RECONSTRUCTION OF STEAM SEPARATORS AND TESTING
OF THE LONG-TIME COOLDOWN SYSTEM AT THE
LENGRAD NUCLEAR POWER PLANT

V. I. Lebedev, N. I. Arbuzov,
L. A. Belyanin, V. V. Pikos,
S. P. Ivanov, and A. V. Churkin

The intravessel separator drums, which have an inner diameter of 2.3 m and were installed in all nuclear power
plants with the first-generation RBMK-1000 reactors and at the third and fourth power-generating units of the Leningrad
nuclear power plant, do not permit storing enough water so as to eliminate the danger of cutoff of the main circulation pumps
(MCPs) when the emergency shielding is actuated at nominal power. The design intravessel devices do not give sufficiently
uniform steam distribution over the width of the inserted perforated sheet and reliable operation of the. hydroseals when water
is drained from the sheet. A break through the hydroseal and a local increase of the steam velocity over the width-of the
inserted perforated sheet degrade the characteristics of the separator drums.

One way to improve the reliability and safety of nuclear power plants with RBMK-1000 reactors is to update the
intravessel drum separator units with an inner diameter of 2.3 m. This will make it possible to increase the store of water and
will allow for long-time emergency cooldown of the steam generating channels through the steam—water pipelines in the case
if the pipeline in the head part of the loop ruptures. This can be done by using, instead of the design construction of the
intravessel units, systems with a collector-type distribution of the steam-water mixture inside the separator drums, as shown
in Fig. 1. These devices include transversely arranged perforated collectors with input pipes, each of which is connected with
the corresponding connection to the steam—water pipeline. The perforated collectors, placed under the inserted perforated
sheet, have 10 mm in diameter openings, placed in two rows at angles of 25 and 45° with respect to the horizontal direction
on both sides of its vertical axis. A nozzle insert is installed at the base of the input pipe, and a special drainage opening is
made, through which the steam-generating channels will be cooled by a back flow of water from the separator drums in the
case of an accident with rupture of the pipeline in the head part of the multiple forced-circulation loop (MFCL). During
normal operation, on account of the rarefaction produced by the nozzle, water from the water volume of the separator is
constantly fed through the above-mentioned opening and therefore it is impossible for steam to enter the channel directly from
the steam—water pipelines. The diameter of the opening is chosen according to the water flow rate required for emergency
cooling of the channel. Components of the design construction, such as the inserted perforated sheet and the perforated cover
shield, are left in the reconstructed intravessel units. The steam—water mixture is fed into the input pipes and then into the
perforated collectors, after which preliminary distribution of steam and water occurs under the perforated sheet. The steam,
together with the remaining water, flows through the opening through the perforated sheet into the steam volume, where it
dries.

To assess the outlook for the new intravessel units, it was necessary to perform experiments to determine their
hydrological and separation characteristics. Such comparative investigations were performed on two models with a wide range
of pressure, steam flow rate, steam content at the entrance, and the water level above the inserted perforated sheet.

The experimental results showed the following [1]:

Leningrad Nuclear Power Plant, O. Yu. Novosel'skii, V. B. Karasev, P. V. Kobzev, A. V. Shishov, and V. N.
November 29, 1996.
the drainage openings in the nozzle inserts with nominal operating parameters and admissible deviations allow for stable circulation from the water space into the input pipe of the perforated collector and do not allow steam to enter the water space of the separator drum;

in the models, the volume steam content in the water space was found to be zero in the entire range of the investigated parameters;

the absence of a steam phase in the water space for the updated intravessel units also agrees with the indications of a level meter, which measured the overall water level in the models; the indications remain unchanged when the steam load (thermal power of the power-generating unit) in the models increases;

for a 150 mm mass level of water above the inserted perforated sheet, the moisture content of the separated steam is less than 0.1%; the working store of water is about 67 m$^3$, which is 2.4 times greater than the working store of water in the separator drum with the design intravessel units;

the highest hydraulic resistance of the intravessel units does not exceed 13.6 kPa with the nonuniformity of the coolant flow rate distribution along the separator drum reaching a maximum value of 1.6; and,

operation is possible with a mass water level above the inserted perforated sheet of 280 mm and a moisture content of 0.1% in the separated steam; this makes it possible to recommend an operational level of 200 ± 50 mm, i.e., 100 mm higher than the accepted value; this will give an additional store of water of 28 m$^3$ for each power-generating unit.

In summary, on the basis of an analysis of the experimental data it can be concluded that reconstructing a 2.3 m in diameter separator drum by installing in the drum updated intravessel units will make it possible to increase the operational safety of the first nuclear power plants with RBMK-1000 reactors.

The intravessel units of the separator drums of the second and first power-generating units at the Leningrad nuclear power plant were updated during major overhauls in 1991-1994 and 1994-1996, respectively. The construction of new intravessel units is convenient for individual feeding of cooling water into each fuel channel. This made it possible to expand, without any additional assembly work, the functions of the emergency cooling system and at the same time ensure cooling during overhaul by a water flowing through the steam-water pipelines from top to bottom and to connect the long-time cooldown system from the separator drums (Fig. 2). The latter system is used for cooling the fuel channels of a reactor by feeding water into each channel through pipelines from a distributing collector located inside a separator drum and can function in two modes. In the mode when the emergency reactor cooling system is operating, the fuel channels are cooled during accidents caused by a rupture of the pipelines in the head part of the MFCL with a flow rate of 500 tons/h for half of the reactor [2]. During operation in the overhaul cooling regime, the best conditions for working on most of the equipment and pipelines of the MFCL without any time limitations are in place. There is no need to perform a substantial volume of preparatory work associated with the assembly of pipelines above the slab floor of the reactor in the central gallery.

In the process of designing this system, it was assumed that in the normal operating regime with the reactor operating at power the pipelines of the long-term cooldown system are not used for circulating coolant. When there is no circulation through the pipes for a long period of time, corrosion products can accumulate in them and after the system is switched on the corrosion products could end up in the MFCL. Furthermore, hydrogen and other noncondensing gases can also accumulate. To eliminate this deficiency, it was suggested that coolant be circulated through the pipelines of the long-time cooldown system in the nominal operating regime, using the pipes for returning the purge water from the purge system and for cooldown. This solution was implemented in the second power generating unit (Fig. 3). The standard scheme for returning the purge water through the mixers to the feed water pipes was retained. The unit was heated and cooled in the same manner as before, and after the nominal parameters were reached the system was switched from the design scheme to the new scheme. In carrying out the second stage of the reconstruction of the first power-generating unit, taking account of the positive experience in operating the second power generating unit for almost two years, it was decided that the purge water should be returned only through the long-time cooldown system in all operating regimes. The design scheme for returning the purge water, together with the mixers, were eliminated. However, this can be done only if a pipe connection is present between the emergency feed pipes and the cooldown pipes in order to cool the down pipes in the natural circulation regime.

The external part of the long-time cooldown system outside the separator drum rooms includes a 325×16 mm water feed pipe from the purge and cooldown system to the distributing units and distributing units with fittings in each half of the MFCL. From these units, water is fed into each room along two pipes into collectors located below the separator drums. This scheme has been implemented in the second power generating unit (see Fig. 3). There are some differences in the scheme used in the first power-generating unit. The water from the distributing units flows along one pipe into the separator drum rooms where after a T-branch it is separated into two collectors located below the separator drums.