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REMOTE TECHNOLOGY IN RBMK-1000 SPENT FUEL MANAGEMENT AT NPP SITE

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Abstract

The report describes the remote technologies employed in the nuclear power plant with RBMK-1000 type. Spent fuel transfer and handling operations at reactor (AR) and away from reactor (AFR) on reactor site (RS) facilities are illustrated by the example of the Leningradskaya NPP and are typical for all NPPs with RBMK-1000. The current approach to spent fuel management at NPP sites is also presented.

1. INTRODUCTION

There are 11 commercial power reactors of RBMK-1000 type now operating in the Russian Federation: 4 power units at the Leningradskaya NPP, 3 units at the Smolenskaya NPP and 4 units at the Kurskaya NPP (commissioning of the 5th unit is also planned). Spent fuel (SF) arisings amount to 550 tU/yr. and the total of 7,700 tU are currently stored at the on-site facilities of the power plants.

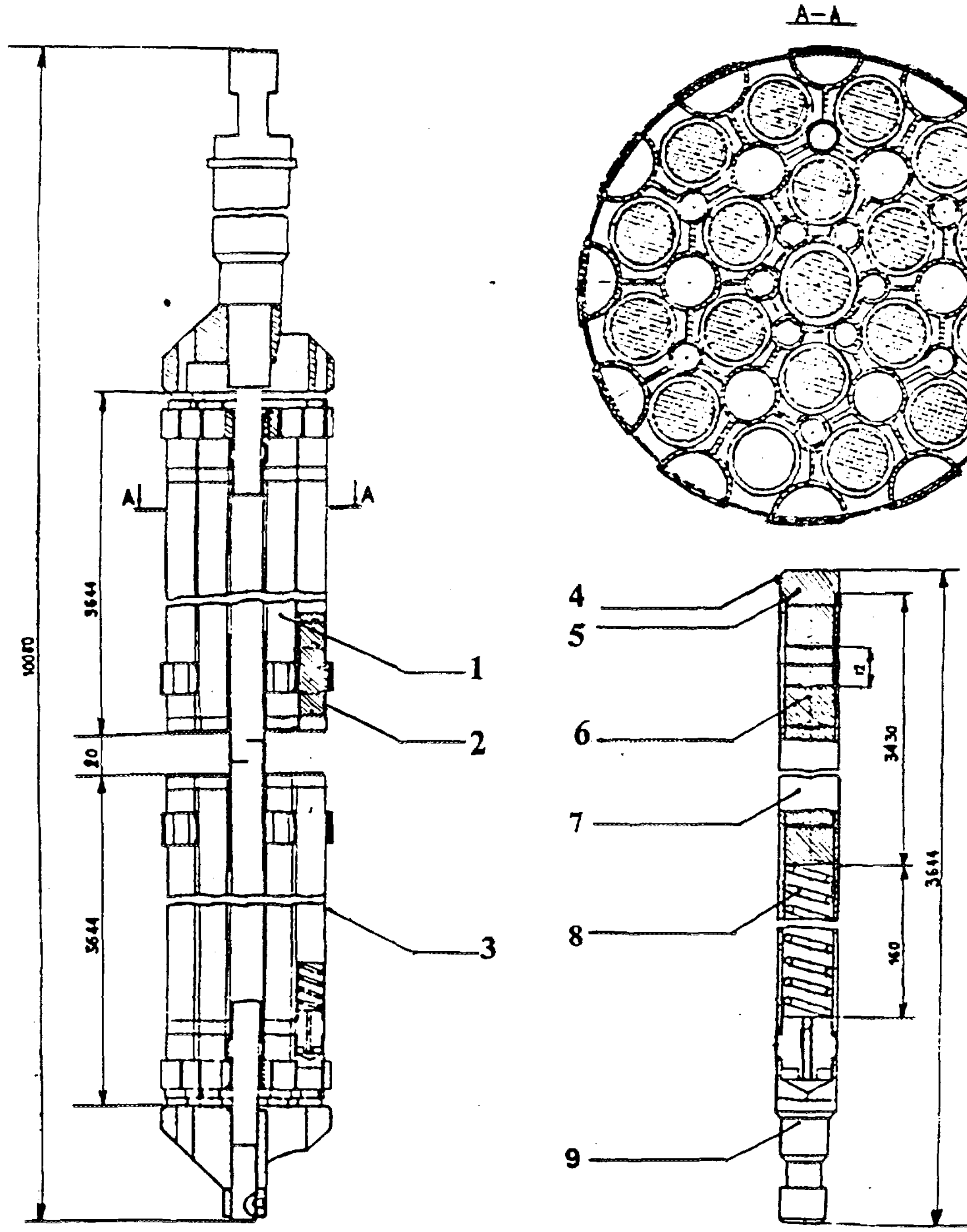
Nuclear fuel of RBMK-1000 type is fabricated from UO_2 in the form of pellets in a leak-tight Zr+1%Nb cladding. The RBMK-1000 fuel assembly consists of 2 bundles of fuel rods (18 rods per bundle) spaced by grids and enclosed into a leak-tight Zr+1%Nb hull. The active zone of the assembly is about 3.5 m (Fig. 1).

The features of RBMK-1000 fuel assemblies (FAs) and fuel rods bundles are listed in Table I. The main characteristics of RBMK-1000 reactors are listed in Table II. The choice of equipment and conditions for SF management largely depend on the characteristics of spent fuel discharged (fuel activity, residual heat release, defectiveness). The fuel discharged from reactors is transferred to AR pools for cooling and reducing the radioactivity level.

The current practice of fuel integrity monitoring (FIM) at the NPP with RBMK-1000 reactors involves a three-step procedure. This approach provides operative monitoring of the core conditions and rejection of failed fuel. The 1st step involves the monitoring of fuel rods behavior in the core of the operating reactors. FIM is performed with the use of regular equipment for a fuel rods batch or a reactor channel control. The 2nd step is aimed at the detection, if necessary, of leaking FAs and is performed at the reactor shut down and cooled. The 3rd step involves the monitoring of the fuel condition in water-filled storage pools (monitoring of water radiochemistry in pool water and cans with FAs). Leaking and damaged FAs discharged from the reactor are stored at the cooling pools in sealed cans.

2. SPENT FUEL TRANSFER AND HANDLING OPERATIONS

Spent fuel transfer and handling operations at AR and AFR-RS facilities are illustrated by the example of the Leningradskaya NPP and are typical for all NPPs with RBMK-1000 reactors.



1. fuel assembly
2. upper bundle of fuel rods
3. lower bundle of fuel rods

4. fuel rod
5. drown
6. Fuel pellet
7. cladding
8. spring
9. end fitting

FIG. 1. RBMK-1000 fuel assembly

TABLE I. FEATURE OF FAs AND FUEL ROD BUNDLES DESIGN

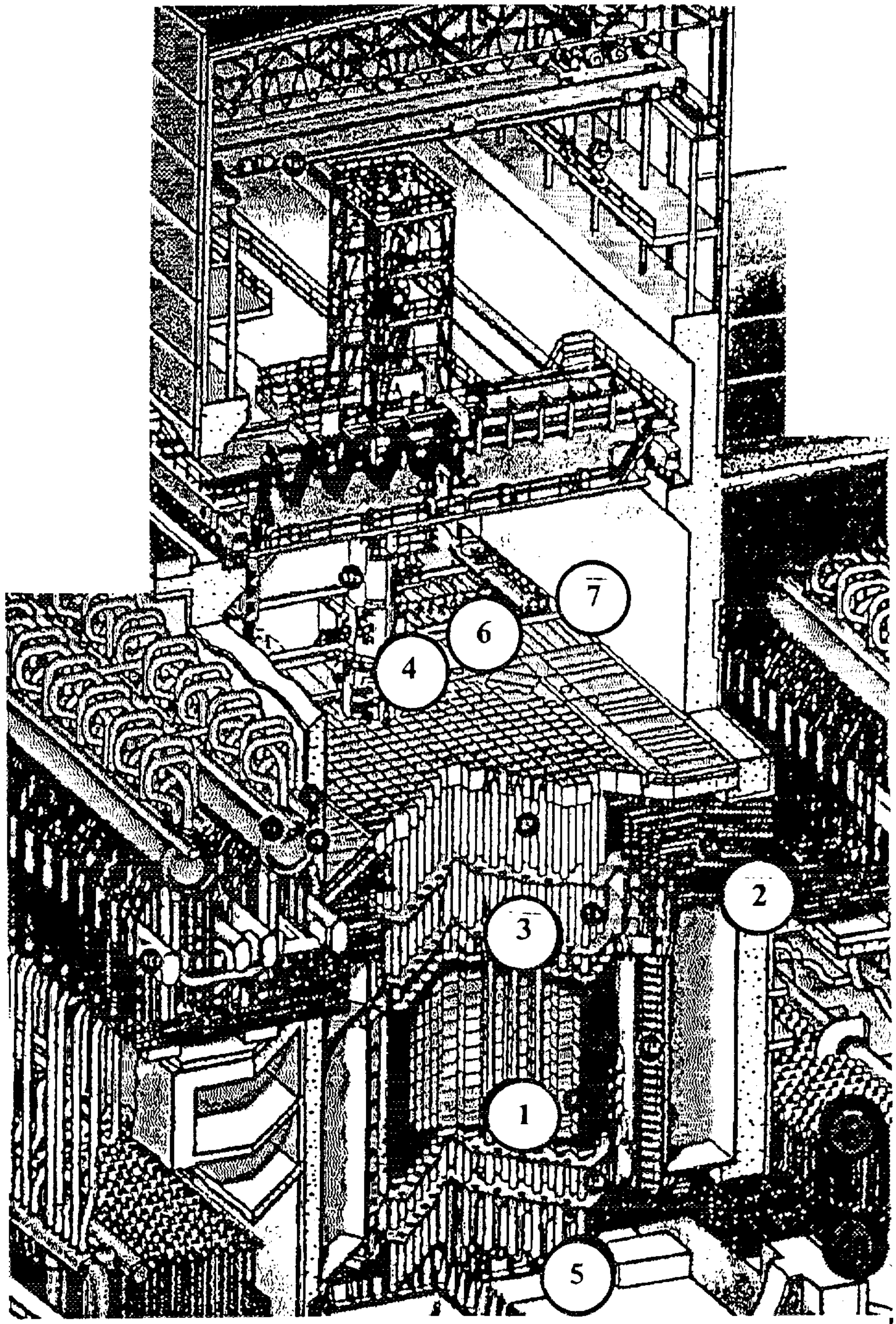
Parameter	Unit	Value
Length of FA	mm	<10,037
Diameter	mm	<79.2
Mass of FA	kg	190.0
Mass of U	kg	114.7 ± 1.6
Number of fuel rods in fuel rod bundle: - at diameter 32 mm - at diameter 62 mm		18 6 12
Outer diameter of fuel cladding	mm	13.6
Minimum thickness of fuel cladding	mm	0.825
Diameter of fuel pellet	mm	11.5
Fuel mass in fuel rod	kg	3.6
Length of heat releasing part of fuel rod	mm	3,432
Fuel composition		UO_2
Cladding material		Zr alloy with 1% Nb (alloy 110)

TABLE II. MAIN CHARACTERISTICS OF RBMK-1000 REACTOR

Characteristics	Unit	Value
Capacity, (heat)	MW	3,200
Initial charge,	tU	180
Initial enrichment, U^{235}	%	2.4
Average burnup	MWd/kg	15.5 - 22.3
Yearly discharge	tU	50
Number of FAs in core		1,604
Activity after 3-yr cooling	mCi/tU	0.5
Heat release after 3-yr cooling	kW/tU	2.5

2.1. AR pool

Spent fuel is discharged from the reactor with the refueling machine (RM), either with the reactor on power (main refueling) or with the reactor shut down (Fig. 2).



1. reactor core
2. steam lines
3. upper biological shield
4. reloading machine
5. lower biological shield
6. water pool
7. transfer cart

FIG. 2. RBMK-1000 reactor

2.1.1. On-power refueling

The 50/10 t crane of the central hall removes the closure plug from a refueled channel. A special program verifies the functioning of RM gears and systems on a training stand. The RM is installed over the channel simulator of the stand and is loaded with a fresh FA with its suspension. Then RM moves toward the reactor, interfaces the refueled channel, retracts a spent fuel assembly, gauges the channel route and loads the channel with the fresh FA. On completing the operation the RM with the spent FA moves toward the fuel canning area of the AR pool, interfaces the head of an empty can (previously installed there with a floor 1 t crane) and loads this with the spent FA with the suspension. The can is capped and the floor crane transfers it along a slit in the floor of the storage area to its storage position in one of the storage pools. The operation is carried out under a shielding water layer. The transportation slits are provided with hinged hatch covers to prevent steam and gases escape from the water surface in the central hall. The operation of the RM is remotely controlled from a special control panel. In emergencies the RM can be manually operated. It is equipped with a shield and special cabin for 2 operators with a system of manual drives.

2.1.2. Refueling with reactor shut down

These refueling operations are similar to the on-load refueling, but at the lower working parameters. The loading of "fresh" FAs into the reactor is performed with the 50/10 t bridge crane of the central hall. Specified conditions for wet spent fuel storage are sustained by support systems for pool water cooling and purification, technological and special control. Spent fuel is transferred from the power unit by an on-site TK-8 container, accommodating a 9-element transfer canister. Defective fuel is not transported from the AR pools. The equipment for fuel handling and transfer is housed in the main hall, railway wagon depot, fuel overloading pit, room of control panel, rooms of support systems (Fig. 3).

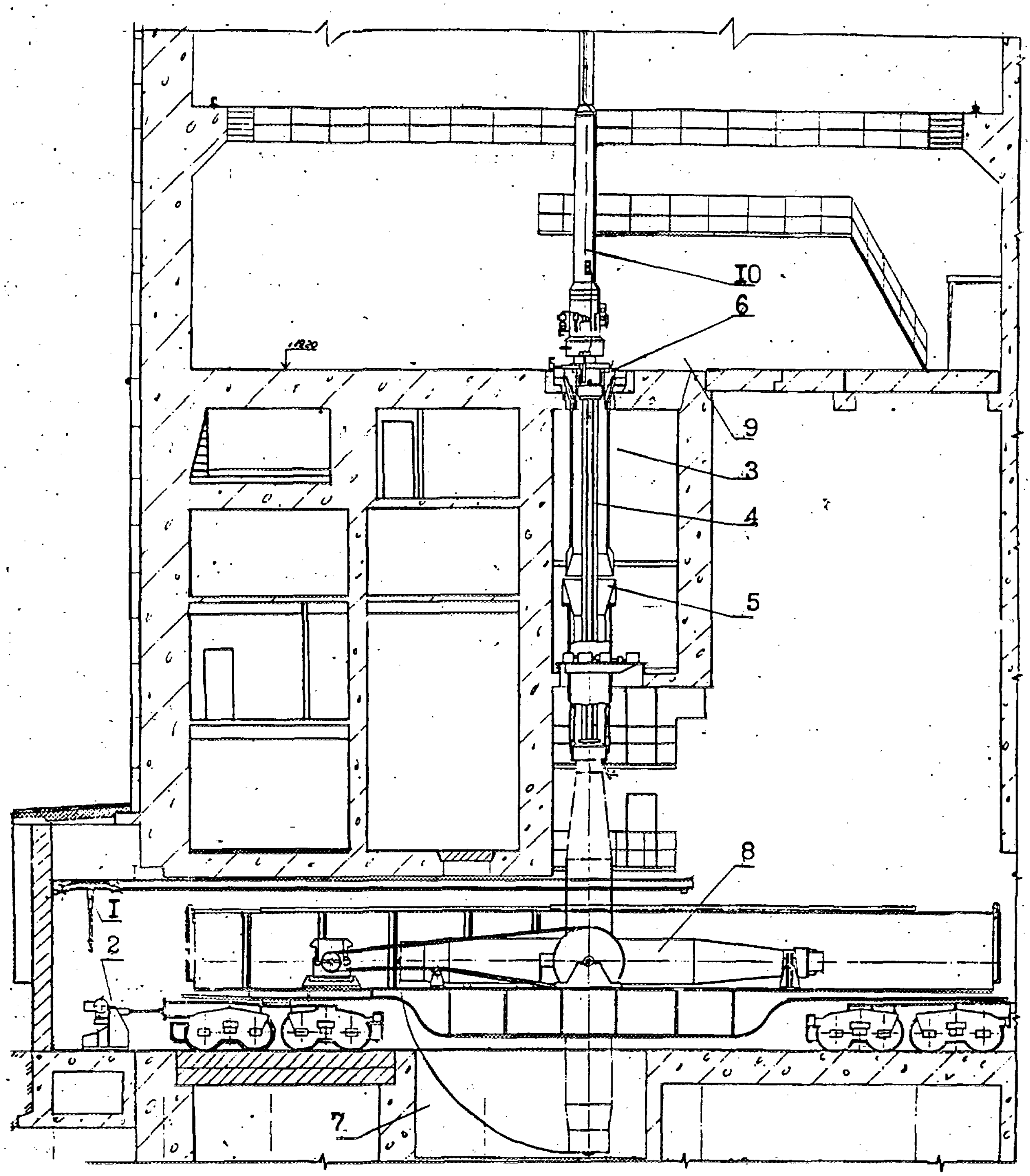
2.2. AFR-RS storage facility

This type of facilities has been designed for the interim storage of RBMK spent fuel. The construction and equipment assemblage were scheduled in 2 phases. The 1st phase involved the construction of rooms for SF reception, unloading and storage (Fig. 4). At present the 1st phase of the storage facility has been put to operation at all NPPs with RBMK-1000 reactors. The 2nd phase should include the construction of a series of hot cells for cutting FAs in two fuel rod bundles, loading and storing them in the transfer canisters with subsequent shipping to a reprocessing plant. The facility includes:

- a SF reception and dispatch area consisting of a transport entrance, main hall (for fuel overloading), support systems rooms (operators', cable-trolley rooms).The main hall has concrete wall and a metallic floor, thus providing personnel safety during remotely handled operations;

- a storage area comprising 5 identical water-filled pools situated in a pool hall. The pools are interconnected by a canyon. Four pools are operating and the 5th is stand-by and can be used in the event of repair in one of the operating pools. When drained the pools are cut off from the canyon by gates. The SF assemblies with their suspensions are stored in cans (one item/can) protecting FAs from unintentional damage and pool water from contamination.

The total design capacity of the storage area is 17,520 FAs. The FAs are moved toward their storage positions and seated on the beams of the metal floor. The operation is performed with a 1-t crane which has a limited lifting height and provides water shielding above the active part of the fuel. The AR pools utilize water cooling and purification systems. The water cooling plant is activated when the water temperature has reached 50^0 C.



1. 5 t crane
2. levelling mechanism
3. guiding pit
4. transfer canister for 9 FAs
5. guiding sleeve
6. loading device
7. areaway
8. TK-8 container
9. central hall
10. protecting transfer (unloading) device

FIG. 3. Placing loaded transfer canister with FA in TK-8 cask

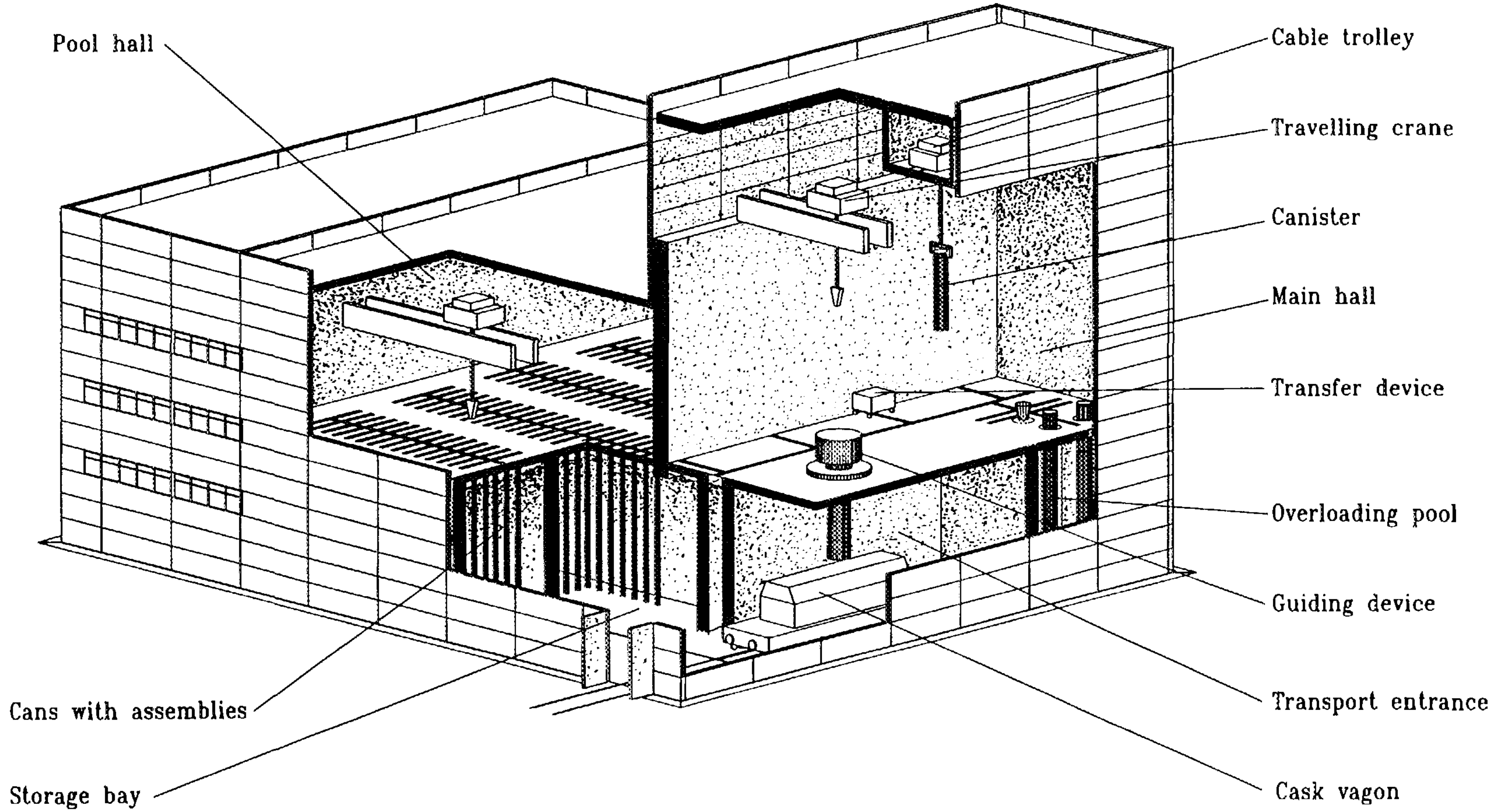


FIG. 4. Interim storage building for RBMK spent fuel

2.2.1. Reception and unloading of transfer canister from TK-8 cask

The TK-8 cask arrives from the reactor unit and is transported by a rail motor car or diesel engine to the transport entrance, where it is fixed and leveled lengthwise (Fig. 5). The wagon roof doors open and wagon mechanisms connect to power. The cask raises to an upright position and gets free of the hood. The movable shield of the guiding sleeve slides on the cask neck. The transfer canister with 9 FAs is retracted from the cask via the guiding device and landed into the water-filled pit of the overloading pool. The operations are performed by a special 15-t cable and 5-t grapple and are controlled via the remote control panel. Then the trolley returns to its starting position. The empty transfer canister is removed from the pit and loaded into the cask by a 20/5 t bridge crane. The movable shield of the guiding device goes to its upper position. The hood is placed atop the cask and fastened to it. The cask neck is decontaminated, if necessary. Then the cask is turned to a horizontal position, the wagon roof doors close and the cask is disconnected from the leveling mechanism and power. The cask returns to the reactor unit for the next loading.

2.2.2. Transfer canister - to - can overloading

The plugs are removed from the canister nests and replaced by adapters of a corresponding type (the adapters being seated on the FA heads). The grapple is hooked to the cable trolley and latched onto the FA head with a mooring rope. The trolley retracts the FA from the canister and places it into the can. The operation is remotely handled. The adapter on the FA is unlatched and replaced by a yoke. The 20/5 t crane transfers the can with the FA to its storage position (Fig. 6). The operation is performed under water shielding. On completing the unloading of the 9th FA the crane retracts the canister from the pit and places it on the brackets of the metal floor of the room for storing transfer canisters.

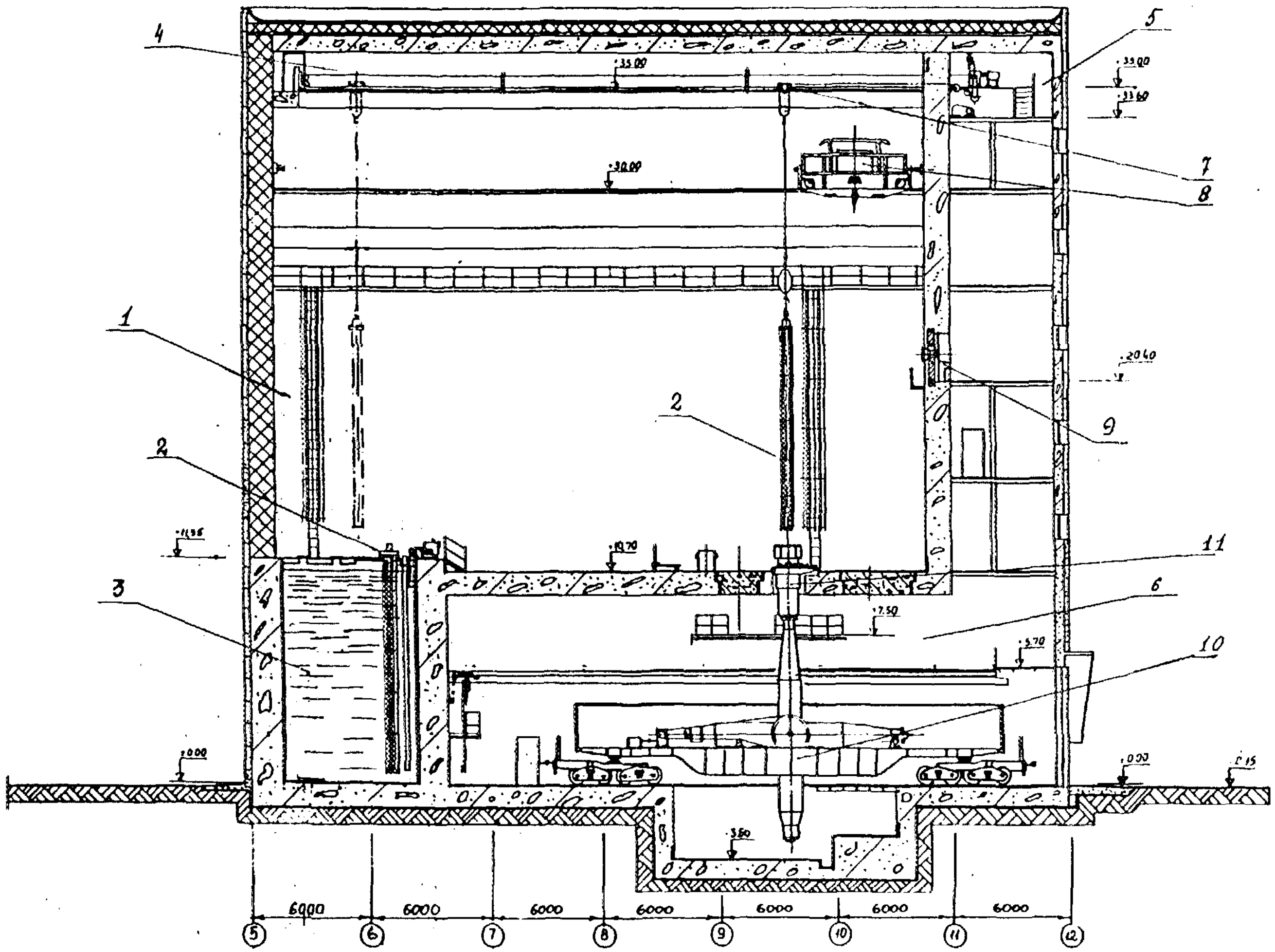
2.2.3. Transferring loaded cans to storage pools

The 20/5 t crane of the main hall transfers the loaded can from the slitted floor of the canyon and places it into the adapter of the corresponding storage pool. The 1 t crane of the pool hall removes the can from the adapter and transfers it along the slit in the metal floor to its storage position (the operation is performed under a shielding water layer). Then the yoke is removed from the can and returned to the can loading area in the main hall. The opened area of the slitted floor is covered again to prevent steam and gas escape from the water surface to the pool hall. The 1 t crane and other overloading operations are controlled by an operator staying in the pool hall.

3. CURRENT APPROACH TO SF MANAGEMENT AT NPP SITES

The approach considers changing over to the dry storage mode after the long-term (10 years) storage in water pools. It was projected to start the construction of a regional facility for storing spent fuel from all RBMK-1000 reactors. The construction was delayed for indefinite periods. Of dry alternatives most suitable is an on-site cask storage facility projected for 10 to 30 yr. service life. Such facility is most efficient from the viewpoint of safe storage conditions and fuel retrievability and complies with the current national rules for SF management. Dual purpose metal-concrete casks are being developed for this purpose (Fig. 7 and Table III). The cost of the cask storage facility comprises the costs of cask, cask loading operation and facility operation, including the costs of hoisting and transfer equipment and a building for casks accommodation. The casks loading costs are currently estimated at 30 to 50 % of the casks costs. Hence, the development of an efficient mode for cask loading is most important.

The RBMK-1000 FAs are distinguished for their size (> 10 m). Before loading into the cask the assembly must be separated into 2 fuel rod bundles and the suspension. The bundles are placed in casks for storage while the suspension goes for decontamination and remelting as radwaste.



1. main hall
2. transfer canister capacity 9 FAs
3. storage of transfer canisters
4. room for crane trolley
5. machine room
6. railway wagon depot
7. crane trolley
8. main hall crane
9. control board N1 for main hall crane
10. cask wagon
11. movable shield

FIG. 5. Technical area of AFR -RS: transport and technical equipment

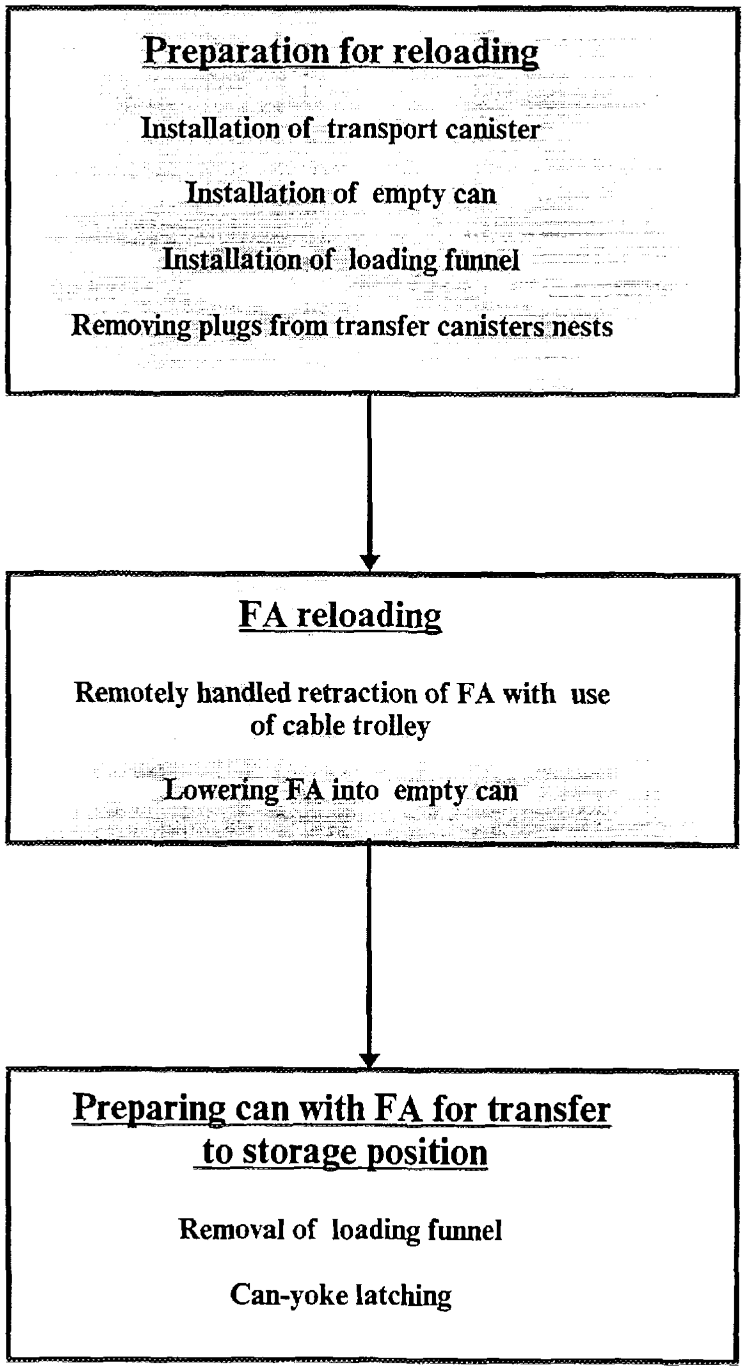
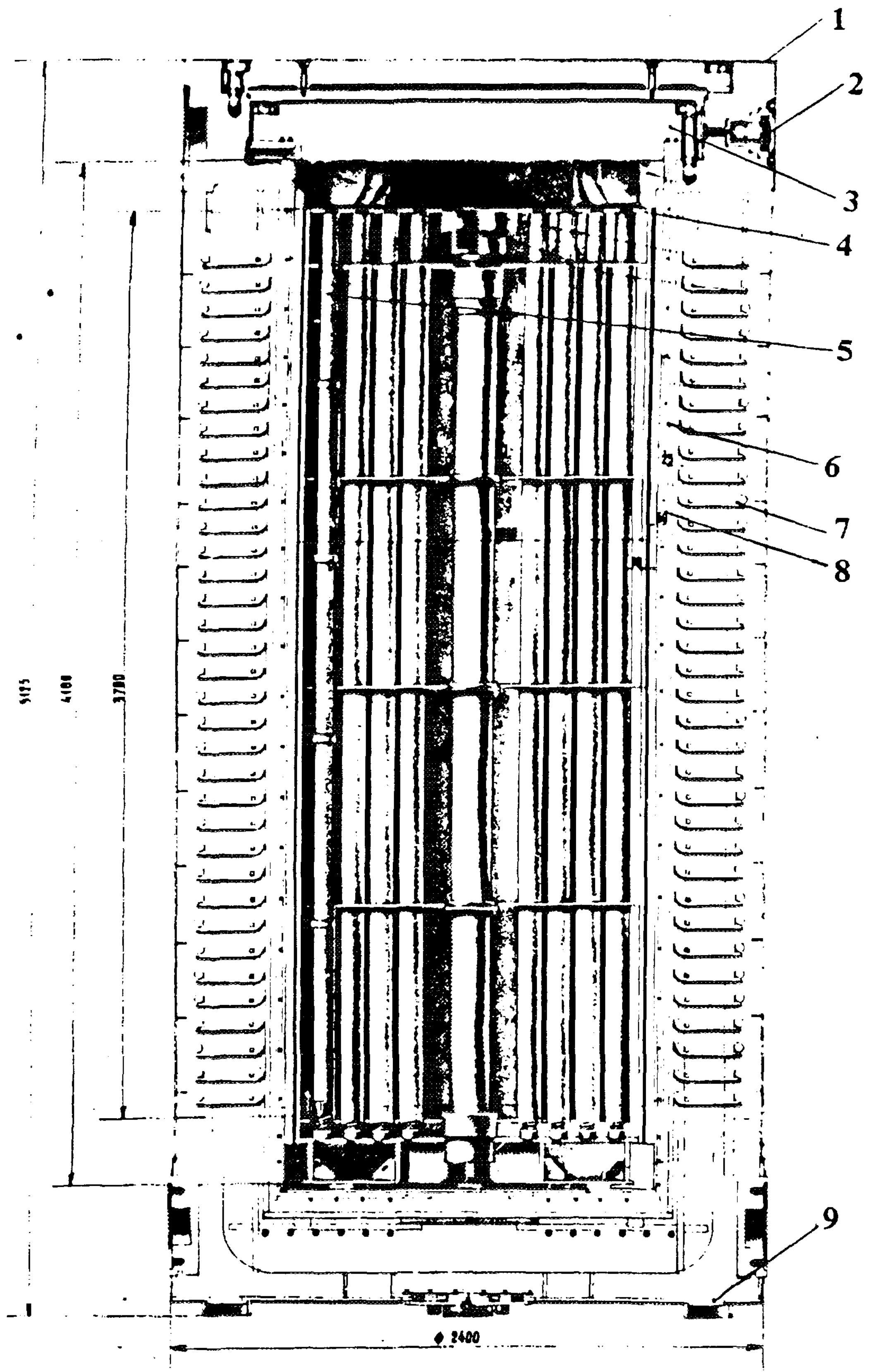


FIG. 6. Flowchart of transport handling operations in FA remote reloading from a transport canister to can



1. sealing plate
2. valve for controlling inter-lid space leak-tightness
3. shielding cover
4. basket
5. fuel bundles
6. reinforcing casing of the inner shell
7. reinforcing casing for strengthening shell
8. modified reinforced concrete
9. perforation for concrete

FIG. 7. Metal concrete cask (MCC) for fuel rod bundle storage

TABLE III. TECHNICAL CHARACTERISTICS OF MCC

Characteristic	Unit	Value
Number of fuel bundles		114
Mass of MCC with the basket and FA	t	95
Basket mass	t	4.8
Empty MCC mass	t	70
including:		
• reinforced B-100	t	4.5
• shielding concrete B-90	t	30
• reinforcement	t	7.7
• steel 092C	t	7.4
• SS 12X18H10T	t	5.0
• steel forging 12X18H10T/09H2MFA-A	t	0.7/14.5
• fastenings	t	0.5

From safety considerations each fuel bundle should be enclosed into an ampoule made of corrosion-resistant steel. The ampoule serves as an additional protective barrier against fuel damage in the case of fuel drop during the cask loading with fuel. Moreover, the ampoule is expected to provide safe unloading of fuel from the cask after 50 year storage. All fuel cutting and loading operations will be carried out in a hot cell and remotely controlled. According to the project being currently developed such cells will adjoin the AFR-RS facility on the plant site. The technology of FA separation in the cells will be as follows:

- Cans with fuel are transferred from the storage pools to a special overloading pool and placed on a transfer cart. The cart has the load capacity of 8 FAs, which corresponds to the cell capacity per working shift.
- The cart transfers the loaded cans via the transport canyon to the cell. Here a cantilever crane places the FAs into a drying stand.
- After drying, each FA is placed in the ampoule by the crane, the lower fuel bundle is cut off by a milling cutter and the upper bundle is transferred to the second ampoule. Here, the suspension is cut off and removed for utilization. The ampoules are covered with lids. This technology has a minimum of hoisting and transfer operations and provides maximum efficiency of the hot cell.
- The ampoules with fuel are placed into a transfer canister (item by item), which is loaded through a sluice into a cask.
- The cell's design involves the use of unified equipment applicable with any type of casks now in use for transportation and storage of the RBMK-1000 fuel (metal-concrete container, TK-11, Constor).
- Upon loading the cask with fuel and setting the protective lid the cask is inspected for leakage; moisture content in the gas medium is measured and the cask cavity dried with hot air, its outer surface decontaminated, if required.

The designed capacity of the cell equipment is 3,500 FAs/yr. With such capacity a period of 9–10 years is required to prepare for dry storage all the fuel now stored in the wet AFR of the Leningradskaya NPP, thus providing the conditions for normal plant operation during the whole service life.