8. THE MANAGEMENT OF RADIOACTIVE SOURCES

According to Article 28.1 of the Joint Convention (see Section 1), each Contracting Party shall, in the framework of its national law, take the appropriate steps to ensure that the possession, re-manufacturing or disposal of disused sealed sources takes place in a safe manner.

Accidents due to radioactive sources predominantly involve industrial radiography sources (about 90%) and teletherapy sources (about 10%): for fatal accidents, the corresponding proportions are approximately 70% and 30%. The radionuclides most commonly involved are ^{129}I, ^{60}Co and ^{137}Cs. About three quarters of accidents are due to procedural failures of the operator and only about 25% result from equipment failures.

Effective national regulatory systems, implemented by knowledgeable people, are the key to preventing such accidents. Such systems must include rigorous control of the inventory of sources, but also must ensure adequate planning of actions to be carried out in the event of loss of control of a source and the capability to carry out such actions.

Radioactive sources out of control can impact upon organizations not regulated by the regulatory system, such as the steel industry. In these cases, regulators may be able to conclude voluntary agreements with such organizations to help maintain or regain control of sources.

The safe disposal of disused sources is basically a national responsibility. If disused sources are stored for long periods of time, this will increase the probability of control somehow being lost. The purchasing price of sources should perhaps include some provision for the eventual cost of disposal.

For countries that have no disposal facilities, safe disposal will most commonly mean transferring disused sources to another country - normally the country of the supplier - that has the infrastructure to dispose of them safely. In this context Article 28.2 of the Joint Convention states, "*A Contracting Party shall allow for reentry into its territory of disused sealed sources if, in the framework of its national law, it has accepted that they be returned to a manufacturer qualified to receive and possess the disused sealed sources.*". A possible alternative would be to develop inexpensive methods for the safe disposal of sources. One alternative under development is the "borehole concept" (see Section 8.1, "Topical Issue: The Borehole Disposal Concept").

Regarding the return of disused sources to suppliers, in many cases the supplier of a source may not be the original manufacturer, therefore, the return of sources to the supplier may, in practice, be simpler and more reliable than the return to the manufacturer.

Some suppliers are prevented by the legal system in their country from - or have shown reluctance to commit themselves to - accepting returned sources. This problem might be eased if attention was focused on those sources that represent the highest risk, i.e. by categorizing sources and seeking commitments at least to accept the return of these types of sources.

When suppliers go out of business, States need to provide a "backstop" to make sure that sources are not allowed to fall out of control as a result.

The relevant issue is one of disused but not necessarily spent sources. In some regulatory systems this can be an important distinction for accepting the return of disused sources (spent sources may be regarded as radioactive waste, but disused sources may not).

Since the late 1980's, the Agency has had on-going activities in support of the management of spent, sealed radioactive sources (SRS). Until recently, the Agency's efforts had been focused in two areas - the provision of technical guidance [8.1] to [8.4] and direct, technical assistance to Member States - see Table 8-I and Table 8-II.

Recently, the Agency has developed, and is currently implementing, "The Action Plan for the Safety of Radiation Sources and the Security of Radioactive Materials" [8.5]. Safety means measures intended to minimize the likelihood of accidents with radioactive sources and, should such an accident occur, to mitigate its consequences. Security means measures to prevent unauthorized access to, and loss, theft and unauthorized transfer of radioactive sources.

The Action Plan covers seven topical areas:

- Regulatory Infrastructures
- Management of Disused Sources
- Categorization of Sources
- Response to Abnormal Events
- Information Exchange
- Education and Training
- International Undertakings

Table 8-III provides an overview of current Agency activities related to radioactive source management. The table is structured according to the seven topical areas of the Action Plan. However the work summarized includes both on-going and Action Plan related activities.

The continuation of the activities started in 1989 and the Action Plan reflect international concern over recent accidents involving both radiation devices and sealed radioactive sources [8.6] to [8.9] and demonstrate the Agency's commitment to improving the use and management of these devices and sources.

Table 8-I: Direct Assistance to Member States - Ra Source Conditioning (1996 - 2000)

The assistance cited was provided under TC Project INT/4/131 and AFRA Project RAF/4/015		
Date	**Member State assisted**	**Technical Leader (see note)**
1996-12	Uruguay	Brazil
1997-05	Nicaragua	Brazil
1997-10	Croatia	IAEA
1997-12	Guatemala	Brazil
1997-12	Chile	Chile
1998-03	Ecuador	Brazil
1998-09	Bosnia and Herzegovina	IAEA
1998-10	Paraguay	Brazil
1998-11	Ghana	South Africa
1999-05	Costa Rica	Brazil
1999-06	Pakistan	Pakistan
1999-06	China	China
1999-10	Tanzania	South Africa
1999-12	Jamaica	Brazil
1999-12	Peru	Peru
2000-02	Madagascar	South Africa
2000-03	Egypt	Egypt
2000-03	Sudan	South Africa
2000-05	Sri Lanka	Pakistan
2000-05	Tunisia	South Africa
2000-08	Venezuela	Brazil
2000-10	Myanmar	Republic of Korea
2000-10	Bangladesh	Pakistan
2000-11	Mauritius	South Africa

Note: Technical Leaders are teams trained by the IAEA to provide assistance.

Table 8-II: Direct Assistance to Member States - Ra Source Conditioning (2001)

Member State to be assisted	Technical Leader	Member State to be assisted	Technical Leader
Bolivia	Brazil	Philippines	Philippines
Colombia	Brazil	Saudi Arabia	Pakistan
El Salvador	Brazil	Singapore	Pakistan
Indonesia	Indonesia	Slovenia	IAEA
Kuwait	Pakistan	Thailand	Republic of Korea
Lebanon	Pakistan	Vietnam	Republic of Korea
FYR of Macedonia	IAEA	Zambia	South Africa
Morocco	South Africa	Zimbabwe	South Africa

Table 8-III: Overview of IAEA On-Going and Action Plan Activities (Part 1)

Regulatory Infrastructures • Agency has a Radiation Safety Regulatory Infrastructure (RSRI) service • main purpose is to ensure compliance with Basic Safety Standards [3.3] • 2000 General Conference urged Member States to use the service to assess their regulatory infrastructures and to improve regulatory services • service started Nov 2000 - peer review in Ireland • information brochure issued Dec 2000

Management of Disused Sources
• four TECDOCs in preparation
  • conditioning and storage of long-lived sources
  initial draft prepared, completion 2003
  • management of high activity sources
  initial draft prepared, completion 2003
  • risk reduction of accidents with disused & spent radioactive sources by proper management
  submitted for publication 2000
  • review of the management of spent SRS involving storage/disposal in boreholes
  final draft completed, completion 2001
• safety document on disposal of spent SRS in boreholes in preparation
second draft prepared, completion 2002
• Technical Committee Meeting on return of sources to suppliers to be held in 2001

Categorization of Sources
• categorization is based on five attribute groupings
  • radiological properties,
  • form of material,
  • practice or activity,
  • exposure scenarios, and
  • end of life considerations
• Category 1 (higher risk)
industrial radiography, teletherapy, irradiators
• Category 2 (medium risk)
brachytherapy, high activity-fixed industrial gauges, well logging
• Category 3 (lower risk)
lower activity-fixed industrial gauges
• categorization approved by IAEA Board of Governors and the General Conference in Sept 2000
• published Dec 2000

Table 8-III: Overview of IAEA On-Going and Action Plan Activities **(Part 2)**

Response to Abnormal Events

- prepare guidance on national strategies & programmes for detection, location & management of orphan sources
  - TECDOC on a model national strategy (completion 2001)
  - leaflet on guidance for action to be taken for inadequately stored sources (issued 2000)
- formulation of criteria for development of radiation detection and monitoring equipment for borders, ports of entry & exit, scrap yards, other facilities (in progress)
- IAEA Emergency Response system - further developing national response capability for radiological emergencies
  - TECDOC-953, "Methods for the development of emergency response preparedness for nuclear or radiological accidents", updated to cover detection, location, and management of orphaned sources (to be published 2001)
  - TECDOC-1162, "Generic procedures for assessment and response during a radiological emergency" published 2000
  - leaflet "How to recognize and Initially Respond to an Accidental Radiation Injury" published in Arabic, Chinese, English, French, Russian, and Spanish (2000)
  - World Health Organization and IAEA jointly developing an emergency response manual (in progress)
- strengthening of the Agency's capabilities for providing assistance in emergency situations
  - updated Emergency Notification and Assistance Technical Operation Manual (2000)
  - co-development of a Joint Radiation Emergency Management Plan of the International Organizations (2000)
  - establishment of an Emergency Response Network (ERN)
    - information leaflet prepared
    - four qualified Member States are needed to establish the ERN - none identified yet

Information Exchange

- International Conference on the Control by National Authorities of Radiation Sources and Radioactive Materials, Dec 11-15, 2000, Buenos Aires
- six regional workshops on safety and security of radiation sources and radioactive material (Nov 2000 - June 2001)
- international database on missing and found Category 1 and 2 orphan sources
  - reporting format and rules for reporting developed
  - evaluation exercise conducted at the end of 2000
- International Catalogue of Sealed Radioactive Sources and Devices
  - Personal Computer based application
  - no consensus (yet) from manufacturers for an Internet version
  - reference database of manufactured sources and devices
  - developed to assist in identification of orphaned sources and devices
  - first version to be distributed on CD Sept 2001

Table 8-III: Overview of IAEA On-Going and Action Plan Activities **(Part 3)**

Information Exchange (continued) • international database on unusual radiation events - RADEV • reporting format and rules for reporting developed • "in house" evaluation by the Agency at the end of 2000 • planned to be in use in 2001
Education and Training • Agency to intensify post-graduate training in accordance with General Conference resolution GC(XXXVI)/RES/584   • updated syllabus of courses to be issued early 2001 • Agency to strengthen regional training centres and promote the harmonization of existing centres (in progress)

International Undertakings
• Agency convened open ended meetings of technical and legal experts to explore development of a possible Code of Conduct on Safety of Radiation Sources and Security of Radioactive Materials (March and July 2000)
• a draft Code of Conduct has been written
    • Board of Governors took note of draft and
        • requested Director General (DG) of the IAEA to circulate it to Member States and relevant international organizations
        • requested DG to "organize consultations on decisions which the Agency's policy-making organs may wish to take"

8.1 Topical Issue: The Borehole Disposal Concept

Today, radioactive sources are widely used in medicine, research, industry, agriculture and consumer products. The majority of sources are small in physical size, the only items of significant dimensions being some industrial radiography units and commercial irradiators. At last count, more than ten years ago, it was estimated that there were over 600,000 sources in existence world-wide (omitting consumer products such as smoke detectors), over 80% of which were industrial gauges [4.27]. The majority of the remaining 20% were medical sources, with only about 25,000 industrial radiography and 150 commercial irradiators in existence. Many thousands of sources are in use in developing countries, which may have limited resources to control and manage them during and after their useful lives.

Despite their predominantly small physical size, sources contain very high concentrations of radioactivity. Industrial and medical sources are typically in the GBq (10^9 Bq) to PBq (10^{15} Bq) range. The radiation emitted from the sources is usually intense, requiring reliable encapsulation for operational use and heavily shielded containers for storage. Owing to their small physical size, they are easily lost or misplaced if not properly managed. This is a particular problem when items of industrial or medical equipment containing sources become obsolete and are replaced, or simply scrapped (disused sources), or when the sources weaken and need to be replaced (spent sources). Bad management practices in many parts of the world have meant that spent sources have been found stored in exposed and unprotected locations and are consequently sometimes in poor condition, perhaps even leaking. There have been a dozen recorded events involving fatalities in the last 40 years as a result of spent sources escaping control completely and being inadvertently mishandled by the public. The activity range of different types of sources and the magnitude of the problem they present when spent is shown in Figure 8-1.

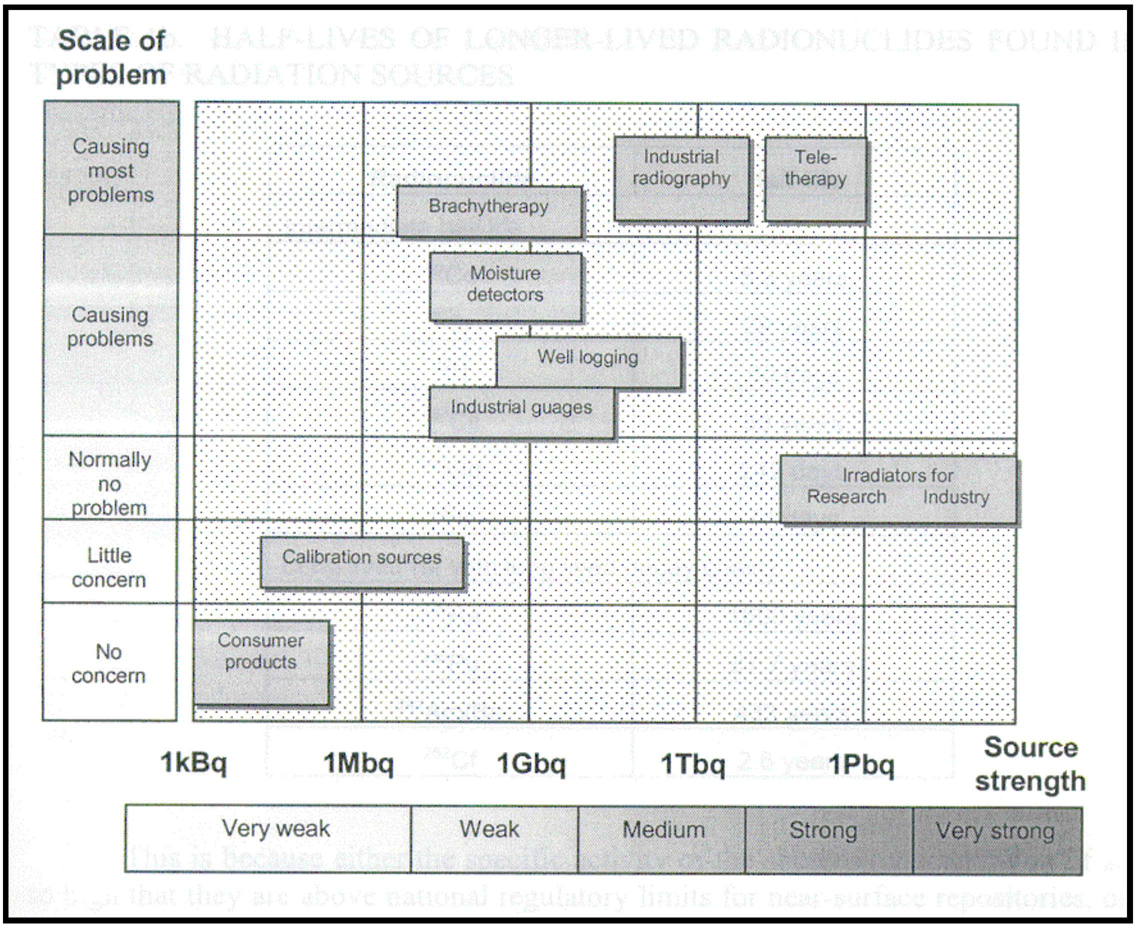

Figure 8-1: Activity Ranges for Some Important Radioactive Sources and the Magnitude of the Problems Caused When They are Spent

Radioactive sources can contain different radionuclides in greatly variable quantities. The nature of the radionuclides depends on the intended use; for example sources used as irradiators usually contain ^{60}Co or ^{137}Cs, power sources contain ^{238}Pu, neutron sources contain ^{241}Am. ^{226}Ra, presently replaced by other radionuclides, has been used extensively in the past in sources for medical applications, resulting in the widespread storage of radium needles around the world (see Table 8-I and Table 8-II).

Clearly, disused and spent sources need to be managed and disposed of carefully. As it is hazardous, impractical or uneconomical to recycle the vast majority, safe long-term storage and disposal are the only routes available. With the exception of sources containing only short lived radionuclides, which decay to harmless levels in a few years (for which storage might be considered an adequate and final management option), most other sources are not acceptable for disposal in the conventional near surface repositories that are used by the nuclear industry.

Sources with intermediate half-life radionuclides need to be placed in facilities that will provide higher levels of containment than a near-surface repository. Borehole disposal (at various depths) has been proposed in this context, and is, indeed, in use in some countries. For sources containing the longest lived radionuclides, deep geological disposal offers the highest level of isolation available within conventional disposal concepts.

There are clearly questions of practicality and real, present-day safety involved here. Currently, and for the next decades, suitable geological repositories do not exist. On-site storage at the point of use of sources is clearly inadequate in many places. Centralized, national storage may be difficult to assure for decades in some regions of the world. The scale of the problem is extremely small in many countries, yet the potential hazards are high. Numerous countries using radioactive sources have limited experience with either radiation protection or they lack an assured, long-term environmental protection infrastructure with elements that deal specifically with radioactive wastes. There is no international initiative for the collection and management of spent sources. In these circumstances, simple disposal solutions that can be operated locally or regionally on a small scale appear to offer the best solution to protecting human health and the environment. Such solutions must still meet rigorous safety standards, as applied to all types of radioactive waste disposal.

An obvious candidate for such facilities is borehole disposal. Boreholes match in size the physical scale of the problem and they can be constructed readily in most countries, using available technology. They provide immediate isolation of the sources and disposal facilities can be operational within a very short period of time. The question then arises as to what types of source might be emplaced, in what designs and depths of borehole, in what type of geological environment in order to provide the required level of protection and long-term safety. Concern has been expressed internationally that some borehole disposal operations, for a variety of reasons, may not be fully consistent with the principles defined by the interagency Basic Safety Standards [3.3]. Examples of possible causes of concern include insufficient depth of the boreholes, the unknown reliability and efficiency of the isolation barriers and the inadequacy of the safety assessments.

Borehole disposal is not conceptually different from either the near-surface or the geological disposal of radioactive wastes. It aims to achieve safety in exactly the same way: by a combination of natural and engineered barriers, located at a site with suitable properties, that operate together to contain activity until it has decayed completely, or to limit releases of activity to insignificant levels. The components of a borehole disposal system fall into the following general categories (please refer to Figure 8-2):

Engineered Barriers

- source radionuclides within the original source containers,
- matrix material inside a disposal package in which sources may be embedded,
- waste package (container),
- borehole backfill materials,
- borehole casing, and
- borehole seals.

The Natural Barrier

- host rock and groundwater system.

A proper assessment of feasibility and safety needs to consider how the complete disposal system functions and evolves with time. Currently these issues are being reviewed by the Agency.

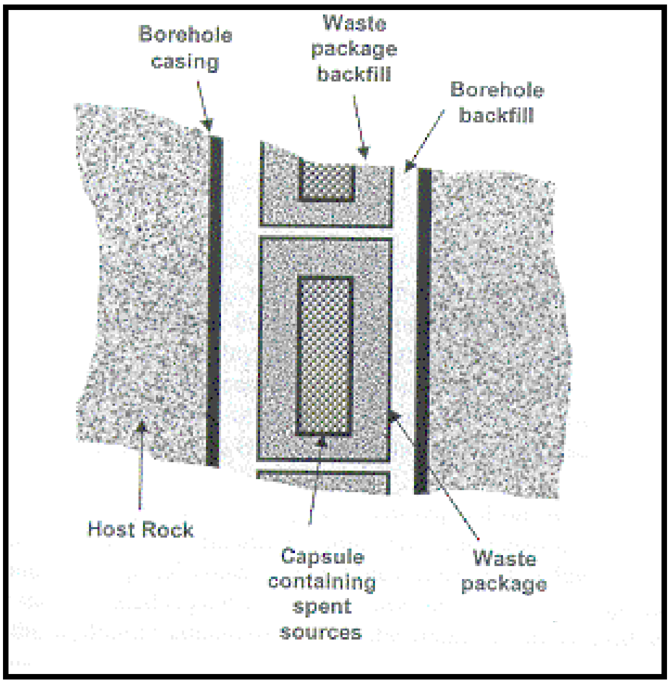

Figure 8-2: Schematic of Possible Components of a Borehole Disposal System

<u>References for Section 8</u>

8.1 “Methods to identify and locate spent radiation sources”, International Atomic Energy Agency Technical Document, IAEA-TECDOC-804, IAEA, Vienna, July 1995.

8.2 “Reference design for a centralized spent sealed sources facility“, International Atomic Energy Agency Technical Document, IAEA-TECDOC-806, IAEA, Vienna, July 1995.

8.3 “Conditioning and interim storage of spent radium sources”, International Atomic Energy Agency Technical Document, IAEA-TECDOC-886, IAEA, Vienna, June 1996.

8.4 “Handling, conditioning and storage of spent sealed radioactive sources”, International Atomic Energy Agency Technical Document, IAEA-TECDOC-1145, IAEA, Vienna, May 2000.

8.5 International Atomic Energy Agency Board of Governors General Conference, GOV/2000/34-GC(44)/7, 9 August 2000.

8.6 P. Ortiz, M. Oresegun, J. Wheatley, "Lessons from Major Radiation Accidents", Proceedings of the 10th International Congress of the International Radiation Protection Association (IRPA 10), Hiroshima, Japan, May 14-19, 2000

8.7 The Radiological Accident in Lilo, International Atomic Energy Agency, STI/PUB/1097, IAEA, Vienna, 2000

8.8 The Radiological Accident in Yanango, International Atomic Energy Agency, STI/PUB/1101, IAEA, Vienna, 2000

8.9 The Radiological Accident in Istanbul, International Atomic Energy Agency, STI/PUB/1102, IAEA, Vienna, 2000

9. MANAGING THE CONSEQUENCES OF PAST PRACTICES

Article 12 of the Joint Convention (see Section 1) states:

> *"Each Contracting Party shall in due course take the appropriate steps to review:*
>
> *…the results of past practices in order to determine whether any intervention is needed for reasons of radiation protection bearing in mind that the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including the social costs, of the intervention."*

Past practices that generated radioactive wastes may have resulted in waste that was not properly managed or not managed according to present standards and there may, therefore, be a need for remediation. Past practices may cover a wide range of situations such as inadequate disposal sites, land contaminated with radioactive material due to accidents, or abandoned mining sites.

The incident with the Chernobyl reactor [9.1] is an example of "land contaminated with radioactive material due to accidents". Strictly speaking, nuclear power generation is not a past practice, however dealing with the consequences of the contamination from Chernobyl is considered (according to the previous paragraph) to be a past practice since the accident resulted in waste that was not properly managed (due to the emergency situation that existed at the time).

It is impossible to present a comprehensive overview of the management of the consequences of past practices in any single issue of this Status and Trends report. As such, some well known examples are discussed in the current issue. Future issues will provide mixtures of updates of these well known examples and discussions of other examples.

9.1 The Chernobyl Shelter

Following the accident of 26 April 1986, the remains of the Chernobyl Nuclear Power Plant (CNPP) Unit 4 were enclosed under exceedingly hazardous conditions in what has become commonly known as The Shelter. The Shelter was never intended to be a permanent solution and it is becoming increasingly unstable. Water is seeping into the structure and there is a risk of collapse and of radioactive contamination of the Dnipro river basin. This danger will persist until the highly radioactive material that is currently inadequately contained within the Shelter is adequately isolated from the environment.

In May 1997, a multidisciplinary construction management program was finalized and designated as the Shelter Implementation Plan (SIP) to carry out remedial work on the Shelter to make it physically safe and environmentally stable, to decommission the CNPP and to implement an adequate waste management plan. Under the management of the European Bank for Reconstruction and Development (EBRD), the Chernobyl Shelter Fund (CSF) was constituted to finance the SIP. The CSF entered legally into force upon the approval by the EBRD Board of Directors of the CSF Rules of 6 November 1997. A framework agreement between the Ukraine and the EBRD relating to the activities of the CSF in Ukraine was signed on 20 November 1997. It was approved by the Ukrainian parliament, the Rada, on 4 February 1998.

The initial cost estimate of the project for the period 1998-2005 amounts to approximately US $758 million (SIP estimate, US $768 million including the licensing support).

European Council Decision 98/381/EC of 5 June 1998, concerning the Community contribution to the EBRD for the CSF, represents the legal basis for a Community contribution to the CSF of (maximum) EUR 100 million, corresponding to a US $100 million pledge made at the 1997 G7 summit in Denver. This was to be paid over the years 1998/99 within the TACIS (see page 19) financial envelope. The first part of the Community contribution of EUR 50 million (US $58 million) was transferred to the EBRD in December 1998.

A progress report on the implementation of the CSF, as foreseen in Article 3(2) Decision 98/381/EC, is available on the Internet at the following URL:

http://europa.eu.int/comm/external_relations/nuclear_safety/cherno_shelter_1st_report/index.htm

Germany organized a successful pledging conference for the CSF in Berlin on 5 July 2000. The conference generated an additional EUR 335 million of commitments to the Fund. This is the second pledging conference, with the first held in New York in November 1997. As the result of the two conferences, the total contributed to the Fund amounts to US $715 million, 93 per cent of the overall project cost estimate. This now allows the EBRD to proceed at full speed with the SIP.

Recent activities on the Shelter within the SIP include a stabilization strategy for the roof structure and supports, B1/B2 beam support on the 50G and 50P axes, a report on the need for an automated system to monitor the condition of the Shelter's structural elements, a decision on the need for a seismic monitoring system, a definition of contained water management needed during the construction of the new Safe Containment system, and preliminary agreement on a strategy for the removal and management of fuel containing material (FCM), including definition of the main requirements for the new confinement system to enable future FCM removal.

9.2 The US-EPA Superfund Activities in Relation to Radioactive Contamination

The Office of Solid Waste and Emergency Response (OSWER) within the United States Environmental Protection Agency (EPA) is responsible for implementing two key laws regulating waste management and cleanup: the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation and Liability Act, CERCLA, which has been nicknamed the "Superfund." [9.2]. The purpose of the Superfund program is to protect human health and the environment over the long-term from releases or potential releases of hazardous substances from abandoned or uncontrolled hazardous waste sites. Within the Superfund remediation framework, radioactive and chemical contamination are dealt with in the same manner. The EPA's OSWER maintains an Internet page concerning its policies for remediating radioactively contaminated Superfund sites at:

http://www.epa.gov/superfund/resources/radiation/index.htm.

The enactment of the Superfund gave the federal government broad authority to respond to hazardous substance emergencies and to develop long-term solutions for the most serious hazardous waste problems. It also enabled the United States Federal government to recover the costs from responsible parties or to force them to clean up the hazardous site at their own expense.

The EPA has developed a human health evaluation process as part of its remedial response program. The process of gathering and assessing human health risk information is adapted from well-established chemical risk assessment principles and procedures. The results of a risk assessment are critical in determining whether responses to protect human health and the environment are justified and in establishing an appropriate cleanup level. The risk assessment also helps the EPA identify potential risks associated with a particular remedy and evaluate risks remaining at a site after cleanup is completed. The EPA has recently issued new guidance that includes updated risk assessment and groundwater leaching for estimating radionuclide preliminary remediation goals for residential land use (see Soil Screening Guidance for Radionuclides: User's Guide" October 2000, OSWER No. 9355.4-16A).

Cleanup levels for radioactive contamination at CERCLA sites are generally expressed in terms of risk levels. Remedial actions must meet cleanup levels and performance standards provided in applicable or relevant and appropriate requirements (ARAR) of other federal and state environmental laws. However, where ARAR are not available or are not sufficiently protective, the EPA generally sets site-specific remediation levels.

Because the diverse characteristics of Superfund sites preclude the development of prescribed ARARs, it is necessary to identify them on a site-by-site basis. Some of the radiation standards most frequently used as ARAR at Superfund sites are the soil cleanup and indoor radon standards developed to address contamination at sites that are subject to the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). When used as an ARAR at Superfund sites, the soil cleanup level for radium 226 and radium 228 combined, or thorium 230 and thorium 232 combined, is 5 pCi/g ($1.85x10^{-1}$ Bq/g) above background, while the indoor radon level is 0.02 working levels inclusive of background.

The current Maximum Contaminant Levels (MCL) for radionuclides are based on a dose of 4 mrem/annum to the whole body or an organ for the sum of the doses from beta particles and photon emitters, 15 pCi/litre ($5.55x10^{-1}$ Bq/litre) for gross alpha, and 5 pCi/litre ($1.85x10^{-1}$ Bq/litre) combined for radium-228 and radium-226. The Superfund program requires MCL be met within the aquifer, not “at the tap”.

The EPA has published concentration tables for each radionuclide that correspond to the 4 mrem/annum level in the Federal Register (FR) notice "National Primary Drinking Water Regulations; Radionuclides; Notice of Data Availability; Proposed Rule" (see 65 FR 21576, 21605-14, April 21, 2000). In addition, a new MCL for uranium of 30 micrograms per litre was issued December 7, 2000 (65 FR 76708).

The EPA’s Office of Water maintains an Internet web page concerning this rule making at: http://www.epa.gov/safewater/radionuc.html). When MCL for radionuclides are changed or added in the future, those new MCL would be considered ARARs for groundwaters that are a current or potential source of drinking water.

Sometimes the Superfund program develops guidance on interpreting a particular ARAR to assist site decision makers. For example, at UMTRCA sites the standard for subsurface soil is 15 pCi/g ($5.55x10^{-1}$ Bq/g), averaged over a 15 cm thick layer of soil more than 15 cm below the surface. This standard for subsurface soil was derived as a tool for use in locating and remediating discrete deposits of high activity tailings (300 to 1,000 pCi/g) found in subsurface locations at UMTRCA sites. Since this range of radioactive contamination differs from that typically found at Superfund sites, which contain the full range of radioactive contamination including lower levels, 15 pCi/g would not necessarily be an ARAR. However, since the subsurface soil standard was used as a finding tool for any contamination above 5 pCi/g ($1.85x10^{-1}$ Bq/g), the EPA has interpreted the cleanup level as 5 pCi/g (combined for radium-

226 and radium-228 or thorium-230 and thorium-232) for purposes of ARAR compliance. This information is found in a Superfund guidance document entitled “Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA sites” [9.3].

The EPA’s CERCLA policy states that if a site cannot be cleaned up to a protective level (i.e., generally within the 10^{-4} to 10^{-6} carcinogenic risk range) for the “reasonably anticipated future land use” because it is not cost-effective or practicable, then a more restricted land use should be chosen that will meet a protective level.

Two examples of radioactively contaminated Superfund sites that have been addressed are the Glen Ridge and Montclair/West Orange sites in the state of New Jersey [9.4]. Over 700 properties were contaminated with radioactive waste materials suspected to have originated from radium-processing facilities located nearby during the early 1900's. Some of the radium contaminated soil was used as fill in low lying areas or was mixed with cement for sidewalks and foundations. Carcinogenic risks to residents posed by site-related indoor radon were estimated to range as high as 4×10^{-1}, while the maximum carcinogenic risks from radium contaminated soil were estimated at 1×10^{-2}. The remedy for these two sites included the excavation of highly contaminated soil and debris material for off-site disposal. The primary contaminant of concern in soil was Radium 226, which decays to radon gas. The ARAR used for radium was soil cleanup standards for uranium millings under 40 CFR 192, namely 5 pCi/g (1.85×10^{-1} Bq/g) over background. For radon, the ARAR used was indoor radon standards under 40 CFR 192 (0.02 working levels, inclusive of background).

9.3 Status of The Dounreay Shaft and Silo Remediation

The Dounreay complex was established as a United Kingdom Atomic Energy Authority (UKAEA) site to develop fast reactor technology. The Dounreay Materials Test Reactor (DMTR) was built and operated first and was followed by the Dounreay Fast Reactor (DFR) and the Prototype Fast Reactor (PFR). Criticality was first achieved in the DMTR in May 1958 and in the DFR in November 1959. The PFR became operational in 1974. The DMTR was shut down in 1969, the DFR ceased operation in 1977 and the PFR shut down in March 1994.

The site had two facilities that had been previously authorized for the disposal of low- and intermediate-level radioactive wastes (LLW and ILW) [9.5]. These are, respectively, the Low Level Waste Pits and the Shaft. The Wet Silo was used to store ILW underwater.

The Shaft was the scene of a chemical explosion in 1977, which dislodged its heavy concrete lid. Although the disposal authorization remained in force at the time, the use of the Shaft for disposal of radioactive waste was immediately halted.

In June 1998, an audit of the Dounreay site was carried by a joint team of Inspectors from the Nuclear Installations Inspectorate (NII) and the Field Operations Directorate (FOD) of the Health and Safety Executive (HSE) and from the Scottish Environment Protection Agency (SEPA) [9.6]. Relevant excepts from the audit report follow:

> ***…R45 Recommendation: UKAEA should develop an integrated decommissioning strategy for Dounreay….***
>
> ***… Dounreay Shaft and Wet Silo***
>
> *258 The emptying of the Dounreay Shaft, which the Government has recently agreed, will be one of the most challenging decommissioning tasks in the UK. At the same time the Government announced that the Wet Silo would be emptied.*

259 UKAEA used the Dounreay Shaft (D1225) for disposal of solid waste between 1959 and 1971. In 1971 the Wet Silo (D9833) came into service as an intermediate level waste store. The Shaft was used until 1977 for items that were too large for the Wet Silo when an explosion in the Shaft led to cessation of input of material. There is considerable uncertainty over the contents of the Shaft, but it is believed to contain equipment contaminated with radioactive material and sodium, chemicals, natural uranium fuel, radioactive sources, incinerator ash, filters, gloveboxes, building materials, sludges, clothing etc. Although the disposals to the Shaft took place in accordance with an authorisation made under the Radioactive Substances Act 1960 (Ref 25), UKAEA accepts that the Shaft does not meet current standards for an intermediate level waste disposal facility. The Government has recently accepted UKAEA's proposal to retrieve the waste and process it to a form suitable for eventual disposal in an intermediate level waste repository. The plan is to carry out this work between 2014 and 2018. UKAEA has commissioned a number of studies into possible waste retrieval and conditioning methods and is about to commission further hydrogeological studies in the vicinity of the Shaft to underpin future work on developing potential methods of waste retrieval. It has also recently completed and published a study to identify the radioactive inventory of the Shaft. Our view is that the Shaft should be emptied as soon as is reasonably practicable, since the position will not improve with time.

R61 Recommendation: UKAEA should make and implement plans to empty the Shaft as soon as is reasonably practicable.

260 The Wet Silo was brought into use to allow the Shaft to be taken out of routine service in 1971. It is a large, water filled, underground concrete vault, accessed via shielded openings in its roof at ground level, into which a range of solid intermediate level waste with a low alpha radioactivity content has been tipped. The waste typically consists of fuel assembly parts (but not fuel), waste from caves and cells such as manipulators and gaiters, and other debris packaged in 8-inch diameter cans. Records, particularly from the early years of operation, may not be complete.

261 UKAEA has recognised that this is no longer an acceptable practice. The plan is that the Silo will eventually be emptied as part of the decommissioning of the site after the Shaft has been emptied. We believe that leaving the Silo in care and maintenance for twenty years is not good practice because the waste is not in a safe passive form. We think that UKAEA should bring forward the removal and treatment of waste from the Silo since experience elsewhere has shown that such facilities can be emptied.

R62 Recommendation: UKAEA should empty the Wet Silo as soon as is reasonably practicable and not wait for the Shaft to be emptied….

… R68 Recommendation: UKAEA, as a matter of urgency should complete a detailed inventory of all current wastes on site, incorporating estimates of wastes which will arise from decommissioning….

…R69 Recommendation: UKAEA should develop a strategic plan for handling, treatment, storage, and disposal of all radioactive wastes on site, integrated with the plans for operation, Post-Operational Clean Out, care and maintenance, and decommissioning….

In response to the audit report, the UKAEA issued its Action Plan on November 30, 1998 [9.7]. Since that time, two annual progress reports on the implementation of the Action Plan have been issued [9.8], [9.9]. The UKAEA's response to recommendations 45 and 69 (see above) was the preparation of a Site Restoration Plan. At time of writing, the latest version of this plan was available at the following Internet page:

http://www.ukaea.org.uk/windex.htm

9.4 International Co-operation for Radioactive Waste Management in the Russian Federation

The Russian Federation has been facing a number of complicated environmental problems related to the management of radioactive waste and spent nuclear fuel. These problems have arisen from past activities in the production of nuclear weapons, the use of nuclear energy for peaceful purposes and reductions in nuclear armaments. By 1995, the amount of radioactive waste that had accumulated in the Russian Federation amounted to more than half a billion m^3 with a total activity of about 7.4×10^{19} Bq. In addition, around 8500 tonnes of spent nuclear fuel had been stored with a total activity of about 1.5×10^{20} Bq.

To better assess the situation, the Nordic countries asked the IAEA to organize a seminar on International Co-operation on Nuclear Waste Management in the Russian Federation. At this seminar [9.10], participants recognized the need to co-ordinate their efforts, to avoid the duplication of work, to assure that priorities would be properly assessed and made known to the international community, and to provide points of contact to facilitate co-operation. A decision to establish a Contact Expert Group (CEG) was taken in September 1995 by a group of interested countries and international organizations (please refer to Section 11.6 for additional information about the CEG and its activities).

Within the CEG framework three high priority activity (HPA) areas have been identified at the 10th CEG meeting in Helsinki, Finland in May 2000.

a) the remediation of the naval bases in NW Russia,
b) the recovery and safe interim storage of SNF afloat, and
c) the management of high level waste at fuel cycle facilities.

It is perceived from the views expressed at previous CEG meetings and the external funding that has been committed to date, that the highest priority is associated with (a) and (b) above. However, access has not yet been obtained to the two most important bases of Item (a) (Andreeva Bay and Gremikha) and, thus, the area where short term aid can be effective is Item (b).

In the immediate future, external governments will only be able to provide a small fraction of the required funding and there is a need to identify where facilities are required most urgently.

The overall situation was reviewed and it was found that, even with the planned rate of defuelling withdrawn submarines, the major bottleneck is the lack of capacity of interim storage and the associated cask-loading and transport facilities. This is reflected in Minatom's strategy for the management of spent nuclear fuel. At the next level of detail Minatom has developed an implementation plan to de-fuel about 20 submarines per year.

An associated cause for concern is the management of the radioactive waste that is produced when the submarines are de-fuelled and prepared for dismantling. This is because some bases, such as Sevmash and Polyarny, have very old facilities or no facilities at all for processing liquid and solid waste and the waste has to be transported to neighbouring facilities in vessels that are coming to the end of their active life.

Thus, to achieve the objective of identifying the immediate priorities, the facilities that are required at each site to implement the Minatom plan have been reviewed, the new or replacement facilities that will be required in the next decade or so and the associated priorities have been identified.

It is found that donors have identified funding for many of these required facilities and some are under construction or recently completed. Others will proceed to completion subject to the satisfactory completion of ongoing design studies and negotiations with the beneficiaries on a number of issues including the scale of funding required.

9.5 Status of the Wismut Remediation

The former German Democratic Republic (GDR) was the scene of large scale uranium mining, which supplied the former Soviet Union (USSR) with raw materials for both nuclear defence and nuclear energy programmes. Mining, milling and processing activities took place within a relatively small but densely populated area in the States of Thuringia and Saxony extending from East to West about 130 km and from North to South about 50 km (see Figure 9-1). More than 40 years of intensive mining and processing resulted in a total production of more than 220,000 tonnes of uranium.

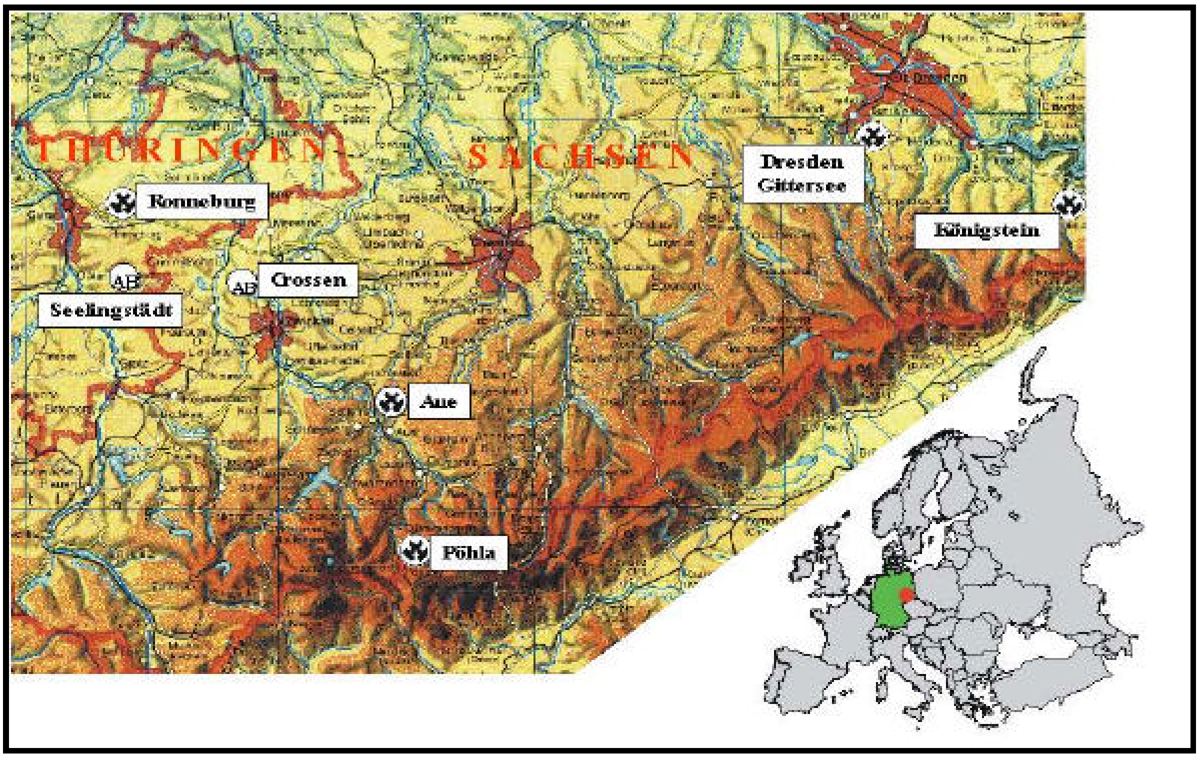

Figure 9-1: Location of Uranium Mining and Milling in Thuringa and Saxony

The mining and processing adversely affected an area of about 100 km^2 resulting in local environmental damage, including widespread soil and groundwater contamination. During the initial years of operation, little care was paid to protection of the health and safety of the workers and the general public and protection of the environment.

Following reunification of Germany in 1990, production was brought to an end. By subsequent corporate restructuring, WISMUT GmbH, as the successor company to SDAG Wismut, was put in charge of decommissioning and rehabilitation of the uranium mining liabilities by a federal law (Wismut Act, 1991). The German Federal Government committed up to 13 billion Deutschmarks to the Wismut remediation project.

The ongoing WISMUT Remediation Programme [9.11], [9.12] deals with the legacy of uranium mining and processing. The programme started with site investigations to determine the degree of contamination of affected areas. An extended environmental monitoring system of the contamination pathways was established. The overall approach follows the general rule of guiding, planning and implementation of the site specific rehabilitation projects to ensure an optimal balance between rehabilitation costs and environmental benefits while complying with the applicable laws and requirements of the permitting agencies.

The WISMUT decommissioning and rehabilitation project is now in its eleventh year and by mid-2000 approximately half of the cleanup had been finished (see Figure 9-2). A well thought out approach to water treatment and timely adjustment to changing conditions will help save water treatment costs. Consideration of the post rehabilitation land use and surveillance requirements are an integral part of the optimization of the remedial measures.

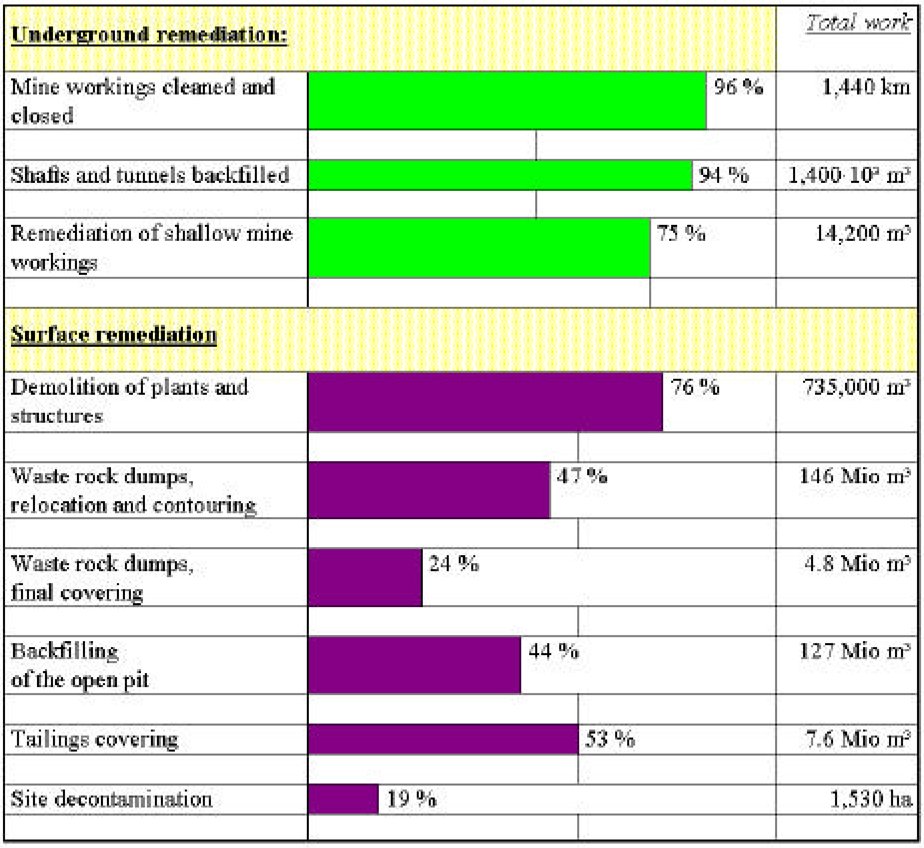

Figure 9-2: Status of WISMUT Rehabilitation (June 2000)

Note: At the time of writing of this status and trends report, the latest status on the Wismut project was available at http://www.wismut.de/ (German language only)

By mid-2000, approximately 6.2 billion Deutschmarks had been invested into the project. The extent of the contaminated sites has been substantially reduced in size and the radiological situation has significantly improved due to reduction of emissions (see Figure 9-3 and Figure 9-4). Viable concepts are in place for the remaining work. Project experience over the years has highlighted an on-going challenge to optimize remedial actions by tailoring them to the site specific conditions.

After completion of the project, some long-term tasks will remain, which include:

- Treatment of contaminated water,
- Care and maintenance of the rehabilitated land,
- Care and maintenance of ancilliary installations,
- Mine damage control and compensation, and
- Environmental monitoring.

Project work has also highlighted the fact that a successful rehabilitation project requires the involvement and trust of the local/community decision makers and the financial and political stakeholders in the rehabilitation process (see Section 2.4, "Topical Issue: Non-Technical Factors Affecting Decision Making for Radioactive Waste Management").

Figure 9-3: Remediation of Waste Rock Dump Hammerberghalde

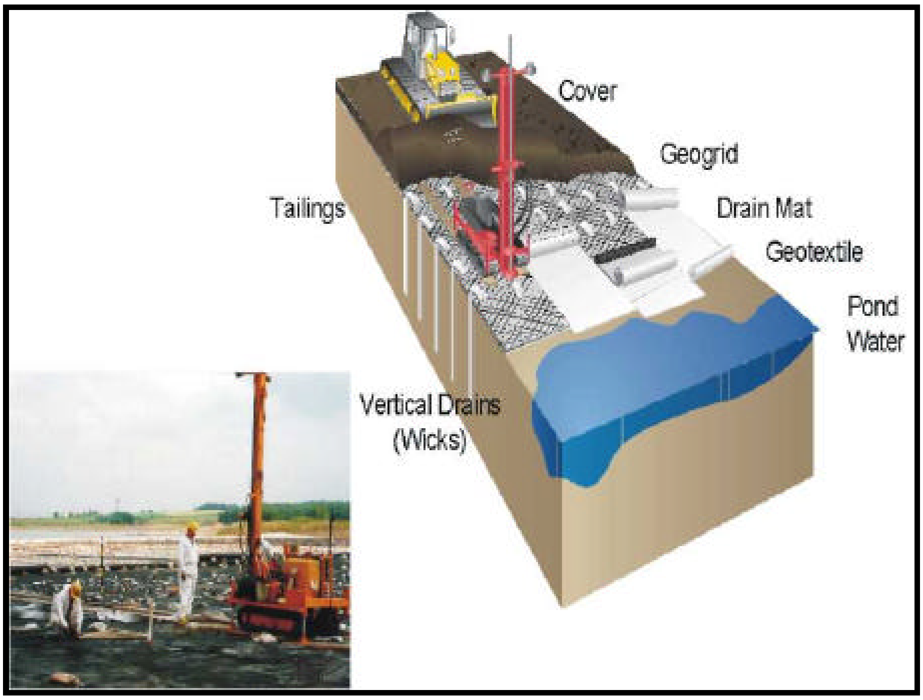

Figure 9-4: In Situ, Dry Remediation of the Tailings Ponds at WISMUT

<u>References for Section 9</u>

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