives; some waste may be economically recoverable because the alternatives are even more expensive.

In the context of international safeguards, economics are a questionable criterion for deciding whether to continue or terminate safeguards. If one assumes that a State has a desire to create an undeclared stockpile of nuclear explosives, recovery of low level residues considered "economically unrecoverable" may be a safer (i.e., less likely to be detected) route to acquisition of the necessary nuclear materials than diversion of higher quality materials. Termination of safeguards is a "final" action; the Agency will have no later opportunity to verify that the terminated quantities have not been recovered.

On the other hand, the opposite extreme should also be avoided. A divertor should not be assumed to have access to an engineering technology which is not known to exist. Failure to recognize this constraint can lead to a desire for excessive levels of safeguards effort to be devoted to materials which may truly be "practicably irrecoverable."

Anticipating a subject which is discussed in greater detail in Section 2.4, some wastes, notably high and medium level waste from reprocessing, will be converted into a form of glass, will be mixed in a bituminous matrix, or will be mixed with concrete prior to final disposal. These processes, which are intended to render the waste materials as near to totally inert as possible, are commonly referred to as "conditioning processes," and the resulting product is commonly referred to as "conditioned waste."

In the interest of better communication, the following definitions are suggested here.

The term <u>waste</u> is defined as referring to any low level residue which the State/facility operator believes has no economically recoverable value. Classification of a material as waste does not imply that the contained nuclear material is practicably irrecoverable, and therefore does not imply that safeguards should be terminated. (Also note that "waste" is here a generic term, and is not synonymous with "retained waste" as defined in INFCIRC/153.)

The term <u>retained waste</u> is defined as referring to waste materials which meet the specific requirements discussed in Section 3.2.1, and which have been transferred to the retained waste category pursuant to the provisions of INFCIRC/153.

The term <u>conditioned waste</u> is defined as referring to waste which has been conditioned in accordance with one of the processes described in Section 2.4 prior to final disposal.

2.1.2 <u>Some Typical Waste Categories</u>. Using the above definitions, one may identify a number of categories or types of nuclear material which would qualify as waste. INFCE/WG 7 identified six categories, as follows [6]:

(1) waste from ore processing
(2) refining, conversion and enrichment wastes
(3) fuel element fabrication wastes;
(4) reactor wastes;
(5) unreprocessed spent fuel;
(6) reprocessing waste.

Of these six, category (1) and portions of category (2) are not subject to safeguards, and category (4) refers to waste which is radioactive but which does not contain nuclear material. Also, category (5) is not here considered as waste, but is considered separately in Chapters 4 and 5.

One may also categorize waste materials according to a more detailed description of the nature of the material, including whether the contained nuclear material is uranium (depleted, natural, low enriched or high enriched), thorium (or ^{233}U), or plutonium. One category would be depleted, natural and low enriched uranium waste materials from enrichment, conversion and fabrication processes. These wastes rarely are considered economically recoverable. Undeclared recovery may be technically feasible, but would require processing of large volumes of waste.

(The expression "large volumes" is meant in a qualitative sense, but some idea of magnitude can be obtained by considering that the presumed goal is 75 kgs ^{235}U, that in practice the enrichment is never greater than 5% ^{235}U, and that residues are unlikely to contain more than a few percent uranium. The minimum quantity to yield 75 kgs ^{235}U thus is at least 100 metric tons. Since depleted, natural and low enriched uranium are not directly usable in nuclear explosive devices, undeclared recovery and use would also require further enrichment or reactor irradiation.)

High and medium level wastes from spent fuel reprocessing logically would constitute a second category. Here the important considerations are fission product radiation levels and the presence of high concentrations of contaminating heavy elements, which make these materials difficult to work with. Recovery of plutonium from high or medium level wastes has not been demonstrated on an engineering scale, but at least one published reference [7] claims that suitable organic extractants have been found which are capable of removing essentially all of the residual plutonium from high level waste. Large quantities of these wastes must be processed to recover significant quantities of plutonium, but high level wastes from larger reprocessing plants are likely to contain several significant quantities per year. Recovery of this material should not necessarily be assumed to be technologically impossible.

(Again "large volumes" is meant to be a qualitative expression, but can be given some sense of dimension by noting that TBP extraction of Pu from fission products generally leaves 10^{-4} or 10^{-5} grams per liter in the aqueous waste stream. Recovery of an assumed 8 kg Pu thus would require that a minimum of 10^{8} liters be processed. Uranium in sea water is a roughly comparable analogy.)

A third category then would comprise low active reprocessing wastes, MOX conversion and fabrication wastes, and wastes from processes which use highly enriched uranium. Although moderately large waste volumes still would have to be processed to recover a quantity of safeguards relevance, this recovery technology also is known to exist and cannot be ignored.

Excerpted portions of a waste categorization table prepared by INFCE/WG / are given in Tables 2.1 and 2.2 [8]. The tables should be understood as reflecting expected waste quantities and forms for an arbitrarily defined reference fuel cycle. (The reference fuel cycle is defined in the INFCE paper.) Specific facilities may generate more or fewer waste packages or quantities, depending on individual plant practices. Also note that INFCE completed its deliberations and issued its reports in 1980; the tables may not represent latest practices.

TABLE 2.1. URANIUM (NON-HEU) WASTE SUMMARY FOR REFERENCE FUEL CYCLE

Waste Stream		U Mass kg/GWa*	U Isotopic Composition	Packaged Waste Form	Number of Waste Packages per GWa*	Number of Waste Packages per Safeguards Target Mass**
	LWR-OT	40	Natural		10	2,600
Enrichment	LWR-R	20		Process Waste in	5	
Maintenance	HWR-Th	2		Unshielded Drums	1	
	HWR-Th	12			3	
	LWR-OT	220	3.02% ^{235}U		200	2,300
UO_2 Fuel	LWR-R	150	3.02% ^{235}U	Process Waste in	130	2,200
Fabrication	HWR-OT	180	Natural	Unshielded Drums	498	29,000
	LWR-R	10	Natural		155	***
MOX Fuel	FBR-R	20	0.17% ^{235}U	Concreted in	318	***
Fabrication	HWR-R	80	0.69% ^{235}U	Unshielded Drums	750	***

* GWa - Gigawatt year electricity.
** Defined as: 75 kg of contained U-235 for U-235 concentration below 20%.
*** Also contains Pu - see Table III for controlling number.
OT Once through fuel cycle.
R With reprocessing.
Th Thorium/^{233}U fuel cycle.

6024B

TABLE 2.2. PLUTONIUM WASTE SUMMARY FOR REFERENCE FUEL CYCLE

Waste Stream		Pu Mass kg/GWa*	Packaged Waste Form	Number of Waste Packages per GWa*	Number of Waste Packages per Safeguards Target Mass**
MOX Fuel Fabrication	LWR-R	0.5	Concreted in Unshielded Drums	155	2,500
	FBR-R	3.0		318	850
	HWR-R	0.7		750	8,600
Spent Fuel	LWR-OT PWR	~216	Unreprocessed Spent Fuel Assemblies in Canisters	53	2
	LWR-OT BWR	~108		22	2
	HWR-OT	660		132	2
Cladding Hulls and Spacers	LWR-R	1.4	Compacted and Immobilized in HWR-Type Canisters	33	190
	FBR-R	9.0		86	76
	HWR-R	2.1		31	120
Vitrified High-Level Wastes	LWR-R	2.3	Vitrified HLW in Canisters	29 or 67	100 or 230
	FBR-R	15.1		23 or 53	12 or 28
	HWR-R	3.6		29 or 67	64 or 150
Medium-Level Wastes	LWR-R	0.9	Concreted in Shielded or Unshielded Drums	137	1,200
	FBR-R	5.9		89	120
	HWR-R	1.5		295	1,600

* GWa - Gigawatt year electricity.

** Defined as: 75 kg of contained ^{235}U for ^{235}U concentration below 20%.

6024B

2.2 Safeguards Experience w/Measured Discards and Retained Waste

2.2.1 Measured Discards. The Agency's safeguards approach for measured discards normally begins with a consideration of what the total quantity from any given nuclear facility and in any given year is likely to be. Limits specified in facility attachments vary, but 50 effective grams per month, 0.01 SQ per month, or up to 0.1 SQ per month may be considered typical values. Some facility attachments define limits in terms of effective grams or SQs per year rather than per month, but the limits are not necessarily much larger than the values quoted here. The general rule is that the facility may remove from the material balance, as measured discards, up to the specified limit without further Agency approval.

Where larger quantities are to be discarded the facility attachment normally states that the Agency is to be consulted in advance, to at least allow an opportunity for verification. Instances where larger quantities have been discarded are few in number; the Agency has not always been consulted in advance regarding these larger discards.

The total quantities associated with measured discards are not a significant safeguards problem. Table 2.3 lists the total quantity discarded during 1987 for each type of nuclear material, together with the number of material balance areas contributing to that total.

Table 2.3. REPORTED MEASURED DISCARDS FOR CALENDAR 1987

Material Type	No. of MBAs	Total Quantity
Depleted uranium	36	1 234 kgs U
Natural uranium	46	1 327 kgs U
Enriched uranium	49	275 623 grams U
		8 990 grams ^{235}U
Plutonium	20	1 695 grams Pu
Thorium	29	344 kgs Th

2.2.2 Retained Waste. The INFCIRC/153 definition of retained waste can be interpreted in at least two ways. The more common interpretation is that the nuclear material has no economically recoverable value and eventually will be disposed of, but that final disposal is being deferred pending decisions on disposal methods or construction of a suitable repository. However in some cases the retained waste classification has also been used for nuclear material which may or will eventually be recovered, but for which recovery is being deferred pending a more precise decision, or pending construction of a suitable recovery facility.

Either way, INFCIRC/153 allows retained waste to be removed from the material balance of the facility (MBA) in question, but does not terminate safeguards. The Agency can and does verify nuclear material quantities at the time of transfer to retained waste. Once nuclear material enters the retained waste category, however, the Agency's verification rights become more questionable, and its technical capabilities become more restricted. Retained waste is still "subject to safeguards," but exactly how those safeguards can or should be implemented is not clear.

In general facility attachments do not specify quantity limitations for retained waste, and larger quantities (i.e., larger than measured discard quantities) have been transferred to the retained waste classification. Measurement procedures used by facility operators vary widely, but those facilities transferring the larger quantities to retained waste generally have developed useful NDA measurement procedures.

Measurements performed on material being transferred to retained waste are, when feasible, verified by observation. Appropriate data are maintained in the safeguards information data base regarding all transfers either to retained waste or to measured discard. However, retained waste is not maintained on the accountancy records at the facility (or, strictly speaking, it is not maintained on any accountancy records shown to the Agency during inspections), and is not included in the inventories periodically reported to the Agency on PIL, MBR, or equivalent reports. This introduces complications regarding inventory verification; the only inventory which could be verified is in fact the Agency's own, derived from an assumption that no retained waste has been "discarded" or lost.

SAGSI, the Agency's Standing Advisory Committee on Safeguards Implmementation, has affirmed the Agency's current policies and practice regarding the verification of quantities transferred to retained waste. However, SAGSI has also noted that in many cases verification implies observation and possibly authentication of operator measurements.

Some retained waste has been "disposed of," in a manner which was not considered adequate to justify a determination of practicably irrecoverable. The Agency understands that an unknown but possibly large fraction of nuclear material recorded as "retained waste" in fact has been discarded as that term is more commonly understood. The "retained waste" designation is frequently used, for example, for material placed in shallow land burial sites. This material is both theoretically and practicably recoverable; occasional land burial sites have been reopened in a search for apparently missing material, and useful quantities have been recovered in such operations.

Some nuclear material has been returned from the retained waste category and processed. The Agency has limited experience, but attempts to verify these return transfers have led to differences between originally assigned book values and Agency verification measurements.

2.3 Waste Measurement Procedures

In fuel fabrication and reprocessing plants, monitoring of nuclear material content is required for both nuclear safety (criticality) and nuclear accountancy (safeguards) reasons. However, both the variety and heterogeneity of waste streams and the associated measurement difficulties prevent a fully comprehensive approach. The present status of monitoring for nuclear material content is highly variable, both between installations and between waste streams.

Homogeneous liquid waste streams can be sampled and measured to excellent accuracy ($\pm$0.1% up to 100 g ^{235}U/l) by destructive analytical methods (e.g. off-line chemical analysis, mass spectrometry or gamma ray spectrometry). Special techniques (e.g. K-edge densitometry) also can monitor variations in U or Pu concentration of liquids on line.

However, most wastes are not homogeneous and this gives rise to the need for an investment in instrumentation for non-destructive analysis techniques required to quantify nuclear material content. These methods may be based on measuring spontaneously emitted radiation (neutron, gamma, heat) in a passive interrogation mode or on inducing fission by a burst of applied radiation (neutron, gamma) in variants of active interrogation. In general these methods are more difficult in the presence of a high radiation background. They also are affected by the nature of the bulk matrix and by self-shielding in the nuclear material.

The most accurate measurements are made in suitably diluted conditions and prior to conditioning or compaction processes. This is often acknowledged by a policy of measurement before conditioning, with later measurements acting as a consistency check of package contents with previous measurements and declarations.

The different detection techniques, their accuracy and their limits of detection for drummed wastes before and after conditioning are given in Tables 2.4 and 2.5. Under ideal conditions well-characterized non-conditioned wastes can be assayed for Pu to ~5 mg and for fissile content to ~1 mg; for conditioned wastes the comparable figures are ~0.5 g and 10 g.

Measurement times for most instruments are on the order of ~15 min., so that complete measurements of plant output are at least feasible. The calorimeter is an obvious exception because of its long measurement time (~5 hours). However, it copes well with high level background radiation in difficult environments and can provide a useful consistency check of waste heat output. Other devices usually will operate in fields up to 10^3-10^4 R/hr before the measurement capability deteriorates. Note that the size of the waste package makes these instruments large, non-portable and a considerable investment.

2.4 Waste Conditioning Processes

2.4.1 Vitrification of Fission Product Waste Materials. All countries which produce heat generating liquid waste (referred to as high level waste or HLW elsewhere in this paper) from the reprocessing of spent nuclear fuel recognize the desirability of solidifying the HLW. The usually favoured solidification medium is borosilicate glass, but some further development work is taking place into the possible use of Synroc, a synthetic rock material which appears to be exceptionally resistant to ground water leaching even at high temperatures.

(Synroc, developed in Australia, consists of the minerals 'hollandite' ($BaAl_2Ti_6O_{16}$), perovskite ($CaTiO_3$), zirconolite ($CaZrTi_2O_7$), barium-feldspar ($BaAl_2Si_2O_6$), kalsilite ($KAlSiO_4$) and leucite ($KAlSi_2O_6$). It is produced by melting a mixture of TiO_2, BaO, SiO_2, ZrO_2, Al_2O_3, CaO and K_2O at ~1300°C followed by slow cooling. In operation it is envisaged that an intimate mixture of powdered Synroc and calcined HLW would be hot-pressed at ~1200 - 1300°C inside a thick-walled nickel canister for final disposal. Waste loadings of up to 20% are expected to be achieved and improved performance with respect to ground water leaching, radiation stability and long-term geological stability are claimed in comparison to borosilicate glass waste forms.)

TABLE 2.4

NON-CONDITIONED WASTE

Applicable to a wide range of well-characterized waste types - combustible and non-combustible, bulk density in the range of 0 - 1 g/cm^3.

Technique	Limit of Detection	Comments
Passive neutron		
(i) Total	5 mg Pu	200 liter drums - interference from other spontaneous fission sources and (α, n) neutron emission
(ii) spontaneous fission neutrons	25 mg ^{240}Pu	200 liter drums
Passive gamma	10 mg ^{239}Pu	200 liter drums*
Active neutron	1 mg of Pu or ^{235}U	200 liter drums*
Active gamma	100 mg total actinides	200 liter drums (estimate)
Calorimetry	10 g Pu	200 liter drums Need isotopics

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* The techniques indicated are subject to the effects of self-shielding when high concentrations of material are present in the drums (e.g. lumps of Pu metal or HEU metal).

Detection limits shown assume low background conditions and no significant concentration of fission products. Limits could be considerably higher in high background areas, and some methods fail completely in the presence of fission products.

TABLE 2.4

CONDITIONED WASTE

The following values are for cemented waste with a bulk density in the range 1.2 - 2 g/cm^3.

Technique	Limit of Detection	Comments
Passive neutron		
(i) Total	0.5 g Pu	200 liter drums - interference from other spontaneous fission sources and (α, n) neutron emission
(ii) spontaneous fission neutrons	0.5 g ^{240}Pu	200 liter drums
Passive gamma	0.5 g Pu	200 liter drums*
Active neutron	10 g of Pu or ^{235}U	500 liter drums* - developments underway could reduce this value substantially
Active gamma	100 g total actinides	500 liter drums
Calorimetry	10 g Pu	(estimate) Measurement times depend on matrix. Need isotopics

* The techniques indicated are subject to the effects of self-shielding when high concentrations of material are present in the drums (e.g. lumps of Pu metal or HEU metal).

Detection limits shown assume low background conditions. Limits could be considerably higher in high background areas.

Two main lines of melter development have been followed world-wide in pursuit of vitrification technology as applied to HLW. These are the French AVM process which has been chosen for the Windscale Vitrification Plant (WVP) and the Joule Ceramic Melter process (JCM) which is favoured in the USA, the German Federal Republic and Japan.

The vitrification process involves evaporation, drying and calcination of the HLW followed by melting with glass-forming materials prior to pouring into a steel container used for storage purposes. The borosilicate glass product has a number of merits:

- A wide range of waste species (usually as oxides) can be incorporated into the matrix;
- A monolithic material which has adequate durability and leach resistance is produced;
- High loadings of waste (e.g. 25 - 35% as oxides) can be accommodated;
- Vitrification temperatures of 1050 - 1150°C can be employed, thus allowing conventional ductile metal alloys to be used in the plant fabrication;
- The product glass exhibits good radiation resistance;
- A controlled size of product is easily obtained by pouring or casting and no applied pressure is required;
- The vitrified product in thick-walled carbon steel containers can be stored in specially designed storage facilities or disposed to a permanent repository.

2.4.2 Conditioning in a Bituminous Matrix. Immobilisation of medium level waste (MLW) in bitumen-based matrices has been extensively researched in the past. The general consensus appears to be that, although it has the advantageous property of water resistance, a number of disadvantages preclude its adoption generally as a favoured immobilisation medium. One disadvantage is that it is susceptible to swelling and embrittlement under radiation. Another is that it may be a potential fire risk during storage or disposal.

2.4.3 Conditioning in a Cement Matrix. Based on many years of research, cement matrices have emerged as probably the most favoured option for MLW immobilisation. The R & D programmes have shown that immobilised products are safer for storage purposes than raw wastes.

Bonding in a cement matrix has been shown to be a low-temperature, simple yet flexible process which uses existing technology Optimisation of the procedures, including the formulation of mixes containing modifiers and additives, has led to products with the following advantageous properties

- Good strength, durability and radiation resistance
- High pH cement environment which minimises actinide solubility and hence migration opportunities.

One disadvantage with a cement matrix is the possibility of chemical reactions taking place with certain waste streams. This might occur, for example, where aluminium or alumino-ferric flocs are used to scavenge dilute waste solutions.

Encapsulated wastes in a cement matrix inside stainless steel storage drums are expected to have a useful guaranteed life for surface-engineered storage and should also remain intact for centuries in a permanent repository.

2.4.4 Other Waste Conditioning Processes. Some work has been carried out on other encapsulation/immobilisation techniques for specialised waste streams:

- Immobilisation of spent ion exchange resins in a water-extendible vinyl ester matrix.
- Fixation of ^{85}Kr in a nickel metal matrix. The results have indicated that the product will retain the gas both under normal storage conditions and during simulated accident conditions.
- Several inorganic iodides and carbonates have been investigated as possible candidate waste forms for ^{129}I and ^{14}C (e.g. lead, silver and bismuth salts).
- Metal matrices, e.g. zirconium are also being considered for the immobilisation of ^{3}H.

2.4.5 Recoverability of Conditioned Waste. It is unlikely that any useful quantity of nuclear material could be recovered from conditioned waste. The first step for glass or synroc waste would necessarily be pulverization. This is a common engineering operation, but a truly fine powder would be required if any subsequent chemical attack is to be successful. The waste materials are not embedded in a glass matrix, they are an integral part of that matrix.

The fact that the desired elements are an integral part of a glass matrix would also complicate chemical processing. The glass presumably would dissolve in HF, but the solution would have to be converted from fluoride to nitrate for further processing, or a new chemical flowsheet would have to be developed.

Bitumenous and cement matrices present their own unique problems. A cement matrix would not be overly difficult to pulverize, but the calcium and aluminium silicates and hydroxides are notorious scavengers; they unquestionably would frustrate subsequent attempts at chemical separation. The organic composition of bitumen would similarly prove very frustrating to the process chemists. The organic solvents for bitumen would not react with the inorganic waste; the inorganic solvents needed for the waste would not dissolve the bitumen, and potentially could react with it in undesired ways.

2.5 Waste Repositories

As noted in earlier discussions regarding measured discards, some low level wastes are disposed of by ocean dumping or, for solid wastes, by shallow land burial. For a variety of reasons, however, these forms of disposal are out of favour, and increasing quantities of wastes of all forms are being reserved or packaged for disposal in deep geological repositories. This is especially true for wastes containing theoretically recoverable quantities of nuclear materials.

Two basic types of geological repositories are being developed. One type is based on deep underground salt domes; the other type is based on "hard rock" (which may be granite, gneiss or basalt). The perceived advantage of burial in salt is that the packaged wastes are assumed to be isolated from the effects of water; the perceived advantage of hard rock is that chemical migration rates for leached cations (if or when the primary containment barriers are violated) are negligibly small. In both systems the presumption (mandated by considerations of environmental protection, not safeguards) is that the combination of waste packaging, burial medium and leach rate should containment be broken are sufficient to keep the waste out of the biosphere for at least 10^6 years.

Most permanent waste repositories are being developed on the assumption that they will be used for unconditioned waste, for conditioned waste where the State either has reprocessing facilities or has a commitment to accept back the conditioned wastes generated at a remote reprocessing facility, and for unreprocessed spent fuel. It is the spent fuel which represents the critical hazard and defines the repository design characteristics; the reader is referred to Section 4.4 for a more complete description of repository design characteristics.

It is important to recognize, however, that the coexistence of waste materials and spent fuel at the same repository forces the development of safeguards policies and procedures which take both materials into account.

3. SAFEGUARDS QUESTIONS WITH REGARD TO WASTE

3.1 Safeguards Concerns

The are two basic safeguards concerns with waste nuclear materials. One, the one usually discussed, is the possibility that the waste material might be processed to recover the contained nuclear material. That is, the waste material itself might be diverted. At present levels, the acquisition of an assumed 8 kgs Pu (or 75 kgs ^{235}U at reactor enrichments) through processing of declared measured discards is at best barely credible. Waste generation, however, is more or less a linear function of plant size. Wastes are by nature dilute and often heavily contaminated with other metal ions or organic materials, but diversion of waste materials is not necessarily to be excluded as unrealistic.

The second problem, not as frequently discussed, is that the nuclear material content of waste materials might be over-stated in order to conceal a diversion elsewhere in the material balance. As a variant of this possibility, the "over-statement" might consist of presenting the same waste quantities for inspector verification more than once. Here too the possibilities are in general only barely credible, but larger quantities associated with larger facilities could permit larger falsifications, and over-statement of waste quantities should not be excluded as unrealistic.

With nuclear material transfers between facilities the Agency always has two verification opportunities. If quantity data related to a nuclear material shipment is falsified and this fact is not detected by verification at the shipping facility, the Agency has a second opportunity to detect the falsification at the receiving facility. Similarly, if a facility attempts to conceal diversion by falsifying physical inventory data, the quantity represented by the falsification is transferred to the next material balance

period and is subject to potential detection at that time. These second opportunities may not be timely, and in some cases they may be more theoretical than real, but they always exist.

In contrast, with measured discards or other situations in which safeguards are terminated, the Agency does not have a second verification opportunity. If waste discard data is overstated to conceal a diversion elsewhere in the material balance, and the Agency's verifications do not detect this fact, then the diversion concealment is successful, and the diversion will never be detected.

3.2 Measurement Requirements

In recognition of the above safeguards concerns, it seems prudent to ask whether all nuclear material waste quantities should be measured, and whether those measurements should be verified, before safeguards are terminated.

> **(Question No. 1 for AGM consideration) Should the nuclear material content of waste materials be determined by agreed measurement procedures, and if so should reported measurement data be verified by agreed inspection procedures, prior to placing those wastes in permanent repositories and agreeing to a termination of safeguards?**

Waste materials frequently are not well characterized prior to discard. Section 2.3 reviewed measurement procedures; the procedures in general have both large uncertainties and unknown but possibly large potential biases. The usual arguments are that the quantities are small, that the material is in any case being discarded, and that therefore the time and effort required for reasonable quality measurements cannot be justified.

The converse argument is that it is not the quantity being discarded, but the uncertainty in that quantity, and the corresponding uncertainty introduced into the material balance as a whole, which determines measurement requirements. It is not important that waste measurements be precise, nor, within limits, is it important that they be accurate. It is important that the measurement uncertainty structure be reasonably well understood, and that the contribution of waste measurement uncertainty in absolute terms be consistent with other measurement uncertainties (likewise in absolute terms).

In the context of international safeguards, the important question is the confidence, or lack thereof, that discard quantities are not being inflated in order to conceal missing material elsewhere in the material balance.

Waste measurements in general are best made on smaller waste volumes and higher nuclear material concentrations. This requirement is not faithfully honored; many facilities accumulate waste materials in 200 liter drums or other large containers, with rather little attempt at physical segregation, before considering measurement possibilities. However, waste which is not to be conditioned typically is not further aggregated, and measurement capabilities are more or less the same regardless of whether measurements are performed immediately after waste collection or at the last moment before final disposal.

For waste which is to be conditioned before final disposal, there are other considerations. There are advantages to measuring unconditioned waste rather than waste which has already been diluted by a further factor of four or more. On the other hand waste which has been conditioned may be more nearly homogeneous and uniform in composition. Measurement procedures which look at signals coming from only a portion of the waste container (which describes most NDA procedures) may be usable with greater confidence than might be possible for unconditioned waste.

Section 3.4 considers safeguards aspects of the question as to whether measurements on conditioned waste should be made before or after conditioning.

In reviewing inspection criteria for all material types and locations, SAGSI has advised that the verification of measured discards and transfers to retained waste should have the same priority as is according inventory verifications of similar materials. Where transfers involve unirradiated plutonium or high enriched uranium in excess of agreed limits, SAGSI has suggested that a somewhat higher priority may be justified, the argument being that the Agency will never have a second opportunity [9].

SAGSI's advice is not inconsistent with current practice, nor is it at variance to the suggestion throughout this paper to the effect that the effort devoted to measurement verification for waste materials should not be out of proportion to the effort devoted to the verification of better grade materials. The important parameter is the magnitude of the quantities being discarded or transferred to retained waste. Where these quantities are small relative to quantities of safeguards interest, little effort is justified. As the quantities increase and become of safeguards interest, a consistent verification effort is a logical requirement.

3.3 Unconditioned Waste

3.3.1 Termination of Safeguards. At the present time the Agency terminates safeguards for waste materials only through the mechanism of measured discards. As discussed in Section 2.2, the Agency has adopted total quantity limits for quantities of nuclear material which can be classed as measured discards without speficic advance approval. Although the limits are deliberately set very low, most existing facilities have kept their measured waste discards below those limits.

Where larger quantities of waste are to be discarded, the desired procedure is that the facility should consult with the Agency, who in turn would either agree to a classification as measured discard or ask that the removal be recorded as a transfer to retained waste. The Agency may also ask to verify the nuclear material content, or to observe the operator's measurements.

If material classified as retained waste remains in some retrievable storage pending later decisions or actions regarding recovery or final disposal, this is exactly what the retained waste category was intended to accomplish. If retained waste in fact is disposed of, for example through shallow land burial, then one may ask whether classification as retained waste has made any positive contribution to safeguards. Retained waste is still subject to safeguards (see Section 2.1.2), but practical implementation of safeguards may be difficult. The Agency does not necessarily know that the waste has (or has not) been buried, and unless the burial site is part of a safeguarded facility the Agency may not know its location. Most burial sites

accept large quantities of non-nuclear waste; performing any kind of verification at a burial site raises a host of unresolved and possibly unresolvable problems.

Larger facilities now being constructed or brought into service will not be able to accept discard limits as low as 0.1 eff. kg per month, which is equivalent in the case of plutonium to only 1.2 kgs Pu per year. Industrial reprocessing plant discardable wastes (hulls, feed clarification sludges, plus high and medium level liquid wastes) will certainly be more than an order of magnitude larger. The Agency needs to define realistic limits, and verification procedures, for termination of safeguards on unconditioned waste quantities.

If total quantity per month or per year is no longer an acceptable measured discard criterion, it may also be questioned whether concentration is a good criterion. Concentration is not usually the critical variable in defining recoverability. A very dilute solution which is otherwise relatively pure probably could be made recoverable by evaporation, while a more concentrated solution which is contaminated by the presence of large concentrations of other (gamma emitting) elements could prove very difficult to recover. The problem of concentration relative to contaminating elements is of major importance in discussing wastes from reprocessing operations. Up to now, however, the Agency has never considered any factor other than total quantity in defining limits for measured discards.

In setting safeguards policy for waste, it is also necessary to consider at what point the waste should be determined to be practicably irrecoverable. For waste which does not require conditioning prior to final disposal, there are two candidate answers to this question. One alternative is that the determination could be based solely on dilution, contamination and total quantity factors. The other is that the determination could be based on a requirement that waste also be placed physically in a permanent repository before safeguards can be terminated.

> (Question No. 2 for AGM consideration) For waste which does not require conditioning prior to final disposal, should the Agency agree to classification of waste materials as measured discards, and thereby to a termination of safeguards, when the total quantities thus classified are expected to be in the range of several significant quantities per year?

(Question No. 3 for AGM consideration) For waste which is classified as measured discards in accordance with question No. 2, should safeguards be terminated prior to the time when the waste has been transferred to a permanent repository, or prior to the time when the waste has passed a specific point in the operation of that facility?

3.3.2 Safeguards Prior to Termination. Regardless of the exact point at which it is agreed that safeguards may be terminated, it is also necessary to consider what safeguards should apply prior to that determination. At the present time material classified as retained waste is considered subject to safeguards, but in fact no safeguards other than record-keeping are applied once the transfer has occurred. (As discussed in Section 2.2, transfers to retained waste are sometimes verified or observed.)

The application of safeguards to retained waste prior to its actual discard logically should imply a significantly lower level of inspection effort. To do otherwise would be to cause the retained waste designation to lose its meaning. The category was defined to permit waste materials to be removed from the material balance; doing so would have no purpose if the resulting level of safeguards effort did not decrease.

(Question No. 4 for AGM consideration) For retained waste, (i.e., waste which is not classified as measured discards), which the facility intends to dispose of in some manner such as shallow land burial, what safeguards measures should the Agency implement?

(Question No. 5 for AGM consideration) What level of safeguards effort should the Agency apply to material which meets agreed criteria for termination of safeguards (measured discards) which has not yet been discarded?

There appears to be no reason to apply considerations of timely detection to stored waste materials prior to the termination of safeguards. Candidate safeguards procedures would include the item counting of containers, the verification of tag data on a random sampling basis, the random verification of seals where significant quantities are stored under seal, etc.. It is tempting to include a limited number of NDA measurements, but the accuracy achievable with portable NDA measurement equipment, when applied to heterogeneous waste materials, does not make this option attractive.

3.4 Conditioned Waste

3.4.1 Termination of Safeguards. The primary waste forms which will be conditioned prior to disposal are high level liquid waste, leached hulls, and various centrifuge sludges and filter cakes, all arising from reprocessing plant operations. Two components of these waste materials make conditioning important, one being gamma radiation levels from fission products, the other being alpha-emitting isotopes of plutonium and trans-plutonium elements.

Unconditioned high level liquid waste is not practicably irrecoverable. It is perhaps not economically recoverable, but papers have described complexing agents which allegedly can remove 99.9% of all plutonium and trans-plutonium nuclides from high level waste [see for example 7]. Aside from possible economic utilization of trans-plutonium nuclides, the motive for performing such recovery would be to reduce the time during which the stripped waste would be of environmental concern, should it escape from its repository. Mixed fission product waste will have decayed to activity levels comparable with natural uranium after 1000 years or so; alpha- emitting plutonium waste will not satisfy this criterion for perhaps 100,000 years or longer.

On the other hand, the purpose of waste conditioning is to place the alpha and gamma emitting nuclides in a chemical form which is as near to totally inert as can be achieved. Small quantities of conditioned waste might conceivably be crushed, dissolved and processed in laboratory experiments, but it is difficult to believe that such laboratory processes could be extended to the scale necessary to recover 8 kgs Pu or more in any practical time frame. The nature of conditioning is to render waste practicably irrecoverable; Agency safeguards logically should agree that this has occurred.

(Question No. 6 for AGM consideration) For conditioned waste, should the Agency determine that waste materials are practicably irrecoverable, and terminate safeguards, when the waste has been conditioned for final disposal in accordance with one of the processes described in Section 2.4, regardless of whether it has been transferred to a permanent repository?

3.4.2 Safeguards Prior to Conditioning. The safeguards measures applied to waste which is to be conditioned and discarded, but which has not yet actually been conditioned, should be similar in principle to measures applied to waste which is not scheduled for conditioning. That is, the material should be transferred to the retained waste category, and some non-zero level of safeguards should be applied where significant quantities are involved, but this level of effort should still be below that applied to materials which remain on the safeguarded material balance. Once conditioning has occurred the waste may be reassigned to the measured discard category, presumably through the bookkeeping mechanism of first taking the material back into inventory, then transferring it to measured discards.

3.4.3 Safeguards After Conditioning. If safeguards are terminated as suggested in Section 3.4.1, the waste would no longer be subject to any form of safeguards once it has been conditioned and transferred to the measured discard category. This specifically applies not only where final disposal occurs, but also in those cases where conditioning is proceeding in advance of a final decision on the location or other details of the permanent repository itself.

4. NUCLEAR MATERIAL SAFEGUARDS FOR SPENT FUEL

4.1 Spent Fuel Definitions and Descriptions

The term "spent fuel" can be used to refer to a broad range of physical and chemical material forms. As examples, "spent fuel" includes:

- MAGNOX and other natural uranium metal fuel forms;
- LWR fuel (which exists in three basic designs (BWR, PWR, WWER) and numerous less important variations);
- On-load reactor fuel (CANDU, also several variations on that design);
- ThO_2UO_2C fuel forms from high temperature gas-cooled reactor designs;
- Various breeder reactor fuel forms;
- A variety of research reactor fuel designs.

Of these various fuel forms, most of the uranium metal (MAGNOX) fuel and much LWR fuel is being or will be reprocessed. The option of placing spent LWR fuel in a permanent repository is being seriously discussed, however, and it is clear that some LWR fuel will be placed in permanent repositories without reprocessing. This is even more true with regard to thermal recycle MOX fuel assemblies, which may contain plutonium with high concentrations of ^{240}Pu and ^{242}Pu.

The general physical characteristics of LWR fuel are well known. In terms of the discussions here, the most important characteristics are that the fuel assemblies are several meters long, that they consist of an assemblage of individual fuel pins which in many cases can be relatively easily

disassembled, and that the total fuel weight is in the range of 250 - 500 kgs. Pu concentration at discharge is generally assumed to be about 1% relative to uranium, but could be less in earlier low burn up fuels. The reader who wishes more information is referred to [10,11,12,13].

On-load refuelling reactors (i.e., the Canadian CANDU reactor and similar designs) were not designed with reprocessing in mind. Some fuel has been reprocessed, and several States are pursuing the reprocessing option, but final disposal in permanent repositories is an important option with regard to on-load reactor fuel. Long-term retrievable storage is also an important option. (The distinction between "retrievable" and "practicably irrecoverable" is discussed in Section 5.1 below.)

On-load reactor fuels are also extensively described in the safeguards literature (see for example [11,14,15]). The fuel assemblies (commonly referred to as fuel bundles) are significantly shorter, and fuel pins are not assembled in a manner which makes for easy disassembly. Since the total burn up is less than 10 000 MWD/t, the final Pu content is only about 0.4% instead of 1%.

It was generally assumed when high temperature gas-cooled reactors (HTGRs) were designed that the associated ThO_2UO_2C fuels would be reprocessed. However, development of a viable reprocessing technology has proven more difficult than was anticipated. The economic incentive for reprocessing has also largely disappeared, and present design assumptions are that these fuels will not be reprocessed.

No "standard" HTGR design has evolved. One design of safeguards interest is the so-called pebble-bed reactor in the GFR, which is fuelled using spherical fuel elements composed of a thorium-uranium-graphite matrix encased in a pure graphite shell. Fuel element diameter is about 6 cm. "Pebbles" will be collected in special drums for storage pending final decisions regarding conditioning and disposal.

As with HTGRs, fast breeder reactors are few in number and in many respects individual in design. All involve a central core region surrounded by a thick blanket region, and all use fuel assemblies composed of relatively small diameter pins. Assemblies normally are welded, making disassembly difficult.

Depleted uranium blanket assemblies from breeder reactors typically are scheduled for reprocessing, as a source of plutonium for subsequent cores. Fuel assemblies in the central core region may or may not be reprocessed, depending at least in part on the ratio of fissile odd isotopes to non-fissile even isotopes. (The fast neutron spectrum in a breeder reactor can remove even isotopes faster than they are produced.) Also, the core and the axial blanket often are contained within the same fuel pins, and the axial blanket definitely contains potentially useful plutonium. Thus some breeder reactor core assemblies may be reprocessed; others may be scheduled for disposal in a permanent repository without reprocessing.

4.2 Spent Fuel Measurement Procedures

The Agency's basic safeguards approach for reactor fuel assemblies is one of item accountancy. It is assumed that fuel assemblies can be treated as identifiable (or at least countable) items, rather than as material quantities. The basic principle is that the integrity of the individual items can be assured, either because fuel assembly tampering would be sufficiently difficult that it can be considered unlikely, or because safeguards measures are implemented to verify or assure that integrity in fact has not changed. The initial U and ^{235}U content as stated (and verified) at the time of fabrication is important in the sense that it is information which will be needed later when the spent fuel is reprocessed, but it is not essential information in terms of safeguards for spent fuel. The Agency's assurance of non-diversion is expressed in terms of an assurance that all assemblies can be accounted for (and have not been tampered with), not in terms of kilograms of U or Pu.

The success of item accountancy as a safeguards approach obviously is critically dependent on the Agency being able to implement measures which provide an acceptable assurance of continued item integrity. Most safeguards

rely heavily on a combination of seals and video or film camera surveillance to provide the required assurance of integrity; more recently the alternative of re-verifying integrity by NDA measurement has been given increased attention.

It is not appropriate here to digress into a discussion of safeguards practices for spent fuel at reactors or away-from-reactor storage facilities. However it is important to note that both relying on C-S measures to preserve integrity and using NDA measures to re-verify integrity have practical difficulties which are unlikely to be resolved in the immediate future.

The problem which does need to be recognised is that spent fuel will arrive at a permanent storage repository (or more correctly at a preparation facility which may or may not be collocated) with a presumption that its integrity has been preserved, but with an important question as to whether this in fact has been the case. As with waste material (see Section 3.1) final disposal removes the nuclear material from Agency verification. If diversion has occurred and has not been detected at the time of disposal, then it will never be detected, because the Agency never will have another verification opportunity.

It is easy to suggest that the Agency should perform one final verification on spent fuel prior to its being placed in a permanent storage repository. It is not so simple to define meaningful and workable verification procedures. Starting from the simplest verification, the choices include (the choices are not mutually exclusive; combinations not only are possible but may be desirable):

1. Visual confirmation that the fuel assembly looks intact, and for LWR fuel, that it bears the correct serial identification. If earlier C-S measures have in fact been effective, then this simple verification assures that the correct fuel assembly is being placed in final disposal, and arguably is all that may be required.

2. Verification that the fuel assembly emits Cerenkov radiation. While this may be a useful verification, it is subject to several problems. One is that at the time of final disposal spent fuel is likely to have cooled for a minimum of 5 or 10 years. (Heat transfer is one of the major design considerations in permanent repository design.) Another is that the fuel assembly either (a) will have been removed from underwater storage at some time prior to shipment to the preparation facility, or (b) will be removed from underwater storage as one of the first preparatory actions prior to disposal. Since Cerenkov radiation is detectable only in transparent hydrogenous media (usually water), this verification may be technically impossible at final disposal preparatory facilities.

3. NDA measurement of gamma or neutron emission, either passively or in an active interrogation mode. NDA confirmation that spent fuel emits neutrons characteristic of plutonium and/or gamma rays characteristic of fission products.

4. True NDA measurement, as a means of confirming that fuel assemblies are 100% intact, is more difficult. During a recent Advisory Group Meeting on "Methods and Techniques for NDA Safeguards Measurements of Power Reactor Spent Fuel" [16], NDA measurements for spent fuel were discussed in detail. All of the methods discussed have recognized problems, but some could be developed for potential use for quantitative verification of spent fuel for final disposal. There is a second problem, however, that the Agency does not know, except in the form of an unverified and probably unverifiable operator statement, how much residual ^{235}U and produced Pu should be present. Determination of how much is present, even under optimistic assumptions regarding accuracy and precision, cannot be used as a verification if the numbers being verified are not known.

The fork detector is generally considered the best available instrument for NDA measurements on spent fuel. The fork detector system was developed by LANL in response to an IAEA request for a transportable detector that could quickly measure Pu content of spent fuel assemblies in a spent fuel pond Since its first use in 1982, this detector and its variants have been used at many nuclear facilities around the world.

The ION-1 fork detector, however, cannot directly measure the uranium and plutonium content of spent fuel assemblies. Neutron emissions are dominated

by transuranic isotopes, and fission product gamma rays make it impossible to see gamma rays from the fuel isotope. Recent studies show that it is possible to detect differences of 20% or more if the operator's stated burn up is accepted as unfalsified. with present instruments it is difficult to detect differences of less than 10%. A recent report by Rinard and Bosler [17] examines the question of using the fork detector to verify the operator's stated burn up, and thereby to use the instrument as a true verification technique.

Another possible technique is active neutron interrogation. This method would be able to provide a quantitative measure of the fissile content of spent fuel, and there are cases of this method being used in reprocessing plants. Due to the complexity of the equipment at the present time, there are no active development projects. Different schemes are feasible, e.g. direct counting of the induced neutrons, coincidence counting or counting of the delayed neutrons, making it feasible in some cases to possibly distinguish between ^{235}U and ^{239}Pu.

The technique or procedure utilized will greatly depend on at what stage the spent fuel will be available for NDA verification before final disposal. It is understood that the methods described here would preferably be used in the preparatory facility, before the fuel becomes inaccessible. Continuity of knowledge presumably would then be maintained by using appropriate surveillance instruments.

It is not clear whether the State Authority or the plant operator would require NDA verifications before final disposal. In such a case it would be useful if in-plant equipment could be authenticated and used by the Agency for its verifications.

4.3 Spent Fuel Conditioning Processes

Most spent fuel will not be conditioned, as that term was used in Chapters 2 and 3, prior to final disposal. Various conditioning schemes have been studied, but most have been dropped as adding significantly to cost while not adding significantly to containment.

This does not necessarily mean that spent fuel will be placed in permanent repositories "as is." Most repository designs call for fuel to be dismantled to reduce space requirements. (The achievable degree of compaction is not likely to be larger than a factor of two, but if shielding is to be left in place even this reduction could be of importance.) This spent fuel "conditioning" could occur either at a surface facility located at the repository site or at a separate preparatory facility.

Either way, the deliberate disassembly of spent fuel for space saving reasons introduces the possibility of undeclared pin removal at the preparatory facility during disassembly operations. Undeclared pin removal is generally recognized as a possibility that is not well covered by current safeguards practices at reactors; clearly it must be an important consideration in the development of safeguards approaches for preparatory facilities and the final disposal of disassembled spent fuel.

4.4 Spent Fuel Repositories

4.4.1 Canada. Canada currently is storing spent fuel underwater, and expects to continue to do so for some decades, at which time the future need for the contained plutonium hopefully will be more clear. Above ground dry storage canister (silos) have also been constructed at two sites, and are demonstrating that long term dry storage is a feasible option. Neither of these possibilities, however, are intended to qualify as final disposal, and neither design details nor safeguards procedures need further consideration here.

However, studies also are in progress with regard to final disposal of spent fuel in plutonic rock (e.g., granite) [18,19]. To give here only the details of potential relevance to safeguards, the conceptual design calls for CANDU reactor fuel bundles to be placed in thin-walled containers, probably constructed of a titanium alloy for corrosion resistance, with the free space being filled with some particulate matter.

The conceptual disposal "mine" has a capacity of 190 x 10^3 metric tons of spent fuel, and would require perhaps 40 years to fill. (The projected "need," if no fuel is reprocessed, is 120 x 10^3 metric tons.) Containers would be placed in vertical holes at a depth of 500 to 1000 meters. The holes would be drilled oversize, back-filled with a mixture of clay and crushed granite, then re-drilled, thereby providing a sand-clay diffusion barrier immediately surrounding the fuel containers.

As portions of the mine are filled, access tunnels would be back-filled with mixtures of crushed granite and bentonite clay, combined with concrete seals at appropriate points. The storage is intended to be permanent, no provisions are included for possible retrievable at an undefined later date.

4.4.2 United States of America. The U.S.A. is studying three potential sites for a permanent repository for spent fuel, but does not expect a selection to be made for some years. Actual operation is currently assumed to begin in 2003 [20].

As an interim measure, the U.S.A. is exploring the development of what is referred to as Monitored Retrievable Storage (MRS). This would be a surface facility with a storage capacity suitable for 5 year storage of spent fuel pending delivery to the permanent repository. The MRS also would serve as a preparation and packaging facility, dismantling assemblies and repackaging the fuel pins in more compact arrays for disposal.

Clearly the MRS cannot be considered as final disposal, justifying a decision to terminate safeguards. However the monitored retrievable storage facility is of interest in the context of this meeting because it includes all the preparation and repackaging actions which will occur in connection with other permanent repositories.

No technical description of the planned monitored retrievable storage facility or the manner in which it will prepare fuel for final disposal is known to have been published.

4.4.3 Sweden. Sweden has elected to follow the once-through fuel cycle, with no reprocessing. (Indeed, Sweden has now elected to phase out nuclear power by the year 2010). After perhaps five to ten years storage at the reactors, spent fuel will be shipped to an interim storage facility known by the acronym CLAB, an underground wet storage facility with a present capacity of about 3000 t U [21, 22]. Some consideration is also being given to dry storage in a manner similar to interim storage at the Gorleben facility in the GFR. There is of course no suggestion that these facilities qualify as rendering spent fuel practically irrecoverable.

Plans for final disposal of spent fuel in Sweden are still being developed. The CLAB facility, possibly augmented by a dry storage facility, is assumed to be adequate for a reference storage time of forty years, allowing time to consider final disposal carefully.

Although UO_2 is commonly considered to be insoluble in water, it is commonly recognized that selected fission products could leach from exposed spent fuel pellets at an unacceptable rate, and that any final disposal of spent fuel must be based on isolation of the fuel from potential ground water leaching. In Sweden it is currently proposed that this should be accomplished by placing a group of fuel assemblies (not disassembled) into a copper container, and then back-filling with either lead or copper powder. In the lead version the container would simply be sealed by welding. In the copper version the container would be sealed by hot isostatic pressing in order to compact and sinter the copper into a solid matrix.

The eventual "mine" is likely to be conceptually similar to other designs which have been published, except that a disposal depth of 500 meters is proposed. Engineering details have not been published, but there is no indication that shielding other than that provided by the reference 4 cm copper container would be left in place when fuel is placed in the permanent storage repository.

4.4.4 <u>German Federal Republic</u>. The German Federal Republic (GFR) is pursuing both reprocessing of LWR fuels at a site near Wackersdorf and final disposal in a facility being developed at a site near Gorleben. In general reprocessing is foreseen as the preferable alternative, but the Gorleben disposal site is needed in any case for "non-heat-generating" wastes, and development of the necessary spent fuel disposal technology is proceeding in parallel with waste disposal technology.

As described in recent references [e.g., 23, 24] fuel assemblies will be brought to the disposal site in standard spent fuel transport casks, probably the dry storage CASTOR-type casks being used for intermediate storage at the Gorleben facility. One design then calls for placing three intact PWR fuel assemblies into a primary carbon steel container; another design assumes disassembly in order to fit larger number of assemblies into a disposal container of about the same dimensions.

The GFR design assumes that shielding necessary in order to move the primary storage container into position would be left in place. This somewhat increases the total storage volume required, but is not as bad as it sounds because the primary storage space consideration is the separation required for heat transfer.

5. SAFEGUARDS POLICY ISSUES FOR SPENT FUEL

It cannot be argued that spent fuel, as it is discharged from the reactor, qualifies as being practicably irrecoverable. LWR fuel is being recovered routinely in several States, and both on-load reactor and FBR fuel has been recovered to a more limited extent. Larger FBR reprocessing plants are on the drawing boards, and presumably will be constructed on a schedule consistent with the operation of fast breeder reactors themselves.

It likewise cannot be argued that spent fuel which has been stored for ten years or longer is practicably irrecoverable. The total fission product radiation from spent fuel decreases significantly in the first years, such that a number of the major problems in reprocessing (radiation damage to organic chemicals, shielding, control of environmental releases, etc..) become easier to deal with as spent fuel is allowed to cool.

HTGR fuel is not necessarily an exception to these generalities, even though commercial reprocessing of HTGR fuel is unlikely. The outline of a recovery process for ThO_2UO_2C HTGR fuels has been defined [25], and although this process may never be economically attractive it is generally agreed that economic considerations should not be accepted as a major deterrent to a divertor.

However, it is equally difficult to define meaningful safeguards procedures for spent fuel placed in permanent repositories without going beyond the basic safeguards model based on independent verification of operator/State material or item accountancy measurement data. (See, for example, [24]). The basic premise of the permanent repository is that the spent fuel is disposed of in a way which isolates it from the biosphere, specifically including accidental access by man. This premise is in direct conflict with the basic premise of international safeguards, that nuclear material can be made available for inspection at suitable intervals.

It is perhaps worth considering briefly what the objective might be in trying to apply safeguards to permanent repositories, without worrying too much whether the objective or means are legitimately within the scope of current safeguards agreements. It should be assumed that safeguards measures applied at the time spent fuel was placed in the repository were adequate to provide an assurance as to what was being disposed of. If this is correct then the Agency likewise should have an adequate assurance that it knows what spent fuel has not been placed in the repository, and therefore is still subject to safeguards. Continuing safeguards measures for spent fuel not in the repository are outside the scope of this paper.

What remains, clearly, is to maintain a continuing assurance that spent fuel placed in a permanent repository is still there. As one alternative this assurance may come from a belief that the repository is as permanent as its name implies, therefore no continuing safeguards measures are needed. A second alternative is to suggest that a repository which has been filled and closed qualifies as permanent, but that a repository which is still open and accepting additional fuel does not qualify. Yet a third alternative, of course, is to argue that even a permanent repository which has been filled and closed requires some continuing level of safeguards to provide an assurance that it has not been reopened.

In both of the latter alternatives one may ask whether it is the fuel or the repository which is being safeguarded. Verification that spent fuel is still present is not really important, what is important is that spent fuel is not being brought to the surface and transferred off site.

Thus, among others, the Advisory Group is asked to consider the following questions:

> (Question No. 7 for AGM consideration) Does the act of placing spent fuel in a permanent storage repository constitute making that spent fuel practicably irrecoverable?
>
> (Question No. 8 for AGM consideration) If the answer to the above question is yes, under what circumstances (e.g., at what point in the process of final disposal) should the Agency determine that the spent fuel has become practicably irrecoverable, and accordingly terminate safeguards?

(Question No. 9 for AGM consideration) If the answer to the above question is no, what continuing safeguards measures should the Agency apply to spent fuel which has been placed in a permanent storage repository?

5.1 Measurement Requirements

5.1.1 LWR Fuel. Section 3.1 argued that it was essential that the nuclear material content of waste be measured and verified prior to final disposal, on the grounds that otherwise the overstatement of nuclear material in waste would constitute an open path which could be used to conceal diversion of more valuable nuclear material forms. A measurement/verification requirement exists for spent LWR fuel, but the justification is significantly different, and the information which must be verified is significantly different.

The Agency's safeguards approach for spent LWR fuel assumes that assemblies can be treated as identifiable items, and that the integrity of the items either can be preserved or can be re-established at suitable intervals. As discussed in Section 4.2, it is not directly important to safeguards how much plutonium is contained in spent fuel at the time of reactor discharge.

The spent fuel verification method most favored by inspectors is commonly referred to as the Cerenkov Night Viewing Device (CNVD). Early versions required that facility lighting be reduced to near zero (which operators understandably were reluctant to do), but the latest versions are sensitive to ultraviolet wavelengths not present in most facility lighting, and eliminate this restriction. The technique requires that the top of the fuel assembly be visually accessible (and that the inspector be able to position himself directly above the assembly), but does not require that assemblies be disturbed.

There are questions, however, about the effectiveness of CNVD in detecting missing fuel pins under the assumption that some form of substitution has occurred. This arises because the CNVD does not detect fuel pins as such, but rather detects a pattern of dark spots (created by fuel pins) in an otherwise more or less uniform blue glow. So long as there are sufficient valid fuel

pins to provide the necessary blue glow, any object of the right shape (a hollow steel rod probably would do) could create a dark spot and therefore appear to represent a fuel rod.

The alternative usually discussed is to verify Pu content. Such verifications suffer from a number of problems.

(a) Currently available techniques are not sufficiently accurate to detect a Pu discrepancy equivalent to 1 or 2 missing fuel pins.

(b) Currently available techniques require that spent fuel be moved, at least to the extent of raising it from its storage location, and facility operators are reluctant to assume the financial liability should fuel cladding integrity be lost during the verification operations.

(c) The inspector normally has no independently verifiable knowledge of how much Pu was present at the time of discharge, and therefore has difficulty in interpreting observed Pu content in the context of possible removals.

(d) Where solutions to the above problems can be identified, verification of spent fuel by Pu measurement may put the inspector in the position of attempting a form of materials accountancy, not item accountancy. (The observation of an anomaly suggesting that diversion has occurred would now be based on apparently missing Pu, not on apparently missing fuel pins.) This problem might be avoided, however, by agreeing that anomalies revealed by NDA measurement should be resolved by a more careful verification of the fuel assemblies in question, using techniques (not here defined) which could detect missing fuel pins.

Where spent fuel is dismantled preparatory to final disposal, some of the above arguments cease to be important. The fuel is now being handled anyway, so an NDA measurement presumably could be integrated into the routine handling sequence. However, new arguments appear. The fuel is no longer under water, so Cerenkov radiation no longer exists. (It may have decayed to non-useful levels in any case, if fuel is stored for a decade or longer prior to final disposal.) Neutron measurements depend on the presence of water to act as a neutron moderator. Neutrons emitted by spent fuel in air are fast neutrons, and have completely different detection characteristics. This might be resolved by using polyethylene moderator blocks as part of the measurement

procedure. Even if all other problems can be resolved, the problem of insufficient measurement accuracy is unlikely to be solved in the near future.

One should not lose sight of the possibility that a selection of redundant and independent C-S measures might also be used to reduce or eliminate the need for NDA verifications. Reactor safety designers have long recognized that if two are necessary for redundancy, then three are necessary to permit one to be out of service. Examples exist where it is generally agreed that more than three are required. The same argument logically could be applied to safeguards; the question is purely one of "how much is enough."

"Redundant and independent" C-S should be understood as meaning exactly that, however. Using two cameras adds little in the way of redundancy and nothing in the way of independence. An "unidentifiable black object" in one camera is likely to be just as unidentifiable in another, and both cameras will fail if the lights are turned out. An infra-red camera, a crane monitor, seals, radiation detectors, and laser surveillance are examples of possibilities which might qualify as redundant and independent. There has been little useful R & D work on adaptation of these technologies to the requirements of international safeguards.

5.1.2 <u>On-Load Reactor Fuel</u>. On-load reactor fuel is not easily dismantled, and so far as is known all permanent repository plans assume that fuel bundles will be packaged and disposed of without dismantling. This somewhat simplifies the safeguards problem, except that this is a long chain, and weak links are likely to develop. Nevertheless, it should be sufficient to apply C-S measures at the surface facility where fuel bundles are packaged for disposal, to ensure that all bundles declared to be placed in disposal containers in fact are placed there. Pu quantity measurements should be unnecessary.

5.1.3 <u>HTGR Reactor Fuels</u>. In all known HTGR reactor designs spent fuel is packaged for disposal, and in many cases conditioned as for waste materials, at the reactor site. No further measurements should be necessary.

5.2 Safeguards Measures Prior to Final Disposal

Aside from the question of spent fuel measurement of verification, it is necessary to recognize a distinction between safeguards to be applied to spent fuel up to the point of final disposal and safeguards to be applied to spent fuel which has been placed in a permanent storage repository. Regardless of whether the Agency terminates safeguards for spent fuel which has been placed in a permanent storage repository, safeguards must still be applied up to the time the storage/disposal container is placed in the underground repository. It is also necessary to make a distinction between a permanent repository which is still open for the receipt of additional fuel and one which has been filled and closed.

This present Section 5.2 addresses the question of safeguards to be applied to spent fuel preparatory facilities prior to actual final disposal. The primary concern is the need to provide an assurance that individual fuel pins (or whole fuel assemblies) were not removed prior to placing assemblies in final storage containers. A secondary concern, however, is the need to provide an assurance that fuel assemblies were intact (i.e., had retained their integrity) on arrival at the preparatory facility. Final disposal of spent fuel gives an assumed divertor an excellent opportunity to bury all evidence of diversion.

Section 5.3 considers the two alternatives, "determine that spent fuel has been rendered practicably irrecoverable and terminate safeguards" and "continue safeguards" in the context of repositories that are still open. Section 5.4 addresses the question of repositories that have been closed. However, this problem is unlikely to arise for some decades and the treatment is accordingly very general.

As a general statement, Agency safeguards policies require that all nuclear material quantities, including those under seal or video surveillance, be reverified. The frequency and extent of reverification is somewhat dependent on C-S measures, but the fundamental requirement is always there

An exception is made, however, for spent fuel classed as "difficult to access". (The classification includes spent fuel in welded containers, spent fuel under liquid sodium, or more generally any spent fuel which could not be moved to a location where verification could occur in less than four hours.) The policy provides that spent fuel which was verified prior to becoming difficult to access need not be reverified, on any frequency, so long as acceptable C-S measures can provide an unbroken confirmation of verification integrity [26].

All spent fuel must be "prepared" for final disposal, meaning thereby that, as a minimum, it must be placed in some sealed outer container. Additional preparatory actions which may occur include dismantling LWR assemblies to achieve more compact storage and filling the space around fuel pins with some inert and absorbent material (e.g., a mixture of sand and clay). These preparatory actions are not necessarily synonymous with conditioning, as that term was used in the Chapters on disposal of waste. Waste conditioning effectively rendered any residual nuclear material content irrecoverable; packaging of spent fuel provides a greater degree of containment, but does not in itself make the spent fuel particularly difficult to access and recover.

No specific permanent repository currently exists, or is likely to exist for some years. However, it is important to recognize that safeguards for spent fuel dismantling or preparatory facilities is an unresolved safeguards problem, and to turn the attention of appropriate technical experts to its resolution.

Several supposed possibilities may be identified and shown to have serious technical problems. Reliance on C-S measures, and in particular on video surveillance systems, is likely to prove extremely complex, especially where fuel dismantling occurs. C-S measures work well in completely static environments; they can work acceptably where nuclear material movements occur but are rare and are well defined. It is unrealistic to expect that inspector interpretation of video images taken at intervals of some minutes can provide an adequate assurance that fuel dismantling activities are 100% in accordance with declared procedures.

The "penetration monitoring' concept of C-S, in which both video cameras and other sensors are used to ensure that no fuel moves through penetrations which conceivably could be used to divert spent fuel, may have some potential advantages. This concept was largely dropped when it was found unsuitable for use in reprocessing plants; it would require a significant amount of R & D work to determine whether it could be used for spent fuel preparatory facilities.

Neither conventional C-S measures nor penetration monitoring in themselves would answer the question raised in Section 4.2 concerning the possibility that diversion might have occurred earlier.

Materials accountancy appears to offer essentially no useful prospects at all. The Agency has no verified knowledge of how much plutonium or residual ^{235}U should be in spent fuel; verifying how much is actually present serves no useful safeguards purpose. (This does not preclude qualitative NDA verifications; the subject is materials accountancy not fuel integrity).

A 100% inspector presence at the conditioning facility likewise has its problems, not the least being the probably unacceptable demands it would place on inspection resources. Inspector presence is always easy to suggest; it is easy to assume that an inspector would recognize a diversion if he were present and saw it happening. The assumption of 100% inspector presence, however, usually means exactly that. If the operator takes a coffee break, the inspector must remain on duty lest some other employee enter the area and effect a diversion in his absence. Guard services, which likewise provide true 100% coverage, assume as many as eight guards to cover a single post. (Most facilities have several posts to be guarded, and the average number of guards per post can be reduced significantly. It is never less than four, however.)

The above somewhat pessimistic review suggests that an increased attention should be given to technical aspects of defining a safeguards approach for preparatory facilities associated with spent fuel disposal.

> The Advisors are asked to discuss the problems outlined above, and to provide suggestions regarding an R & D program leading to the development of an acceptable safeguards approach for spent fuel dismantling/preparatory facilities.

5.3 Safeguards for a Repository which is Open

5.3.1 Permanent Repository versus Long-Term Retrievable Storage. If safeguards for spent fuel are to be terminated on the argument that the fuel has been rendered practicably irrecoverable, it is important to draw a distinction between permanent repositories and long-term retrievable storage facilities. Several States have considered that the spent fuel reprocessing decision should be postponed for some number of decades, but that an irreversible decision at this time that spent fuel would never be reprocessed might be unwise.

In line with this "decision to postpone a decision," so-called long-term retrievable storage facilities have been designed. These facilities in many respects accomplish the same objective as permanent repositories in that they remove spent fuel from the biosphere, but they do so in a manner consciously designed to permit later retrieval. In most cases eventual retrieval is more or less mandatory, in that the facilities are designed for decades or even a century or so, but are not expected to provide the desired degree of isolation for 10^4 or 10^5 years, the usual assumption with permanent repositories.

Given that the storage facility was specifically designed to preserve or facilitate the eventual retrieval option, it is difficult to argue that the contained spent fuel has been rendered practicably irrecoverable. The discussions in this paper should be understood as applying specifically to permanent repositories, not to long-term retrievable storage facilities.

5.3.2 Determination of Practicably Irrecoverable. There have been various suggestions that a repository would constitute a "plutonium mine" which, if safeguards were not applied, could be tapped by a divertor without fear of detection. The engineering feasibility of tapping this plutonium mine is a subject which could be debated at length. The industrial world's major architect-engineering firms have considerable engineering expertise; there is little basis for arguing that they would find the task impossible. On the other hand it is certain that they would find the task difficult, and that they would require time, money and manpower.

The re-opening of the original vertical access shaft and horizontal access tunnels should present no significant difficulties, given that accurate maps of the original locations were still available. The time required to perform this re-opening presumably would be comparable to the time required for the original initial construction. Once these basic access tunnels were complete, however, the diversion team necessarily would have to move more carefully, the danger being that the heavy earth-moving equipment might break a fuel assembly and expose plutonium to the working environment. In the initial years the spent fuel may reasonably be expected to be where it was placed, but migration is one of the geological phenomena allowed for in the design work, especially for salt formations, and as the time since placement increases the diversion team might need to give an increased consideration to the possibility that the fuel was no longer exactly where the drawings said it should be.

This latter consideration, the danger that the diversion team might break a fuel assembly, suggests that one important safeguards consideration perhaps should be the degree of structural containment left in place around embedded fuel assemblies. Repositories which place fuel assemblies in shielded containers and leave the shielding in place may be at least marginally easier to "mine" than those which recover the shielding and leave the assemblies in relatively thin-walled containment canisters.

Leaving aside the question of whether a permanent repository constitutes a plutonium mine, the basic premise in placing spent fuel in a permanent repository is that the fuel should be totally removed from the biosphere - it should be <u>disposed of</u> in the everyday meaning of that expression. A repository will require continuous monitoring by State authorities even after it has been closed and sealed, but this monitoring will be performed on the ground surface above the repository, or in test borings drilled for the purpose around the disposal site, and will not involve access to the spent fuel itself.

> (Questions No. 10-13 for AGM Consideration) Should the Agency determine that spent fuel which has been placed in a permanent repository has become practicably irrecoverable, and terminate safeguards?
>
> If the answer is in the affirmative, at what point on its route from reactor to possible AFR storage to preparation facility to permanent repository does spent fuel become practicably irrecoverable?

What measurements or verifications should be performed on spent fuel prior to a determination that it is practicably irrecoverable?

What verifications or continuing safeguards measures should be required subsequent to measurement yet prior to determination that the fuel has become practicably irrecoverable?

5.3.3 Continuation of Safeguards. The counter argument to Section 5.3.2, the alternative answer to the first question posed at the beginning of this Chapter, is that spent fuel should not be considered practicably irrecoverable even when it has been placed in a permanent repository designed to provide "final disposal," and that some presumably reduced level of safeguards effort should be continued indefinitely. The arguments in support of this alternative are essentially the opposite of those presented in Section 5.3.2. In particular the argument is that a permanent repository constitutes a plutonium mine which in the absence of safeguards could be tapped without fear of detection.

Without here arguing the merits (or lack of merit) of the above arguments, it is important to give some consideration to the nature of the safeguards which might be applied. Materials accountancy (or its close counterpart, item accountancy), which according to INFCIRC/153 is to be the primary safeguards measure, simply would not be possible. The Agency can (and presumably should, in any case) maintain book records on the spent fuel placed in the repository. No spent fuel shipments would occur, though it is not clear how the Agency would verify this fact. However, the spent fuel has been rendered inaccessible; any attempt to take or verify a physical inventory would be completely out of the question. Without physical inventories materials accountancy has no meaning.

At least some States would like to see the Agency maintain records on total quantities placed in permanent storage repositories; this seems both logical and feasible with essentially no inspection resources beyond those required to verify the fact of disposal. However, a distinction should be drawn between keeping records on material which is subject to safeguards, but in fact is not verified, and the actual application of safeguards. If safeguards are not to be terminated, then something more tangible than record-keeping should be identified as a feasible safeguards approach.

Some measures to ensure that spent fuel canisters are not lowered into the mine on one day and brought back out the next certainly are desirable. This would protect, for example, against the possibility of the inspectorate being presented repeatedly with the same canister.

If considerations related to the repository are separated from considerations related to the possibly collocated preparatory facility, conventional C-S measures may be useful. Final disposal packages are expected to move down a shaft into the storage repository; nothing resembling a final disposal package is expected to move back up. Thus video surveillance units might be used to confirm this absence of an upward flow. Published reports have not discussed a possible upward movement associated with packages which have been damaged by handling equipment and are being returned to the surface for repair or repackaging; such occurences presumably would be rare but might not be non-existent. If there is a collocated preparatory facility these unusual movements logically could be handled via advance inspector notification.

Most repository designs provide for several final disposal packages per day, and this may create problems in inspector visual interpretation of video images. A more advanced microprocessor-based system which eliminated all movements clearly related to the downward transfer of final disposal packages, and which alerted on-site inspectors to the need for investigation of video images that did not meet computerized evaluation criteria, would have distinct safeguards advantages. Such a system would require some development effort, but as noted previously there is time if R & D efforts are initiated promptly.

> **(Question No. 14-16 for AGM Consideration) Should the Agency determine that placing spent fuel in a permanent repository does not constitute making that spent fuel practicably irrecoverable, and accordingly continue to apply safeguards?**
>
> **What measurements or verifications should be performed on spent fuel prior to its being placed in a permanent repository?**
>
> **What safeguards measures should be required for spent fuel which has been placed in permanent storage repositories while those facilities are still open?**

5.4 Safeguards for a Repository Which is Closed

It is unlikely that any permanent disposal facility will be loaded to capacity, back-filled with sand and clay as described in published reports, and officially sealed before perhaps the year 2030. This leads to the suggestion that a political discussion of safeguards measures for a repository which has been closed can (and should) be postponed for later discussion. Apart from political considerations, the technological nature of IAEA safeguards forty years in the future is difficult to predict. It would be extremely discouraging to suggest that no useful technological advances will have been made in the interim.

Two possibilities perhaps deserve brief mention. One is the use of seismic detectors in combination with site visits at a frequency of perhaps once or twice per year. On first examination this appears to be both feasible and likely to be accepted as effective. Repositories supposedly are located in areas which are not tectonically active; false alarms caused by earthquakes should be rare and in any case easily resolved by visual observation.

Another suggestion is the use of commercially available satellite photos. The advantage of photos is that they would not require periodic site visits; the alleged disadvantage is that the area could be camouflaged to conceal earth-moving activities. Whether this is true is not known; like so many other diversion-related statements, it is not necessary to demonstrate that camouflage would be possible, the mere suggestion places the burden of proof on the advocate to show that camouflage would not be possible.

(Topic for AGM discussion) It is suggested that the Advisors may wish to discuss these and other possibilities for safeguards at closed spent fuel repositories, and to outline an R & D program directed at eventual development of mutually acceptable procedures.

6. PROBLEMS REQUIRING FURTHER STUDY

The final version of this Chapter should be developed in the course of the Advisory Group Meeting itself. Reviewers of the current draft, however, may wish to suggest items which they believe should be included. In this way the Agency could prepare a first draft for discussion by AGM participants.

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APPENDIX C
LIST OF PARTICIPANTS

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LIST OF PARTICIPANTS

(6278B)
Department of Safeguards
Division of Development and Technical Support

1988-09-09
Page 1/6

NOTIFICATION OF A MEETING HELD AT HEADQUARTERS
(Second Revision)

Title of Meeting: Advisory Group Meeting on Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel.

		Opening Meeting	09:30 hrs., Monday 12 September
		Responsible Officer:	Mr. J. Lovett
Dates, inclusive:	12 - 16 September 1988	Room:	A 1366
Place:	UNIDO Board Room C04	Ext:	2194

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APPENDIX D
ADVISORY GROUP MEETING AGENDA

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ADVISORY GROUP MEETING AGENDA

AGM-660

UNIDO Board Room

12 - 16 September 1988

ADVISORY GROUP MEETING ON SAFEGUARDS RELATED TO FINAL DISPOSAL OF NUCLEAR MATERIAL IN WASTE AND SPENT FUEL

Draft Agenda

Monday Morning, 12 September

1. (09:45 am) Opening Remarks - K. Naito, Director, Division of Development and Technical Support.
2. Selection of Chairman.
3. Opening Remarks by Chairman.
4. Adoption of Agenda.
5. Opening Statements by Participants.
   Recess (coffee break) about 10:45 am.
   Recess (lunch) about 12:30 pm.

Monday Afternoon, 12 September

5. (2:30 pm) Opening Statements by Participants (continued).
   Recess (coffee break) about 3:30 pm.
6. Introduction of IAEA Working Paper, Part I: Waste - J. Lovett, System Studies Section.
7. Additional Information on IAEA Experience with Discards and Retained Waste - A. Fattah, System Studies Section.
   Adjourn for day about 5:30 pm.

Tuesday Morning, 13 September

8. (09:30 am) Discussion of Policy Questions Related to Waste Materials.
   Recess (coffee break) about 10:45 am.
   Recess (lunch) about 12:30 pm.

Tuesday Afternoon, 13 September

8. (2:30 pm) Discussion of Policy Questions Related to Waste Materials (continued).
   Recess (coffee break) about 3:30 pm.
   Adjourn for day about 5:30 pm.

6:00 pm Wine and cheese reception hosted by Deputy Director General for Safeguards, VIC Restaurant

Wednesday Morning, 14 September

9. (09:30 am) Introduction of IAEA Working Paper, Part II: Spent Fuel - J. Lovett, System Studies Section
10. Discussion of Policy Questions Related to Spent Fuel
    Recess (coffee break) about 10:45 am
    Recess (lunch) about 12:30 pm

Wednesday Afternoon, 14 September

10. (2:30 pm) Discussion of Policy Questions Related to Spent Fuel (continued)
    Recess (coffee break) about 3:30 pm
    Adjourn for day about 5:30 pm

Thursday Morning, 15 September

10. (09:30 am) Discussion of Policy Questions Related to Spent Fuel (continued)
    Recess (coffee break) about 10:45 am
    Adjourn for day about 12:30 pm

Thursday Afternoon, 15 September

Subgroup meeting (or separate subgroups on waste and spent fuel) to draft conclusions and recommendations to be reported to the Director General

Friday Morning, 16 September

11. (10:00 am) Adoption of Conclusions and Recommendations to be reported to the Director General
    Recess (coffee break) about 10:45 am
12. Concluding Remarks
    Adjourn by 12:30 pm.

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APPENDIX E
U.S. POSITION PAPER

APPENDIX E
U.S. POSITION PAPER

US Responses to Questions Posed in the IAEA Working Paper (STR-243) for the Advisory Group Meeting on Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel - September 12-17, 1988

General Comment

Both topics being addressed by this Advisory Group are complex and both have a number of safeguards questions which are currently unanswered. The US recommends that one or more consultants meetings be convened to address the technical issues in a more informal setting. We encourage the member states to undertake the requisit safeguards related R&D to support the meetings of consultants.

Questions Presented in the Introduction to the Working Paper

Questions Primarily Related to Nuclear Material in Waste.

Question 1: Under what circumstances should the Agency determine that nuclear material in waste has been diluted or has become practicable irrecoverable such that safeguards may be terminated?

Answer 1: It is generally agreed that one should have criteria for terminating IAEA safeguards on nuclear waste. One approach is to define thresholds below which the IAEA may terminate safeguards. There does not appear to be agreement, at this time, on the parameters to be used, the values of the parameters which are acceptable as thresholds, or on ancillary factors which would influence a decision of practicable irrecovery. Parameters which have been suggested as relevant include:

- nuclear material concentration,
- nuclear material type,

- total amount of nuclear material,
- contained radioactivity,
- chemical physical form including the characteristics of the matrix and completion of conditioning processes.
- degree of dispersal of the material, and
- disposal method (e.g. on site, shallow burial, geologic)

Question 2: Where waste materials are "conditioned" in anticipation of placing them in a permanent storage repository, is the act of conditioning itself sufficient to qualify the waste as practicably irrecoverable, or is it necessary that the Agency verify the conditioned waste is in fact transferred to a geological formation?

Answer 2: In general, the conditioning of waste materials is not sufficient in itself to qualify the waste as practicably irrecoverable. The IAEA has to address all of the parameters suggested in the response to question 1. as well.

One might have several different safeguards procedures depending on the type of nuclear material, the concentration of nuclear material, the total amount and the type of conditioning.

- In all cases the IAEA should have the opportunity to verify the declared amount of nuclear material (probably before the final conditioning step).

- Where the conditions for termination include emplacement in a repository or closure of a repository, which might be the case for high amounts and concentrations, C/S should be continued until repository closure with procedures possibly similar to those for spent fuel.

- For intermediate amounts and concentrations one might terminate safeguards after the material is emplaced and the drift backfilled.

- For low amounts and concentrations one might terminate safeguard at the conditioning step.

Independent estimates of the difficulty of recovery should be the subject of member state R&D to permit a more informed approach to the safeguards on waste.

Question 3. To what extent should the Agency insist that the nuclear material content of waste be measured prior to its being placed in a permanent repository?

Answer 3. The IAEA should insist upon material balance accounting based on measurement in all bulk handling facilities. Therefore the State (the facility) should measure waste at some time prior to being placed in a repository and the IAEA should be given the opportunity to verify the State's measurements. The measurement "extent" should be the same as for any other removal from the material balance. The IAEA verification can include random sampling as appropriate for the amount and type of nuclear material.

The final measurement of waste need not occur at the repository. Wherever the last measurement is made, if the amount of nuclear material and concentration are above a threshold to be determined, provision should be made for highly reliable (redudant) C/S to maintain continuity of knowledge until the time it is emplaced in final storage and the long term monitoring initiated, if warranted for the amount and concentration of nuclear material involved.

Question 4: What measurement verification procedures should the Agency implement (and at what stage) prior to agreeing to the termination of safeguards for waste?

Answer 4: Measurement verification procedures prior to termination of safeguards for waste are those to verify that the material is below the termination thresholds to be established for waste (see answer question 1). The safeguards on waste may be terminated at any stage where it is determined that the threshold criteria for waste safeguards termination are met.

The measurement procedures will depend on several factors which include the parameters in the answer to question 1. One of the tasks for a consultants group could be to catagorize the measurement circumstances. For certain materials and forms one would expect that a final measurement is made prior to conditioning with C/S used to preserve the continuity of knowledge until termination is acceptable.

Question 5: Where nuclear material is transferred to the retained waste category pursuant to INFCIRC/153, what safeguards measures should the Agency implement?

Answer 5: The Agency should require proper records and reports as for any material balance area. Where the retained waste is in item form, the IAEA should have occasional item identity verification. The transfers into retained waste should be based on measured values. It is possible that additional verification procedures should be followed on an occasional frequency. The subject of safeguards to be applied to retained waste should be the subject of a review.

Questions Primarily Related to Spent Fuel.

Question 6. Under some circumstances a State may wish to place in permanent storage nuclear material of a form which in itself the Agency cannot agree has been diluted or has become practicably irrecoverable. Does the act of placing nuclear material (e.g., spent fuel) in permanent storage constitute making that material "practicably irrecoverable"?

Answer 6: In general no. Possibilities exist for the recovery of the nuclear material up through and following closure of a permanent geologic repository. Any country that has emplaced waste or spent fuel can at some time later retrieve it.

Other forms of permanent storage would have to be considered should they be proposed.

Question 7: Both "permanent storage facilities" and "long-term retrievable storage facilities" are being developed. What specific characteristics should a storage facility possess in order for the Agency to agree that nuclear material placed therein has been rendered practicably irrecoverable?

Answer 7: The only characteristics a storage facility can possess that would make contained material practicably irrecoverable are those that would eliminate all credible possibilities for the recovery of the material.

Question 8: To what extent should the Agency insist that spent fuel be measured prior to being placed in a permanent repository?

Answer 8: To meet the objectives of safeguards it is more important to assure the continued integrity of the fuel than to have a direct measurement of the special fissionable materials content. Currently the Pu content is based on measurement of the uranium at the fuel fabricator and an estimate by the reactor operator of the produced Pu. Agency safeguards use this value coupled with C&S and attributes NDA safeguards measures to assure the integrity of the fuel assembly.

Spent nuclear fuel that remains accessible until emplacement in a repository could be (and currently is) periodically verified by NDA to verify that the item is spent nuclear fuel and that the integrity of the assembly has been maintained. It may be necessary that material handling operations that change the containment of the spent nuclear fuel rods (e.g. consolidation) be preceded and followed by measurements to verify that the nuclear material content does not change.

Safeguards approaches for spent fuel consolidation operations should be addressed in a suitable R&D task. It is expected that there will be a number of features which will make the safeguards approaches facility specific.

Question 9: What measurement verification procedures, and at what stage, should the Agency implement prior to agreeing to the termination of safeguards, or prior to the placing of spent fuel in permanent storage?

Answer 9: The Agency should not agree to the termination of safeguards on spent nuclear fuel.

The stage at which the spent fuel is verified is not as critical as the provision of redundant and successful C/S following the last verification by measurement. The measurement procedure will depend on the stage at which the final measurement is to be performed. The review of recommended measurement procedures as a function of the circumstances surrounding the spent fuel should be a topic for the follow-on consultants meetings.

Question 10: To the extent that spent fuel placed in permanent storage facilities or long-term retrievable storage is not determined to be practicably irrecoverable, what safeguards measures should the Agency implement?

Answer 10:

(1) Reliable and redundant C/S sufficient to assure successful C/S should be maintained following verification by NDA.

(2) Item accounting and associated records and reports should be maintained for all sealed containers (spent fuel as well as consolidated rod packages).

(3) Proper accounts showing amounts and locations of all items should be maintained for the repository.

(4) Prior to closure, C/S should be sufficient to provide assurance of no unauthorized or unaccounted for removal of material.

(5) Continuation of safeguards following closure of the repository will require an assessment of the applicable C/S. The safeguards approach must not interfere with or preclude the function of the permanent repository. The safeguards approach

should be designed to detect any attempts to compromise the containment provided by the geologic matrix of the repository for retrieval of the nuclear matterial. This approach might include the use of vibration monitors and other detectors that would detect any drilling or other tunnelling activity in the proximity of the repository. In addition, measures to verify that no open tunnels exist in, or in the proximity of, the repository might be required. Periodic IAEA visits would be required to verify the condition of the accessible tamper-indicating devices and of the detection equipment. The IAEA safeguard approach might also include tours of the area immediately surrounding the repository site to verify that no tunnelling or mining activities are occuring.

The specific details of C/S at the storage site will probably be site specific. Identification and evaluation of applicable C/S should be undertaken.

Safeguards Questions with regard to Radioactive Waste and Spent Nuclear Fuel.

Question 1.(Sec 3.2) : Should the nuclear material content of waste materials be determined by agreed measurement procedures, and if so should reported measurement data be verified by agreed inspection procedures, prior to placing those wastes in permanent repositories and agreeing to a termination of safeguards.

Answer 1.(Sec 3.2) The nuclear material content of waste materials should be determined by agreed measurement procedures prior to terminating safeguards on them. In general, all components of the material balance, including wastes should be based on measured values. By difference accounting should not be used. The nuclear material content of wastes which is destined for permanent repositories or for termination of safeguards and which contain nuclear material in excess of agreed diminimus amounts

should be verified. The state's measurements and the IAEA's verification thereof should be made at a suitable stage in the processing of the waste, and C/S applied thereafter, to preserve the continuity of knowledge until the conditions for termination of safeguards have been met.

Question 2.(Sec. 3.3.1) For waste which does not require conditioning prior to final disposal, on what basis should the Agency agree to classification of waste materials as measured discards, and thereby to a termination of safeguards, when the total quantities thus classified are expected to be in the range of several SQ per year?

Answer 2.(Sec 3.3.1) Criteria or guidelines for termination of safeguards, i.e. for determination by the IAEA that the nuclear material "has been consumed, or has been diluted in such a way that it is no longer useable for any nuclear activity relevant from the point of view of safeguards or has become practicably irrecoverable", are needed for all types of wastes, including those which do not require conditioning. The fact of conditioning and its nature are among the factors expected to affect the criteria for termination.

Question 3.(Sec 3.3.1) For waste which is classified as measured discards in accordance with the question immediately above, (2)(Sec 3.3.1), should waste be terminated prior to the time when the waste has been transferred to a permanent repository, or prior to the time when the waste has passed a specific point in the operation of that facility?

Answer 3.(Sec 3.3.1) At the time the material meets the criteria for termination, safeguards can be terminated. The location should not, in general, be a determining factor. If the material meets the criteria before emplacement in geologic storage, then safeguards can be terminated at the time and place where the

material is determined to meet the conditions for termination. No further safeguards measures are needed after termination except to assure that the material is not resubmitted for termination as a part of a process to overstate measured discards.

In general, the factors to be reflected in the criteria for termination should include the stage of processing or conditioning and the recoverability of the contained nuclear material as affected by its introduction into a repository and the status of the repository. Until the necessary studies and assessments are completed, however, and criteria for termination adopted, generalizations on the sort raised in this question are not possible.

Question 4.(Sec 3.3.2) For retained waste, (i.e., waste which is not classified as measured discards), which the facility intends to dispose of in some manner such as shallow land burial, what safeguards measures should the Agency implement?

Answer 4.(Sec 3.3.2) In all cases accounts should be kept which show the amount, form, and location. The situation identified in question 4 is among those anticipated in the second sentance of paragraph 35 of INFCIRC/153. The "appropriate safeguards measures" will depend on the circumstances and probably on the same kinds of parameters on which the criteria for terminations should be based. Necessary inputs for the development of any advice on this subject include information on the nature andextent of use by the IAEA of "retained wastes" and on any difficulties and other experiences to date in these uses.

Question 5.(Sec 3.3.2) What level of safeguards effort should the Agency apply to material which meets agreed criteria for termination of safeguards (measured discards) which has not yet been discarded.

Answer 5.(Sec 3.3.2) As indicated in the anwer to question 4, it is not now possible to generalize on the nature or intensity of safeguards on the materials identified in question 5. Safeguards should not be terminated on measured discards until the IAEA has determined that the conditions for termination have been met. These conditions may or may not include actual discard (dispersal), depending on all of the factors that should be taken into account in establishing termination criteria and taking into account the need to ensure that material is not resubmitted for termination in order to overstate measured discards. As a principle, C/S should be used from the time of verification of the content of the material until the conditions are met.

The Agency should apply similar considerations to retained waste. The criteria for acceptability for classification as retained waste and the safeguards measures appropriate for various circumstances relating to retained waste should be established. In addition, in principle, C/S should be used, depending on the quantity, type, etc. of the material, to ensure completeness of knowledge of transfers from retained waste or of material remaining in retained waste.

Question 6.(Sec 3.4.1) For conditioned waste, should the Agency determine that waste materials are practicably irrecoverable, and terminate safeguards, when the waste has been conditioned for final disposal in accordance with one of the processes described in Section 2.4, regardless of whether it has been transferred to a permanent repository?

Answer 6.(Sec 3.4.1) Termination crieria should be defined for conditioned waste, and these may be a function of the type of conditioning and emplacement in a repository as indicated in the answer to question two.

The continued reference to the use of termination criteria rather than the act of conditioning is to assure that an unusually high concentration or amount of nuclear material in a special case will not introduce a vulnerability into the safeguards system.

Questions Relating to Spent Fuel.

Question 7.(Sec 5) Does the act of placing spent fuel in a permanent storage repository constitute making that spent fuel practicably irrecoverable?

Answer 7.(Sec 5) No. Potential pathways exist for the recovery of the nuclear material up through and following closure of a geologic repository. A nation which has emplaced spent nuclear fuel can use the same technology and skill to retrieve it.

Question 8.(Sec 5) If the answer to the above question is yes, under what circumstances (e.g., at what point in the process of final disposal) should the Agency determine that the spent fuel has become practicably irrecoverable, and accordingly terminate safeguards?

Answer 8.(Sec 5) The answer to question 7 was no.

Question 9.(Sec 5) If the answer to the above question (question 7) is no, what continuing safeguards measures should the Agency apply to spent fuel which has been placed in a permanent storage repository?

Answer 9.(Sec 5) Item materials accounting should be perform-

ed by the State which provide, inter alia, records of the items, content, and location in the store. IAEA knowledge of the amount of contained nuclear material is preserved from the reactor through fuel consolidation by means of verification NDA and C/S. Knowledge of the amount of contained nuclear material from consolidation through repository closure is preserved by C/S. Careful consideration of such C/S systems is needed to minimize the risks of failure and to provide means for reestablishing continuity of knowledge in the event of C/S failure.

The Agency's safeguards approach for spent fuel in geologic repositories during the time the repository is in the process of being filled will differ from that following closure of the repository.

(a) During the filling of the repository, the following are some candidate ideas which might warrant detailed analysis:

- Following emplacement, the emplacement cavity could be sealed and a fingerprint radiation measurement taken at the plug of the emplacement cavity.

- Following backfilling of a drift, the drift could be sealed and sensors located to detect any physical activity within the sealed drift.

- Following backfilling of a tunnel, the tunnel could be sealed and sensors located to detect any physical activity within the tunnel.

(b) Following backfilling of a repository, the following are candidate ideas:

- The repository could be sealed and sensors located to detect any physical activity within the repository.

- Geologic soundings could be made to verify that there are no unfilled tunnels leading to the repository.

- The repository site could be visited periodically:
  - to verify the condition of the surface seals (including tamper-indicating devices),
  - to verify the condition of the detection equpment, and
  - to assure that no excavation work is occurring which could be associated with retrieval of nuclear material.

- Satellite photographs of the repository area might provide information that no excavation work is being performed.

Request (Sec 5.2) The Advisors are asked to discuss the problems outlined above, and to provide suggestions regarding an R&D program leading to the development of an acceptable safeguards approach for spent fuel dismantling/preparatory facilities.

Response to request (Sec 5.2) The spent fuel dismantling/preparatory step and the fuel consolidation step represent some unanswered safeguards problems. The specific safeguards measures which would comprise an effective, practical safeguards approach would be process design specific.

Studies that may need to be performed to derive an acceptable safeguards approach are:

- Survey of the proposed and actual designs of spent fuel dismantling and preparatory facilities to determine the common elements and to identify the unique differences.

- Determine measurement techniques that may be capable of directly determining the nuclear material contained in the spent fuel.

- Determine key measurement points where the spent nuclear fuel is placed in interim storage before and after dismantling and preparatory activities.

- Identify potential C/S systems.

- Assess the advantages of having the dismantling and preparatory activities a separate material balance area.

- Based on the above, define alternative safeguards approaches for dismantling and preparatory activities.

Question 10.(Sec 5.3.2) Should the Agency determine that spent fuel which has been placed in a permanent repository has become practicably irrecoverrable, and terminate safeguards?

Answer 10.(Sec 5.3.2) For the repositories identified to date, no. Placement of the spent fuel in such a repository leaves the fuel open to recovery. The technology and capabilities which were used to originally emplace the spent fuel can be used to retrieve it.

Question 11.(Sec 5.3.2) If the answer is in the affirmative, at what point on its route from reactor to possible AFR storage to preparation facility to permanent repository does spent fuel become practicably irrecoverable?

Question 12. (Sec 5.3.2) What measurements or verifications should be performed on spent suel prior to a determination that it is practicably irrecoverable?

Question 13. (Sec 5.3.2) What verifications of continuing safeguards measures should be required subsequent to measurement yet prior to determination that the fuel has become practicably irrecoverable?

Answer 11, 12, 13 (Sec 5.3.2) The answer to question 10 was in the negative.

Question 14. (Sec 5.3.3) Should the Agency determine that placing spent fuel in a permanent repository does not constitute making that spent fuel practicably irrecoverable, and accordingly continue to apply safeguards?

Answer 14. (Sec 5.3.3) Yes. R&D programs should be defined and performed to determine the safeguards measures to be appropriate for the various planned repositories to enable conclusions by the IAEA that the material continued to be present in the repository.

Question 15. (Sec 5.3.3) What measures or verifications should be performed on spent fuel prior to its being placed in a permanent repository?

Answer 15.(Sec 5.3.3) Safeguards measures sufficient to assure the Agency of the nuclear material content of the spent fuel and sufficient to verify the materials accounting of the State. In general this would be verification by NDA measurement at some stage followed by redundant C/S to assure the continuity of Agency knowledge following that measurement. Specific measures depend upon the specifics of the materials handling for that fuel and that repository. A detailed specific response to this question should be one of the products of the R&D and consultants meetings recommended above.

Question 16. (Sec 5.3.3) What safeguards measures should be required for spent fuel which has been placed in permanent storage repositories while those facilities are still open?

Answer 16. (Sec 5.3.3) This answer to this question is contained in part (a) of the answer to question 9.

Suggestion (Sec 5.4) It is suggested that the Advisors may wish to discuss these and other possibilities for safeguards at closed spent fuel repositories, and to outline an R&D program directed at eventual development of mutually acceptable procedures.

Response to suggestion (Sec 5.4) The US believes that these possibilities and a related R&D program are appropriate subjects for consultants meetings convened to lead to agreement on acceptable procedures. Initial ideas for such R&D are contained in part (b) of the response to question 9.

APPENDIX F
WEST GERMAN POSITION PAPER

APPENDIX F
WEST GERMAN POSITION PAPER

Ref.: Advisory Group Meeting on Safeguards related to final disposal of nuclear material in waste and spent fuel

- Criteria for the termination of safeguards

R. Weh, DWK - Hannover
G. Stein, KFA - Jülich
R. Gerstler, BMFT - Bonn

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1. According to Art. 11 of INFCIRC/153 "... safeguards shall terminate on nuclear material upon determination by the Agency that the material has been consumed or has been diluted in such a way, that it is no longer usable for any nuclear activity relevant from the point of view of safeguards, or has become practically irrecoverable."

   Article 35 spezifies that where the conditions of article 11 are not met, but the State considers that the recovery of safeguarded nuclear material from residues is not for the time being practical or desireable, the Agency and the State shall consult on the appropriate safeguards measures to be applied.

   Although the definition of measured discard and retained waste are specified in Article 107 (in addition to Articles 11, 35), the wording of these Articles is all interpretable and allows a wide range of discretion.

2. Especially in the backend of the fuel cycle, it is highly important that the designer of a nuclear facility can rely on practicable and clear criteria and guidelines for termination of safeguards on waste with the necessary commitments by the parties involved.

...

He needs - early in the design phase and long before starting with construction of a plant - a clear and binding statement, what is meant by "practically irrecoverable" or "no longer of any nuclear use" to care for suitable arrangements for measurement and advice on possible requirements for storage facilities, which are not to be in contradiction to national regulations in his national nuclear licence procedures.

3. In the course of the international discussion on safeguards concepts for reprocessing plants, this idea was often stressed, that an exchange of information and discussion on safeguards relevant features are essential to effective safeguards beginning at an early stage in the design process and cooperation between the state and the IAEA in the development of the safeguards approach and its interaction on plant design and operation.

   In an industrial reprocessing plant nearly 50 % of the work shops are related to waste treatment, indicating the importance of waste treatment with regard to safeguards.

4. However neither in the framework of the SIR-criteria nor in bilateral discussions definite criteria for termination of safeguards have been established for practical application.

5. General considerations on termination of safeguards

   5.1 In accordance with national regulations of the state as regards radiation protection measures in transfering nuclear material into waste, this then defined material category should be treated as "measured discards".

   - the decision of a state is based on the fact that this material is practically no longer usable for any nuclear activity or has become practically irrecoverable.

...

- the category "retained waste" creates in day-to-day plant operation a problem for the state/operator as well for the inspectorates,
  - for the operator: large amounts of waste material in a plant which may conflict with licence requirements (delayed final disposal, capacity limitations, radiation regulation)
  - for the inspectorates: large amounts of material with extremely low concentrations of nuclear material, impossible to be measured accurately and binding a significant amount of manpower if to be verified - a material category of extremely low importance in view of proliferation potential.

5.2 Termination should be performed at the facility producing this waste as early as possible in the process and where verification is still possible, but definitely before conditioning.

5.3 Termination should be based on qualitative and/or quantitative plant specific criteria, also based on those for national radiation protection regulations.

5.4 The general rule that a facility may remove material in defined limits as "measured discard" without further approval by the Agency has demonstrated its practicability and should be continued with regard to manpower and cost-savings.

5.5 Improvements in termination procedures for non nuclear use are necessary to avoid safeguards at installations without any relevance for theoretical diversion.

5.6 If waste is recovered, it is the obligation of the state to treat this material as nuclear material imported or at the starting point of safeguards.

...

5.7 Because of the large amount of strategic important material in spent fuel, decrease of radioactivity with storage time and thus better accessibility for recovering the fissile material, spent fuel placed in permanent storage should not be considered to be terminated.

However, safeguards concepts as currently discussed within the Agency should be changed for these applications into intensive use of containment/surveillance systems.

5.8 Within the German support programme these problems have been identified and specific tasks with regard to technical criteria for termination of safeguards as well as safeguards approaches for conditioning facilities and final disposal have been mutually agreed.
(Task Descriptions are attached)

6. Answers to Questions for AGM consideration

(Question No. 1 for AGM consideration) Should the nuclear material content of waste materials be determined by agreed measurement procedures, and if so should reported measurement data be verified by agreed inspection procedures, prior to placing those wastes in permanent repositories and agreeing to a termination of safeguards?

6.1 Yes, but measurement and inspection procedures should take into account plant specific situations, as early as possible before conditioning processes and final disposal. The material category "retained waste" should be avoided.

(Question No. 2 for AGM consideration) For waste which does not require conditioning prior to final disposal, should the Agency agree to classification of waste materials as measured discards, and thereby to a termination of safeguards, when the total quantities thus classified are expected to be in the range of several significant quantities per year?

6.2 Yes, if this is considered to fulfill quantitative and/or qualitative criteria of measured discard.
Neither the absolute amount of fissile material nor the fact of further conditioning should be the yard stick for this classification.

...

(Question No. 3 for AGM consideration) For waste which is classified as measured discards in accordance with question No. 2, should safeguards be terminated prior to the time when the waste has been transferred to a permanent repository, or prior to the time when the waste has passed a specific point in the operation of that facility?

6.3 Safeguards should be terminated when the waste has passed a specific point in the operation of the facility concerned to make use of unambigious measurements and verification procedures.

(Question No. 4 for AGM consideration) For retained waste, (i.e., waste which is not classified as measured discards), which the facility intends to dispose of in some manner such as shallow land burial, what safeguards measures should the Agency implement?

6.4 It is generally questionable whether "retained waste" can be disposed of at all.
If it is disposed it should be preferably terminated (measured discard), otherwise a comparable amount of inspection as for final disposal of spent fuel must be implemented to apply credible safeguards.

(Question No. 5 for AGM consideration) What level of safeguards effort should the Agency apply to material which meets agreed criteria for termination of safeguards (measured discards) which has not yet been discarded?

6.5 This depends on plant specific situations, generally verification procedures should concentrate on those locations "where nuclear weapons could readily be made" (Art. 6 c).

(Question No. 6 for AGM consideration) For conditioned waste, should the Agency determine that waste materials are practicably irrecoverable, and terminate safeguards, when the waste has been conditioned for final disposal in accordance with one of the processes described in Section 2.4, regardless of whether it has been transferred to a permanent repository?

6.6 Yes, see 6.1

...

(Question No. 7 for AGM consideration) Does the act of placing spent fuel in a permanent storage repository constitute making that spent fuel practicably irrecoverable?

(Question No. 8 for AGM consideration) If the answer to the above question is yes, under what circumstances (e.g., at what point in the process of final disposal) should the Agency determine that the spent fuel has become practicably irrecoverable, and accordingly terminate safeguards?

(Question No. 9 for AGM consideration) If the answer to the above question is no, what continuing safeguards measures should the Agency apply to spent fuel which has been placed in a permanent storage repository?

(Questions No. 10-13 for AGM Consideration) Should the Agency determine that spent fuel which has been placed in a permanent repository has become practicably irrecoverable, and terminate safeguards?

If the answer is in the affirmative, at what point on its route from reactor to possible AFR storage to preparation facility to permanent repository does spent fuel become practicably irrecoverable?

What measurements or verifications should be performed on spent fuel prior to a determination that it is practicably irrecoverable?

What verifications or continuing safeguards measures should be required subsequent to measurement yet prior to determination that the fuel has become practicably irrecoverable?

(Question No. 14-16 for AGM Consideration) Should the Agency determine that placing spent fuel in a permanent repository does not constitute making that spent fuel practicably irrecoverable, and accordingly continue to apply safeguards?

What measurements or verifications should be performed on spent fuel prior to its being placed in a permanent repository?

What safeguards measures should be required for spent fuel which has been placed in permanent storage repositories while those facilities are still open?

6.7 - 6.14

Spent fuel placed in permanent storage and final disposal should not be considered to be terminated for safeguards, because for these large amounts of strategic important nuclear material criteria like consumed, diluted or practicably irrecoverable are not applicable.

The Agency should have an adequate assurance that spent fuel has been placed into the repository and after filling and closing of the repository is still present.

In studying the safeguards problems it seemed to be advantageous in any case to differentiate between the time the repository is open for filling operation and the time after which the repository is closed.

It is obvious that during emplacement actions, an effective safeguards approach is much more difficult to be implemented than in a static situation.

Safeguards measures are heavily depended on the degree of inspector access envisaged to the underground facilities including the waste disposal area, which depends on the plant specific emplacement technology, the design of the site, the choice of the repository medium, the specific method of conditioning spent fuel and the form and typ of spent fuel itself. It should be considered whether the necessary assurance the Agency has to provide could be obtained by surface routine inspection activities only.

In any case the current Agency policy that all nuclear material quantities even under successful C/S have to be reverified cannot be applied in these situations.

APPENDIX G
FRENCH POSITION PAPER

APPENDIX G
FRENCH POSITION PAPER

ADVISORY GROUP ON SAFEGUARDS RELATING TO FINAL DISPOSAL OF NUCLEAR MATERIALS IN WASTE AND SPENT FUEL

COMMENTS FROM THE FRENCH CONSULTANTS ON THE SECRETARIAT WORKING PAPER STR 243.

1) A preliminary remark refers to the objectives of the advisory group. The combination of the issues relating to wastes and to spent fuel makes the matter somewhat confusing. It should be more efficient to concentrate the tasks of the consultants :

- either on the **problem of termination of safeguards** in respect of para 11, 12, 13 and 35 of the INFCIRC 153, including "**measured discards**".
- or on the problem of "**retained wastes**" (which may include the issues arising from the final disposal of spent fuel from another scope of considerations).

The secretariat working paper deals with two quite different problems which, in our opinion, should not be dealt with in the same document, nor by the same working group. One is the categorization of nuclear wastes, and the way of safeguarding "**retained wastes**" or terminating safeguards on "**measured discards**". The other is the way of safeguarding nuclear fuel stored in retrievable or nonretrievable storages. Nuclear fuel in permanent repositories will never be technically irrecoverable for a State, but should rather be considered as a "plutonium mine", because of the quantities of plutonium contained, and safeguards can therefore not be terminated on them.

.../...

2) Another remark relates to the wording used in the working paper. Terminology is a very important problem. It is indeed noted that the word "**waste**" requires a clear meaning,otherwise the discussions will be less constructive and bring some misunderstanding. In this context the word "**waste**" **should apply only to nuclear material which has been consumed or diluted** in such a way that it is no longer usable **for any nuclear activity relevant from the point of view of safeguards** or has become practicably irrecoverable and which consequently is disposed of, that is to say "**measured discards**".

This includes inter alia what is defined in another context as "**radioactive waste**" which is "any material, that contains or is contaminated with radionuclides at concentrations or radioactivity levels greater than the exempted quantities established by the competent authorities and for which no use is foreseen".

The word "**effluent**" should apply to "any nuclear material, which could be evacuated in the environment, subject to controlled and regulated prescriptions".

Generally liquid wastes are either solidified and related to solid wastes and/or disposed of as "**effluent**".

In conclusion, the word "wastes" will apply only in relation with the "measured discards" category : "nuclear material in concentrations or chemical forms which do not permit economic recovery and <u>which is designated for</u> <u>disposal</u>".

.../...

3) In the field of health and safety, issues relating to final disposal of nuclear materials contained in wastes have been under continuous consideration from french authorities for many years.

This examination was prompted by several objectives :

- safety rules and prevention against criticality hazards.
- good management practices, in particular accurate closing of material balance.

These different considerations have led to a very strict waste management policy, implying wastes sorting performed by the operators, measurement and control of nuclear materials deemed to be no longer usable before transfer to "**measured discards**" category.

In accordance with safety authorities, french operators have set up quality assurance procedures defining the various steps of wastes management since the wastes have been generated.

The secretariat working paper seems to have been willing to replace the distinction between "**retained waste**" and "**measured discard**", by a distinction between "**conditioned wastes**" and **not conditioned wastes,** which does not seem to have any legal or technical basis. Dilution is explicitely mentioned by INFCIRC 153 (corrected) (para 11) and INFCIRC/66/REV.2 (para 26.C) as a characteristic for terminating safeguards without any reference to the need of any kind of special conditioning for final disposal. Actually, nuclear material in waste streams are practically irrecoverable for any use of safeguards significance, independently of the fact that they are, or not, conditioned for final disposal.

In our opinion, notwithstanding the presence of the word "waste", the **retained wastes**" category includes different nuclear materials such as what is commonly defined as "scraps" (rejected nuclear material removed from the process stream) or "residues" in respect of section 35 of INFCIRC 153, reprocessed depleted uranium awaiting for commercial possibilities of use or reenrichment, spent fuel in repositories..

These nuclear materials which are not at present recovered or used for economical or technical reasons, but which can be recovered, if desirable, at a later stage, must remain subject to some form of appropriate safeguards procedures, which may include "freezing the accountancy".

Indeed it appears unrealistic to devote to such category an effort for verification with the same detection probability and defect tests than for the other nuclear materials transferred from or present in the M.B.A. at the time of the PIT/PIV. Only acceptable containment/surveillance devices, gross defect tests, as applicable, with a medium detection probability appear to be reasonable, whatever the safeguards agreement is.

The justification of the procedures described in the secretariat working paper relating to the "**retained wastes**" seems consequently to be ambiguous and questionable. Great difficulties are arising when implementing safeguards measures to nuclear materials which are no longer reported to the Agency or at least maintained in the operating and accounting records of the material balance area.

.../...

This category of nuclear materials should be used only in very limited specific cases subject to previous arrangements with the Agency.

5) Concerning the safeguards measures applying to the nuclear materials, amongst which those intended to be disposed of as "**measured discards**", the Agency has a sufficient technical knowledge of the operating and management procedures by way of the detailed design information given on the interested facility. This information has to be verified by means of examination and inspections as foreseen in para 46, 47 and 48 of the INFCIRC 153 (corrected) and 30, 31 and 32 of INFCIRC/66/REV.2.

The operations of transferring nuclear materials to the "**measured discards**" category should be verified at the different levels of operating and accounting records and reports.

Technical justifications of the discarded quantities should be made available to the inspectors as measurements results or estimates.

The determination procedures of the quantities contained in the **measured discards** are essentially variable according to the specific features of the relevant facility and the characteristics of the discarded materials.

.../...

It is essential for the Agency to be informed of these procedures in order to be able to determine or estimate as well as possible the quantities substracted from the inventory of the material balance area.

The possibility of independent verification by the Agency of operator's measurements before discard in an industrial context, in respect with para 4 b) and c) of INF CIRC 153, is doubtful.

Observation of the operator's measurements could be made under agreed procedures [see appendix, answer to question 4 (introduction)].

6) **The long term storage of spent fuel assemblies is quite another matter.**

These nuclear materials are still safeguarded, but become inaccessible (or very difficult to access) to item counting, item identification and nondestructive measurement. The Agency is consequently not in a position to perform the usual material accounting verifications.

It is highly expected that containment-surveillance techniques should be more intensively used for giving the necessary means of providing evidence of nondiversion.

Special effort of research and development should be devoted to this specific topic through the assistance of the support programmes.

The following conditions should be met :

- the nuclear material is verified by item counting and identification before to be packed and shipped to the storage.
- The packaging is identified and the continuity of knowledge is maintained during the transfer to the long term storage.
- The location of each packaging is verified and monitored by an appropriate system.
- The operating and accounting records should be kept at the relevant storage facility.

.../...

- The design information provided to the Agency is verified at appropriate frequencies to confirm the storage conditions.
- Containment/surveillance systems are implemented in order to maintain the continuity of knowledge.

APPENDIX : Preliminary answers to STR 243.

APPENDIX

PRELIMINARY ANSWERS TO THE SPECIFIC QUESTIONS OF THE DOCUMENT STR 243

I - INTRODUCTION

Answer to question 1 :

This a matter of fact to be evaluated for each facility according to technical realities, and to be defined in each Facility Attachment. The only thing the Working Group can do is to give some examples, like fission products, hulls, etc...

Answer to question 2 :

Conditioning is not a necessary condition for the termination of safeguards on waste streams.

Answer to question 3 :

Wastes to be disposed of in a permanent repository are, by definition, and contrary to fuel elements, "**measured discards**". Such discards are supposed to be measured, to the extent feasible, not before disposal in the permanent repository, but at the output of the MBA where they are generated.

.../...

Answer to question 4 :

The measurement by the operator of nuclear material contained in "**measured discards**" may vary from one waste flow to another, and from one operator to another. No advice can be given as to the kind of verifications to be performed by the Agency, without knowing what the operator does. This is to be settled in each Facility Attachment. It is likely that, in many cases, the measurements and verifications will relate to thresholds, rather than to precise measures.

Answer to question 5 :

There is no general answer to such a question. **Retained wastes** may be as different as reprocessed uranium or depleted uranium awaiting for commercial possibilities of reenrichment, metallic or UO2 scraps of enriched uranium, fabricated defective fuel not considered worthwile recycling for the time being, wastes containing more nuclear material than acceptable to be considered as "**measured discards**", etc... It is up to each Facility Attachment to determine the nature of safeguards measures to be implemented, according to the specificities of each case. It is likely that, in most cases, containment verifications will play a predominant role.

Answer to question 6 :

No

.../...

Answer to question 7 :

There is no conceivable way of making the material contained in fuel elements deposited in a permanent storage facility practicably irrecoverable for a State willing to divert it.

Answers to questions 8 and 9 :

Such measurement, if practicable, is only necessary if the identification of the fuel assembly is not possible, or in case there is doubt about its integrity.

Answer to question 10 :

As indicated on page 53 of the document, it is unlikely that any permanent repository will be closed before 2030. An open permanent repository or a retrievable storage being quite similar to an interim storage for practical safeguards purposes, it will be ample time to start studying the problem after 2000, and the Agency has other priorities.

.../...

II - SECTION 3

Answer to question 1 :

See answers to questions 3 and 4 of the Introduction. Measurement or verification of the threshold of nuclear material content of waste streams is to take place at the output of the MBA where these wastes are generated.

Answer to question 2 :

All nuclear materials diluted in wastes streams in such a way as to make them practicably irrecoverable for purposes related to IAEA Safeguards should be classified as "**measured discards**" and thereby no more subject to safeguards, whatever are the quantities involved.

Answer to question 3 :

Safeguards should be terminated when the wastes have been transferred to the **measured discards** category, that is to say, in most cases, when they leave the MBA where they have been generated.

.../...

Answer to question 4 :

It is highly unlikely that "retained wastes" as they are defined legally in the framework of INFCIRC 153 be ever disposed of in the way suggested. Such disposal would probably be the proof that the so-called "**retained wastes**" were actually "**measured discards**".

Answer to question 5 :

None

Answer to question 6 :

As already indicated. safeguards should be terminated, when the wastes have been transferred to the measured discards category (see answer to question 3).

III - SECTION 5

Answer to question 7 :

No

Answer to question 9 :

To be studied case by case, according to the specificity of each permanent repository. Safeguards measures should be set up by year 2000.

.../...

Answers to questions 10-13 :

See preceeding answers

Answer to question 14 :

Yes

Answer to question 15 :

The measurements to be performed on spent fuel prior being placed in a permanent repository depend on the measurements already made since the unloading of the fuel from the reactor, and on the assurances one may have or not concerning the fuel integrity. If identification and integrity of the fuel element can properly be verified, if feasible one NDA verification of the nuclear materiel content of such fuel element between reactor unloading and permanent repository should be sufficient.

Answer to question 16 :

As long as a permanent repository is still open, it is similar, for safeguards purposes, to a retrievable storage.

APPENDIX H
EURATOM POSITION PAPER

COMMISSION
OF THE EUROPEAN
COMMUNITIES

Directorate-General of Energy

Directorate of Euratom Safeguards

Luxembourg 31 JUL 1988

APPENDIX H
EURATOM POSITION PAPER

Answers to Questions 1-10 in the introduction to the paper

Question 1: Under what circumstances should the Agency determine that nuclear material in waste has been diluted or has become practicably irrecoverable, such that safeguards may be terminated?

Answer (personal view of participant) Waste containing U-235 or Pu may be said to be irrecoverable if the hypothetical cost of recovery of pure U-235 or Pu under standard conditions of quantity and availability of technology is considerably higher (say by a factor of 10) than the cost of recovering pure U-235 from a mine or pure Pu from spent fuel. This concept can indeed be interpreted to apply to waste which has been made inaccessible either by the choice of location or by conditioning. The arguments opposing this view on p6 of the working paper are misconceived. The advantage of a cost estimate is that cost is the only yardstick in which can be amalgamated the components of difficulty of recovery attributable to different factors such as matrix dilution, isotopic dilution, chemical or mechanical treatment, radioactivity, and the various types of geographical, geological, mechanical, radiological (etc) inaccessibility.
Comparison may be made with the measure of the difficulty of a golf course where the yardstick might be the estimated number of strokes for a zero-handicap player. For individual players the difficulty of the course depends on an amalgamation of this estimate and their personal qualities, but this range of variability does not throw doubt on the usefulness of the single yardstick.

Question 2: Where waste materials are "conditioned" in anticipation of placing them in a permanent storage repository, is the act of conditioning itself sufficient to qualify the waste as practicably irrecoverable, or is it necessary that the Agency verifiy that the conditioned waste is in fact transferred to a geological formation?

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Answer (personal view of participant) The above test should be applied to given types of conditioned material. It will be remembered that the criteria for conditioning, as mentioned too briefly in the working paper (p 21) is "mandated by considerations of environmental protection, not safeguards". The paper states that conditioned material is practicably irrecoverable. No argument is given for this conclusion, and no primary or even secondary literature on this topic is given in the list of 26 references. In our view an examination of such references would not always support the conclusion given.

Question 3: To what extent should the Agency insist that the nuclear material content of waste be measured prior to its being placed in a permanent repository?

Answer The Agency should insist on doing the best measurements which are practically possible, of sufficient quality to exclude the overstatement diversion scenario

Question 4: What measurement verification procedure should the Agency implement (and at what stage) prior to agreeing to the termination of safeguards for waste?

Answer The measurement of waste is difficult, inaccurate and costly. To the extent that measurement cannot be satisfactorily achieved, to that extent must reliance be placed on containment and (human and instrumental) surveillance measures. The several references on the working paper to "basic premises" of safeguards, laying stress on material accountancy and physical inventory are not supported. The basic mission of safeguards is to detect and deter diversion by the best and most practical means available. In no case must theoretical argument be used to make the theoretically perfect the enemy of the best which is practically possible.

Question 5: Where nuclear material is transferred to the retained waste category pursuant to INFCIRC/153, what safeguards measures should the Agency implement?

Answer Efforts should be made to persuade operators of the benefits of keeping this material on inventory. Safeguarding should rely primarily on containment and surveillance methods. especially if retention on inventory is not possible.

Question 6: Under some circumstances a State may wish to place in permanent storage nuclear material of a form which in itself the Agency cannot agree has been diluted or has become practicably irrecoverable. Does the act of placing nuclear material (e.g., spent fuel) in permanent storage constitute making that material "practicably irrecoverable"?

Answer No.

Question 7: Both "permanent storage facilities" and "long term retrievable storage facilities" are being developed. What specific characteristics should a storage facility possess in order for the Agency to agree that nuclear material placed therein has been rendered practicably irrecoverable?

Answer See answer to question 6.

Question 8: To what extent should the Agency insist that spent fuel be measured prior to being placed in a permanent repository?

Answer The Agency should insist, to avoid the overstatement scenario, and since no further measurements will be practicable. Practicable measures are available. In this case it is re-iterated that the working paper's arguments tending to devalue neutron/gamma measurements on the grounds of lack of accuracy or, alternatively, too great accuracy to fit with Agency doctrine on item accountancy, is misconceived. These methods are the best which are practically available.

Question 9: What measurement verification procedures, and at what stage, should the Agency implement prior to agreeing to the termination of safeguards, or prior to the placing of spent fuel in permanent storage?

Answer See answer to question 8. Measurements should be applied at the latest practicable stage, and followed up by containment and surveillance measures. At no stage is spent fuel practicably irrecoverable. Termination of material accountancy and material verification inspection activities should not be confused with termination of safeguards, i.e. termination of all activities designed to detect and deter diversion.

Question 10: To the extent that spent fuel placed in permanent storage facilities or long-term retrievable storage is not determined to be practicably irrecoverable, what safeguards measures should the Agency implement?

Answer Long-term and permanent storage of spent fuel must remain under safeguards. The measures to be taken (as yet undefined) must rely on containment and (human and instrumental) surveillance, supplemented by occasional physical verification in the case of anomalies, and where practicable.

Answer to Questions in the text of the working paper

(Questions posed in the introduction of the working paper are referenced as, for example, I-9)

(Question No. 1 for AGM consideration) Should the nuclear material content of waste materials be determined by agreed measurement procedures, and if so should reported measurement data be verified by agreed inspection procedures, prior to placing those wastes in permanent repositories and agreeing to a termination of safeguards?

Answer In principle, yes

(Question No. 2 for AGM consideration) For waste which does not require conditioning prior to final disposal, should the Agency agree to classification of waste materials as measured discards, and thereby to a termination of safeguards, when the total qunatities thus classified are expected to be in the range of several significant quantities per year?

Answer See answer to I-1

(Question No. 3 for AGM consideration) For waste which is classified as measured discards in accordance with question No. 2, should safeguards be terminated prior to the time when the waste has been transferred to a permanent repository, or prior to the time when the waste has passed a specific point in the operation of that facility?

Answer Material which qualifies as measured discards can be so declared as soon as it is established that it qualifies as practicably irrecoverable material

(Question No. 4 for AGM consideration) For retained waste, (i.e., waste which is not classified as measured discards), which the facility intends to dispose of in some manner such as shallow land burial, what safeguards measures should the Agency implement?

Answer Transfer to retained waste requires retention at the plant which produces the waste. If the material has to be moved, it should be transferred from retained waste, be the subject of a domestic shipment or export, and transferred again to retained waste at the receiving plant. Safeguards measures should rely primarily on containment and surveillance.

(Question No. 5 for AGM consideration) What level of safeguards effort should the Agency apply to material which meets agreed criteria for termination of safeguards (measured discards) which has not yet been discarded?

Answer See answer to Q3

(Question No. 6 for AGM consideration) For conditioned waste, should the Agency determine that waste materials are practicably irrecoverable, and terminate safeguards, when the waste has been conditioned for final disposal in accordance with one of the processes described in Section 2.4, regardless of whether it has been transferred to a permanent repository?

Answer See answer to Q3

(Question No. 7 for AGM consideration) Does the act of placing spent fuel in a permanent storage repository constitute making that spent fuel practicably irrecoverable?

Answer No

(Question No. 8 for AGM consideration) If the answer to the above question is yes, under what circumstances (e.g., at what point in the process of final disposal) should the Agency determine that the spent fuel has become practicably irrecoverable, and accordingly terminate safeguards?

Answer See answer to Q7

(Question No. 9 for AGM consideration) If the answer to the above question is no, what continuing safeguards measures should the Agency apply to spent fuel which has been placed in a permanent storage repository?

Answer See answer to I 10

Questions No. 10-13 for AGM Consideration) 10. Should the Agency determine that spent fuel which has been placed in a permanent repository has become practicably irrecoverable, and terminate safeguards?

Answer No.

11. If the answer is in the affirmative, at what point on its route from reactor to possible AFR storage to preparation facility to permanent repository does spent fuel become practicably irrecoverable?

Answer See answer to Q10

12. What measurements or verifications should be performed on spent fuel prior to a determination that it is practicably irrecoverable?

Answer See answer to Q10

13. What verifications or continuing safeguards measures should be required subsequent to measurement yet prior to determination that the fuel has become practicably irrecoverable?

Answer See answer to Q10

(Questions 14-16 for AGM Consideration) 14. Should the Agency determine that placing spent fuel in a permanent repository does not constitute making that spent fuel practicably irrecoverable, and accordingly continue to apply safeguards?

Answer Yes.

15. What measurements or verifications should be performed on spent fuel prior to its being placed in a permanent repository?

Answer See answer to I-9

16. What safeguards measures should be required for spent fuel whih has been placed in permanent storage repositories while those facilities are still open?

Answer See answer to I-10

APPENDIX I
IAEA REPORT ON MEASURED DISCARDS

(6298B)

APPENDIX I
IAEA REPORT ON MEASURED DISCARDS

IAEA Experience with Safeguarding of Measured Discards.

INTRODUCTION

INFCIRC/153 permits two kinds of inventory changes namely measured discards and retained waste for recording and reporting of deletions of nuclear material from the safeguarded inventory when conditions established in paras. 11 and 35 are met. INFCIRC defines measured discards as

> nuclear material which has been measured or estimated on the basis of measurements, and disposed of in such a way that it is not suitable for further nuclear use, and

retained waste as

> nuclear material generated from processing or from an operational accident, which is deemed to be unrecoverable for the time being but which is stored.

INFCIRC/66/Rev. 2 does not define terms like measured discards or retained waste. There are conditions defined in Para. 26(c) under which safeguards could be terminated. It does not make any provision for retained waste such as for reporting deletions from the inventory. However, under conditions defined in para. 35 of INFCIRC/153 safeguards for nuclear material in retained waste are not terminated. Although it does not appear in the inventory, the material is stored and reappears at a later stage when the operator requires it for further use. This paper, therefore, concentrates on the Agency's experience with nuclear material reported as measured discards which normally fulfils the condition in para. 11 of INFCIRC/153 (corrected) and INFCIRC/66/Rev. 2 for termination of safeguards.

Agreements

The facility attachments in force normally contain a paragraph called "specific provisions and criteria for termination of safeguards on nuclear material". Typically such agreements state that safeguards on measured discards will be considered to be terminated upon receipt by the Agency of the inventory change report pertaining to such discards. However, in case of quantities of material exceeding an agreed amount per month, the operator and State are obliged to consult the Agency before such discards take place. The agreed amount depends on the type of facility and its operating condition which varies from .01 Ekg to .1 Ekg per month. Some facilities have yearly limits in addition to monthly limits and some facility attachments do not permit termination of safeguards on measured discards upon receipt of the inventory change report by the Agency. In such a case the material is kept for the Agency for verification prior to termination of safeguards.

It should be understood here that the material so declared is "no longer usable for any nuclear activity". Disposal of the material is possible only at disposal sites authorized by the State after conditioning in accordance with the State's regulations. Safeguards at such waste disposal sites are not at present applied and a confirmation of disposal by the Agency is hardly practicable.

Safeguards Evaluation Criteria

The degree of verification to be applied is dictated by, among other things, by the evaluation criteria in force. Current criteria allow up to 1 SQ of nuclear material in "the sum total of discards, accidental loss and transferred to retained waste..." that may remain unverified during a material balance period. In any case a minimum accountancy measure requiring a gross defect test confirming the presence of nuclear material will suffice the current criteria. The measures to be applied also depend on other constraints like availability of methods, procedures, instruments and manpower.

IAEA Experience

In order to investigate the current status on measured discards a survey has been made for the calendar years 1984-1987. The values in element quantities for all facilities reporting measured discards is extracted from the inventory change reports based on the operator's declarations. The results are given in Tables 1 to 4.

Table 1 shows the amount of each material category reported as measured discard for all facilities under safeguards for the calendar year 1984-1987. The amount reported is very small compared to the total amount of material under safeguards. The decreasing tendency in the amount of measured discards may indicate increasing success by operators in minimising the loss of nuclear material. Table 2 shows a breakdown of different types of facilities reporting measured discards, and Table 3 gives the amounts of material in significant quantities discarded by different types of facilities. These tables suggest that the amount of measured discards reported is dominated by fabrication plants, as expected. Table 4 shows the share of measured discards reported by fabrication plants in significant quantities and percentage of total amount discarded for each calendar year. Reprocessing plants have reported even smaller quantities of discards. The following conclusions can be made:

a) Quantity limit in the facility attachment generally varies from .01 Ekg to .1 Ekg per month and on very rare occasions the declared quantity of measured discards exceeded the monthly limit;
b) The amount of measured discards reported so far is small;
c) Since small quantities are involved verification is not normally performed;
d) In some facilities verification has been carried out for gross defect usually using the operator's/State inspector's device;
e) Disposal of nuclear material in measured discards is not being verified.

(6291B/1)

Table 1. Quantity of Material Reported as Measured Discards.

Material Category	Calendar Year							
	1984		1985		1986		1987	
	Amount	SQ	Amount	SQ	Amount	SQ	Amount	SQ
Depleted Uranium (kg)	1196	.06	973	.05	1559	.08	1235	.06
Natural Uranium (kg)	1376	.14	942	.09	1014	.10	1327	.13
Enriched Uranium (g)	523083	-	583241	-	368095	-	275623	-
U-235 (g)	15433	.21	16554	.22	10644	.14	8990	.12
U-233 (g)	7	0	11	0	6	0	4	0
Plutonium (g)	4310	.54	6966	.87	7257	.91	1695	.21
Thorium (kg)	669	.03	470	.02	307	.02	344	.02
Total (SQ)		.98		1.25		1.25		.54

(6291B/2)

Table 2. Number of MBAs Reporting Measured Discards.

Calendar Year	Facility Type								
	B	C	D	E	F	G	H	I	Total
1984	5	4	16	6	5	2	16	42	96
1985	9	4	17	5	3	1	18	44	101
1986	6	3	18	3	6	1	19	37	93
1987	8	2	15	4	4	1	18	36	88

Note: B = Research reactor and critical facility.
C = Conversion plants.
D = Fabrication plants.
E = Reprocessing plants.
F = Enrichment plants.
G = Separate storage installations.
H = Other facilities.
I = Other locations.

(6291B/3)

Table 3. Quantity of Material in Measured Discards According to Facility Type.

Calendar year	Material in SQ															
	Indirect-use								Direct-use							
	B	C	D	E	F	G	H	I	B	C	D	E	F	G	H	I
1984	.001	.008	.279	.030	.006	.007	.059	.047	0	0	.274	.105	0	.015	.136	.008
1985	.004	.021	.238	.021	.005	0	.058	.046	0	0	.689	0	0	.017	.120	.009
1986	.001	.002	.188	.016	.011	0	.058	.059	0	0	.761	.053	0	.004	.083	.006
1987	0	.002	.195	.011	.008	0	.075	.038	0	0	.107	.039	0	0	.063	.003

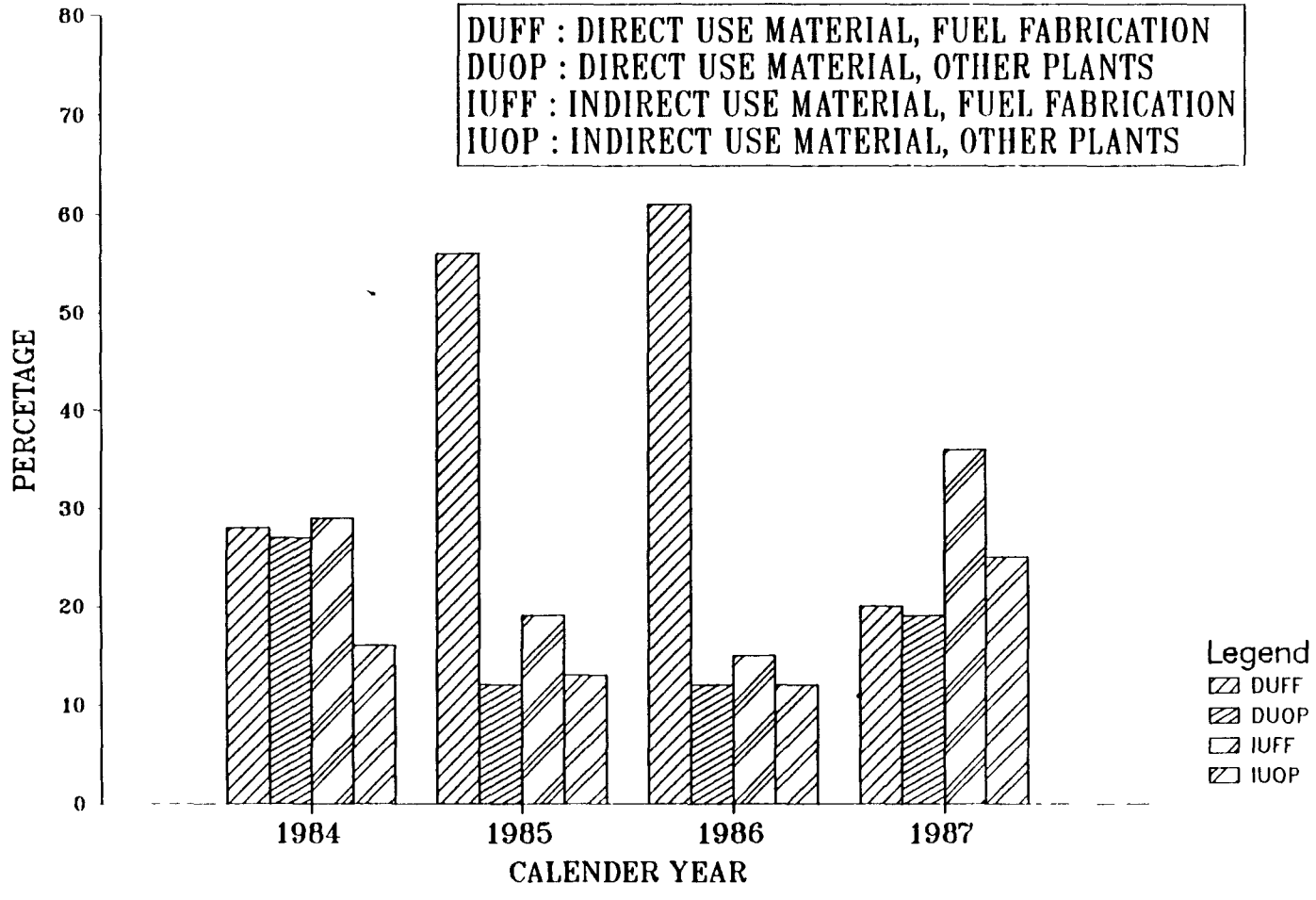
Note: B = Research reactor and critical facility.
C = Conversion plants.
D = Fabrication plants.
E = Reprocessing plants.
F = Enrichment plants.
G = Separate storage installation.
H = Other facilities.
I = Other locations.

(6291B/4)

Table 4. Amount of Measured Discards in Fabrication Plants.

Calendar Year	Indirect-use				Direct-use			
	Total Amount		Fab. Plants		Total Amount		Fab. Plants	
	SQ	%	SQ	%	SQ	%	SQ	%
1984	.437	45	.279	29	.538	55	.274	28
1985	.393	32	.238	19	.835	68	.689	56
1986	.335	27	.188	15	.907	73	.761	61
1987	.329	61	.195	36	.212	39	.107	20

DISTRIBUTION OF MEASURED DISCARDS



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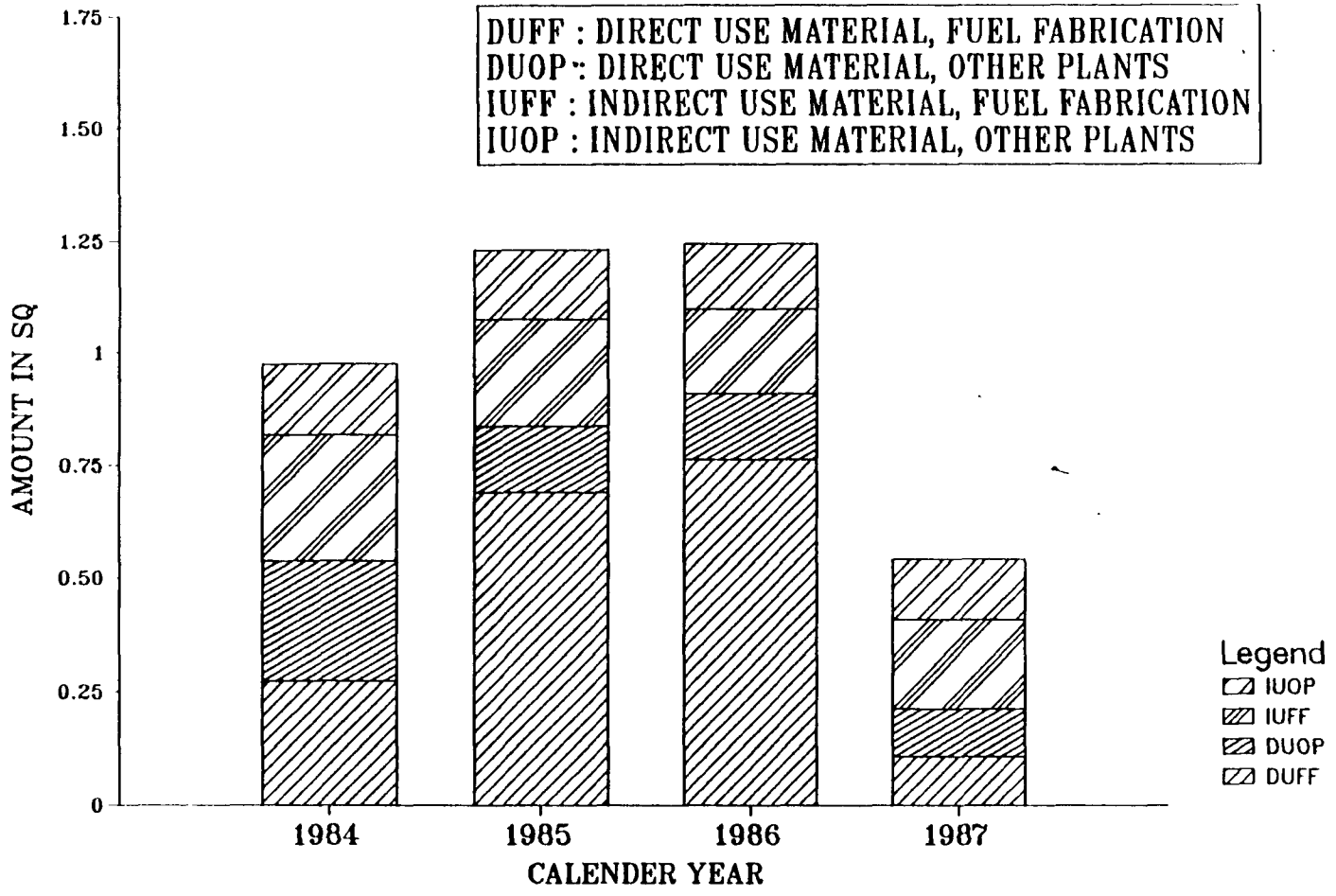

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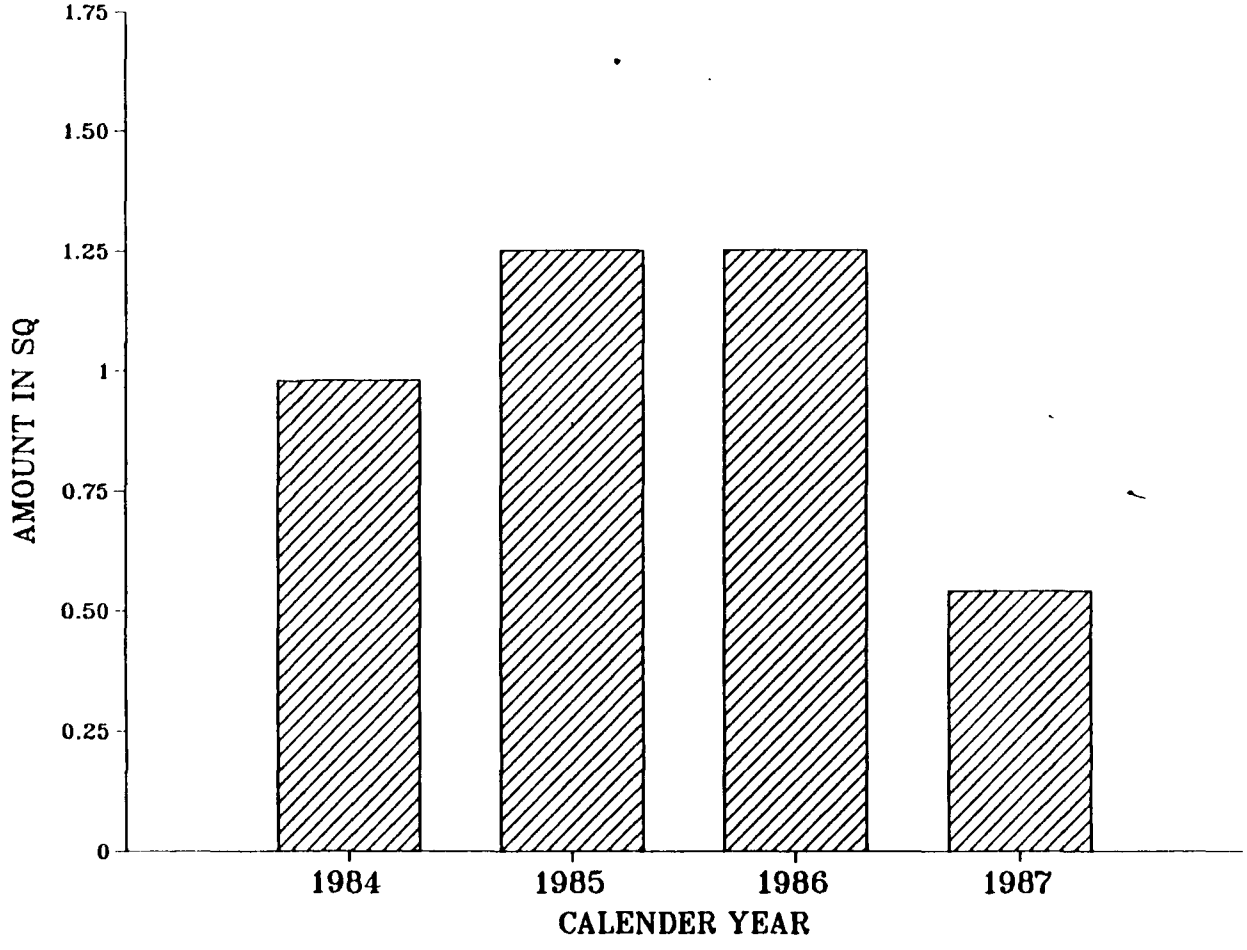

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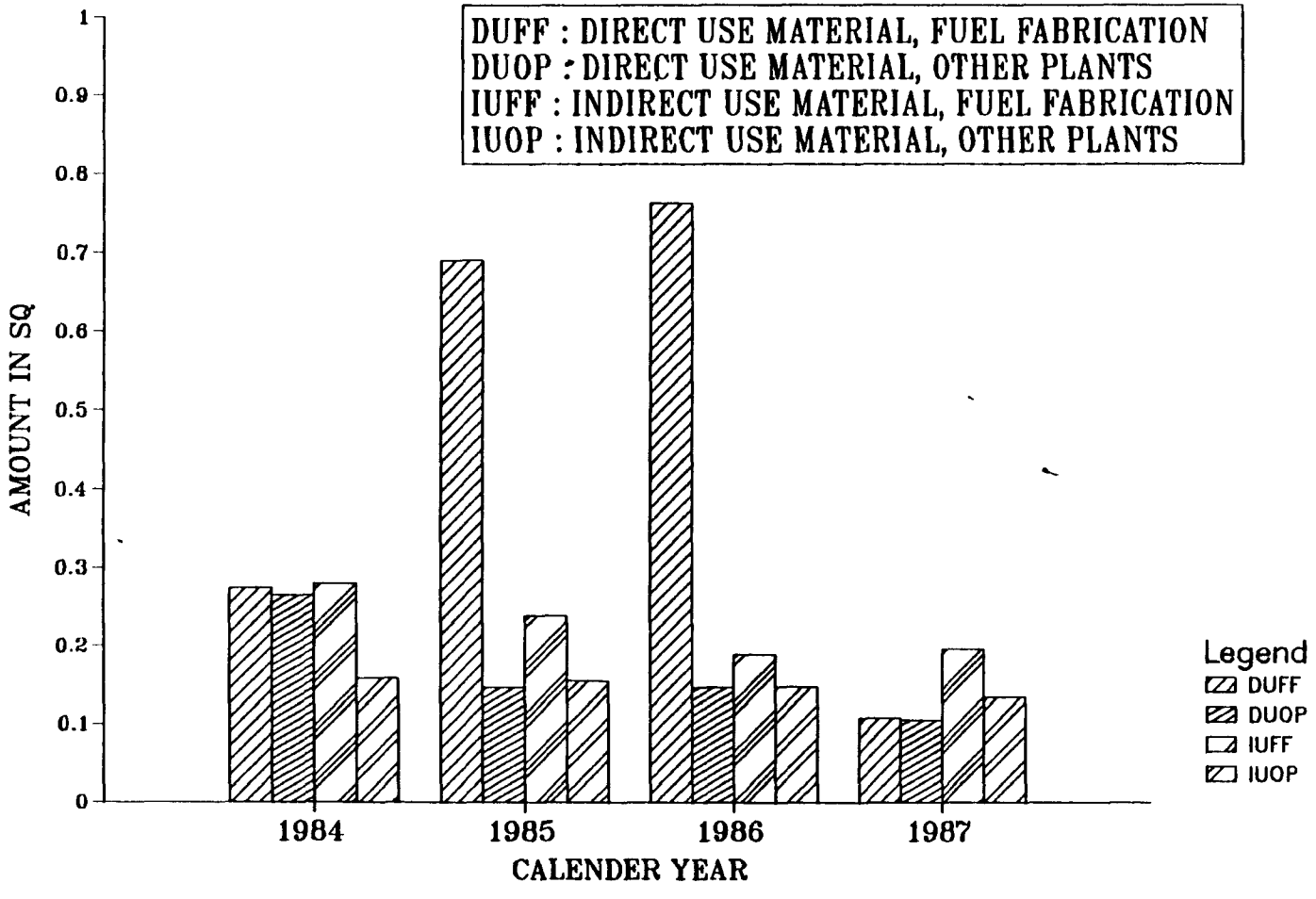

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APPENDIX J
ADVISORY GROUP CONCLUSIONS AND RECOMMENDATIONS

APPENDIX J
ADVISORY GROUP CONCLUSIONS AND RECOMMENDATIONS

INTERNATIONAL ATOMIC ENERGY AGENCY
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МЕЖДУНАРОДНОЕ АГЕНТСТВО ПО АТОМНОЙ ЭНЕРГИИ
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1988-09-20

Dear Mr. Moran,

Enclosed is a final copy of the Conclusions and Recommendations agreed to during last week's Advisory Group Meeting on Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel. This version differs editorially from the version adopted during the meeting (e.g., consistent use of present tense, R&D instead of R and D, etc.). No other changes have been made. In due course I plan to re-issue the Agency's working paper with a new Introduction to indicate that the meeting was held, and with these Conclusions and Recommendations incorporated as Chapter 6. Copies will be distributed when they become available.

I would like to take this opportunity to thank all participants for their cooperation. In my opinion it was a most useful meeting.

Best regards,

Yours sincerely,

J. Lovett
Scientific Secretary
Advisory Group Meeting

Enclosure

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CONCLUSIONS AND RECOMMENDATIONS

1. The Advisory Group was asked to advise the Agency on the circumstances under which the Agency might logically implement Section 11 of INFCIRC/153, or the comparable Section 26c of INFCIRC/66/rev2, which provides for a determination that nuclear material is "practicably irrecoverable," and that therefore safeguards could be terminated. This advice was sought, and in the paragraphs that follow is given, in two areas. One relates to "waste," which the Group understands as referring to material which contains nuclear material that the State/facility operator believes has no economically recoverable value and for which no further use is foreseen. The other relates to spent fuel, which in some cases may be placed in geological "permanent repositories."

WASTE.

2. With regard to waste, as a general statement the Advisory Group believes that most waste generated under normal operating conditions might be described as being practicably irrecoverable, and accordingly might also qualify for classification as "measured discard" and termination of safeguards. However, the Advisory Group recommends that the Agency should, in consultation with Member States, undertake to define specific criteria. Later paragraphs in this report discuss factors which the Advisory Group believes should be given consideration in developing these criteria.

3. Waste which meets the resulting criteria and which have been verified by the Agency should be considered to have no further safeguards relevance. Safeguards should be terminated as discussed in the next two paragraphs when the waste has been transferred from the MBA. The Agency should not attempt to apply safeguards designed to ensure that measured discards are in fact disposed of in any given manner.

4. The determination that a candidate material qualifies as being practicably irrecoverable should be made at the earliest logical point in the process, and plant operators should be encouraged to provide appropriate measurement procedures to facilitate these determinations. Once appropriate nuclear material quantity measurements have been performed, it has been established that a given material meets established criteria, and the material has been transferred from the MBA, the contained nuclear material should be removed from the accountancy records as measured discards.

5. The Group recommends that the Agency should verify both nuclear material content and other factors which qualify a waste material for the determination of practicably irrecoverable.

6. Use of the retained waste classification (for INFCIRC/153 facilities; no similar classification exists under INFCIRC/66/rev2) for nuclear material which meets the criteria for measured discards should be avoided. Once appropriate criteria for the determination of practicably irrecoverable have been developed, plant operators should examine their inventories of material classified as retained waste with a view to reclassifiying any nuclear materials which satisfy the relevant criteria and for which there is no expectation of possible future recovery as measured discards, and thereby terminating safeguards.

7. The Advisory Group believes that the criteria for making determinations of "practicably irrecoverable" include waste material type, nuclear material concentration, chemical and physical form, and waste quality (e.g., the presence or absence of fission products). Total quantity, facility-specific technical parameters, and intended method of eventual disposal should also be considered. An effort should be made to apply equivalent criteria to similar materials generated in similar facilities in different States.

8. The Advisory Group believes that there is no direct relation between criteria for a determination of "practicably irrecoverable" in the context of Agency safeguards, and State regulatory discard criteria in the context of public safety and environmental protection.

9. The Advisory Group believes that the Agency, in consultation with Member States, should give further consideration to the question of waste which do not meet established criteria for a termination of safeguards, as well as to the future role of the "retained waste" category.

SPENT FUEL.

10. The Advisory Group recognised four stages in the flow of spent fuel from reactors to final disposal

(i) Reactors and away-from-reactor stores
(ii) Preparation of the spent fuel for disposal (conditioning)
(iii) Positioning in the final repository
(iv) Closure of the repository.

The Advisory Group concludes that spent fuel does not qualify as being practicably irrecoverable at any point prior to, or following, placement in a geological formation commonly described as a 'permanent repository'. The Advisors recommend that the IAEA should not terminate safeguards on spent fuel.

11. For the stage involving fuel in reactors, away-from-reactor stores, and up to the start of the conditioning of the fuel, the Advisors are of the opinion that the material could be safeguarded using adaptations of existing safeguards measures.

12. The Advisory Group recognises that the process starting with conditioning of the fuel and ending with the final placing in the repository raises new safeguards problems. These arise from the possible dismantling and consolidation of the original fuel assemblies, the placing in the disposal container, and the placing of the container in its final resting place. This would require increased reliance upon C-S, including other monitoring systems, to assure continuity of knowledge of the flow and inventory of the material. The Advisors note that where the safeguards system fails to provide the assurance required it will, under most circumstances, not be possible to re-establish the inventory by re-measurement. The Advisors recommend that R & D to provide a wide variety of C-S and monitoring systems for this stage of the process should be started with high priority following the necessary systems study. The Advisory Group expresses again the wish that in order to facilitate the application of C-S measures, early consultations should take place between the State/designer and the Agency.

13. The Advisors recognise two cases where spent fuel could be considered to be virtually inaccessible for physical verification. The first occurs in an operating repository when a particular area or 'drift' is backfilled, and the second, when all operations in the repository are completed and the repository is closed.

14. Closed drifts in operating repositories create unique problems which must be solved by R & D. The group recommends that the R & D programme should include this problem but with a lower priority than given to the problems discussed in paragraph 12.

15. The Advisors recognise that there are technical and legal problems that have to be solved before implementing safeguards for a closed repository. It is likely that several decades will elapse before a repository is closed. The Advisors recommend that problems associated with closed repositories should be addressed, but with a low priority.

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