JNMM

Journal of Nuclear Materials Management

Published by the Institute of Nuclear Materials Management ■ Volume XXV, Number 4 ■ August 1997

JNMM

JNMM (ISSN 0893-6188) is published four times a year by the Institute of Nuclear Materials Management Inc., a not-for-profit membership organization with the purpose of advancing and promoting efficient management and safeguards of nuclear materials.

SUBSCRIPTION RATES: Annual (United States, Canada, and Mexico) $100.00; annual (other countries) $135.00 (shipped via air mail printed matter); single copy regular issues (United States and other countries) $25.00; single copy of the proceedings of the Annual Meeting (United States and other countries) $65.00. Mail subscription requests to *JNMM*, 60 Revere Dr., Suite 500, Northbrook, IL 60062 U.S.A. Make checks payable to INMM.

ADVERTISING, distribution, and delivery inquiries should be directed to *JNMM*, 60 Revere Dr., Suite 500, Northbrook, IL 60062 U.S.A., or contact Don Wink at (847) 480-9573, fax (847) 480-9282, or e-mail B.Scott@inmm.com. Allow eight weeks for a change of address to be implemented.

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INMM
INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

Worldwide Growth — An Exciting Challenge

The past few years have been a time of exciting growth for INMM, and this year is no exception. I am pleased to report that since the start of INMM's fiscal year, the Executive Committee has approved the formation of two new chapters: a Northeast Chapter in the United States and an additional Russian Chapter in Obninsk.

INMM's first chapter outside the United States was the Japan Chapter, which is the largest and one of the most active. Other international chapters include Vienna, Korea, and two in Russia. There are five chapters in the United States: Northwest, Southwest, Central, Southeast, and Northeast. Other international groups have expressed interest in becoming INMM chapters, and the association will continue to promote and form additional chapters.

Chapters play an important role in INMM's framework and provide many opportunities for member participation. The information that chapter representatives provide to the Executive Committee about the operation of INMM also is very valuable. To facilitate international participation, the head of every INMM chapter outside the United States with at least 50 members is an ex-officio member of the Executive Committee.

The committee encourages members to take advantage of the opportunities available through INMM chapters, which routinely conduct meetings, social events, and workshops to promote professional development. Chapter meetings regularly sponsor technical presentations featuring topics such as the accelerator production of tritium, nuclear smuggling, tags and seals technology, and IAEA remote-monitoring activities.

Chapters are also instrumental in the organization and oversight of regional and, in some cases, international meetings. The Russian Chapter in Moscow played a major role in the international conference on Nonproliferation and Safeguards of Nuclear Materials in Russia, and the Vienna Chapter supports the International Safeguards Symposium, which is scheduled for October 1997. The Southeast Chapter supports the Annual WATTec Conference in Knoxville, Tennessee, and the Japan Chapter conducts an Annual Meeting that includes two days of technical presentations by international experts.

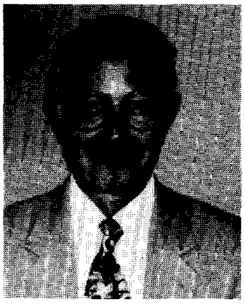
In addition to technical programs, many of the chapters are involved with community activities. Chapters routinely support annual student science fairs by making monetary donations and volunteering to serve as judges. Other outreach activities include participating in Engineers Week and on technical councils, as well as coordinating tours and visits.

If you are not actively involved with an INMM chapter, I encourage you to contact the regional leader in your area:

- Pacific Northwest — Don Six, president
- Southwest — Cindy Murdock, organizational point of contact
- Central — John Hehmeyer, chair
- Southeast — Lori Brownell, president
- Northeast — Amy Whitworth, organizational point of contact
- Vienna — Jill Cooley, president
- Japan — Tohru Haginoya, chair
- Korea — Hong Jong-Sook, chair
- Moscow, Russia — Vladimir Shmelev, chair
- Obninsk, Russia — Gennady Pshakin, organizational point of contact

Obie P. Amacker, Jr.
INMM president
Pacific Northwest National Laboratory
Richland, Washington, U.S.A.

Surfing the 'Net



Recently, while connected to the Internet (to read the Los Alamos National Laboratory's bulletin — the only way it can be read these days), I decided to explore a little to see if there is anything out there of interest to nuclear material management folk. I think this is called surfing. Perhaps it's already known to all of you, but I was surprised to find how much information really is available. In any case, here is some of what I found.

At the website *www.doe.gov/html/servers/lablogos.html*, there is a list of DOE laboratories and facilities that provides access to laboratory telephone books (not only a source of telephone numbers, but also of e-mail addresses). There also is information about each lab's organization, news about current activities, and job opportunities.

At *www.doe.gov*, there are links to information about the DOE mission, plans, organizational structure (probably always out of date), and accomplishments. You also can investigate departmental resources and learn about DOE news and hot topics, including DOE Directives and Orders and the Code of Federal Regulations. There also is a list of DOE employees with telephone numbers, e-mail addresses and mailing addresses.

At *www.c3.lanl.gov/inmm*, you can find the INMM annual meeting proceedings from 1989 through 1996. The proceedings can be browsed by subject, author, and table of contents. The papers themselves are fully searchable. Statistics provided indicate that this website is visited between 1,000 and 2,000 times a day!

A search using the Alta Vista search engine (*altavista.digital.com*) and the key words nuclear safeguards turned up about 400 responses. I had time to investigate only a few of them but found several that might be of interest to you.

At *www-safeguards.lanl.gov*, you can find a history of safeguards research at the Los Alamos National Laboratory, a complete list of publications by the Safeguards System group from 1977 through 1996, and links to other nuclear information. You can see the text of the Non-Proliferation Treaty, the IAEA's INFCIRC-153, the Treaty of Tlateloco, the Rules of Warfare (Conventions) from 1899 to the present, and much more. This site is well worth a visit.

At *www.ccnr.org/myth_2.html*, there is an interesting history, by Gordon Edwards, of Canada's nuclear industry from the 1940s to the 1980s. I wasn't even aware that Canada played a role in the development of the atom bomb.

The website at *willow.sti.jrc.it/weng/nfc/nfchome.htm* describes safeguards research at JRC Ispra and safeguards practices within the European Union.

Finally, *www.iaea.or.at/worldatom/inforesource/bulletin/bull371/priest.html* gives a very interesting overview, by Jan Priest, of the IAEA's verification role and its relationship to the Treaty on the Non-Proliferation of Nuclear Weapons.

These were all the sites I had time to browse. Now back to work.

This issue of JNMM contains three technical papers. The first, "Safeguards Termination Limits on Immobilized Nuclear Material," by the DOE's David Crawford, provides a convincing technical justification for the safeguards termination limit for immobilized nuclear materials being established at 5% special nuclear material by weight.

The second paper describes a new safeguards approach for the High Temperature Engineering Test Reactor in Japan. The approach combines an Unattended Fuel Flow Monitor System and a Dual Containment/Surveillance system to overcome the difficulty in inventory verification of the core and spent fuel storage. Safeguards efforts would be reduced from 230 man-days per year to several man-days per year. The paper is titled "Safeguards Concept for High Temperature Engineering Test Reactor Using Unattended Fuel Flow Monitor System." The authors are Kiyonobu Yamashita, Fujio Miyamoto, Sigeaki Nakagawa, and Toshiyuki Tanaka of the Japan Atomic Energy Research Institute.

"A Physical-Model-Based Diagnostic Aid for Safeguarding Nuclear Material in a Liquor Storage Facility" has nothing to do with those marvelously beautiful storage vessels for Scotch whiskey. Instead, the paper describes the main features of a prototype diagnostic aid that has been developed to provide the capability of identifying and, when necessary, sounding alarms of unusual activities and measurement errors produced by on-line instrumentation in liquor (liquid) storage facilities. The aid also enables safeguards personnel to explore why the anomalies have occurred and to examine alternative explanations. The authors of the paper are John Howell and Stephen Scothern of the University of Glasgow.

Darryl Smith
JNMM technical editor
Los Alamos, New Mexico, U.S.A.

Secretary's Corner

The INMM Executive Committee met in March 1997 in Chicago. The agenda included reports from technical divisions, ANSI committees, standing committees, and ad hoc committees.

Finances
Current assets are $356,473 and the Merrill Lynch Trust Account contains $163,518. The 1997 fiscal year financial statement through February was approved by Executive Committee.

Secretary Announcements
Darryl Smith was approved for Emeritus membership, and Rich Strittmatter was appointed to the Executive Committee as a member-at-large by electronic balloting before the meeting. Strittmatter fills the seat left vacant by the resignation of Scott Strait.

Technical Division Reports
International Safeguards. The committee is planning a joint INMM/ESARDA workshop in Albuquerque, New Mexico, in September or October 1998.

Material Control and Accounting. Dennis Brandt of Los Alamos National Laboratory was appointed MC&A Division chair by the Executive Committee to replace Rich Strittmatter. The workshop on "International Inspection of Fissile Material" was well attended and financially successful. Other workshops are planned.

Physical Protection. The committee is still considering two upcoming workshops. One workshop would explore the possible methods of integrating physical security and MC&A, and the second would deal with the different aspects of explosive detection and protection.

Waste Management. The committee has begun coordinating the Low Level Waste Management Seminar to be held in Spain in October 1997. The publication of the monograph on Spent Fuel Management is still underway.

Committee Reports
Government Liaison. The Executive Committee approved a proposal to extend the Annual Meeting to Thursday afternoon, so the Government Liaison session, previously held as an adjunct to the Annual Meeting, will be the closing session.

Membership. The paid membership was reported as 723, including 23 corporate memberships. The Executive Committee also approved Francis Haas for Emeritus Membership.

Chapter Reports
The Russian Federation Chapter has been very active. The Executive Committee approved a dues structure for the Russian Chapter commensurate with Russian financial conditions.

The Korean Chapter members submitted a final version of its constitution and bylaws for approval.

The Southwest Chapter has been reactivated and will hold its election this summer.

Old Business
The Executive Committee approved a memorial fund for the Institute. The details of the fund will be announced at the Annual Meeting.

The Institute also has continued working with members from Obninsk, Russia, to form a Russian sectional chapter.

A copy of the complete meeting minutes can be obtained from INMM headquarters, 60 Revere Drive, Suite 500, Northbrook, IL 60062; 847/480-9573; fax:, 847/480-9282; e-mail, inmm@inmm.com.

Vincent DeVito, INMM secretary
Management System Evaluations
Waverly, Ohio, U.S.A.

Division Reports

International Safeguards

The next meeting of the INMM International Safeguards Division (ISD) will be held July 20, 1997, during the 1997 INMM Annual Meeting in Phoenix. The "Discussion Topics for July 1997 ISD Meeting," which was distributed in June, will be the starting point for the division's discussions.

At the meeting, Roger Howsley, head of Security and International Safeguards at British Nuclear Fuel plc, based in Risley, England, will be nominated to become the next vice chair of the division. Paul Ek, who has been the vice chair since the division's first meeting, will no longer be able to participate actively in the division's activities. Ek participated in the original organization of ISD, as well as the early meetings that heralded the significant changes that have occurred and are occurring in international safeguards.

Plans are proceeding for the 1998 Joint ESARDA/INMM Workshop on Science and Modern Technology for Safeguards. The Workshop will be held in Albuquerque, New Mexico, in September or October 1998. The U.S. Department of Energy and Sandia National Laboratories will assist in the sponsorship of this workshop. The conduct and format for the workshop, with principal emphasis on invited speakers and safeguards practitioners, will be the same as that used at the 1996 workshop held in Arona, Italy.

Cecil S. Sonnier, chair
International Safeguards Division
Albuquerque, New Mexico, U.S.A.

Chapter News

Vienna Safeguards Symposium

The Vienna Chapter held its annual INMM Safeguards Symposium March 13 at the Vienna International Centre.

The keynote address was delivered by Garry Dillon, deputy leader of IAEA's UNSC 687 Action Team, who delivered a report about the status of ongoing monitoring and verification activities in Iraq. Vienna Chapter President Jill Cooley served as chair of the symposium, and Maribeth Hunt organized the event.

The one-day symposium included 14 papers delivered by staff members from the IAEA Departments of Safeguards, Nuclear Energy, and Research and Isotopes. Papers covered themes such as information review and evaluation, strategic management, safeguards for spent fuel disposal, no-notice inspections, and the use of mixed oxide fuel in light water reactors.

As has become the tradition, one paper from among the Safeguards Department staff presentations was selected by a review panel for presentation at the 1997 INMM Annual Meeting. The travel expenses of the presenter will be paid by the office of Deputy Director General Bruno Pellaud. This year's selected paper was written by Manfred Zendel and is titled "Use of Neutron/Gamma Monitoring Systems as Safeguards Tools for the Ignalina RBMK Reactors."

The Vienna Chapter Symposium provides a forum for exchange of new technical information and concepts being developed within the agency. It also introduces the INMM to the international community of IAEA.

Jill Cooley, president
INMM Vienna Chapter
International Atomic Energy Agency
Vienna, Austria

Pacific Northwest

The INMM Pacific Northwest Chapter held a successful dinner meeting, which featured Bob Ferguson, chair of Technical Resources International in Richland, Washington. During the late-winter meeting, Ferguson spoke about Hanford Excess Plutonium Disposition to an overflow audience. His topic prompted several questions and a lively discussion.

In other news, chapter leaders are distributing the approved revisions to the chapter constitution and bylaws.

Chapter members voted recently to support the Columbia River Exhibition of History, Science, and Technology (CREHST) with a donation toward the group's new facilities. CREHST was established in 1996 to replace the Hanford Museum and Science Center, which was financed by the U.S. Department of Energy.

CREHST now is a nonprofit museum and science center that promotes public understanding of the impact of people and technology and celebrates the history and technological awareness of the Columbia Basin region of south central Washington.

The chapter also decided to continue its long-time support of Engineering Week activities, which supports a science fair and competition for local students. The funds provided by the Pacific Northwest Chapter help send regional winners to the national competition.

Deanna Osowski, secretary/treasurer
INMM Pacific Northwest Chapter
Westinghouse Hanford Co.
Richland, Washington, U.S.A.

Japan Annual Meeting

The Japan Chapter's 18th Annual Meeting will be held November 27-28 at Gakuskikaikan, Tokyo, Japan. The meeting will feature a panel discussion that focuses on the implementation and expectations of the 93+2 Programme, as well as a poster and instrumentation demonstration.

Industry experts from around the world will offer presentations during several sessions, and a general reception will conclude the meeting's first day of events. The registration fee is 4,000 yen for members and 7,000 yen for nonmembers. The cost covers handout materials, a meeting synopsis and a copy of the proceedings, which will be mailed to attendees after the meeting. The reception fee is 6,000 yen per person.

For more information, contact Keisuke Kaieda, Japan Chapter Program Committee chair, at 3-3592-2365; fax, 3-3592-2129; e-mail, kaieda@hems.jaeri.go.jp.

Keisuke Kaieda
Japan Chapter program committee chair
Japan Atomic Energy Research Institute
Tokyo, Japan

Chapter News

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(l to r) Myron Kratzer, former U.S. deputy assistant secretary of state; Dr. Eklund, former IAEA director general; Jill Cooley, INMM Vienna Chapter president.

Vienna

The Vienna Chapter maintained a high level of activity in the spring. Luncheon meetings were held in March and April 1997.

In March, Myron Kratzer, former U.S. deputy assistant secretary of state, spoke about "INFCIRC/153 After 25 Years." Kratzer described the history of INFCIRC/153, which is extremely relevant to the safeguards implementation issues being addressed today.

David Fischer, former director and assistant director general of IAEA's Division of External Relations, visited chapter members in April to discuss "Fifty Years of Nonproliferation and Safeguards." Fischer provided a fascinating account of the history of safeguards and IAEA. His book, titled *A History of the IAEA 1957–1995,* will be published later this year. Both luncheons were very well attended.

The annual chapter safeguards symposium was held in Vienna in mid-March. The keynote address, which described ongoing monitoring and verification activities in Iraq, was presented by Garry Dillon; 14 technical presentations followed.

The chapter also provided financial and organizational support for the 1997 International Science and Engineering Fair, held in Vienna in mid-April. Sponsored jointly by the Vienna Chapter of INMM and American Nuclear Society, the Science Fair was open to junior and senior high school students who attend Vienna's seven international schools. More than 190 students participated in the 1997 fair, which was organized by chapter members Shirley Johnson and Maribeth Hunt. Numerous chapter members assisted with the planning, promotion, conduct, and judging of the fair, helping to make it a huge success. This type of support to the community is an important function of the INMM Vienna Chapter.

Plans are underway for chapter members to serve as hosts during a reception at the October IAEA Safeguards Symposium in Vienna. The reception will be jointly sponsored by the Vienna and Japan Chapters of INMM.

Jill Cooley, president
INMM Vienna Chapter
International Atomic Energy Agency
Vienna, Austria

Russian Federation

The Russian Federation Chapter elected its 1997 officers.

Vladimir Shmelev takes over as chapter president, Vladimir Sukhoruchkin is vice president, and Alexander Roumiantzev is secretary/treasurer. All three newly elected chapter officers conduct research at the Kurchatov Institute in Moscow.

The Russian Federation Chapter consists of 14 members from nine governmental and nongovernmental organizations. Chapter members are reviewing membership applications from an additional six industry representatives.

In 1996 and 1997, chapter members worked diligently to upgrade materials control and accountability in the Russian Federation, focusing on export-control activities, nuclear-arms reduction, and international safeguards. The chapter has made significant contributions in these areas.

Vladimir Shmelev, president
Russian Federation Chapter
Kurchatov Institute
Moscow, Russia

N-14 Committee Report and Standards Update

N14 Committee Update

The 1997 N14 Committee annual meeting will be held November 6, 1997 in Washington, D.C. Mimi Welch resigned as N14 secretary and has been replaced by Paul Crawford of Oak Ridge Institute for Science and Education.

For information or questions relative to N14 activities, you may contact: John Arendt, 109 Caldwell Drive, Oak Ridge, TN 37830; phone, 423/483-1401; fax, 423/482-9580; e-mail, jwarendt@aol.com or Joreé O'Neal, Oak Ridge Institute for Science and Education, MS-20, P.O. Box 117, Oak Ridge, TN 37831-0117; phone, 423/576-7434; fax 423/576-6675; e-mail, onealj@orau.gov.

A standards status report follows.

N14.1-1995 Packaging of Uranium Hexaflouride for Transport

R.I. Reynolds, chair

The standard was approved December 1, 1995 and published. The chair is requesting information for a proposed revision and is tentatively scheduling a writing group meeting in January 1998.

N14.2 Tiedowns for Transport of Fissile and Radioactive Containers Greater Than One-Ton Truck Transport

R.E. Glass, chair

This standard prescribes general requirements for securing packages of radioactive materials so they are not likely to come off their vehicles in the worst non-accident events of highway transportation. Present plans call for this draft to be balloted by N14 in late 1997.

Estimated completion: 1998

N14.5-1987 Leakage Tests on Packages for Shipment

L.E. Fischer, chair

This standard specifies methods for demonstrating that Type B packages comply with the package containment requirements of Title 10 of the Code of Regulations, Part 71, September 1983, as amended, or of the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6, 1985, or verification, and periodic verification. The draft standard has been approved by N14.5 writing group and the ballot will close June 15, 1997.

Ballot: June 15, 1997

Resolve comments: September 1997

Estimated completion: December 1997

N14.6-1993 Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More for Nuclear Materials

George Townes, chair

This standard sets forth requirements for the design, fabrication, testing, maintenance, and quality assurance programs for special lifting devices for containers weighing 10,000 pounds (4,500 kg) or more for radioactive materials. Review for an update will start in 1998.

Estimated completion: Complete

N14.7 Guide to the Design and Use of Shipping Packages for Type A Quantities of Radioactive Materials

R.B. Pope, chair

This standard provides guidance for persons responsible for activities involving the packaging of radioactive materials in Type A quantities. Comments on the initial draft are being evaluated and incorporated. There is currently no activity on this draft standard. Funding should be available in 1997.

Ready for ballot: End of FY 1997

N14.8 Fabricating, Testing, and Inspection of Shielded Shipping Casks for Irradiated Reactor Fuel Elements

D. Dawson, chair

This activity will utilize the Peer Panel Review to determine standards that should be developed. Currently not active. Will be activated when documents are received for standards consideration.

Estimated completion: N/A

N14.10 Guide for Liability and Property Insurance Aspects in Shipping Nuclear Materials

This guide discusses conventional liability (general and automobile liability), insurance policies, and the attendant nuclear liability exclusion (Broad Form) as they apply to nuclear liability arising out of the transportation of nuclear material. May be reactivated.

Estimated completion: N/A

Ancillary Features of Irradiated Shipping Casks

This standard sets forth requirements for the performance, design, fabrication, testing, operation, maintenance, and quality assurance of the ancillary features of irradiated fuel shipping casks. Standard has been withdrawn. Status of this standard is being evaluated based on ballot results. Need for standard is questionable. Possible adoption of ISO standard on trunnions.

Estimated completion: N/A

N14.23 Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater Than One Ton in Truck Transport

Ken Gwinn, chair

This standard specifies minimum design values for shock and vibration in highway transport, by truck or tractor-trailer combination. A final draft is currently being prepared for N14.23 Committee approval and then to N14 for balloting. All comments from the recent meeting have been incorporated.

Estimated completion: 1997

N14.24-1985 (R1993) Domestic Barge Transport for Highway Route Controlled Quantities of Radioactive Materials

This standard identifies the organizations, equipment, operations, and documentation that are involved in domestic (i.e., between U.S. ports) barge ship-

N-14 Committee Report

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ments of highway route controlled quantities of radioactive material on inland waterways and in coastwise and ocean service. Reaffirmation was approved June 28, 1993. A new writing group chair is to be appointed and new scope prepared by January 1, 1998. Expand beyond HRCQ.
Estimated completion: N/A

N14.25 Tiedowns for Rail Transport of Fissile and Radioactive Material Containers
Bob Glass, chair
This standard applies to attachment or tiedown of containers of radioactive materials to railroad cars where the gross weight of the containers exceeds one ton. A preliminary draft was sent to the N14 Management Committee for review and comment. A Project Initiation Notification System will be prepared for submission to ANSI. The scope will be sent to the N14 Committee for approval prior to submitting to ANSI.
Estimated completion: 1998

N14.26 Fabrication, Inspection, and Preventative Maintenance of Packaging for Radioactive Materials
Kevin Nelson, chair
This standard provides requirements for the fabrication, maintenance, and inspection to ensure the packaging is (1) properly fabricated in accordance with appropriate specifications, (2) properly maintained, (3) properly inspected, and (4) properly assembled for shipment. Reusable Type A packages. A new chair has been appointed and the writing group will be expanded.
Estimated completion: TBD

N14.27-1986 (R1993) Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents
Bill Pitchford and Mike Keane, co-chairs
This standard encompasses the preparation and execution by carriers and shippers of their emergency response program. It does not include the responsibilities of the first-on-the-scene response personnel, the actions of governmental authorities, or the specific responsibilities of the carrier or shipper during recovery operations. Reaffirmation was approved June 28, 1993. Writing group co-chairs have been appointed. Planning will start on a new scope and an extensively revised standard in 1997. Need 20 new volunteers: 10 government, 10 industry.
Estimated completion: 1999

N14.29-1988 Guide for Writing Operating Manuals for Packaging
Dennis McCall and Mike Burnside, co-chairs
This guide describes the preparation and distribution of operating manuals for the use, maintenance, and inspection of packages for shipping radioactive material. It prescribes the contents of such a manual and its arrangement, and contains a sample manual. A draft has been prepared and is being reviewed internally prior to sending to the writing group for their review and approval.
Estimated completion: 1998

Radioactive Loads
Ralph Best, chair
This standard established the design fabrication, and maintenance requirements for the highway transport of weight-concentrated radioactive loads (any payload that exceeds 1,000 pounds per lineal foot over any portion on the semi-trailer). In addition, the standard provides detailed procedures for inservice inspections, testing, and quality assurance. Revision of this standard will start in 1997. Ralph Best, SAIC, is the new writing group chair.
Estimated completion: 1999

N14.31 Standard Tiedowns on Legal Weight Transport System (80,000 lbs) for Packages Containing Hazardous Materials and Weighing Greater Than 500 Pounds
Larry Shappert, chair
This standard provides a method for defining an appropriate tiedown system via the Tiedown Stress Calculation Program. The standard describes general requirements for tiedown securing hazardous materials packages to conventional trailers. The packages have a suitable base plat or flat base, and appropriate size arrangement of tiedown assemblies for packages that are within weight and dimensional limits of the equipment. The writing group commented that the text and computer model need work. Results of a recent IAEA Technical Committee meeting on package securement need to be considered in modifying the draft standard. Funding may be available in FY 1997 to accommodate above actions and send a redrafted standard to the writing group.
Estimated completion: 1997

N14.32 Gas Generation in Packages Used for the Storage or Transport of Radioactive Materials
L.E. Fischer and Phillip Gregory, co-chairs
This standard includes, but is not limited to radiolysis, chemical reactions, thermal expansion, and biological degradation. The standard would provide a consistent approach to testing, analysis, and mitigation of gases that could cause a pressure building up or a potentially flammable mixture in a package containing radioactive materials. A PINS form has been prepared. An N14 ballot approved the title and scope. A writing group is forming and work will start on preparing the first draft.
Estimated completion: 1999

John Arendt, chair
INMM Standards Committee
John Arendt Associates Inc.
Oak Ridge, Tennessee, U.S.A.

Safeguards Termination Limits on Immobilized Nuclear Material

David W. Crawford
U.S. Department of Energy
Germantown, Maryland, U.S.A.

Abstract

This paper provides a technical justification for the safeguards termination limit (STL) for immobilized nuclear materials being established at 5% special nuclear material (SNM) by weight, as so stated in recent Office of Safeguards and Security (OSS) guidance on this subject.[1] This justification is important in assessing the appropriateness of the STL in terms of environmentally sound storage of vitrified waste at the Waste Isolation Pilot Plant, near Carlsbad, N.M., and the use of this STL as ceilings under which individual sites may operate their vitrification plants based upon process limitations, disposal criteria, and transport criteria. It is also important that STLs in general accommodate current disposition plans for excess fissile material, particularly plutonium.

Discussion

The Department of Energy recently announced that U.S. disposition of plutonium will consist of burning as mixed oxide (MOX) fuel in commercial power reactors and immobilization prior to deep underground disposal.[2] The immobilization option, as recommended by the National Academy of Sciences (NAS) 1994 study of plutonium disposition "Management and Disposition of Excess Weapons Plutonium," recognizes that plutonium in a vitrified matrix may be recoverable, given enough time and resources, particularly by an advanced nuclear weapons state. This point was iterated in the conclusion of the NAS study that vitrification of excess plutonium without radioactive fission products would not in itself be sufficient to meet what is referred to as the "spent fuel standard;" that is, making excess plutonium as inaccessible and unattractive for weapons use as plutonium in spent fuel. Secondly, vitrified SNM forms, whether bonded in cement, bitumen, borosilicate (glass), Synroc, or polymer, have many characteristics that preclude practical recovery of the SNM. These include physical and chemical bonding of the SNM to the matrix material, the monolithic nature of the SNM in the matrix, difficulty in handling because of the weight and the lack of operating production processes specifically designed to recover plutonium from these matrices. Regarding the latter point, recovery efficiencies and economics can only be postulated based on benchscale research and development or speculative extrapolation of data from what would be considered similar processes. Therefore, an upper bound on the SNM content in immobilized matrices must be established that is linked to attractiveness and extant processing technology. The issue then becomes one of what the upper bound should be, given the need that this value be a direct function of the recoverability of the vitrified SNM in the immobilized matrix and its desirability to a potential weapons proliferant.

Plutonium and other SNM can be recovered from any matrix. However, it is not true that every matrix is attractive to potential nuclear weapons proliferants simply because recovery is theoretically or even technically possible. The real constraints of technology availability, resources, availability of sufficient inventory, and visibility/detection work synergistically to affect attractiveness for proliferation purposes. When SNM has been conditioned in refractory matrices such as glass or exists in an inert or solid solution with refractory materials and is destined for geologic disposal (the NAS plutonium disposal scenario), the material cannot be deemed attractive to diversion considering that other avenues for obtaining SNM exist. SNM recovery from immobilization matrices involves substantial time and effort and cannot be accomplished by simply breaking the matrix and leaching in hydrochloric acid as is widely supposed. Recovery from matrices such as glass is a very difficult process that requires milling, dissolution, and many subsequent processing steps.

Rationale for Current STL

Given the difficulty in recovering SNM from immobilized matrices, is the 5% SNM by weight concentration level as the STL for immobilized forms reasonable? OSS considers this threshold appropriate and sufficiently conservative for the following reasons:

1. *The 5% STL represents a constraint on immobilization processes.* West Valley has demonstrated that the ability to achieve a 6% radionuclide concentration in glass makes the 5% STL a constraint on vitrification technology. This STL constrains a facility from discarding SNM irresponsibly.
2. *The 5% threshold makes the immobilized SNM less attractive than other potential sources for SNM.* Both irradiated and unirradiated nuclear material, such as fuels,

would be far more attractive materials for proliferation purposes than immobilized SNM below the current STL. The 5% threshold represents a quantitative duplication of the graded safeguards approach, as the level of difficulty in removing the SNM from other matrices prescribed in the OSS guidance used for defining STLs is much greater for immobilized matrices than in simpler forms, such as salts, precipitates, low- to moderately-radioactive nonrefractory alloys, and solutions. A case in point is the following: Los Alamos National Laboratory plutonium processing experts contend that recovery of microencapsulated materials at ≤5 weight % (such as immobilized SNM) is 10 times more difficult than obtaining the same quantity of fissile material from a mining/milling/enrichment cycle. The consensus opinion of the same experts is that in the current world environment, recovery of plutonium from microencapsulated or immobilized matrices would be the least attractive of all credible options available for potential proliferants interested in obtaining fissile materials.[3]

3. *The 5% threshold is consistent with and supports the NAS recommendations and the recently announced U.S. decision on immobilization of excess plutonium as a disposition option.* The 5% STL does not apply to all inventories of SNM that are being considered for disposal, not even all low-grade materials. The OSS guidance considers primarily the degree of difficulty of recovery by non-nuclear entities (e.g., rogue states or subnational groups) and not the capabilities of advanced and responsible nuclear states, such as those with extant reprocessing capabilities. The guidance does have a technical application to disposal of excess plutonium inventories. In the case of vitrification of spent MOX fuel, a greater than 6 weight % actinide content in borosilicate glass is readily achievable (refer to the West Valley experience discussed above). The 5% actually constrains extant stabilization technologies. Therefore, lowering the limit would not make vitrified SNM any less attractive; however, it would make disposal more expensive and difficult. So, the 5% represents an appropriate balance between cost, effort, extant technology, and safeguards. Furthermore, if, at some later date, the United States pursues direct disposal of irradiated MOX fuel as a consequence of the NAS recommendations and the U.S. decision on excess plutonium because the contained plutonium meets-the spent fuel standard, a 5% limit serves to mandate the degree of MOX reactor irradiation. MOX fuel for fast reactors is about 15% plutonium oxide and MOX fuel enrichment (Pu-239 + U-235) for LWRs is 6–7%. Consequently, a burnup of approximately 30 Gwd(t)/MT would be required to meet the STL of 5%. This indirectly mandated irradiation is directly consistent with the NAS recommendations and accommodates their implementation.

Conclusion

In summary, the current 5% STL for immobilized SNM is deemed to be appropriate because of the current state of demonstrated and extant recovery technologies necessary to separate the SNM from its matrix form. Increasing the limit would increase the attractiveness of the immobilized form and decreasing the limit would provide no additional safeguards or proliferation benefit. The current STL also supports the NAS recommendations for the long-term management of excess plutonium and recently announced plans for the disposal of excess plutonium.

Acknowledgement

The author wishes to thank Mark A. Robinson of the Los Alamos Nuclear Material Technology Division for his technical input.

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Safeguards Concept for the High Temperature Engineering Test Reactor Using Unattended Fuel Flow Monitor System

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Abstract

The High Temperature Engineering Test Reactor (HTTR) is an HTGR-type research reactor — direct access to the core for inspection is difficult because of strong radiation from the burned fuels and the long fuel reloading time. Opening the upper-hemisphere of the reactor vessel is not possible, unlike other water-cooled research reactors. It takes about 200 days to carry out item counting by reloading the fuel blocks from the core. Furthermore, it takes about 30 days to reload the fuel blocks in the spent fuel storage. The inspection efforts are very extensive when the inspection is carried out by discharging the fuel blocks from the core and spent fuel storage. These areas are defined as "difficult to access." Therefore, an adequate safeguards approach for the HTTR cannot be found among the established techniques for research reactor and critical assemblies (RRCAs).

A new specific safeguards approach that is appropriate for the HTTR is needed. The difficulty in inventory verification of the core and spent fuel storage is overcome by introducing an unattended fuel flow monitor system (UFFM). Safeguards efforts are reduced from 230 man-days per year to several man-days per year by the UFFM and application of the dual C/S for the spent fuel storage.

Introduction

The Japan Atomic Energy Research Institute (JAERI) has been constructing the HTTR since March 1991. About 95% of the facility is completed. The receipt of fuel will start in July 1997. The HTTR will go into the first criticality by the end of the year. The core will be fully loaded with fuel blocks in the beginning of 1998. The HTTR will be operated at full power at the end of 1998.[1,2]

The objectives of the HTTR are to carry out the necessary research and development for establishing and upgrading the HTGR technology base, and to conduct innovative basic research on high temperature technologies, such as advanced ceramics and fusion materials. The HTTR is an HTGR-type research reactor with thermal output of 30 MW and outlet coolant temperature of 950°C, employing low-enriched uranium fuels. The major specification of the HTTR is summarized in Table 1. The total amounts of U-235 and U in the fresh core are 52 kg and 900 kg, respectively. All the fuel blocks burned up in the reactor core are replaced with fresh fuel once after every burnup cycle. The average fuel burnup reaches 22 GWday/t in the whole core (after three years with the availability of 60%).

Table 1. Major Specifications of the HTTR

Thermal power	30 MW
Core height	2.9 m
Core diameter	2.3 m
Average power density	2.5 W/cc
Fuel block	Hexagonal
Number of fuel blocks	150
Fuel	UO_2
Fuel type	Coated fuel particle
Uranium enrichment	3-10 wt%
Number of different enrichment of uranium	12
Moderator	Graphite
Outlet coolant temperature	950°C
Coolant pressure	4 MPa
Reactor pressure vessel	Steel
Coolant	He
Average fuel burnup	22 GWday/t
Maximum fuel burnup	33 GWday/t
Refueling	All fuels
Refueling period	Every three years

Figure 1. Horizontal cross section of the reactor building

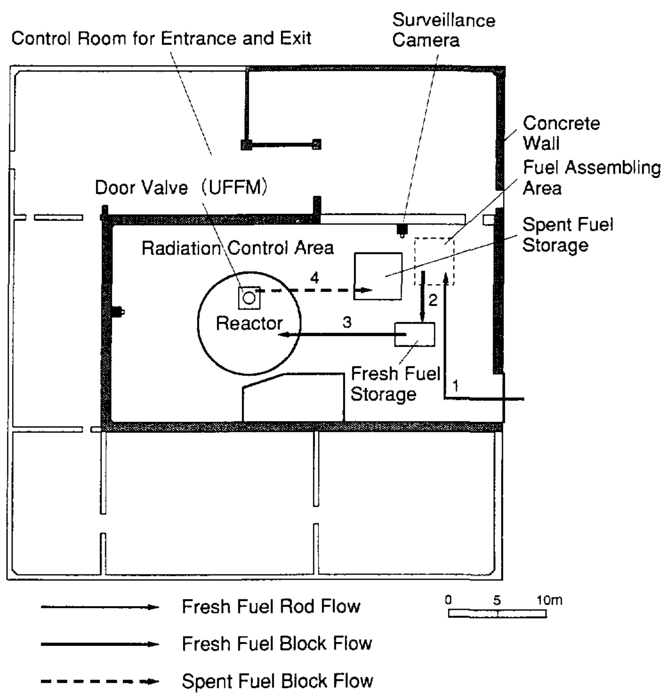
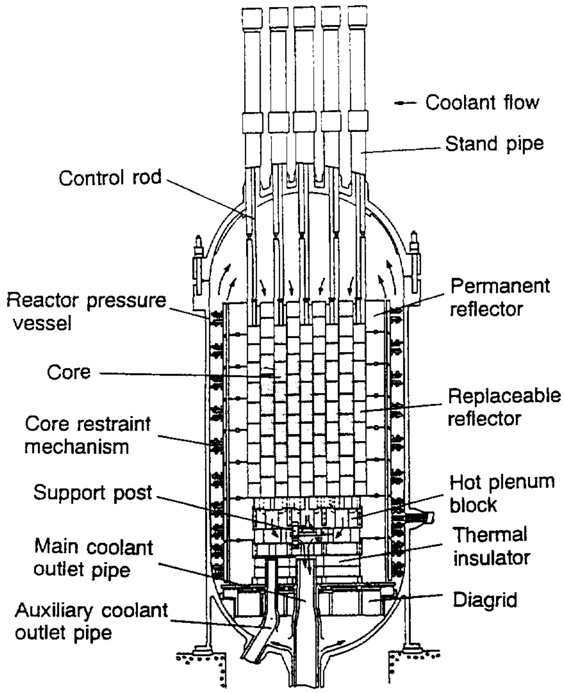


Figure 2. Vertical cross section reactor



The total amount of Pu in all the spent fuel blocks amounts to about 6.5 kg after one burnup cycle.

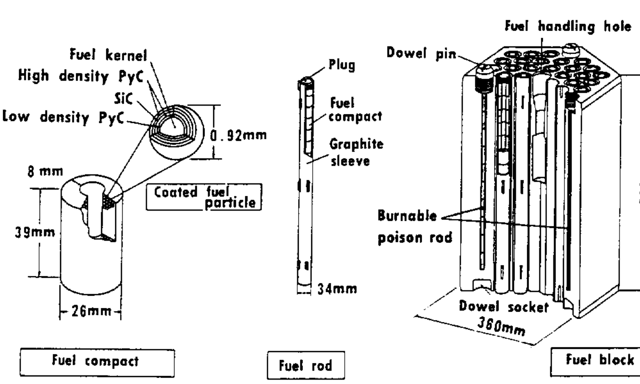
Implementation of general safeguards is specified in IAEA Safeguards Criteria,[3] mainly for conventional water-cooled research reactors. The criteria cannot be directly applied to unusual reactors like the HTTR. Therefore, a new safeguards approach must be developed in consideration of the characteristics of the HTTR. The resulting safeguards approach would satisfy the requirements of the criteria.

Outline of the HTTR

Fresh fuel storage, the reactor core, and the spent fuel storage are located in the reactor building, as shown in Figure 1. The reactor core is nearly in the center of the reactor building, and is contained in the reactor vessel. The core, 2.9-m in height and 2.3-m in diameter, comprises 30 fuel columns. Each fuel column consists of five fuel blocks arranged vertically. The vertical cross section of the reactor is shown in Figure 2. There are a total of 150 fuel blocks in the core. The core is surrounded by top, side, and bottom replaceable reflector blocks. Sixteen pairs of control rods are inserted into the control rod guide column in the core and side reflector. The permanent reflectors surround the side replaceable reflectors and are fixed by the core restraint mechanism. The uranium enrichment ranges between 3 and 10 Wt% in the core to optimize the power distribution. The number of different uranium enrichments is 12.

The fuel block consists of a graphite block and fuel rods. The structure of the fuel block is shown in Figure 3. A fuel rod contains fuel compacts in which coated fuel particles are dispersed.

Figure 3. Stucture of fuel block



A coated fuel particle consists of a UO_2 kernel coated with pyrocarbon layers and an SiC layer. The fuel rods are inserted into vertical holes in the graphite block. A fuel block contains 31 or 33 fuel rods. The weight of a fuel block is about 100 kg. The uranium enrichment of each compact is the same in a fuel block. Helium gas flows through an annular gap between the hole's wall and the fuel rod to remove heat.

Fresh fuel storage is located in the reactor building as shown in Figure 1. The geometrical arrangement of the fresh fuel storage is similar to the spent fuel storage shown in Figure 4. The fresh fuel blocks are stacked in the rack vertically, the same as the spent fuel storage. The fresh fuel storage consists of 35 racks. Fresh fuel blocks are stacked in each rack together with the graphite blocks to be used for the top and bottom reflectors. The

Figure 4. Stucture of spent fuel storage

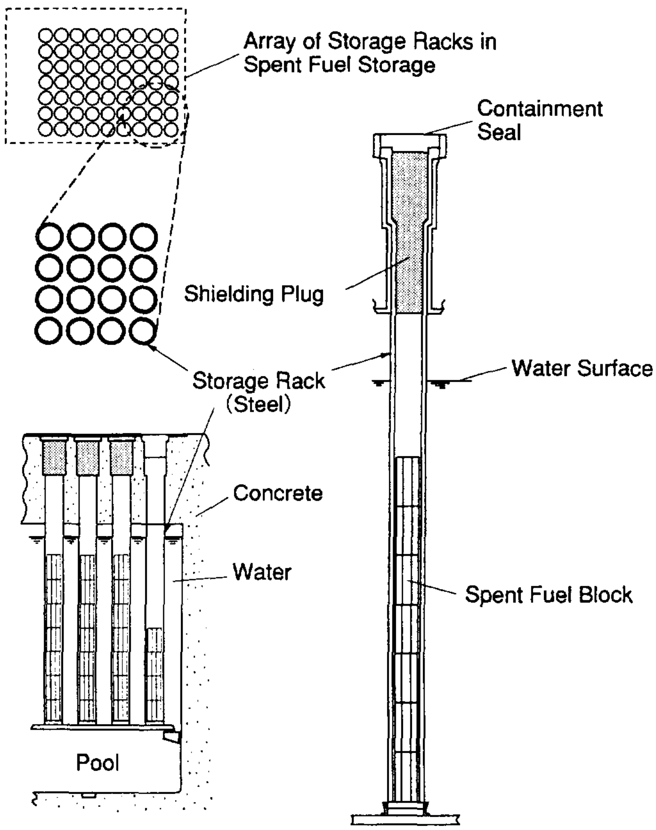


Figure 5. Fuel movement in the facility

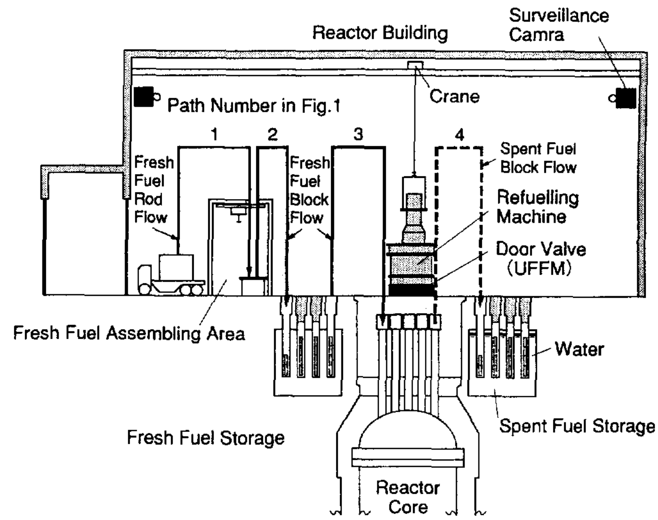


Table 2. Inventory of Each KMP

Nuclear Materials	Fresh Fuel Storage	Core	Spent Fuel Storage
^{235}U (kg)(SQ)	52 (0.69)	52 (0.69	32 (0.43)
Pu (kg)(SQ)	0	0	6.5 (0.81)

array of these blocks is the same as the axial array of the reflector and fuel blocks in fuel columns of the reactor core. Each rack is closed with a plug.

The spent fuel storage is located in the reactor building, as shown in Figure 1. Spent fuel blocks are stacked in the rack vertically as shown in Figure 4. The fuel blocks are moved by the refueling machine from the core. Each rack is closed with a shielding plug. The spent fuel storage is filled with water. The spent fuel blocks are cooled from the outside of the rack dipped in water. The spent fuel storage is covered with the concrete lid. The observation of the spent fuel is not possible, unlike conventional research reactors.

Fresh fuel rods and graphite blocks are transported separately to the reactor building from a fabrication plant. They are assembled to form fuel blocks at a fuel assembly area. The flow of the fuel is given in Figure 5. The assembled fuel blocks are inserted into the fresh fuel storage by the fresh fuel handling machine. The reactor is charged by the refueling machine, which transports the fresh fuel from fresh fuel storage to the core. All of the fuel blocks in the reactor core are replaced with fresh fuel blocks every three years. It takes about 200 days to change all the fuel blocks in the reactor core with the refueling machine. Spent fuel blocks are discharged from the reactor core with the refueling machine. They are transported through stand-pipes after dismantling the stand-pipe closure and control rod driving mechanisms. The upper hemisphere of the reactor vessel cannot be removed for refueling, because the radiation from the reactor core cannot be shielded by cooling water. Contrary to the situation for conventional light water reactors, direct visual verification of the fuel in the reactor core cannot be applied.

Characteristics of the Facility

Nuclear material accountancy and control are performed by establishing a single material balance area. The key measurement points (KMPs) are fresh fuel storage, the reactor core, and spent fuel storage. The characteristics of the HTTR are summarized from the standpoint of safeguards in the following:

(1) Practice of safeguards

One of the main factors for implementing safeguards is enrichment and inventory. The maximum uranium enrichment is less than 10 wt%. The inventory of each KMP is smaller than a significant quantity, as shown in Table 2.

(2) Spent fuel reprocessing

The technique for spent fuel reprocessing has not yet been established on an industrial basis. The difficulty in the reprocessing will act as an obstacle to diversion.

(3) Separability of fuel rods from the fuel block

Fuel rods are inserted in the coolant channels of the fuel block.

The fuel rod is connected loosely with the fuel block, and can be dismantled easily from the fuel block.

(4) Function of the HTTR
A variety of research activities are planned for the HTTR. Many irradiation test specimens in different forms will move into and from the core. The irradiation materials are advanced fuels, metals, ceramics, etc. It requires a monitoring system that can distinguish fuel from non-nuclear materials.

(5) Difficult-to-access
Direct verification of the fuel in the core and spent fuel storage is difficult. The strong radiation from the core and spent fuel storage precludes opening the reactor pressure vessel and the plug of the spent fuel storage rack, respectively. These areas will be defined as "difficult-to-access" in terms of safeguards.

(6) No observation of Cerenkov effect in the spent fuel storage
The Cerenkov effect cannot be observed in the spent fuel storage because the fuel rods are not placed directly into water. The steel racks containing spent fuel blocks are covered with shielding plugs.

(7) Refueling time
It takes about 200 days for the refueling of the fuel in the core, and about 30 days for taking out spent fuel blocks from the spent fuel storage. Inspector-attended verification of fuel in the core and the spent fuel storage will require an unacceptably large effort for a small quantity of fuel.

Safeguards Approach

The items 1 and 2, above, act to mitigate the required degree of safeguards. The safeguards approach study is carried out in consideration of the HTTR characteristics from items 3 to 7. Efforts are made mainly for covering difficult-to-access areas and maintaining the continuity of knowledge. The results are given in the following.

On receipt, each fuel rod is regarded as an item, and the item-counting is applied. After they are assembled into the fuel block, one fuel block is regarded as one item. Five fuel blocks are stored vertically in a rack. Verification of the fresh fuel blocks is performed by a random sampling method. Nondestructive assay is applicable for some fuel rods in the sampled fresh fuel blocks. The dismantlement of fuel rods from the fuel block will be surveyed by cameras to detect unreported dismantlements.

The inventory in the core is confirmed by the verification of fuel flow. The core is defined as a difficult-to-access area. The inflow of the fuel into the core is verified by the combination of the inventory verification in the fresh fuel storage and surveillance cameras. The inflow can be evaluated from the difference between the quantity of receipt and remaining inventory in the fresh fuel storage. The camera is used to survey abnormal movements of the refueling machine on the operation floor.

The inventory of the spent fuel storage is confirmed by the records of an unattended fuel flow monitor system (UFFM), with reference to the record of the camera that all the spent fuel blocks are stored properly in the spent fuel storage by appropriate movement of the refueling machine. The surveillance camera covers the spent fuel storage after the installation. Furthermore, each shielding plug of the rack is sealed in conformity with the idea of the dual C/S system. The utilization of the UFFM, surveillance camera, and sealing clearly explains and confirms all movement of fuel in the reactor building.

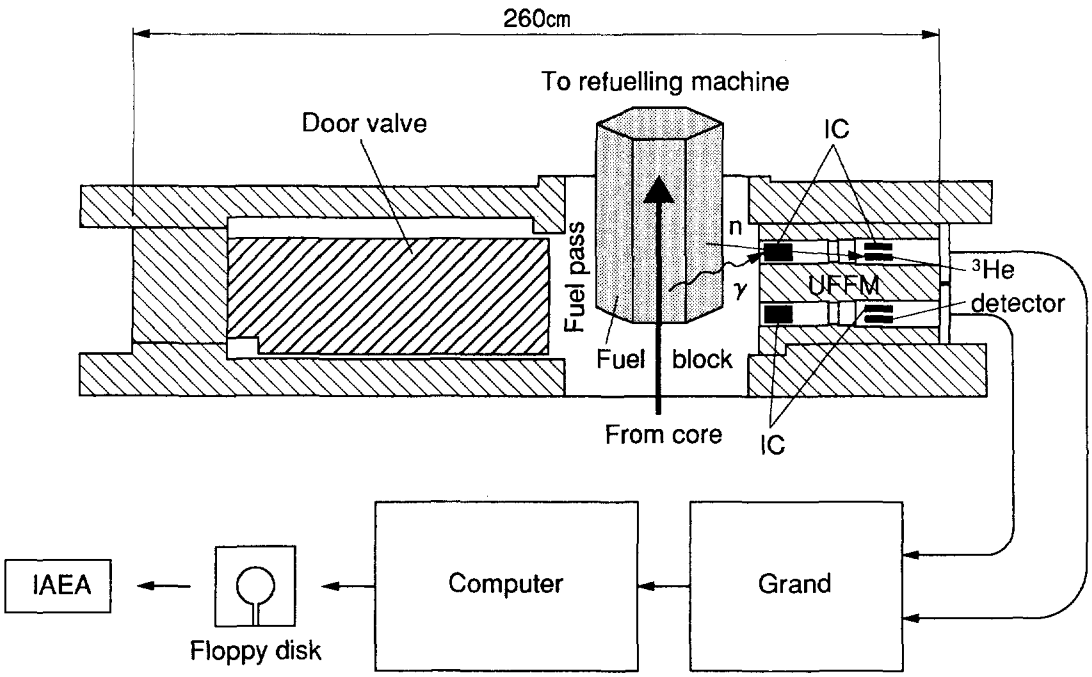
Inspector attendance during refueling (about 200 days) and handling the irradiation test specimen (about 30 days) become no longer necessary because of the introduction of the UFFM. The inspection will be carried out only by confirmation of the UFFM record. Discharging of the fuel blocks (about 30 days) becomes no longer necessary for spent fuel storage because of the combination of the UFFM and dual C/S system. The item counting will be carried out simultaneously by the UFFM at the transfer of the fuel blocks to the spent fuel storage. The information for item counting is recorded by the UFFM computer. The verified knowledge is maintained by the dual C/S system, which consists of the seal for the shielding plug and the survey camera. The inspection for the spent fuel storage will be carried out by confirming the records and the reliability of the dual C/S system. When at least one system of the dual C/S system is evaluated as acceptable, no remeasurement is necessary. It reduces the inspection effort for the spent fuel storage. The whole inspection effort for the HTTR is reduced from 230 man-days per year to several man-days per year by applying the UFFM and the the dual C/S system.

Unattended Fuel Flow Monitor System

The outflow of the spent fuel blocks from the core is monitored with the UFFM. Two sets of the radiation detector systems are installed along the fuel pass-in door valve. Figure 6 shows the positions of the detector sets in the door valve. The signals from all the detectors are processed in the GRAND and computer. The fuel flow direction is determined by which detector system first senses the radioactivity from the spent fuel. All spent fuel blocks pass through the door valve. The door valve is located between the refueling machine and the stand pipe over the reactor pressure vessel, as shown in Figure 5. The original function of the door valve is to stop the flow of contaminated coolant gas from the reactor vessel to the atmosphere. A radiation detector system consists of a ^{3}He neutron detector and two ionization chambers. The UFFM can distinguish nuclear materials and non-nuclear materials of irradiation test specimens. Neutrons and γ-rays are detected as nuclear materials pass, and only γ-rays are detected as nonnuclear pass materials. Unreported movements of nuclear materials from and to the core can be detected by the UFFM.

The IAEA and Japan have agreed to use the UFFM for effective safeguards of the HTTR. To accomplish this, the UFFM is being developed through the Japan Support Program for Agency Safeguards (JASPAS) and joint research and devel-

Figure 6. Fuel flow control with UFFM in the door valve



opment by JAERI and the U.S. Department of Energy involving Los Alamos National Laboratory.

Conclusion

A new safeguards approach needs to be developed for the HTTR because there currently is no available format. We have proposed a safeguards approach in which the fuel flow is controlled in an inspector unattended mode. The flow of material into the core is verified by the remaining inventory in the fresh fuel storage and the records of survey cameras. The flow of material out of the core and the flow into the spent fuel storage is controlled by the UFFM. Fuel movements through the refueling machine are continuously surveyed by cameras. Dual C/S is applied for the spent fuel storage to satisfy the item-counting in the PIV.

The difficulty of inventory verification in the difficult-access areas is solved by introducing the concept of flow verification. Replacing the conventional visual observation of the core fuels by the idea of flow control will lead to reasonable safeguards implementation. The safeguards efforts will be reduced from 230 man-days per year to several man-days per year by the fuel flow control in unattended mode and application of the dual C/S.

Acknowledgments

The authors express their sincere thanks to Y. Maeda, H. Nishimura, K. Shimizu, and H. Menlove for valuable comments and support.

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A Physical-Model-Based Diagnostic Aid for Safeguarding Nuclear Material in a Liquor Storage Facility

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Abstract

A prototype model-based diagnostic aid has been developed to help with the safeguarding of nuclear material in liquor storage facilities. Its primary purpose is to enhance confidence in the safeguarder's knowledge of the status of the facility and of its on-line instrumentation. As a consequence, this will enable physical inventories to be formed with confidence, when required. The basis behind the aid is outlined by showing how it could be used to diagnose three scenarios that might be observed on a simple storage facility. The implementation is then described briefly. The underlying concepts are generic; the long-term intention is to extend the system to cover all parts of a nuclear fuel reprocessing plant that contain liquid solutions.

Introduction

One of the main ways to ensure the security of nuclear materials is to keep an accurate and frequently updated account of the material contained in a plant. This requires the frequent closure of a balance obtained by comparing the total net material imported with measured plant inventory.[1] Known as near-real time accountancy (NRTA), this approach depends somewhat on the safeguarder's ability to obtain an accurate physical inventory while placing no undue burden on plant operations. With the introduction of automated data collection in nuclear materials safeguards,[2] there is now the data processing capability to form physical inventories at a rate sufficient to satisfy timeliness criteria and to form and analyze the resulting materials balances automatically. However, for the safeguarder to have confidence in these procedures, this analysis must take into account the various assumptions pertaining to the inventory in unmonitored pipes and process units; in addition, it must ensure the validity of combining the various pieces of data collected to estimate physical inventories. Thus, both the procedures and the safeguarder must have the capability to obtain knowledge of the status of the plant and of its on-line instrumentation at any time. This capability can be summarized as follows:

- to identify and, when necessary, to alarm activities and measurement errors of any significance, automatically;
- to enable the safeguarder to explore why these have occurred and to examine possible alternative explanations.

This paper describes the main features of a prototype diagnostic aid that has been developed to provide such a capability. Based on a model-based diagnostic method by Howell[3] and implemented in the real-time environment, G2,[4] the aid first seeks to hypothesize a table of events (Events Table) to explain the data collected; a user interface is then provided to enable the safeguarder to examine further both these hypotheses and others that might be equally applicable. If he so wishes, the safeguarder can then select one of these alternatives or input one of his own. Once formed, and where considered necessary, simple if-then rules can be applied to the table to activate alarms. The construction of this table is not that straightforward; this is partly because of the need to include both events that occur relatively abruptly and others that occur over longer periods of time, partly because of the need to accommodate the temporary disappearance and reappearance of material to and from unmonitored pipework and process units, and partly because of the need to ensure that all alternative hypotheses are made available for selection, as far as is practicable. For the sake of clarity, the approach here is to make use of three scenarios, all pertaining to the same simple facility, to elaborate on the various stages that the aid goes through to produce the most likely table. A user interface is then described that would be appropriate for this simple facility. The ways in which the safeguarder might interact with the aid, if confronted by each of these scenarios, is then discussed. For completeness, a brief description is then given of how the aid has been implemented in G2 and, the paper concludes by looking into the future.

Note that the emphasis is on models and on rules. A computer simulation is used extensively. It is constructed to predict plant measurements, to detect the occurrence of an activity, to diagnose its cause, and to provide a visual display of what the trends, in various key measurements, would look like if these activities were to occur. It is worth making the following observations because these have had a bearing on the formation of the aid:

1. Sensors installed for safeguards purposes are often relatively sparse and certain measurements might be recorded infrequently.
2. The inspector is unlikely to have a complete verifiable knowledge of the boundary conditions that are needed to solve model equations.
3. The inspector is only seeking explanations for those anomalies that are, in some way, deemed to be significant.
4. *Accurate* predictions are only required for those measurement records that are specified; the model need not be accurate in general.
5. From the end-user's point of view, any physical-model-based approach will only be acceptable if computer models can be readily generated.

Automatic Hypothesis Generation

This section describes the automatic procedure developed to produce the Events Table. The procedure has three distinct stages that make extensive use of four conceptual components:

1. a simple, rule-based, hypothesis generator,
2. a computer simulation,
3. a model-based diagnostic tool, and
4. a rule-based, sub-event combiner

The approach here is to explain the function of each of the three stages by referring to an appropriate example. The entire procedure is then summarized in the final sub-section. Use is made of three examples: Example A focuses on Stage 1, Example B on Stage 2, and Example C on Stage 3. All examples pertain to the same very simple plutonium nitrate liquor storage facility (Figure 1) consisting of only two tanks, of significantly different volumes, plus a single transfer device. In this facility, liquor is first fed into the smaller tank, Tank 1, where it is accounted for prior to transfer to the larger tank, Tank 2. Extensive pipework is provided to enable recirculation, sampling, import, and export; level, density, and temperature might be measured in both tanks.

Stage 1: Diagnosing a Straightforward Sequence of Abrupt Events

Example A is introduced as an example of a typical sequence of abrupt events. Event list generation is then explained by stepping through the procedure.

Figure 1. A simple Pu liquor storage facility

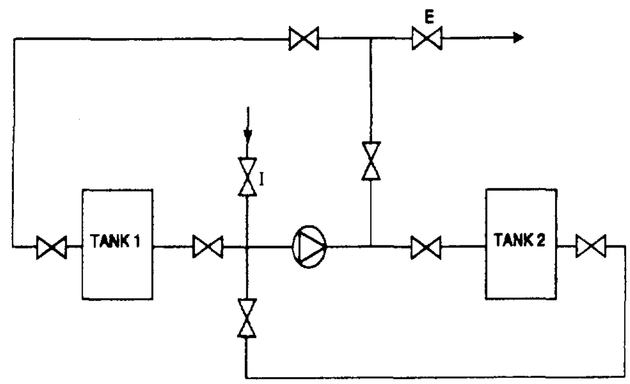
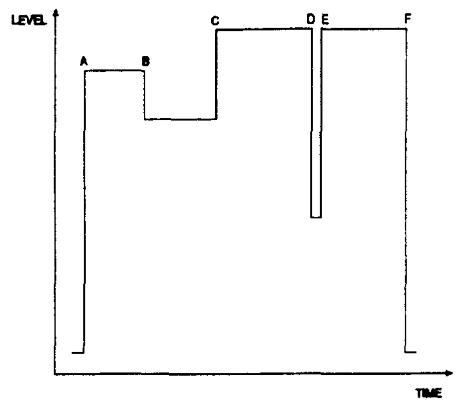


Figure 2. Tank 1 Level



Example A. Imagine that the level in Tank 1, recorded over a period of time t: $t_A < t < t_F$, is as shown in Figure 2 whilst the level in Tank 2 is constant and the export valve, Valve E, is kept closed. This transient might have been caused by the activities itemised in Table 1.

Overall aim. Our aim must be to reconstruct Table 1 from the various measurement histories available because any of these activities might be of interest to the safeguarder. Having done this, it is relatively straightforward to single out activities that might be of importance from a safeguards point of view by applying a set of simple if-then rules (i.e., productions) to this information in conjunction with data collected. There are two fundamentally different ways to produce this Table (Figure 3): (1) the observations must be correlated in some way with predictions derived by hypothesizing and then evaluating a complete list of possible activities, or (2) the boundary equations and parameters pertaining to a plant model can be adapted until the *correct* observations are predicted via computer simulation. We argue for the latter on the basis that the former should be ruled out largely because of the need for a "lateral" capability; that is, it should be ruled out because of worries about completeness and because of the list of activities becoming known to a potential diverter, who could then think of a strategy not

Table 1. List of Activities		
Activity	**Time**	**Description**
1	t_A	Tank 1 filled
2	t_B	Tank 1 partly emptied into recirculating pipework
3	t_C	Inlet reopened and additional liquor introduced "pushing" the pipe contents back into Tank 1
4	$t_D \rightarrow t_E$	Recirculation/sampling
5	t_F	Contents of Tank 1 transferred to Tank 2

covered by the list. However, the latter requires a computer simulation and hence a model including its assumptions, boundary conditions, and parameters.

Computer simulations. Bearing in mind item 5 in the Introduction section, a generator has been developed specifically to enable the automatic production of an appropriate simulation. Based on a connectivity diagram approach, it is outlined by Howell and Scothern.[5] For the simple example, the first step would be to specify the plant representation as shown in Figure 4: here n1 and n2 denote the two tanks, c1 is the transfer device and pipework that is common to both recirculation loops, and c2 and c3 are those parts of the recirculation loops that are not common. Directed arrows indicate routes taken by mass transfers and, where thought necessary, energy transfers. Nodes h1 and h2 are added to accommodate transfers that might neither have come from nor gone to any monitored unit; in safeguards jargon, flow to and from hidden inventory. Additional hidden inventories (h3, h4, and h5) might be added to each of the connecting pipeworks, but these are omitted here to keep the diagrams simple. Having specified this notation, it is worthwhile to note that our aim (i.e., the table to be reconstructed) could be rewritten as that shown in Table 2. Note that

- five activities have been replaced by four *events* because Activity 2 represents only a partial action because the material returns at the end of recirculation;
- each sub-event takes place *abruptly*; it is the begin time and quantity that really matters, the actual time history is irrelevant;
- sub-events i1 → n1 and n1 → n2 are both compound paths; e.g., i1 → n1 is composed of i1 → c1 → c2 → n1.

The computer simulation would now be constructed automatically from a library of process unit models; data files pertaining to plant parameters like tank calibration coefficients would then be edited by the user. At present, the library only contains simple lumped parameter models based on mass and energy balances; these have been found adequate for the applications analyzed to date. With the exception of pipe hold-ups, initial conditions are derived from plant data. Although pipe hold-up can obviously vary during transfers, the simulation

Figure 3. Alternative strategies

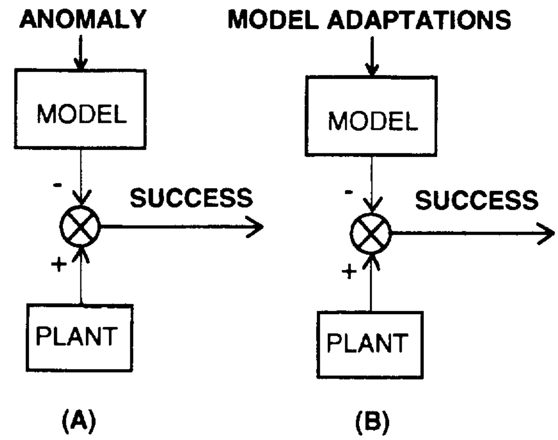
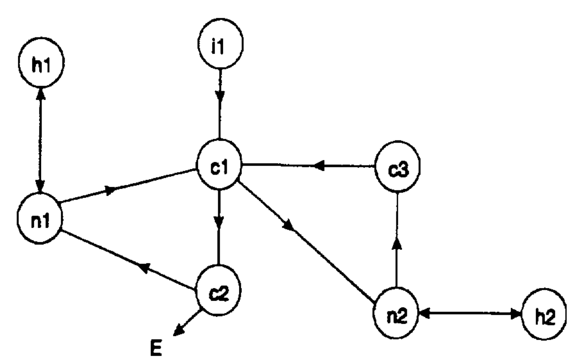


Figure 4. Associated connectivity diagram



assumes that the total hold-up in the pipework is always the same at the end of every transfer; the possibility of an overall change in hold-up is then examined by declaring to the diagnostic procedure that the initial hold-ups might be suspect. The justification for this is that because no absolute values would be available anyway, it is the change in hold-up that is important. This will be of particular concern when Stage 3 is discussed.

Note that this computer simulation lacks boundary conditions which, in the example here, are simply the times at which, and quantities involved when, material is transferred. These boundary conditions describe some of the activities that we seek, and hence, once identified, they can be entered into the Events Table. The identification of these particular activities is part of the process called *sub-event hypothesis.*

Sub-event hypothesis. Every notable change in level is deemed to signify that something (a *sub-event*) has occurred, and on the assumption that every change results from a transfer of material, a hypothesis for the source and sink of each transfer is produced. Where either a source or sink are not readily identifiable, material is deemed to transfer to and from hidden inventory. Thus, for example, Activity 5 can be marked as a sub-event because the level in Tank 2 rose when that in Tank 1

Table 2. Event Diagnoses

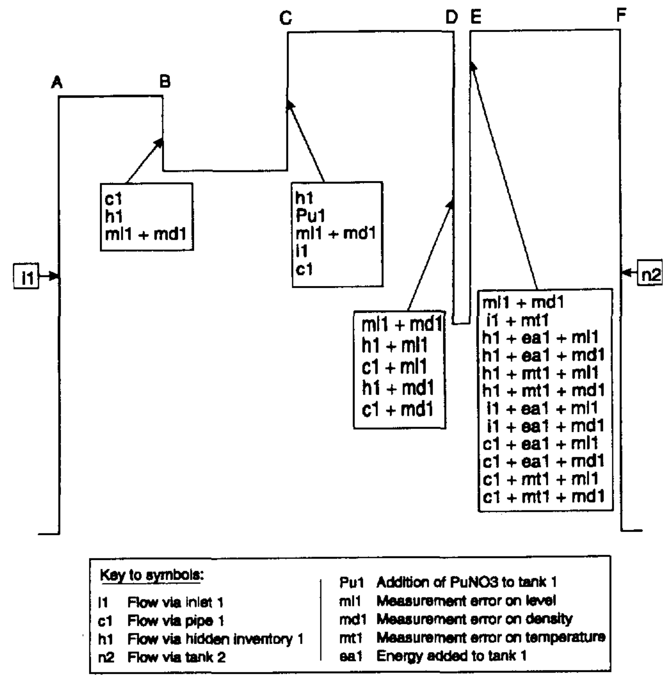
Event	Time	Sub-event	Description
1	t_A	i1 → n1	Tank 1 filled
2	t_B	n1 → c1	Tank 1 partially emptied into pipework
	t_C	c1 → n1	Pipework emptied back into Tank 1
	t_C	i1 → n1	Additional input into Tank 1
3	t_D	n1 → c1	Recirculation — pipe filled
	t_E	c1 → n1	Recirculation — pipe emptied
4	t_F	n1 → n2	Tank 1 emptied

fell and by an 'equivalent' amount; the two changes in mass need not be precisely the same because allowance must be made for, for instance, measurement errors and for evaporation. It is extremely likely that Activity 1 represents another sub-event, in fact an input, by virtue of its size and by the fact that nothing happened, at that time, in Tank 2. Activities at t_B, t_C, t_D and t_E would then be marked as separate sub-events in need of diagnosis and would be viewed, at least temporarily, as representing transfers to or from hidden inventory . Small, gradual reductions in level would be attributed to evaporation. To summarise, although certain activities have been identified, explanations are still sought for other sub-events.

Sub-event diagnosis and interpretation. Diagnosis is based on a method proposed by Howell[3] and enhanced further by Howell and Scothern.[6] In essence, parameters pertaining to a simulation of the facility are adjusted until simulation predictions match the various measurement histories pertaining to a particular sub-event. These corrections are then deemed to be a diagnosis.* The algorithm first examines whether adjustment of a single parameter would lead to a match (i.e., a one-parameter search is performed). This is followed by a two-parameter search and then a three-parameter search; a successful solution at one level will cause only the next level of search to be invoked. To reduce the large set of solutions so generated, the results of the higher level search are screened to remove any solutions that are simply the lower level search combined with a spurious extra parameter. If no suitable diagnoses are found, then the initial hypothesis (i.e., flow to or from hidden inventory) will be the only interpretation of the sub-event that is made available to the interpreter. Figure 5 shows the more credible corrections that would result from analyzing Example A;

* Explanations of why the simulation fails to predict plant measurements are produced in terms of combinations of flows along identifiable paths to explain any re-distribution of mass or energy (called path errors), and non-path errors, to explain more local effects.

Figure 5. Individual diagnoses



for instance, the sub-event at time t_B could be explained by either a transfer of material to pipe c1, a transfer of material to hidden inventory h1, or by the occurrence of measurement errors, simultaneously, in both level and density (e.g., because of a common mode fault). In every case, each transfer would be quantified.

These diagnoses now need to be interpreted. The approach is to identify any sub-event that might represent a separate activity (i.e., event) per se and to identify those groups of sub-events that, if combined, could also represent an event. Of importance here is the fact that the diagnosis is unlikely to be unique; for instance, there is always a possibility, however ridiculous it might seem, that all transients can be explained as a set of measurement errors. Thus the interpreter must choose the most likely. The combination process is described in detail in Howell and Scothern;[7] a brief overview is sufficient here. Based on rules, it has three parts: rule definition, categorization, and application. A rule-set is first constructed for each type of event. The object is to identify the occurrence of that type of event from a sequence of diagnoses pertaining to sub-events. For instance, recirculation could be composed of n1 → c1 followed by c1 → n1. These rule-sets are then categorized by noting that, as far as the safeguarder is concerned, the occurrence of certain events is preferable to certain others. For instance, the safeguarder would prefer to explain what is observed as a sequence of normal operational activities rather than as a loss or gain. For this reason events can be categorized by the perceived desirability of their individual effects and by the likelihood of their occurrence; very common events are given the highest desirability, while uncommon events and events with poor supporting evidence are given a low desirability. A search algorithm is now applied; starting with the rule-sets pertaining to the most desirable event category, these are applied to find permutations of one, two, or three sub-events that, if combined on the basis of the appropriate rule-set, could represent that event; other levels of desirability are then considered. The output from applying this procedure to the example should then result in the generation of the events listed in Table 2.

If, after trying all rules at all desirability levels for all combinations of one, two, and three sub-events, some sub-events are still not matched successfully, then this will need intervention by the user. A list of all unmatched sub-events is first presented to the user, together with all that is known about them: times of occurrence, magnitudes, and explanations generated by the diagnostic procedure. The user then has a choice of either manually selecting sub-events that can be combined together or writing new rules to classify the sub-events based on the information provided and of then rerunning the sub-event combiner. The choice depends on whether the sub-events in question form a commonly occurring feature or a one-off occurrence. When manually combining sub-events, the user must perform a number of activities: select sub-events to be combined into a single event, choose a diagnosis for each sub-event from all of the possible results found by the diagnostic algorithm, and finally input a description of the combined event; this will appear in the event list. This must be repeated until all of the sub-events are matched to events.

Alarm generation. Finally, a set of simple rules is applied, both to alarm any event involving a transfer with hidden inventory and to alarm any other event that is likely to cause the inspector concern. There is nothing untoward in Table 2, so no alarms would be generated.

Continuity of events. Clearly, it is quite possible for an event to start during the period of time under examination but finish sometime during the next period. For instance, the partial emptying phase of a recirculation could occur during one time interval, and its filling phase could occur during the next. Failure to accommodate this possibility would result in incorrect diagnoses, with both parts incorrectly classified as transfers with the pipework. To resolve this problem, the diagnostic procedure must take into account any events that occurred during the previous period and that could be combined successfully with current events to produce a more desirable result. The first step is to identify how far back in time the combiner need look; i.e., the time interval, Δt_{max} minutes, corresponding to the largest possible event duration, must be specified. Any sub-events that occurred during the last Δt_{max} minutes of the previous period must be considered as well. The event combiner is invoked as before, selecting the most desirable event for inclusion in the event list. Any events that contain sub-events from the previous period are compared with the earlier hypothesis, and the most desirable event is selected. It is also possible that the new data made available at the start of a new period will actually change the initial classification of a sub-event; e.g., a single tank-to-tank transfer that spans the end of the period may be initially classified as having a magnitude of 20 kg, but the next period's data might reveal that the transfer had not actually fully completed, and it required a magnitude of 25 kg. If this were to be the case, the old sub-event would be deleted, along with all of its diagnoses, and any events that make use of the incorrectly specified sub-event would be discarded; the old sub-event would be replaced by the new, improved sub-event and its associated diagnoses prior to running the sub-event combiner.

Stage 2: Diagnosing Events That Last Longer

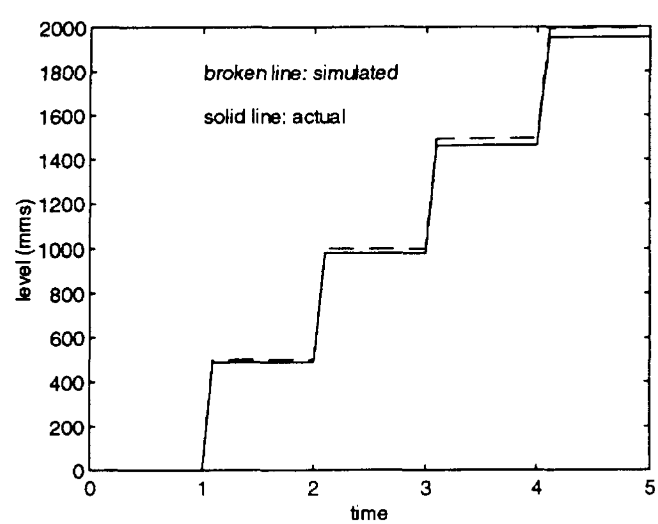
Having applied Stage 1 to the plant data, a simulation would now be performed to assess whether having modeled all the events hypothesized, the simulation-based measurement predictions now match the plant histories recorded. If disparities were still to be observed, the model-based diagnostic procedure would be reapplied, but this time with the focus on so-called gradual anomalies or events. To avoid confusion, Example A was deliberately constructed without any gradual anomalies, so Example B is introduced to discuss these.

Example B. Suppose that, following a sequence of four transfers from Tank 1 to Tank 2, the actual and simulated Tank 2 levels are as shown in Figure 6. Assume that, although the individual differences between model prediction and plant are sufficiently small that they would not have been detected during Stage 1, the accumulated differences start to become significant.

Gradual analysis. The purpose is to identify any of three main types of gradual events:

1. the gradual transfer of material, where a small amount of material is transferred over a long period of time;
2. a sequence of abrupt transfers pertaining to a particular unit is modified; for instance, all transfers into Tank 1 from the inlet might be scaled by a small amount to compensate for incorrect estimation of the amounts transferred; and
3. calibration errors that can only be detected by analyzing a

Figure 6. Effect of Tank 2 calibration error



sequence of measurements.[6]

The approach is very similar to that for abrupt anomalies but with a few important differences[6]: the simulation is performed over a much longer period of time; measurement models are now included explicitly because there are likely to be sufficient measurements with which to perform a correlation; and higher level gradual searches are only performed when lower level searches fail, because of the large amount of processing time needed to perform a gradual diagnostic search. Any gradual events thus identified are added to the list of events. In the case of Example B, alternative diagnoses might be generated as an error in the multiplicitive coefficient of the tank calibration equation or as a gradual transfer of material either to or from a hidden inventory attached to the connecting pipework; the former is clearly selected in preference to the latter.

It is important to note that the diagnostic process here is largely an averaging process, because correlation is performed over a significant period of time; the anomaly is assumed to be constant in time. This then prompts the question "what about a composite gradual/abrupt event?" For example, one that starts t as a gradual event and then suddenly turns into an abrupt Stage 3 is intended to search for these.

,age 3: Diagnosing a Hybrid Gradual/Abrupt Event

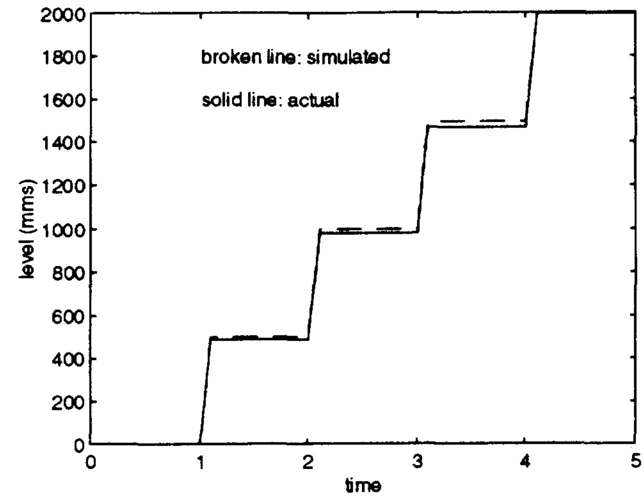
Example C. Suppose that during a sequence of three transfers from Tank 1 to Tank 2 a small amount is left behind each time in the pipework. Thus a gradual event would be observable. However, suppose that all this material is washed out during the next transfer. The actual and simulated Tank 2 levels might then look like those shown in Figure 7. Depending on the magnitudes involved, it is possible that these activities would not be observed during Stage 1 and that, although detecting discrepancies, the averaging process of the gradual analysis would fail to produce any realistic solutions also.

Further abrupt analysis. The approach is now to focus on those events whose hypotheses were generated at the sub-event hypothesis stage and thus were omitted from the model-based diagnostic analysis. The purpose is to superimpose additional sub-events onto those already hypothesized. Thus, for each of the events in question, the sub-event diagnostic procedure is reapplied over the time interval as specified in its hypothesis, but this time with the event hypothesis included in the simulation. Additional sub-events generated are then appended to the appropriate events. Thus, in Example C, and as described in Stage I, on each occasion the additional sub-event would be attributed to a decrease in initial hold-up; this would then signify the fact that the residual pipe hold-up had increased during each of the three transfers.

Summary of Entire Procedure

1. By looking at the plant data, the simple hypothesis generator attempts to produce an initial description of plant activity by identifying and then attempting to explain all individual mass transfers. Those transfers that cannot be explained on the basis of a few rules are then termed *abrupt anomalies*. Alternative diagnoses are then generated for each of these anomalies by first performing model-based analysis on individual sub-events and then using a sub-event combiner to interpret one or more sub-events as events. The most desirable are then hypothesized as having occurred.
2. Based on these hypotheses, a plant simulation is now produced, the output of which is compared with plant data. If any significant differences still remain, the model-based analysis is repeated, this time focusing on *gradual anomalies,* and additional hypotheses are generated to explain them.
3. If, in the unlikely event that significant differences still remain, a model-based analysis is performed on those events whose hypotheses were generated in Stage 1, and where necessary, additional hypotheses are generated to explain them completely. If, in the extremely unlikely event that significant differences still remain, a further gradual analysis can be performed.

Figure 7. Effect of pipe hold-up on Tank 2 level



User Interaction

The aid is based on diagnostic methods that are, with today's low-cost computational facilities, relatively time consuming. It is therefore envisaged that, if the package were to be installed in a facility, it would be programmed to start to analyze the previous day(s) records soon after midnight so that its results would be available by the time the safeguarder arrived in the morning. All three stages of the procedure would be applied automatically. The safeguarder might then be faced with a computer screen display like that shown in Figure 8. This has three main features that have been configured for the simple plant of Figure 1: a plot window, a mimic, and various buttons to affect these windows, open new ones, perform simulations, and so on. By interacting with the system, the safeguarder would then either confirm, modify, or act on the conclusions reached. An accept button would be provided to enable the user to declare his acceptance of the day's diagnoses.

Figure 8. Main window for Example A

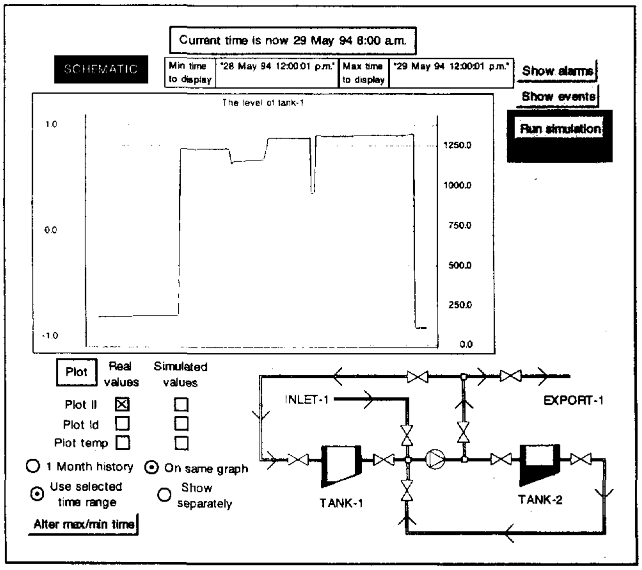
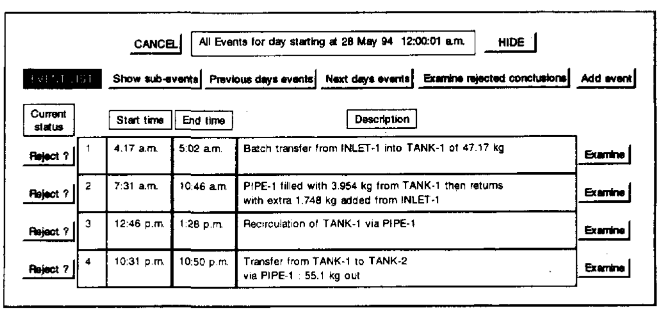


Figure 9a. Event list for Example A



This section is divided into two parts: the first part describes the kind of interactions that might be made in response to the three examples described in the previous section, the second part gives a more general overview of the features that are available.

Typical Interactions

Suppose that Example A occurred on May 28, 1994; on the following morning the safeguarder might be faced with the display as shown in Figure 8. He might immediately seek to examine the list of the events hypothesized (Figure 9a) and the list of alarms generated (none) by clicking on the appropriate buttons. Additional information pertaining to each event would be accessible by clicking on the appropriate examine button (Figure 9a). Thus, for instance, the user could view all the sub-events that make up Event 2 (Figure 9b) and all of the alternative diagnoses that were suggested for Sub-Event 2 (Figure 9c). Sub-Event 2 has two alternative diagnoses; Diagnosis 1 consists of some linear combination of two activities, whereas Diagnosis 2 has only a single possible explanation involving two parameters. A full list of all of the sub-events could also be displayed, as could events hypothesized on previous days. If the user were to disagree with

Figure 9b. Explanation for Event 2, Example A

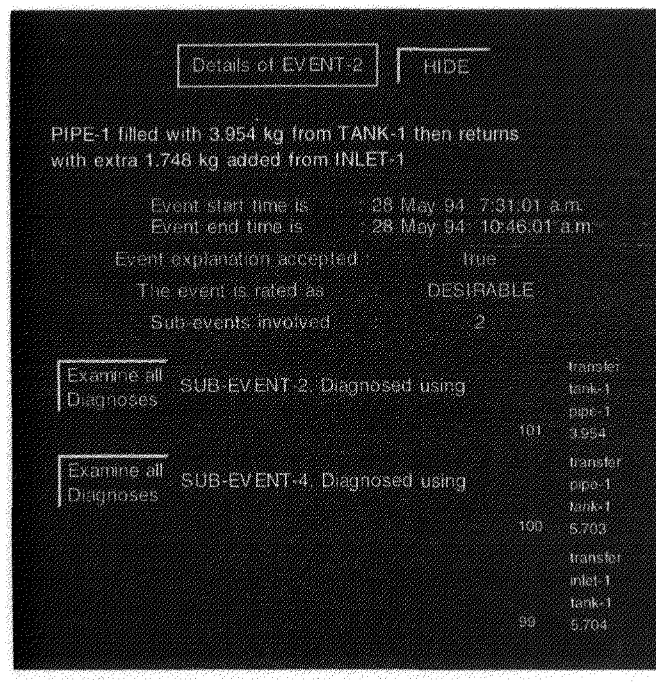
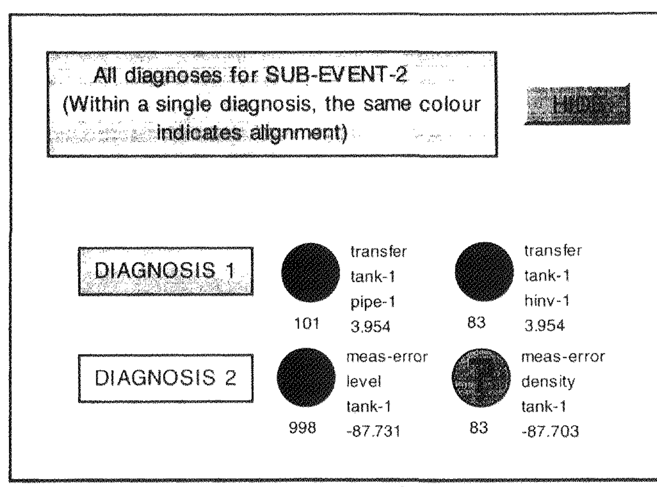


Figure 9c. Diagnoses for Sub-Event 2, Example A



any of the hypotheses generated—for instance because an alternative sub-event diagnosis is preferred—then any of the events presented could be rejected. The user could then rerun the sub-event combiner, with the rejected conclusions prohibited, to produce a new event list. This process could be repeated until the user was satisfied with all of the events generated.

Figure 10a shows the Event List that would be generated for Example B, while Figure 10b shows the description of the diagnoses of the gradual event (Event 1) generated. Note that there are four alternative diagnoses, two of which are aligned (i.e., they have the same affect on the data[4]); although the first parameter of Diagnosis 2 has been chosen, it is quite possible that material has gradually disappeared into pipework. The Event List generated for

Figure 10a. Event List for Example B

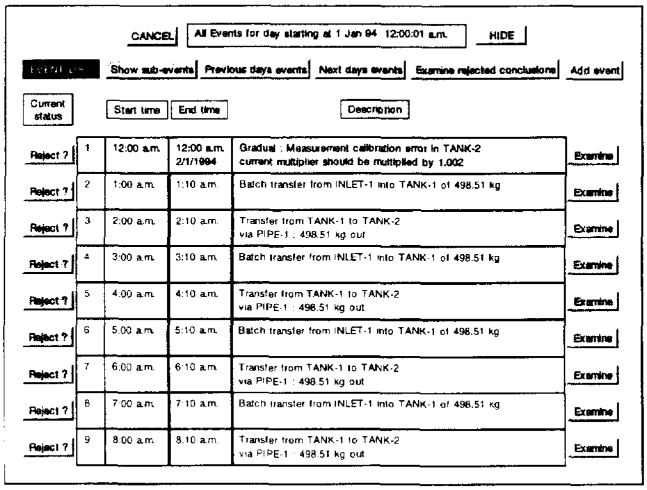
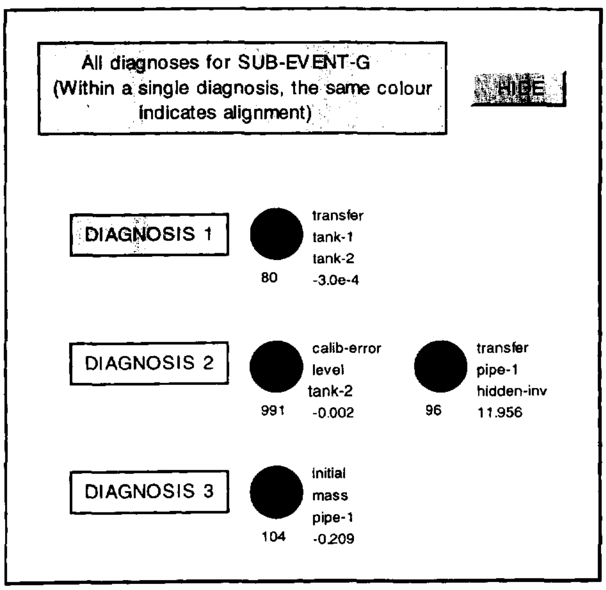


Figure 10b. Diagnoses for the sub-event for Event 1



Example C (Figure 11a) is subtly different; other than by highlighting, there is no explicit mention that material was held up in the pipe prior to the final transfer. However the various hold-ups are declared in Sub-Event descriptions like that pertaining to Event-2, which is shown in Figure 11b.

General Overview

The main features of the user interface are itemized below. This is intended to give a general impression of the prototype.

Measurement record display. The user can examine any of the plant data available for any tank in the system, just by clicking on its icon representation in the plant schematic. Plots can be made of records pertaining to any measurement source, for instance of level dip-tube pressure (ll), of density dip-tube pressure (ld), and of temperature. All measurements can be super-

Figure 11a. Event List for Example C

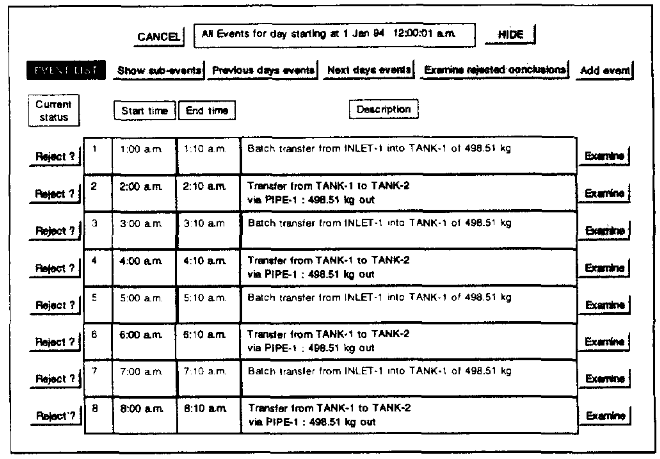
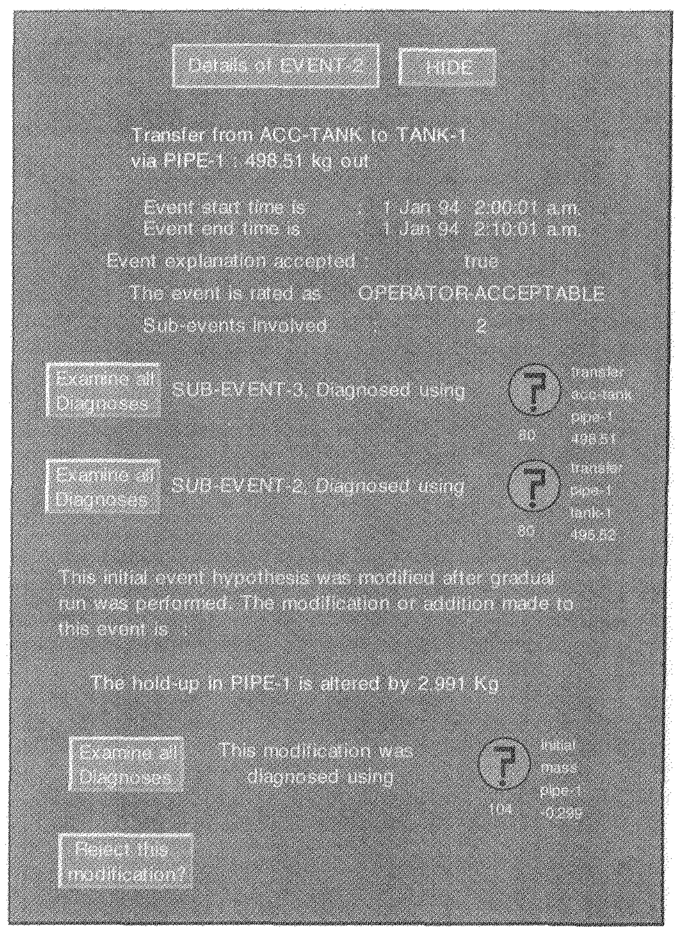


Figure 11b. Description of Event 2, Example C



imposed on a single graph, or the user can choose to cycle through the various measurements. (An action button, to move on to the next graph, will automatically appear if the separate graphs option is chosen. By default, the time scale of the graph is set for the current day, but any time period can be specified by using the '*Alter max/min time*' and '*1 month history*' buttons.

Animation. Here the plot window is configured as a trend chart (i.e., it is made to scroll with time), and the mimic is updated to reflect the 'current' state of the plant. The 'current' time can be changed gradually and the 'current' state is driven by the list of events. Animation allows the user to view the main window as a speeded-up version of an operator's console. The speed of animation can be altered by the user, as can various options, such as giving a description of each event as it occurs, or pausing the animation at the end of each event to facilitate inspection of the data.

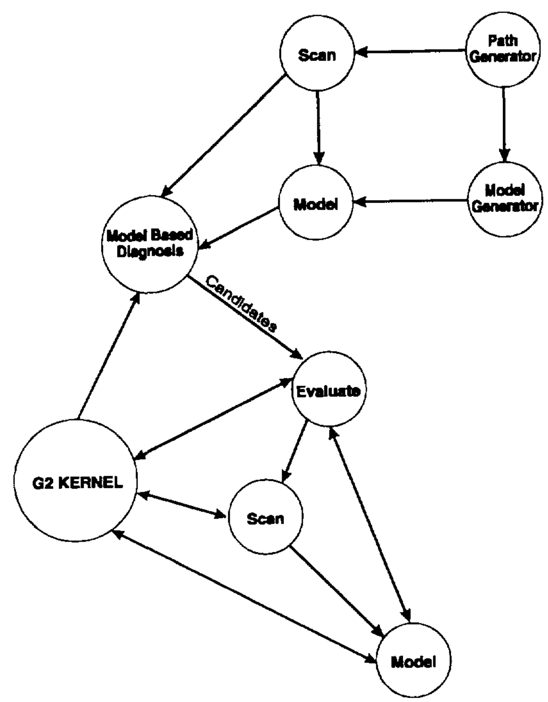
Running the simulation. The simulation can be run over any chosen time range. Once a time range has been selected, any events that are not flagged as rejected by the user and fall within the specified time range are included in the simulation. When the simulation is complete, the trend chart is modified so that it plots both real and simulated values, superimposed, on a single graph. Animation of the trend chart and plant mimic is automatically begun from the start time of the simulation.

Inspecting the event list. The information used to reach a particular diagnosis for any particular event can be examined by clicking on the appropriate '*Examine*' button. A sequence of windows can now be viewed to examine, for instance, each sub-event, its diagnosis, and its alternatives. The alternative diagnoses are arranged as rows (Figure 9c), with each row pertaining to a separate diagnosis: each disc represents an individual parameter, discs colored green relate to the first parameter, those colored blue relate to the second, and those colored yellow relate to the third. It is quite common for more than one disc of the same color to be displayed on a row. This indicates that there are alternatives within that diagnosis; either one disc can be selected from each color group or some weighted combination of each color group can be chosen.

Interacting with the sub-event combiner. Suppose the user believes that an event has been diagnosed incorrectly; having rejected this event, the user would be given two options, to re-diagnose with rejected conclusions prohibited or to diagnose manually. Clicking on a '*Re-diagnose*' button first causes the rejected event descriptions (i.e., diagnoses) to be moved to a rejected conclusions list and then causes the sub-event combiner to be reinvoked, but this time rejecting any diagnosis already entered on the *rejected conclusions* list. Revised event and rejected conclusions lists can then be inspected on request. The user can continue to reject event hypotheses until all alternatives have been exhausted. At this point, the user would be asked to manually intervene to input a preferred diagnosis.

Manual intervention. At any time the user might wish to either manually overwrite an event description or to modify or add to the rules applied by the sub-event combiner. The former is relatively straightforward, but the latter, requiring some knowledge of G2, is best left to a systems developer. To enable the user to communicate effectively with the systems developer, provision is made to output a file describing the current status of the diagnostic system. Manual intervention therefore gives the user two options: '*Combine and explain sub-events*' and

Figure 12. The aid's main components



'*Output a diagnostic file.*' By examining the various diagnoses for any sub-event, the user can suggest which groups of one or more sub-events should be combined into a single event. Combination can then be initiated and this leads to a request for both a description of the combined event and for the most appropriate diagnoses from all those available. If within the selected diagnosis, there are aligned vectors (that is, discs of the same color), the user is asked to specify which disc or weighted combination of discs is most appropriate.

Viewing hold up in headers. After running a simulation, the user can view the hold up in any of the common headers in the system by clicking on the desired pipe representation in the plant schematic. The plot shown is the deviation in the mass of the pipe from the default nominal value. Clearly, plots of the mass in the pipe are always of simulated values, so any plot options chosen for viewing tank measurement data (i.e., ll, ld, temp, etc.) do not apply. The choice of time scale for the graph can be altered in exactly the same way as for tank data. Because the model makes use of common headers rather than modeling each pipe section separately, many of the pipe sections present in the plant schematic will cause the same common header state to be displayed.

Implementation

The prototype is built around a G2-based[4] kernel, which initiates, then coordinates all activities. The real-time environment G2 was chosen for ease of development and to demonstrate what is now possible using readily available, well-supported commercial software development environments. For computational efficiency, the simulator and most quantitative aspects of the diagnostic analysis are called externally. The main components with data flows connecting them is shown in Figure 12.

To summarize that which could largely be gleaned from the previous sections, a computer representation of the plant must first be produced by inputting a description of the plant connectivity into a path generator. The generator's outputs, a list of paths that describe the plant flows, both internally and externally, plus other information, are then available for input to both a boundary condition generator called Scan and an automatic model generator. Boundary conditions and computer simulation thus generated are then accessible to both the G2 kernel and to the diagnostic procedure. Once candidate explanations have been produced, they are evaluated by rerunning the simulation.

A brief description of the G2 kernel might be worthwhile for those unfamiliar with the product. G2 is an object-oriented package, and much of the data used in the diagnostic analysis is stored within G2 in the form of objects. Each object has its own attributes, which could be simple values or other data structures such as lists or even other objects. Objects may be connected to other objects in various ways, and this is represented in G2 in the form of 'relations.' These relations define how objects are linked with each other and can be given meaningful English names to aid in the formation of inference rules. For instance, a relation named 'a-diagnosis-of' links diagnoses with sub-events, allowing the formation of meaningful statements such as

if D is *a-diagnosis-of* SUB-EVENT-1 then ...

G2 inference rules can be activated in a number of different ways, such as by forward and backward chaining and by the explicit INVOKE command. All ways have one thing in common: new activations are handled in parallel with any other G2 process or rule already activated; there is no built-in mechanism to enable the program to detect when a particular rule or set of rules has finished invoking. This contrasts with procedures that have two methods of calling, CALL and START; the former suspends other operations until the procedure returns, while the latter performs the procedure in parallel. Thus, G2 lacks a ready-made structure to perform sequential or compartmentalized rule-based inference. This was a problem when implementing the sub-event combiner, which required some method of ensuring one rule set had completed before moving onto the next in a procedural manner, but without resorting to coding all of the rules in actual procedures. A meta-rule[8] structure was therefore adopted to control the order in which rule-sets are invoked.

Conclusion

This paper has described a prototype diagnostic aid that has been developed specifically to enable safeguarder's to explore the potential of such tools. As such, no aspect of it is intended to be sacrosanct. The completed aid has been delivered to the International Atomic Energy Agency with the intention that they identify those aspects that are worth implementing in a safeguarded facility. The prototype has been deliberately centered on a commercial software development environment so that a final, durable implementation can be tailored to requirement. If alternative diagnostic techniques are thought to be worthy of further consideration, they can be interchanged readily, partly because it is straightforward to call external computer programs.

Acknowledgments

This work was funded by the U.K. Department of Trade and Industry through the Safeguards R&D Programme in support of International Atomic Energy Agency Safeguards. The results of this work will be used in the formulation of government policy, but views expressed in this report do not necessarily represent government policy.

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John Howell graduated from the University of Sheffield, UK in 1975 and subsequently joined the Control and Dynamics Group of the U.K. Atomic Energy Authority. He worked on various aspects of the fast reactor project including the commissioning of the PFR power station, the modeling and control of the solvent-extraction plant associated with its reprocessing plant and near real-time materials accountancy. He joined the lecturing staff of the University of Glasgow in 1984 and received a PhD in model-based fault detection in 1990. His main area of research is in fault detection, diagnosis, and anomaly resolution.

Stephen Scothern graduated with a degree in mathematics from Hull University in 1991, and an M.Sc. in industrial mathematics from Strathclyde University the following year. After a brief period working on applying fluid dynamics software to steam releases for Nuclear Electric, he took up his current position as a research assistant at Glasgow University researching into anomaly diagnosis in near real-time material accountancy.

Peer Review Team Approves WIPP Models

An independent group of experts approved the output from 24 computer-generated models that assess the viability of the Waste Isolation Pilot Plant (WIPP) as a safe underground repository for the permanent disposal of defense-generated transuranic nuclear waste.

"The U.S. DOE's [Department of Energy] highest goal is to protect human health and the environment," says George Dials, manager of the DOE's Carlsbad Area Office. "The peer review process is designed to ensure the safety and long-term performance of the WIPP. I believe that has been accomplished."

In its January 1997 second supplementary report, the Conceptual Models Peer Review Team expressed reservations about the WIPP conceptual models and members said they would need additional information before they could determine the output from the models was "adequate." The panel includes experts in hydrology, geology, and geomechanics.

In the group's third supplementary report, issued in April, panel members reported DOE representatives had sufficiently answered questions concerning spallings, or the possibility of a radioactive materials release caused by accidentally drilling into the WIPP; and chemical engineered backfill, or materials that may be placed in the WIPP underground disposal rooms with radioactive waste to control the chemistry of the disposal rooms. However, the review team indicated that "further refinement in understanding and predictive capability for spallings events would be desirable as part of a new conceptual model."

Organizations to Customize Software for Nuclear Safeguards and Waste

EG&G Ortec, based in Oak Ridge, Tenn., and Los Alamos National Laboratory (LANL) entered into a licensing agreement for specialized software designed for nuclear safeguards applications.

The agreement authorizes Ortec to use the latest version of LANL's PCFRAM code, which analyzes HPGe detector gamma-ray spectra generated from materials containing plutonium and uranium and then determines the isotopic distribution of the radioactive materials.

Ortec also recently signed a licensing agreement with Lockheed Martin Energy Systems to develop software for nuclear waste applications. To customize the software, Ortec will use the latest version of the ISOTOPIC code, which was developed at the Oak Ridge K-25 facility. ISOTOPIC, in conjunction with Ortec's GammaVision, analyzes HPGe detector gamma-ray spectra from waste in a wide variety of forms, geometries and matrices, without the need for representative standards. It also can determine ^{235}U enrichment in fissile waste.

Book Details Nuclear Waste Management In USSR

Battelle Press announced the release of *Behind the Nuclear Curtain: Radio active Waste Management in the Former Soviet Union.* Written by Don Bradley and David Payson, both of Pacific Northwest National Laboratory, the book describes 50 years of nuclear waste management activities and contamination incidents in the former Soviet Union.

The 726-page book, which includes 40 full-color maps and figures, costs $95, plus shipping costs. For more information, contact Battelle Press at 505 King Ave., Columbus, OH 43201; 614/424-6393; fax, 614/424-3819; e-mail, press@batelle.org.

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INMM's 38th Annual Meeting The Pointe Hilton at Squaw Peak, Phoenix, Arizona. Contact: INMM headquarters, (847) 480-9573; fax, (847) 480-9282; e-mail, inmm@inmm.com.

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Meeting of the ASTM Committee C-26 on Nuclear Fuel Cycle, Doubletree Hotel-Pentagon City, Arlington, Virginia. Sponsor: ASTM. Contact: Felicia Quinzi, ASTM, (610) 832-9738; e-mail, fquinzi@astm.org.

October 7–8, 1997
Institute of Environmental Sciences Short Courses on Contamination Control, Framingham, Mass. Sponsor: Institute of Environmental Sciences. Contact: 847/255-1561; fax, 847/255-1699; e-mail, instenvsci@aol.com.

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International Conference on Physical Protection of Nuclear Materials: Experience in Regulation, Implementation, and Operations, Vienna, Austria. Sponsor: IAEA. Contact: Susan Melnicove, American Society for Industrial Security 703/522-5800; fax, 703/243-4954.

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INMM Japan Chapter Annual Meeting, Gakuskikaikan, Tokyo, Japan. Sponsor: INMM Japan Chapter. Contact: Keisuke Kaieda, Japan Atomic Energy Research Institute, 3-3592-2365; fax, 3-3592-2129; e-mail, kaieda@hems.jaeri.go.jp.

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