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REPORT OF FOREIGN TRAVEL
TRAINING COURSE ON NUCLEAR MATERIAL
SAFEGUARDS FOR ENRICHMENT PLANTS

VIENNA, AUSTRIA

NOVEMBER 14-18, 1988

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SUMMARY

J. N. Cooley, manager, Safeguards Studies Department; E. Von Halle, head, Technical Resources Section; and D. W. Swindle, Jr., director, International Technology Programs Division, Martin Marietta Energy Systems, Inc., traveled to Vienna, Austria, November 9-20, 1988, to conduct a 5-day uranium enrichment safeguards training course for the International Atomic Energy Agency (IAEA). The course was developed and conducted by Energy Systems for the IAEA through the U.S. Program for Technical Assistance to IAEA Safeguards (POTAS) under Task B.48.

Titled "Nuclear Material Safeguards for Enrichment Plants," this second session of the course was held on November 14-18, 1988, for 15 IAEA inspectorate and support division personnel. The course was developed and initially taught in 1987 to train IAEA professionals whose responsibilities require knowledge of safeguarding nuclear material at enrichment plants on the safeguards-relevant principles of enrichment technology, particularly as related to centrifuge enrichment facilities. Based on comments received during the initial training session, the course and reference materials were revised, updated, and expanded. The main objective of the course is to provide participants with the necessary skills to perform their inspection activities at enrichment plants. Overall, the course was very well received; the four-part course manual was especially appreciated because of the text accompanying the view graphs. The general consensus was that the course should be repeated so that inspectors who could not be accommodated in this session will have a chance to be trained in this important area of safeguards.

Because of the breadth of the information presented in the course, an IAEA staff member, A. von Baeckmann of the Safeguards Deputy Director General's Office, and a POTAS cost-free expert, J. Olivier of the Safeguards Training Section, assisted in conducting two of the lecture sessions. In addition, D. A. Close, a POTAS cost-free expert from Los Alamos National Laboratory currently with the IAEA's Development Division, conducted a half-day measurement equipment demonstration at Seibersdorf. Technical sessions presented during the 5-day course are as follows: general principles and processes of uranium enrichment, basic separation and cascade theory, properties of uranium hexafluoride, gas centrifuge separation theory, centrifuge enrichment plant description, IAEA safeguards at a gas centrifuge enrichment plant, facility material control and accountability procedures, diversion of declared material, material balance verification activities, enriching beyond declared levels, and safeguards inspection techniques.

It is expected that the IAEA will request POTAS to support a third session of this course in the spring of 1990. Based on the wrap-up discussions and the course critiques prepared by the participants, recommendations to be incorporated into a third session of this course include the following: (1) update the safeguards technical information presented to be consistent with current IAEA practices and procedures, (2) use the same training manual format, (3) incorporate more practical examples and exercises, and (4) expand the discussion scenario sections.

INTRODUCTION

During the period of November 9-20, 1988, J. N. Cooley, manager, Safeguards Studies Department; E. Von Halle, head, Technology Resources Section; and D. W. Swindle, Jr., director, International Technology Programs (ITP) Division, Martin Marietta Energy Systems, Inc., traveled to Vienna, Austria, to conduct a 5-day uranium enrichment safeguards training course for the International Atomic Energy Agency (IAEA). The course was developed and conducted by Energy Systems for the IAEA through the U.S. Program for Technical Assistance to IAEA Safeguards (POTAS) under Task B.48. The points of contact at the IAEA were E. Woelfl (SGSTR), the responsible training officer, and J. Janov (SGOA), the technical coordinator for the course. The travelers' itineraries are given in Appendix A.

Titled "Nuclear Material Safeguards for Enrichment Plants," this second session of the training course was conducted on November 14-18, 1988, for 15 IAEA inspectorate and support division personnel. (Appendix B includes the course announcement; Appendix C lists the course participants and their IAEA organizational affiliations.) The course was developed and initially taught in 1987 to train IAEA professionals whose responsibilities require knowledge of safeguarding nuclear material at enrichment plants on the safeguards-relevant principles of enrichment technology, particularly as related to centrifuge enrichment facilities.¹ Based on comments received during the initial training session, the course and reference materials were revised, updated, and expanded. The main objective of the course is to provide the course participants with the necessary skills to perform their inspection activities at enrichment plants.

PREPARATION ACTIVITIES

The first day of Cooley's travel schedule, November 11, was devoted to completing the final arrangements for the course (for which she had overall coordination responsibilities) planned for the following week at the IAEA's headquarters in Vienna, the Vienna International Centre (VIC). Because of the breadth of the information being presented in the course, several IAEA personnel had been asked to be guest lecturers. Contact was made with these individuals to reconfirm their availability and lecture schedule. Specifically, A. von Baeckmann (SGDDG) agreed to present the session describing the objective of IAEA safeguards at a gas centrifuge enrichment plant (Session 8), and J. Olivier, a POTAS cost-free expert in the Safeguards Training Section, would describe two measurement techniques used in material balance verification (Session 11.6). In addition, D. A. Close, a POTAS cost-free expert from Los Alamos National Laboratory currently with the IAEA's Development Division, agreed to conduct a demonstration of the pipe-monitoring technique that he was instrumental in developing for centrifuge enrichment plant safeguards (Session 6).

SAFEGUARDS TRAINING COURSE

The course began on Monday morning, November 14, at 9:00 a.m. D. Perricos, acting director of the IAEA's Standardization, Training, and Administrative Support Division, opened the meeting by welcoming the

course participants as well as the lecturers and detailing the course objectives. Swindle followed with a general overview of the course, introductions of the course lecturers, and a request that the course critiques to be handed out in mid-week be completed by the final session. Appendix D includes the schedule for the training course; Appendix E, an extended course outline.

The lecture sessions of the training course were held in the Safeguards Training Room (A1381) in the VIC. A half-day equipment demonstration session was conducted at Seibersdorf on the third day of the course. Lectures were held from 9:00 a.m. to noon and from 2:30 p.m. to 4:30 p.m. each day. All lecture sessions were videotaped. During the course, four chart books containing reproductions of the presentation view graphs, together with accompanying text as a reference source, were distributed.²⁻⁵

In the first technical session of the course (Session 2), Cooley began by reviewing the general principles of uranium enrichment including uranium isotopics for natural and reprocessed uranium, the elements of the nuclear fuel cycle, and basic enrichment cascade concepts. Swindle continued the session by introducing the various uranium enrichment processes and describing parameters used to compare them. He then gave a historical perspective of uranium enrichment followed by a review of worldwide uranium enrichment capacity. In Session 3.1, Von Halle discussed basic separation theory by explaining the concepts of material balance, value, and separative work. The day ended with Von Halle describing process and plant operating characteristics for a variety of enrichment processes including gaseous diffusion, gas centrifuge, aerodynamic, chemical exchange, laser isotope, and electromagnetic.

Day 2 began with a discussion of cascade theory (Session 3.2). Von Halle compared ideal cascade theory and real cascade design and illustrated the concepts with calculations of flow rate, stage requirements, and separative capacity. In Session 4, Cooley defined the physical, chemical, and toxic properties of uranium hexafluoride (UF_6). Criticality considerations and safeguards implications for measuring contained UF_6 were then detailed. In Session 5, Von Halle explained design and operating parameters of a gas centrifuge. Separative capacity, separation efficiencies, and the basics of centrifuge flow theory were then reviewed.

The third day of the course included a morning demonstration session at the IAEA's facilities at Seibersdorf. Close explained the enrichment verification pipe-monitoring technique being developed for use by the IAEA for measuring cascade header pipes in gas centrifuge enrichment plants. Historical development data were reviewed, and the detection hardware and software were described. The measurement technique was then demonstrated on a section of sealed cascade header pipe containing UF_6 . The participants reconvened at the VIC for an afternoon lecture session on the various components and systems of a centrifuge facility (Session 7). Swindle reviewed cylinder-handling operations, the feed and withdrawal systems, cascade arrangements, waste handling, and typical centrifuge facility operation and maintenance activities.

Dr. von Baeckmann began Day 4 with a lecture on the objectives, detection goals, and safeguards concerns associated with IAEA safeguards at a gas centrifuge enrichment plant. Specifically, he described the

Hexapartite Safeguards Project (HSP) and the safeguards approach for gas centrifuge enrichment plants agreed upon by the HSP. In Session 9, Cooley presented centrifuge facility material control and accountability procedures including typical operator measurements for uranium flows and inventories and the operator's material balance determination. Swindle then introduced scenarios for diversion of declared material at a centrifuge plant (Session 10) including explanations of the general strategies of diversion into MUF (i.e., material unaccounted for) and falsification of measurements or records. The day ended with a discussion of IAEA material balance verification activities (Session 11). Cooley described the attributes/variables measurement approach and detailed safeguards measures used by the IAEA to verify the operator's nuclear material balance including examination of records and reports, evaluation of the operator's measurement system, verification of nuclear material flows, and verification of physical inventory.

Session 11 continued on the final day of the course with Olivier discussing two UF_6 cylinder measurement techniques. Equipment, procedures, and precautions associated with nondestructive assay (NDA) and load-cell-based weighing measurements of UF_6 cylinders were described. In Session 12, Swindle presented techniques for enriching beyond declared levels in a centrifuge facility. Requirements for producing highly enriched uranium (HEU) were described, and examples of production scenarios including operator concealment techniques were discussed. In the final technical session of the course, Cooley described safeguards inspection techniques that may be used inside cascade areas to detect HEU production. First, inspection activities agreed to by the HSP were detailed including visual observation, NDA measurements, sampling, and seals. Other measurement and surveillance techniques under development that may be applicable to cascade area inspections including surveillance cameras, area neutron detectors, in-line enrichment monitors, and in-line flow meters were then described. The training course ended with a review and critique session followed by the awarding of the training course certificates.

COURSE CRITIQUES

Each course participant was asked to complete two critiques — one prepared by the course developers, the second prepared by the Safeguards Training Section. The results of both (from 13 of the 15 class members) were tabulated and compiled and are included in Appendix F. Overall, the safeguards training course was very well received; the four-part course manual was especially appreciated because of the text accompanying the view graphs.

The overall lecture schedule (i.e., 5 h/day with 3 h in the morning and 2 h in the afternoon) seemed appropriate. Several course participants suggested that a short break (e.g., 5 to 10 min) be taken after every hour of lecture time with the accompanying suggestion that students should be requested to remain in the classroom during these short breaks. Regarding the course material, most participants felt that all of the topics presented were of relevance, contained the right amount of technical detail, and were presented in a logical sequence. Suggested topics to be expanded upon included low-enriched uranium (LEU)

and HEU diversion scenarios, safeguards at a gas centrifuge enrichment plant, and UF₆-handling information. As many students made the suggestion to shorten the separation and cascade theory sessions as did to expand the coverage of these topics. The Seibersdorf demonstration of the pipe-monitoring inspection technique was considered very instructive. Other ideas were to introduce more exercises to further the understanding of the theory sections and to include hands-on training. It was the opinion of all that the training course should be repeated so that inspectors who could not be accommodated in this session of the course will have a chance to be trained in this important area of safeguards.

CONCLUSIONS

The second session of the training course on "Nuclear Material Safeguards for Enrichment Plants" - preparation, presentation, and coordination, together with IAEA collaboration - went extremely well. It is expected that the IAEA will request POTAS to support a third session of this course in the spring of 1990. In anticipation of this request, recommendations for preparing a third session of this course follow:

1. maintain the current topical agenda but plan for short breaks (e.g., 5 to 10 min) every hour;
2. keep the same training manual format (i.e., view graphs with accompanying text);
3. update the safeguards technical information presented in the course to be consistent with current IAEA practices and procedures;
4. incorporate more practical examples and exercises in the separation and cascade theory sections;
5. expand both the LEU and HEU diversion scenario sections; and
6. obtain film footage on UF₆-cylinder-handling operations for use in Session 7, Centrifuge Enrichment Plant Description, and Session 9 Centrifuge Facility Material Control and Accountability Procedures.

REFERENCES

1. J. N. Cooley, et al, *Report of Foreign Travel, Training Course on Nuclear Material Safeguards for Enrichment Plants, Vienna, Austria, November 9-13, 1987*, K/ITP-193, Martin Marietta Energy Systems, Oak Ridge Gaseous Diffusion Plant, April 1988.
2. *Nuclear Material Safeguards for Enrichment Plants. Part 1. Uranium Enrichment: General Principles and Processes*, K/ITP-156/P1/R1 (ISPO-284/R1), Martin Marietta Energy Systems, Oak Ridge Gaseous Diffusion Plant, October 1988.
3. *Nuclear Material Safeguards for Enrichment Plants. Part 2. Cascade and Centrifuge Separation Theory; Uranium Hexafluoride*, K/ITP-156/P2/R1 (ISPO-284/R1), Martin Marietta Energy Systems, Oak Ridge Gaseous Diffusion Plant, October 1988.
4. *Nuclear Material Safeguards for Enrichment Plants. Part 3. Gas Centrifuge Enrichment Plant: Description, Material Control and Accountability Procedures, and IAEA Safeguards*, K/ITP-156/P3/R1 (ISPO-284/R1), Martin Marietta Energy Systems, Oak Ridge Gaseous Diffusion Plant, October 1988.
5. *Nuclear Material Safeguards for Enrichment Plants. Part 4. Gas Centrifuge Enrichment Plant: Diversion Scenarios and IAEA Safeguards Activities*, K/ITP-156/P4/R1 (ISPO-284/R1), Martin Marietta Energy Systems, Oak Ridge Gaseous Diffusion Plant, October 1988.

Appendix A
ITINERARIES

7/8

Appendix A
ITINERARIES

Traveler: J. N. Cooley

November 9-10, 1988	Travel from Knoxville, Tennessee, to Vienna, Austria, via plane
November 11, 1988	Final preparations for the safeguards training course; Vienna International Centre, Vienna, Austria
November 12-13, 1988	Open days (weekend)
November 14-18, 1988	Training course on "Nuclear Material Safeguards for Enrichment Plants"; Vienna International Centre, Vienna, Austria
November 19, 1988	Travel from Vienna, Austria, to London, England via plane
November 20, 1988	Travel from London, England, to Knoxville, Tennessee, via plane

Traveler: E. Von Halle

November 12-13, 1988	Travel from Knoxville, Tennessee, to Vienna, Austria, via plane
November 14-16, 1988	Training course on "Nuclear Material Safeguards for Enrichment Plants"; Vienna International Centre, Vienna, Austria
November 17, 1988	Travel from Vienna, Austria, to Knoxville, Tennessee, via plane

Traveler: D. W. Swindle, Jr.

November 12-13, 1988	Travel from Knoxville, Tennessee, to Vienna, Austria, via plane
November 14-18, 1988	Training course on "Nuclear Material Safeguards for Enrichment Plants"; Vienna International Centre, Vienna, Austria
November 19, 1988	Travel from Vienna, Austria, to London, England via plane
November 20, 1988	Travel from London, England, to Knoxville, Tennessee, via plane

Appendix B
COURSE ANNOUNCEMENT

11/12

Appendix B
COURSE ANNOUNCEMENT

NUCLEAR MATERIALS SAFEGUARDS FOR ENRICHMENT PLANTS

Technical Coordinator(s):

Mr. J. Janov

Responsible Training Officer:

Ms. E. Woelfl

Course Location/Sponsor:

IAEA - Room A1381/Seibersdorf/US Support Programme

Course Duration:

14 - 18 November 1988

Intended Audience:

Maximum of 16 Safeguards professionals of the Department of Safeguards

Major Course Objective:

To provide the participants with the necessary skills to perform their inspection activities at enrichment plants.

General Description:

The course covers the Safeguards aspects of enrichment technology particularly in relation to centrifuge enrichment plants. Topics include, basic separation and cascade theory, UF₆ properties, operator's UF₆ handling procedures, possible diversion scenarios, enrichment plant safeguards measurement procedures and material balance evaluations. Upon training completion, the participants should be able:

- to know the basic principles of enrichment technology and enrichment plant design;
- to understand the role of the visual indicators associated with the cascade operation;
- to understand potential diversion scenarios at enrichment plants.

Specific Prerequisites:

Administrative:

Participants are nominated:

- by Section Heads with Directors clearance

Technical:

Professionals whose responsibilities require knowledge of safeguarding nuclear material at enrichment plants

Criteria for successful completion:

1. Attendance of all course sessions.
2. Participation in all practical exercises.

Appendix C
COURSE PARTICIPANTS

Appendix C
COURSE PARTICIPANTS

<u>Name</u>	<u>Division</u>	<u>Section</u>
D. Amundrud	Operations A	OA2
A. Bazan	Operations B	OB1
W. Bush	Operations C	OC1
A. Camerata	Safeguards Evaluation	EEE
C. Charlier	Operations C	OC2
K. Czock	Operations B	OB3
C. Fernando	Operations C	OC2
T. Fitzsimmons	Operations A	OAP
O. Heinonen	Operations A	OAP
H. Lewis	Operations A	OA2
G. Madueme	Operations A	OA3
J. Patrick	Operations A	OA1
G. Saringer	Operations A	OA1
V. Schuelein	Operations C	OCP
Z. Starovich	Operations C	OC1

Appendix D
SAFEGUARDS TRAINING COURSE:
SCHEDULE OF ACTIVITIES

Appendix D

SAFEGUARDS FOR ENRICHMENT PLANTS

**SAFEGUARDS TRAINING COURSE
A1381**

**SCHEDULE OF ACTIVITIES
1988-9-16**

	MONDAY - 14 Nov. 1988	TUESDAY - 15 Nov.	WEDNESDAY - 16 Nov.	THURSDAY - 17 Nov.	FRIDAY - 18 Nov.
09:00	1.1 Address of Welcome D. Perricos	3.2 Elements of Cascade Theory E. von Halle	6. Field Trip To Seibersdorf D. A. Close	8. IAEA Safeguards at a Gas Centrifuge Enrichment Plant A. von Baeckmann	11.6 Material Balance Measurement Techniques J. Olivier
15 30	1.2 Course Overview D. W. Swindle, Jr.				
45					
10:00	2.1 Uranium Enrichment				
15	2.4 General Principles and Processes J. N. Cooley				
30	D. W. Swindle, Jr.				
45					
11:00	3.1 Basic Separation Theory E. von Halle	4. Uranium Hexafluoride J. N. Cooley Video: UF ₆		9. Centrifuge Facility Material Control and Accountability Procedures J. N. Cooley	12. Enriching Beyond Declared Levels in a Centrifuge Facility D. W. Swindle, Jr.
15					
30					
45					
12:00				10. Diversion of Declared Material at a Centrifuge Plant D. W. Swindle, Jr.	
14:00					
15					
30	2.5 Uranium Enrichment Technologies E. von Halle		7. Centrifuge Enrichment Plant Description D. W. Swindle, Jr.		13. Safeguards Inspection Tech- niques That May be Used Inside the Cascade Hall J. N. Cooley
45		5. Gas Centrifuge Separation Theory E. von Halle		11.1 Centrifuge Facility Material Balance Verification Activities J. N. Cooley	
15:00				11.5	
15					
30					
45					
16:00					14. Course Wrap-up and Critique
15					
30					
45					
17:00					

19/20

Appendix E
EXTENDED COURSE OUTLINE

Appendix E

EXTENDED COURSE OUTLINE

NUCLEAR MATERIAL SAFEGUARDS FOR ENRICHMENT PLANTS

1. Introduction and Course Overview [Time: 0.5 h]
 - 1.1 IAEA Address of Welcome
 - 1.2 Course Overview
2. Uranium Enrichment - General Principles and Processes [Time: 3.0 h]
 - 2.1 General Principles
 - 2.1.1 Concept of an Isotope
 - 2.1.2 Uranium Isotopics
 - 2.1.3 Nuclear Fuel Cycle
 - 2.1.4 Reprocessed Uranium
 - 2.1.5 Separating Elements and Cascades
 - 2.2 Uranium Enrichment Technologies, Selection Factors, and Comparison
 - 2.2.1 Uranium Enrichment Processes
 - 2.2.2 Process Selection Factors
 - 2.2.3 Process Comparisons
 - 2.3 Brief History of Uranium Enrichment
 - 2.3.1 The Origins of Isotope Separation and Uranium Enrichment
 - 2.3.2 The War Efforts
 - 2.3.3 1946-1960s
 - 2.3.4 1960s-Present
 - 2.4 Worldwide Uranium Enrichment Capacity and Facilities
 - 2.4.1 Current Activities on Uranium Isotope Separation
 - 2.4.2 Pilot and Demonstration Plants
 - 2.4.3 Commercial Enrichment Plants
 - 2.5 Overview of Enrichment Technologies
 - 2.5.1 Gaseous Diffusion
 - 2.5.2 Gas Centrifuge
 - 2.5.3 Aerodynamic Processes
 - 2.5.4 Chemical Exchange and Ion Exchange
 - 2.5.5 Laser Isotope Separation Processes
 - 2.5.6 Electromagnetic Processes
3. Basic Separation and Cascade Theory [Time: 3.0 h]
 - 3.1 Basic Separation Theory
 - 3.1.1 Separation Basics
 - 3.1.2 Material Balances
 - 3.1.3 Value Function
 - 3.1.4 Separative Work
 - 3.2 Elements of Cascade Theory
 - 3.2.1 Separating Element, Stages, and Cascades
 - 3.2.2 Ideal and Real Cascade Concepts
 - 3.2.3 Cascade Separative Capacity
 - 3.2.4 Cascades with Small Separation Factors
 - 3.2.5 Cascades with Large Separation Factors

- 4. Uranium Hexafluoride [Time: 1.5 h]
 - 4.1 Use in Uranium Enrichment
 - 4.2 Physical Properties
 - 4.3 Chemical Properties
 - 4.4 Toxic Properties
 - 4.5 Criticality Considerations
 - 4.6 Safeguards Implications
- 5. Gas Centrifuge Separation Theory [Time: 1.5 h]
 - 5.1 Gas Centrifuge Design
 - 5.2 Physical Parameters and Operating Conditions
 - 5.3 Enrichment Process
 - 5.4 Separative Capacity and Separation Efficiencies
 - 5.5 Centrifuge Flow Theory and Models
- 6. Demonstration of the Enrichment Verification [Time: 4.0 h]
Measurement Technique for Cascade Header Pipes

Field Trip to Seibersdorf
- 7. Centrifuge Enrichment Plant Description [Time: 2.0 h]
 - 7.1 UF₆ Cylinder Handling
 - 7.1.1 Cylinder Descriptions
 - 7.1.2 UF₆ Handling Operations
 - 7.1.3 Cylinder Weighing
 - 7.1.4 Cylinder Sampling
 - 7.2 Feed System
 - 7.3 Withdrawal Systems
 - 7.4 Cascade Arrangements
 - 7.5 Waste Handling and Management
 - 7.6 Utility and Support Systems
 - 7.7 Operating Transients
- 8. IAEA Safeguards at a Gas Centrifuge [Time: 1.5 h]
Enrichment Plant
 - 8.1 IAEA Safeguards Objectives
 - 8.2 The Hexapartite Safeguards Project
- 9. Centrifuge Facility Material Control [Time: 1.0 h]
and Accountability Procedures
 - 9.1 Material Balance Structure
 - 9.2 Measurement Assurance
 - 9.3 Records and Reports
 - 9.4 Physical Inventory Taking
 - 9.5 Material Balance Closure
 - 9.6 Facility Operation and Associated Source Data

- 10. Diversion of Declared Material at a Centrifuge Plant [Time: 1.0 h]
 - 10.1 Diversion Goals
 - 10.2 Diversion into MUF
 - 10.3 Diversion by Biasing
 - 10.4 False Material Loss Incident
- 11. Centrifuge Facility Material Balance Verification Activities [Time: 2.5 h]
 - 11.1 Function of Material Balance Verification
 - 11.2 Key Concepts
 - 11.3 Attributes and Variables Measurements
 - 11.4 Material Balance Verification Procedures
 - 11.4.1 Examination of Records and Reports
 - 11.4.2 Evaluation of Operator's Measurement System
 - 11.4.3 Verification of Nuclear Material Flow
 - 11.4.4 Verification of Physical Inventory
 - 11.5 IAEA Detection Strategies
 - 11.6 Measurement Techniques
 - 11.6.1 UF₆ Cylinder Measurements
 - 11.6.2 Portable Load-Cell-Based Weighing System (5-ton and 20-ton capacity)
- 12. Enriching Beyond Declared Levels in a Centrifuge Facility [Time: 1.5 h]
 - 12.1 Review of Centrifuge Cascade Characteristics
 - 12.2 Requirements for HEU Production
 - 12.3 HEU Production Scenarios
 - 12.3.1 Cascade Flow Adjustments
 - 12.3.2 Cascade Reconfigurations
 - 12.3.3 Batch Recycle
 - 12.3.4 Undeclared Separative Capacity
 - 12.4 Criticality Considerations and Conclusions
- 13. Safeguards Inspection Techniques which May be Used Inside Cascade Areas [Time: 1.5 h]
 - 13.1 HSP Inspection Activities
 - 13.1.1 Visual Observation
 - 13.1.2 NDA Measurements
 - 13.1.3 Sampling
 - 13.1.4 Seals
 - 13.2 Other Techniques
 - 13.2.1 Surveillance Camera
 - 13.2.2 Area Neutron Detector
 - 13.2.3 In-Line Enrichment Monitor
 - 13.2.4 In-Line Flow Meter
- 14. Course Wrap-up and Critique [Time: 0.5 h]

Appendix F
PARTICIPANTS' COMMENTS AND EVALUATION FORMS

Appendix F
PARTICIPANTS' COMMENTS AND EVALUATION FORMS

Nuclear Material Safeguards for Enrichment Plants
14-18 November 1988
Results of
Participants Comments and Evaluation Form I

1. YOUR BACKGROUND

Type of work: [11] Inspector [1] Inspection Assistant
 [1] Technical Staff
2. OVERALL COURSE CONTENT
 - 2.1 Did the course meet stated objectives?
Yes [11] Partly [3] No [] (One participant wrote yes and partly.)
If no, with respect to:
-The relevance of basic cascade and centrifuge theory to safeguards.
 - 2.2 Do you believe that the course material will be useful in your work?
Yes [11] Partly [2] No []
 - 2.3 Was the course format and schedule satisfactory to you?
Yes [9] Partly [4] No []
If no, what changes would you suggest?
-The course covers too much material already familiar to IAEA inspectors. It seems to be designed for complete beginners and maybe should be filtered for IAEA presentation.
-The separation and centrifuge theory sections were too long
-Sessions in the afternoon were too long; suggest a break
-Suggest a short stretching break every 50 minutes (i.e., don't let the class leave the room).
3. LECTURES AND DEMONSTRATION
 - 3.1 Was the proportion of time/effort between lectures, exercises and the demonstration satisfactory?
Yes [9] No [2] No response [2]
If no, what parts should have been increased or decreased?
-Introduce exercises to further the understanding of cascade areas.
-More hands-on training is needed,
-Some lectures are too long and/or of debatable necessity.
 - 3.2 Were the contents of the lectures instructive to you?
Yes [10] Partly [3] No []
 - 3.3 How did you find the presentation?

	Poor	Satisfactory	Good	Excellent
General Principles of Uranium Enrichment	[1]	[1]	[10]	[1]
Basic Separation Theory	[2]	[4]	[6]	[1]
Uranium Enrichment Technologies	[1]	[2]	[9]	[1]

	Poor	Satisfactory	Good	Excellent
Elements of Cascade Theory	[2]	[4]	[6]	[1]
Uranium Hexafluoride	[]	[2]	[10]	[1]
Gas Centrifuge Separation Theory	[1]	[6]	[6]	[]
Demonstration-Cascade Header Pipe Monitoring Technique	[2] No response	[1]	[7]	[3]
Centrifuge Enrichment Plant Description	[]	[4]	[9]	[]
IAEA Safeguards at a Gas Centrifuge Enrichment Plant	[]	[3]	[8]	[2]
Centrifuge Facility Material Control and Accountability Procedures	[]	[3]	[10]	[]
Diversion of Declared Material at a Centrifuge Plant	[]	[3]	[8]	[2]
Centrifuge Facility Material Balance Verification Activities	[]	[4]	[8]	[1]
Enriching Beyond Declared Levels in a Centrifuge Facility	[]	[2]	[9]	[2]
Applicable Safeguards Inspection Techniques Inside Cascade Areas	[]	[3]	[8]	[2]

3.4 Were your questions raised given satisfactory answers?
 Yes [12] No [] No response [1]

3.5 Additional comments regarding the lectures
 -Well done but sometimes too long without a break.
 -Some parts of the lectures were duplicated.

4. INSTRUCTIONAL TECHNIQUE

4.1 Did you experience any communication problems during the course?
 Yes [] No [13]
 -Instructors were willing to answer questions at any point in time.

4.2 Were the visual aids (diagrams, charts, pictures, etc.) clear and understandable?
 Yes [11] No [1] No response [1]
 If "no", please describe which could be improved:
 -Good set of course notes.
 -Some of the originals were in color and some of this information was lost in the black/white chartbooks.

4.3 Of what value were the chartbooks and handouts?
 -Excellent reference source (2).
 -Very good (2).
 -Should provide good reference for the future (2).
 -First class.
 -Very big value.
 -Very useful (2).
 -Clear and well presented.

5. GENERAL SUGGESTIONS, COMMENTS

- 5.1 The overall length of the course was
too long [3] too short [3] about right [7]
- 5.2 Overall, the material was
too technical [] not enough technical [1] about right [10]
no response [2]
- 5.3 Which parts of the course should be expanded?
-Some parts were too technical and some parts too easy.
-General principles.
-Separation and cascade theory (3).
-Safeguards at a Gas Centrifuge Enrichment Plant.
-Include calculations for students to perform.
-Sessions on diversion scenarios; UF₆ session.
- 5.4 Which parts of the course should be shortened (or omitted)?
-None (3).
-Centrifuge and diffusion theory (2).
-Have short introduction to theory with explanation of diffusion equations but not so much detail.
-Shorten oral presentation of theory sections (2).
-In Session 10, only describe difference between enrichment plant accountability practices and normal ones (and similarly some other sessions).
- 5.5 In your opinion should the training course be offered again?
Yes [13] No []
- 5.6 Which parts of the course were of greatest value to you?
-UF₆ properties; Seibersdorf; diversion scenarios; HEU production.
-UF₆ handling procedures and properties; overview of enrichment technologies; UF₆ NDA techniques; pipe demonstration.
-Session 6, Seibersdorf demonstration; Session 8, IAEA safeguards at a centrifuge plant.
-All.
-Practical examples.

6. ADMINISTRATION

- 6.1 How did you find the overall administration of the course?

Poor	Satisfactory	Good	Very Good	Excellent
[]	[]	[]	[8]	[5]

7. PERSONAL COMMENTS

Please make further comments on any subject that could assist the course organizers to improve the course in the future.

-From an inspector's point of view, more time on diversion scenarios and less time on theory; explain exactly how an operator would divert by the various methods (i.e., diversion into MUF).

- Course is fine for parties knowing nothing of inspection practices and IAEA methods; for IAEA personnel, suggest redesign of course to delete all things we (are supposed to) already know and devote time to exercises on cascade design and practical experience in NDA techniques currently in use.
- Have demonstration exercises at a real plant for greater effectiveness.
- The theory parts were too long; part of the course was duplicated (e.g., parts on IAEA safeguards at a centrifuge plant); material balance measurement session (11.6) was given by a "theoretical" person who did not understand the problems faced by an inspector at a facility.
- I believe the course is good as is, except possibly that topics by von Halle should be slightly expanded.
- Since the course is mainly for safeguards inspectors, expand the lectures on the inspection procedures for a centrifuge plant.

SAFEGUARDS FOR ENRICHMENT PLANTS
14-18 November 1988

Results of Participants Comments and Evaluation Form II

I. BACKGROUND

1. Type of work: [11] Inspector [1] Technical Staff [1] General Services
2. Total number of hours per week spent on homework 0-2 hrs./wk.

II. CONTENT

	Very Low	Low	OK	High	Very High	No response
3. Proportion of the material that was new to you.	[]	[3]	[5]	[4]	[]	[1]
4. Degree to which the module materials and presentations supported the stated objectives.	[]	[]	[5]	[6]	[1]	[1]
5. The amount of reading and homework expected of you.	[2]	[2]	[3]	[2]	[1]	[3]
6. The technical level of the material presented relative to your needs.	[]	[]	[7]	[6]	[]	
7. Value to you of any notes and handouts provided by the instructor.	[]	[]	[2]	[6]	[5]	
8. Value to you of any film(s) or videotapes shown.	[]	[]	[7]	[4]	[2]	

III. INSTRUCTOR

If more than one instructor made presentations, rate each one separately.

9. Degree to which the communication of the lecture material was effective.						
J. Cooley	[]	[]	[6]	[5]	[2]	
D. Swindle	[]	[1]	[4]	[7]	[1]	
E. von Halle	[]	[2]	[6]	[4]	[1]	
D. Perricos	[]	[2]	[7]	[2]	[1]	[1]
D. Close	[]	[]	[2]	[8]	[1]	[2]
A. von Baeckmann	[]	[1]	[6]	[2]	[3]	[1]
J. Olivier	[]	[]	[5]	[8]	[]	
10. Your satisfaction with the amount of discussion allowed during the class time.						
J. Cooley	[]	[]	[5]	[6]	[1]	[1]
D. Swindle	[]	[]	[4]	[7]	[1]	[1]
E. von Halle	[]	[]	[5]	[5]	[2]	[1]
D. Perricos	[]	[]	[7]	[4]	[]	[2]
D. Close	[]	[]	[3]	[7]	[]	[3]
A. von Baeckmann	[]	[]	[5]	[6]	[1]	[1]
J. Olivier	[]	[]	[4]	[8]	[]	[1]
11. Adequacy of instructional help received outside of class time if you required it.						
J. Cooley	[]	[]	[2]	[5]	[1]	[5]
D. Swindle	[]	[]	[2]	[5]	[1]	[5]
E. von Halle	[]	[]	[2]	[5]	[1]	[5]
D. Perricos	[]	[1]	[4]	[2]	[]	[6]
D. Close	[]	[]	[2]	[5]	[]	[6]
A. von Baeckmann	[]	[1]	[3]	[3]	[1]	[5]
J. Olivier	[]	[]	[2]	[6]	[]	[5]
	Too Short	Short	About Right	Long	Too Long	No response
12. Length of module	[]	[]	[5]	[3]	[]	[5]
13. Length of time spent on lectures	[]	[]	[4]	[5]	[]	[4]
14. Length of time spent in problem sessions/exercises.	[1]	[2]	[5]	[]	[]	[5]

15. What topic(s), if any, should be expanded?

- Exercises.
- Safeguards at a Gas Centrifuge Enrichment Plant.
- Diversion scenarios.

16. What topic(s), if any, should be decreased or deleted?

- Separation and centrifuge theory (3).
- Sessions 9, 10, and 11.

17. What topic(s), if any, should be added?

- Exercises for further understanding of cascade areas.

18. Which session of the module do you consider to be of the greatest value to you?

- Principles of centrifuge separation theory.
- Diversion of Declared Material (Session 10).
- All.
- Plant description; Seibersdorf field trip; HEU production scenarios.

V. COMMENTS

20. Please give your constructive comments on how the Safeguards Training Unit could improve the module.

- Remove all things that the inspector should already be familiar with (i.e., only teach things specific to enrichment plants that are over and above what are known from inspections at other plants).
- Visit an enrichment plant.
- Well presented; well organized.

ACRONYMS AND INITIALISMS

HEU	highly enriched uranium
HSP	Hexapartite Safeguards Project
IAEA	International Atomic Energy Agency
ITP	International Technology Programs Division
LEU	low-enriched uranium
MUF	material unaccounted for
NDA	nondestructive assay
POTAS	U.S. Program for Technical Assistance to IAEA Safeguards
VIC	Vienna International Centre

DISTRIBUTION

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