A TEST-RIG STUDY OF THE STARTUP MODES
OF THE I. V. KURCHATOV NUCLEAR POWER
STATION, BELOYARSK

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The results are given of an experimental investigation carried out on a test-rig of the hydrodynamic
stability of the coolant flow in the channels of the first and second reactors of the Beloyarsk Nuclear
Power Station. The choice of methods of startup of the Nuclear Power Station units, which are ac-
ceptable to the experimental final adjustments, is justified. The results are given of a study of the
startup modes.

Channel type reactors are used in the I. V. Kurchatov Nuclear Power Station, Beloyarsk. Water boiling is ac-
complished in one group of channels and steam superheat in the other group of channels [1]. In the initial state of
the reactor the superheat channels and the steam ducts are filled with water. During startup, it is necessary to free
these channels from water and to convert to steam cooling of the superheat channels. As a result of this, preliminary
heating and startup of the NPS units must be undertaken without an extraneous source of heat.

In the startup period, just as in the nominal mode of operation of the station, it is necessary to provide reliable
cooling of the fuel elements (absence of a heat transfer crisis, assurance of hydrodynamic stability). Papers [2 and 3]
were devoted to a study of the noncrisis cycles of cooling of the fuel elements by a steam-water mixture. The pres-
ent paper describes the results of an investigation into the hydrodynamic flow rate stability of coolant in the channels
in the boiling cycle; the problem is discussed of the transition of the superheat channels from the water cooling cycle
to the steam cycle, with subsequent attainment of nominal parameters.

In order to carry out the investigation, experimental thermo-technological test-rigs were constructed, whose
basic circuits corresponded to the technological circuits of the first and second units of the NPS [4]. The test-rig for
the first unit consisted of two independent circuits, a closed loop and an open loop. Three evaporative channels are
included in the first loop and one superheat channel is included in the second loop. The test-rig for the second unit
is a closed single-loop circuit with an internal circulatory sub-loop. Two evaporative and two superheat channels
were included in the loop. Chemically demineralized water was used as the coolant.

The experimental evaporative and superheat channels were made to natural size [1, 4]. In the evaporative
channels, the coolant through the central tube was directed into the lower cap and then lifted upwards through six
peripheral tubes, passed through the heating zone and entered the upper cap. The design of the superheat channels
of the first unit of the NPS is similar to the evaporative channels. In the superheat channels of the second unit there
is no central tube. The coolant moves downwards through three tubes and upwards through three tubes. The coil
compensators for linear expansion in the evaporative and superheat channels of the first NPS reactor are located be-
low the active zone and in the superheat channels of the second reactor they are above the active zone in the de-
scending tubes.

The experimental channels, in contrast from the operating channels, have no fuel elements. The coolant in
the experimental channels was heated by a low-voltage electric current over a length corresponding to the active
zone of the reactor. All the tubes of the channels in the heated zone were connected in parallel with one another,
by common current-feed contacts. The central tube of the evaporative channels was electrically insulated from the
peripheral tubes. For the purpose of certain approximation the nature of the heat release throughout the height of the experimental channels towards the heat release in the operating channels of the heated zone was divided into six sections of different length. By choosing the lengths of the sections, a stepwise character was achieved for the heat release which approximates to cosinusoidal.

The experimental channels have several conduits for connecting the thermo-technological control instruments. In the evaporative channels the throttling discs, which serve simultaneously also for measuring the feeds through the channel tubes, are installed beyond the coil compensators.

As mentioned above, the experimental evaporative channels were represented by a system of a bundle of parallel steam-generating tubes, coupled between two collectors (the upper and lower caps). It is known from test operation of steam boilers that pulsations and vortexing of the feeds can occur in a bundle of parallel heated tubes. These occurrences are unacceptable, because feed pulsations are accompanied by frequent and repeated temperature fluctuations of the tube walls which may lead to their rupture, and vortexing of the feeds in the tubes of the bundle may lead to overburning of the latter. Therefore, the choice of operating cycles of the channels without pulsations are of great practical importance.

The stability of the coolant feed in the evaporative channels was studied over a wide range of pressures, feeds, and powers. The main consideration was given to determining such parameters as pressure, feed rate, steam content, and power, the combination of which created the conditions which cause the onset of the pulsations; consideration was also given to the temperature cycle of the steam-generating tubes during the feed pulsations. As a result of the investigation, it was established that with specified conditions in the peripheral tubes of the channels, feed pulsations can occur.

Feed pulsations of the coolant in the tubes of the evaporative channels in all cases when they occurred, originated as a result of reaching saturation temperatures at the channels exits. The pulsations represented periodic fluctuations of the coolant supplies in the peripheral tubes both to the side of increase and reduction. The feed fluctuations in individual tubes move in phase: when the supply in some of the tubes increased, it decreased in others. The total feed through the channels, however, remained constant.

By maintaining unchanged all the parameters at which the pulsations originated, the pulsation mode was delayed for an unlimited time. Further increase of the heat content of the water at the inlet to the evaporative channels (after start of the pulsations) led to an increase in amplitude of the pulsations and the attainment of a maximum value; the amplitude of the pulsations was then reduced. On reaching a specified steam content at the channel outlet, the pulsations ceased (Fig. 1a). The pulsation frequency in the low steam content region was three to six oscil-