Nuclear inspections in Iraq: Removing final stocks of irradiated fuel

An unprecedented operation succeeds in safely removing all declared stocks of nuclear-weapons-grade material from Iraq

by Fernando Lopez Lizana, Robert Ouvrard, and Ferenc Takáts

When the last consignment of highly enriched uranium in spent fuel left Iraq's Habbayina airport in February 1994, a milestone was reached in the IAEA's monitoring and verification of the former Iraqi nuclear programme. Nearly 3 years earlier, on 12 April 1991, the United Nations Security Council had adopted Resolution 687 which *inter alia* demanded that Iraq "place all its nuclear-weapons-usable materials under exclusive control, for custody and removal, of the International Atomic Energy Agency, with the assistance of the United Nations Special Commission".

The operation to remove the spent fuel —carried out in two shipments on 4 December 1993 and 12 February 1994 — effectively completed the removal of declared stocks of nuclear-weapons-grade material from Iraq. Substantial technical problems had to be overcome to remove the fuel, some of which was buried under the rubble of a research reactor destroyed during the 1991 war.

The removal stands among a range of operations undertaken by the IAEA over the past 3 years under terms of UN Security Council resolutions. In 1991, following its initial inspections in Iraq, IAEA inspection teams removed gram quantities of plutonium that Iraq was found to have separated, and they supervised the removal of nuclear material, including fresh nuclear fuel, that was part of Iraq's declared nuclear inventory under IAEA safeguards. Though declared stocks of nuclear-weapons-grade materials now have been removed from Iraq, the IAEA's work in the country is continuing. It includes the implementation of a plan for long-term monitoring and verification of Iraqi nuclear activities.

In this article, the job of removing the spent fuel is described, most notably from the standpoint of technical challenges that were faced and considerations of safety and radiation protection that had to be taken into account.

Preparing for the operation

In planning the operation, the IAEA requested various governments to assist with contractual arrangements for the removal, transportation, and disposal of all irradiated fuel assemblies located at research reactors in Iraq. In June 1993, a contract was signed between the IAEA and the Committee of International Relations on behalf of the Russian Ministry of Atomic Energy (Minatom) for the removal, transportation, and reprocessing of the irradiated fuel assemblies, and for the permanent storage in Russia of the wastes generated during the reprocessing process.

While Minatom was responsible for the overall operation, there were two main subcontractors: the Nuclear Assurance Corporation (NAC) of the United States for handling, cleaning, and packaging the irradiated fuel; and the air cargo company Touch and Go Ltd. of Russia for the transportation, by air, of the containers between Iraq and Russia. The technical and financial discussions to conclude the contract with Minatom (which was signed on 21 June 1993) took several months. Several missions to Iraq also were required to secure the necessary assistance of the Iraqi side and to monitor progress in preparation of the sites.

In technical terms the task included the following sequences of operations:

- gaining access to the fuel,
- cleaning the fuel to remove dirt and possible radioactive contaminants from its surface,

Mr. Lopez Lizana is a staff member in the IAEA Division of Nuclear Safety and Mr. Ouvrard is the Division's Acting Section Head for Radiation Safety Services. Mr. Takáts is a staff member in the IAEA Division of Nuclear Fuel Cycle and Waste Management.

Spent fuel assemblies removed from Iraq

Type	Number
IRT-2M assemblies — tubular type (80% enrichment)	96
EK-10, EK-36, EK-NU assemblies (10%, 36%, natural)	74
Tamuz II MTR assemblies (93% enrichment)	32
Tamuz II control assemblies (93% enrichment)	6
Total	208

- verification of each assembly (type and serial numbers),
- loading in a transport cask,
- transfer of the cask by road from the loading place to the airport,
- transport of the casks by air from Baghdad to Yekaterinburg in the Russian Federation, and
- transport of the cask by road from Yekaterinburg to the Chelyabinsk reprocessing plant.

Preparations included:

- the manufacturing of some technological equipment (i.e. for cleaning fuel and storage water);
- manufacturing or procurement of equipment and spare parts which were considered to be necessary for the work, but which could not be purchased locally (container support structure, truck spare tires, crane spare parts etc.);
- licensing of the transport container by the Russian regulatory body; and
- preparing radiation protection equipment and a dose recordkeeping system by IAEA staff.

The preparatory work was accomplished during summer 1993. Actual field work began on 6 October 1993 and the last consignment of irradiated fuel left Iraq on 12 February 1994. Throughout this period, IAEA staff members were rotated in the field to supervise the contractual work and assure the co-operative link with Iraqi authorities.

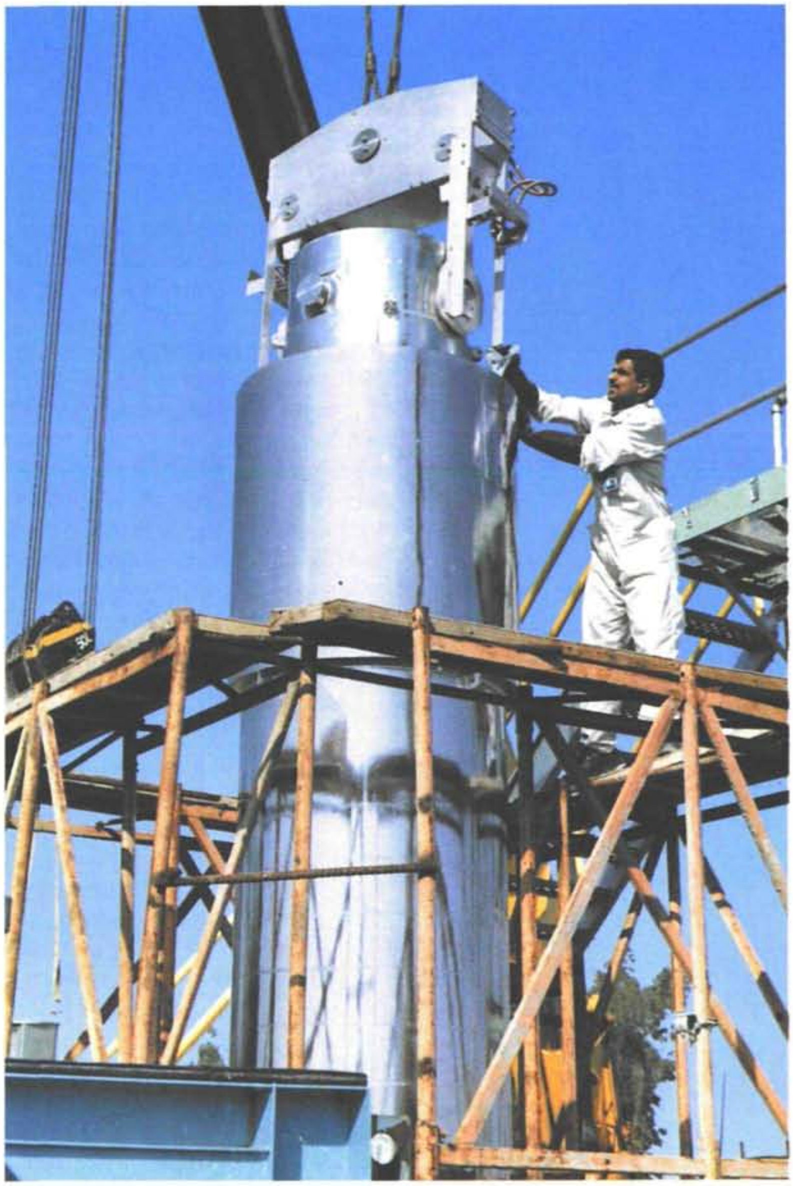
A great amount of work was done by the Iraqi counterparts. It included removal of debris and cleaning of the sites; supplying cranes, trucks, and other equipment; and constructing a transfer cask, concrete platforms, and two cleaning pools. In addition, the Iraqi counterparts provided operational and radiation protection staff, site offices, and all support activities necessary for the operations.

The sites of the spent fuel assemblies

The irradiated fuel assemblies removed from Iraq came from the two research reactors at the Tuwaitha Nuclear Research Centre. They were stored in two different locations, one at Tuwaitha and the other at Garf al Naddaf, a farming area not far from Tuwaitha. All told, more than 200 spent fuel assemblies had to be removed. *(See table.)*

The IRT-5000 research reactor. This water-cooled, pool-type reactor at the Tuwaitha Nuclear Research Center had an original power of 2 megawatts-thermal (MWth), which was increased to 5 MWth in 1978. There was fuel in the reactor pool, and in an auxiliary spent fuel storage pool.

The reactor as well as other nuclear facilities at Tuwaitha were destroyed by coalition air raids during the first days of the war in 1991. Fortunately, the pools were not directly hit, and the fuel assemblies were not damaged. However,



An Iraqi worker helps prepare a spent fuel cask for shipment. *(Credit: Iraq Atomic Energy Commission)* debris from the collapsed structures covered the reactor pool. Substantial clearing was necessary to get access to the pool before recovery operations could start. From this site, 76 fuel assemblies had to be removed.

Location B. During the first days of the war, the Iraqis moved some irradiated fuel assemblies stored at Tuwaitha to prevent their destruction from bombardments. They were taken to a site located about 5 kilometers north of the Tuwaitha Nuclear Research Center. The IAEA has named this site, located in the Garf al Naddaf district, as "Location B". It was far from being an ideal storage place for nuclear fuel. It is just an acre or so of farm land, has no built structures, and no support facilities, such as water or electricity. There is no road on the site, and the soil is soft clay, so it is difficult to move after heavy rains.

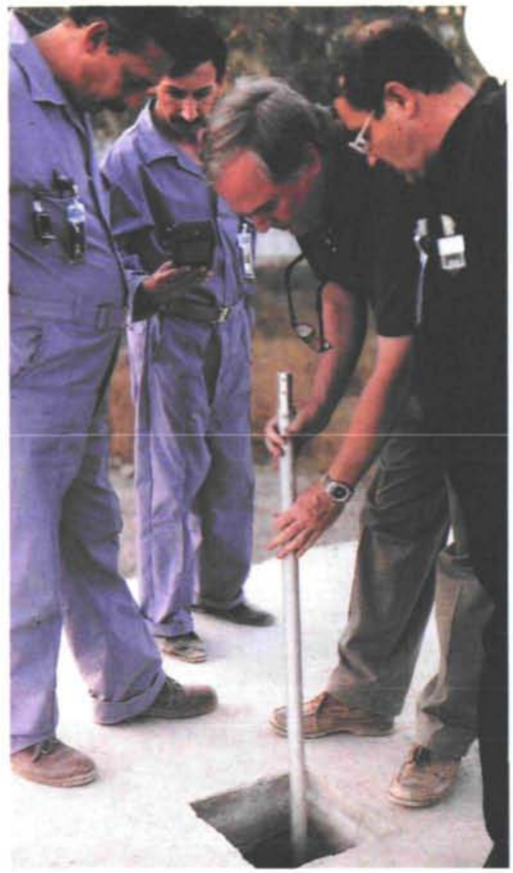
Sixteen concrete storage tanks were buried here in the open air and filled with water. Aluminum racks holding the irradiated fuel assemblies were placed in carbon steel drums. Each tank contained up to two drums. The tanks (which were, in fact, buried below the surface level) were covered with a reinforced concrete plate, with a hole in the center for water refilling. This was covered by a second, smaller concrete plate.

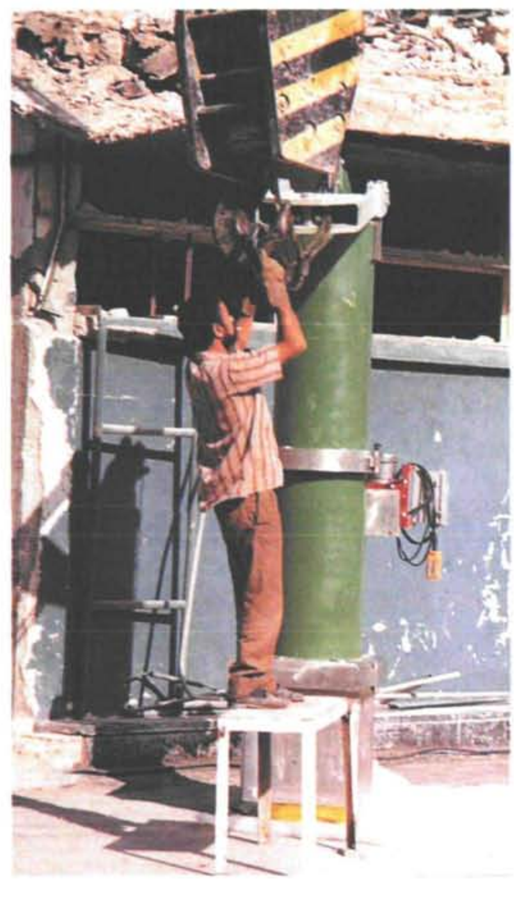
At the end of January 1992, following a period of flooding, the storage conditions had to be modified, for fear of leakage and groundwater contamination. Fourteen new concrete tanks were constructed to replace the original 16. The original inner drums of carbon steel were replaced with tin-plated steel drums. The 14 new tanks were buried so that the rim partially extended one meter above ground to avoid penetration of groundwater. From this site, 132 fuel assemblies of different types had to be removed.

Tools of the operation

The cleaning stations. Due to the presence of all kind of debris, stones, sand, and other materials, the fuel assemblies had to be cleaned before placing them in the transport cask. Two cleaning stations had to be installed, one on each site. They were about 4 meters deep, to allow safe handling of the irradiated fuel assemblies. The walls were made of concrete, covered with an additional steel liner to make it leakproof.

The cleaning stations were equipped with a handling tool (upender), into which individual assemblies were introduced for cleaning, and an appropriate water filtration system. The assemblies were turned upside down to let the bigger parts fall out, then the fuel was washed from above using pressurized water.





Scenes from the removal operation: Over a period of 5 months in late 1993 and early 1994, the IAEA organized and supervised the removal of all declared stocks of nuclear-weapons-grade material from Iraq's Tuwaitha Nuclear Research Centre and a nearby storage site. All told, highly enriched uranium in the form of 208 assemblies of spent nuclear fuel were recovered, cleaned, loaded into 23-ton transport casks, sealed, and flown out of Iraq. Shown here are scenes from the complex and technically demanding operation, which involved 170 workers, including Iraqi personnel, IAEA experts, and US and Russian contractors. *(Credits: R. Ouvrard, IAEA; Iraq Atomic Energy Commission)*

The transfer cask. To transfer the fuel assemblies from the storage locations into the cleaning station and then to the transport casks, a shielded transfer cask was used. The transfer cask, provided by NAC, had a lead shield thickness of 13.2 centimeters and a bottom ball valve. Its lower part was designed so as to fit either a lead collimator, when positioned on storage tanks, or a trolley when used on the cleaning station and on the transport cask adapter.

Different types of grapples controlled by compressed air were used to pick up the assemblies. The fuel was pulled into the cask or lowered down with an electric hoist.

The transport casks. The transport casks were designed and provided by NAC. They were of the type known as NAC-LWT packages normally used for the transport of one pressurized-water reactor fuel assembly or two boiling-water reactor assemblies. They were modified for the Iraqi operation in order to receive fuel assemblies from Iraqi research reactors (24 Tamuz-II fuel assemblies, and 28 IRT-5000 fuel assemblies). Inside the cask, the fuel assemblies were placed into two stainless steel fuel baskets on two levels.

The transport containers satisfy the requirements of the IAEA Safety Series No. 6, *International Regulations for the Transport of Radioactive Material* (1985 Edition, as amended 1990). Since the US Nuclear Regulatory Commission (NRC) had not yet adopted the current IAEA requirements, a license to use the NAC casks had to be obtained from the Russian regulatory body.

Each cask is made of stainless steel (total weight: about 23 tons). The gamma shielding, surrounding the fuel assemblies, is made of:

- lateral sides: 1.9 centimeter lead, 16.6 centimeter steel, 3.0 centimeter lead. The original neutron shielding, made of a tetra-borate potassium solution, had been drained out for this particular operation;
- lower side: 10.16 centimeter steel, 7.62 centimeter lead, 8.89 centimeter steel;
- upper side: 28.57 centimeter steel.

The fuel assemblies were introduced from the top; the transport casks were maintained in vertical position inside the container support structure.

Taking into account the airplane's loading capacity, four transport casks were needed for this operation. This meant that for all of the spent fuel, two air shipments were necessary.

According to the requirements of the IAEA transport regulations, the following dose rate limits were to be respected: 2 millisieverts per hour (mSv/h) at the surface of the cask; 0.1 mSv/h at 2 meters from the surface of the transport vehicle; and 0.02 mSv/h at the level of transport personnel.

Operational procedure

With minor differences, the same operational procedure was followed at both sites, and included the following steps:

Each individual assembly was transferred from its existing storage location to the cleaning station. The fuel assembly was first lifted from its storage location into the transfer cask, using a grapple tool attached to a cable. Then the bottom ball valve of the transfer cask was closed, the cask was lifted, moved to the cleaning station, and lowered onto an adapter directly above this cleaning station. The bottom ball valve was reopened and the fuel assembly lowered into the cleaning tool. Once the fuel assembly was correctly seated, the grapple was remotely disengaged and withdrawn into the transfer cask. The ball valve was closed and the transfer cask removed.

Each fuel assembly was first cleaned by high-pressure water to remove the rubble and slit within the fuel assembly. For this, the assembly had to be turned upside down, the high pressure stream being applied through the lower end fitting of the fuel assembly. The assembly was then uprighted to its original position and visually inspected. Whenever needed, the cleaning process was repeated.

The cleaned assembly was then transferred to the transport cask, using the transfer cask. Once loaded with the fuel assembly and closed, this cask was lifted and moved to the shipping area and lowered onto the adaptor plate, directly above the shipping cask. The bottom ball valve and the adaptor plate shield valve were then opened and the fuel assembly was lowered into the shipping cask. Once the assembly was correctly seated, the grapple was remotely disengaged and withdrawn into the transfer cask. The ball valve of the transfer cask and the adaptor plate shield valve were closed and the transfer cask removed.

The above operations had to be repeated until a whole shipping cask was completely loaded (in fact, cleaned assemblies were temporarily stored in the cleaning station, to allow continuous work between storage tanks and cleaning station). Then the shipping cask was transferred to a decontamination area, for cleaning to the required shipping levels.

The cask was then rotated to the horizontal position, fitted with its impact limiters, and secured into its ISO container. A final radiation survey was performed to verify that IAEA requirements were met and safeguards seals were installed.

Four shipping casks were so prepared during each of the two campaigns and then transported, under escort, to Habbaniya airport, where they were loaded into an Antonov-124 airplane for onward transport to Russia.

Safety considerations

Owing to the circumstances, the conditions at the two sites before the operation started could not be considered as normal from the safety point of view.

At the IRT reactor, the site was full of rubble, and what was left of the building threatened to collapse. However, the radiation levels were low.

Completely different was the situation at Location B. Although the general radiation levels were low, i.e. 10 to 30 micro-sieverts per hour (corresponding to normal levels at controlled areas), the dose rates were considerably higher on the top of each storage tank, where workers would have to operate. The dose rates further were strongly dependent on the water level above the fuel assemblies. (Radiation levels up to 10 mSv/h had been recorded during previous inspections.) Moreover, the manual pre-cleaning of the assemblies required the removal of the smaller upper concrete shielding plates. This would have exposed workers (even for a short time) to unacceptable radiation levels, namely, in some cases, up to 1 Sv/h (100 rem/h).

Therefore, considerable preparatory work was necessary before the actual removal operations could start. The work included supplying water and electricity to the site, installing offices and facilities, and reinforcing the ground for heavy load-bearing equipment.

Radiation protection measures

More important from the point of radiation protection was the preparation of additional concrete shielding to be used on the storage tanks. This shielding was made of two concrete frames (5 meters by 5 meters, 80 centimeters thick, and 60 to 77.5 centimeters high). They were designed to allow two of these frames to be stacked and to completely surround each tank.

In addition, two large concrete cover plates were prepared. In its center, each plate had a suitable hole, either to allow manual cleaning of the assemblies, or to accept a lead collimator on which the transfer cask had to sit. This additional shielding was sufficient to reduce the radiation exposure to an acceptable level, that is, to less than 0.2 mSv/h (20 millirem/h) at working position, and less than 0.02 mSv/h (2 millirem/h) around the shielded tank.

Two tanks were shielded at one time, in order to optimize the operations of the cranes. Before any transfer of irradiated fuel started, a check of radiation levels was always done and, as requested, water was added to the tanks. In addition, water samples from the tanks were taken to control possible water contamination with fission products, in order to detect at an early stage any breach of the fuel cladding's integrity. The gamma spectrometry analysis was done by the Iraqi health physics group.

For monitoring individuals, each worker was provided with a:

- thermoluminescent dosimeter (TLD), distributed at the beginning (October, January) and read at the end (December, February) of each of the two campaigns);
- an electronic personal dosimeter (EPD) read at the end of each working day.

Additionally, a computer program to record dose data, specially prepared for this purpose, was used in the field daily.

The removal operation was performed in two campaigns: from 6 October to 12 December 1993 and from 6 January to 12 February 1994. During each period there were activities at both sites.

In total, 170 persons were involved. The collective dose amounted to 0.11 man-Sv with an average individual dose equal to 0.66 mSv. The maximum individual dose was 8.5 mSv, which is about 17% of the annual dose limit.

Co-operative effort

The removal by air of irradiated fuel from Iraq —an unprecedented operation — was performed on schedule and without any significant problems. The individual radiation exposures were kept reasonably low, far below the level which could have been expected for such a difficult operation. This testifies to the co-operative preparatory work and high level of expertise involved in the operation.

The removed spent fuel was flown from Iraq in an Antonov-124 directly to Yekaterinburg in Russia. From there, it was transported to a reprocessing facility at Chelyabinsk. After dilution to lower enrichment at Chelyabinsk, the residual nuclear material will be available for sale under IAEA supervision for use in peaceful nuclear activities. ❐