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11. ABSTRACT (200 words or less)

There were 68 breakdowns in 1989 in nuclear power plant operation which are summarized in this report. 21% of the failures were due to poorly made equipment, 21% were due to defects in equipment, and 36% were due to personnel mistakes. There were 15 breakdowns in the protective equipment, one of which resulted in an emergency in the power unit. It is concluded that equipment failures mainly occurred due to poor quality of repairs, poor finishing of the parts, and defective construction.

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Analysis of Safety System Failures at AES (Nuclear Power Plants).
Lessons Learned.

V. M. Vitkov, M. A. Belozertsev, V. P. Solov'ev

ALL-UNION SCIENTIFIC RESEARCH INSTITUTE ON THE USE OF NUCLEAR
PLANTS

CENTER OF INFORMATION AND ANALYSIS OF THE USE OF NUCLEAR PLANTS

ANALYSIS OF THE BREAKDOWNS IN THE OPERATION OF AES WITH
VVER (Water moderated water-cooled) RELATED WITH SAFETY
SYSTEM EQUIPMENT FAILURES

1. BREAKDOWN STATISTICS FOR ALL AES

In 1989 68 breakdowns in AES operation were recorded for all AES (in 1988 there were 33 breakdowns) which were related with safety system (SB) equipment failures, including VVER-1000 - 5; breakdowns (75%), VVER-440 - 8 (~ 12%), RBMK (Graphite Moderated Channel Tube Reactor) 7 (10.3%) and other types of reactors - 2. Of all of these 5 breakdowns resulted in emergencies; 13 resulted in an unplanned shutdown and unloading of the AES' power unit with an overall production loss of 396.3 million kWh, including a production loss of 247.09 million kWh for AES with VVER. The total downtime of the power units due to SB failures was 237.4 h (see Tables 1, 2, 3, 4, 5). Four of the cases of SB equipment failure occurred during the development of breakdowns related with failures of other AES equipment.

In 10 cases SB failures resulted in a breakdown in safe operating conditions (NUBZ- breakdown in safe operating conditions), which is 15% of the total breakdowns due to SB (YUK (Yuzhno-Ukrainskaya - Southern Ukrainian - 1 NUBZ; BAL (Balakovskaya - Balakova) - 1 NUBZ; KhME (Khmel'nitskaya - KhMel'nits)-
1 NUBZ; KLN (Kalininskaya - Kalinin) - 1 NUBZ; ZAP (Zaporozhskaya-Zaporozh) - 1 NUBZ; NVO (N. Voronezhskaya - N. Voronezh) - 1

NUBZ; KUR (Kurskaya -Kursk) - 1 NUBZ; LEN (Leningradskaya - Leningrad) - 2 NUBZ).

There were 38 failures of the SB equipment found during systematic inspections and tests of the SB. Of these 30 failures occurred during the operation of the power units on power. These cases of SB failures did not lead to emergency states but are potentially dangerous from the standpoint of the AES safety and lead to repairing of the SB channels which reduces the degree of reserve for a given system. The remaining failures occurred in constantly operating SB equipment: emergency power supply system, continuous supply unit (ABP), commercial (OP) water supply system as well as that used for the pneumatic cut-off equipment, the high speed blocking cut-off channels (BZOK), the high speed reduction unit for venting vapors to the atmosphere (BRU-A) when operating on demand.

- 14 (21%) of the failures occurred because of poorly made SB (pneumatic cut-off equipment, BZOK) and when the SB is operating on demand (6 cases).

- 14 (21%) of the failures took place because of equipment defects in the constantly operating systems.

Breakdowns in the AES's operation because of SB failures are distributed as follows according to offending groups :

- fault of AES personnel - 24 breakdowns or 36% of the total number of breakdowns:

YuUK - 2; BAL - 1; KhME - 5; KLN - 0; ROV (Rovenskaya - Rovensk) - 1; ZAP - 5; NVO - 1; KOL (Kol'skaya - Kol'skii) - 4; KUR - 1; LEN - 1; IGN (Ignalinskaya - Ignalin) - 1; BIL (Bilibinskaya - Bilibinsk) - 2.

Of these 7 failures were due to faults of repair personnel.
- faults of the production plants - 18 breakdowns (~27%);
- faults of the design and construction organizations - 18
breakdowns.

The remaining breakdowns occurred because of assemblers and loaders.

The greatest number of breakdowns occurred in AES with VVER-1000 - 51 breakdowns. Of these 25 breakdowns occurred on newly installed power units (KhME - 1 - 12/31/87; BAL - 2,3 - 10/8/87 and 12/25/88; YuUK - 3 - 9.20/89; ZAP - 4,5 - 12/21/87 and 8/31/89. The significant number of breakdowns for new power units is mainly explained by:

lack of proper qualifications for the personnel at all responsibility levels such as operating, repairing, and supervisory;

insufficient time of operating the equipment;
errors in design.

The results of this, as shown by practice, is a long period for "mastering" the power unit. This period is 2-3 years. This fact is aggravated by the use of newly created equipment and media which have not been sufficiently developed by the construction units and mastered by the producers and users for AES with Ru pr. 320 (x-ray unit). For example ASU TP (automatic control system for technological processes), ABP, DG (diesel generator) ASD-5600 etc.

In addition to the foregoing information, data are given in the chapter on the number of SB triggerings which occur because of actual faulty signals, including alarm systems for the emergency

power supply for the 2nd group of responsibility (DG), Cases of triggering of BRU-A, BZOK are treated separately and the specific significance of SB triggerings which lead to the power unit are given (see Tables 6, 7).

2. BREAKDOWNS IN THE SAFETY SYSTEM'S OPERATION FOR AES WITH VVER REACTORS.

2.1. Equipment Failures for A Reason Which Is Independent of the Initial Event and Which Often Repeat Themselves.

The breakdowns with independent SB equipment failures are given in Table 8. In all 9 independent failures have been recorded 8 of which took place during the process of developing the breakdown. The independent failures make up 15% of all of the failures for the given period of time. Four of the independent failures took place in the emergency electrical supply system of which 2 were DG failures. Of the independent failures 55% were related with BZOK, BRU-A, IPK PG (steam generator) failures.

To a greater extent the potentially dangerous breakdowns for AES safety are the failures which take place for general reasons. All failures for general reasons occurred during testing (see Table 9). As an example of a characteristic failure due to general reasons we cite the events which occurred at NVO- 2, where on 10/26/89 the discharge of the storage battery (AB) occurred because of the spontaneous switching off of the

rectifying recharging unit due to the fact that the control switch relay (RKV) was out of order. This made it impossible to start up the system for the emergency addition of boron automatically. Therefore a breakdown occurred in the safe operating conditions - inability of the safety system to operate for 20 min. This event was classified as an emergency state; the fault was assigned to the supervisory personnel of RTTs-1 (units 1 and 2) who clearly did not define the official instructions of responsibility and the interaction with the BShchU-1 (control panel) personnel and also the lack of conscientiousness on the part of the ETs personnel in watching the central signal panel.

Of all of the SB breakdowns for general reasons in the power units of AES with VVER-1000, two groups of breakdowns can be isolated which occur because of failures of the same equipment (see Table 9).

In the first group we find breakdowns because of VE-6 type switch failures; the reason being the low mechanical reliability of the switch's drive elements in one case and the hypothetical electromagnetic interferences which arise in the switch control circuits when SB mechanisms start up in the other case. In all 10 failures or 17% of all recorded failures in AES with VVER.

In the second group we find breakdowns due to failures of the control valve (RK) of the I68051-500-02 type which is used in the commercial (OP) water supply systems and in other AES systems; the reasons being structural defects in the unit for the rod-control unit attachment (7 failures or 12% of all the recorded values for VVER).

Failures for these two reasons in 1988-89 occurred at the

Khmel'nitskoi, Balakovskoi, Zaporozhskoi AES and made up about 30% of all of the failures in AES with VVER in 1989.

2.2. Breakdowns in AES Operation Because of SB Failures Resulting in Shutdown and Unloading The AES's Power Units

In 1989 there were 10 breakdowns in AES operation which as they developed resulted in unplanned shutdowns and 2 breakdowns that resulted in the unloading of the power units as the result of SB equipment failures. The total production loss was 247.0 million kWh, the downtime was 197 h. All of the breakdowns are classified as failures (see Tables 1, 3).

The failures which lead to shutdowns and unloading are distributed in the following way with respect to the types of SB equipment:

- 5 stoppages due to failures in the element of the continuous supply unit (ABP) of the emergency power supply system of the 1st category: YuUK - 1 - 2/5/89; ROV - 3 - 4/989 and 11/23/89; KOL - 3 4/7/89; ZAP - 5 - 10/11/89; loss of power production 50.03 million kWh.

- 3 cases are due to the unsanctioned closing of the pneumatic cut-off unit of the emergency locating system (SLA) in the oil system GTsN (main circulation pump) which resulted in a triggering of the pump protection against elevated oil pressure in the GTsN system and also to a triggering of the unit protection shutdown at BAL-1 9/20/89 and 2 unloadings BAL-3 7/12/89, KAL-1 1/5/89); loss of power production 31.28 million kWh;

- 1 shutdown at KhME - 1 9/19/89 triggering ZA-1 from a false signal for a pressure increase under the hermetic casing (GO) of more than 0.3 kgf/cm because the hermetic valve of the (SLA)

remained in the closed position during the planned testing of two SB channels. The reason was a flaw in the algorithm for the supply control circuit and the rupture of the circuits in the primary monitors. The loss of power production was 18.54 million kWh.

- 1 shutdown BAL-1 - 1/4/89 because of a false triggering of the 2 channels for protecting SB channel 2 (hereafter 2SB) because of a defect in the cable insulation for supplying the monitors which showed up when water from the fire quenching apparatus (UAPT) fell on the 2SB. The UAPT was triggered because cable shaft 5 was closed and the false triggering of the fire warning devices of the DIP-1 type was due to poor reliability. The loss in power production was 18.35 million kWh.

- 2 shutdowns occurred as the result of BZOK failures (protective SB) - BAL-3 11/23/89 and KhME-1 8/9/89. The loss of power production - 128.9 million kWh.

In 5 cases the power unit shutdowns occurred because of the voltage fluctuations or current cut-offs in the SUZ (control and protection system) control circuits and supply circuits of the SAOZ (system for emergency cooling of the active zone) protective monitors because of unsteady operation and the switching off of the ABP elements. The loss of power production because of the power unit shutdown due to ABP failures is 50.03 million kWh or 20% of all of the production loss.

On 10/11/89 a shut down of the reactor unit took place at ZAP-5 triggering emergency precautions (AZ-1) because of the failure of channel 1 in the power supply system for group 1 security consumers which resulted in the false triggering of the

interruption precaution and placing BRU-A and SB in standby conditions. The initial event was the switching off of the RTS-125 ABP-1500 inverter (RTS - registratsiya tekushchikh sobytii (recorder of ongoing events)) due to a defect in the trigger circuit. The switching off occurred with the spattering of U_{output} 50% greater than U_{initial} and its going out of phase. This caused surges in the magnetizing current in the feeders to the consumers and the switching off of the automatic feeds (AP) to the monitor units that form the 3rd and 4th channels of interruption protection of the SB's 1st channel. A study of the breakdown showed that the forming circuit for the interruption protection of the SB's 2nd circuit did not conform to the requirements of the OPB-82 p.p. (po poryadky - serial number) 2.9.2, 2.6.4, and 2.6.9. False triggerings associated with power losses in the individual elements of the protective channels are not excluded in the design of the circuits for SB protection. The AP which supply the power supply units for the monitors without taking into account the conditions for switching off the PTS were not properly selected. The category of the breakdown was taken as a failure, shutdown of the AS (atomnaya stantsiya - power plant) by signals in the automatic control system circuits, technological precautions, and interlocking without a shutdown of the system's parameters and equipment.

The shutdown on 4/9/89 at ROV-3 by the action of AZ (avariinaya zashchita - emergency precaution) because of the disconnection of 2 channels of protection 2 PAK-2 because the AP circuit controlling the RTS during AVR (avtomaticheskii vvod rezerva - automatic loading of reserve) was switched off during

the disconnection of the section ST-1, which resulted in conditions of unsynchronized operation of the PTS during which time the thyristor in the TKEP underwent breakdown. The switching off of the automatic supply (AP) in the PTS control circuit occurred because of the improper selection of the automatic device and because the directions of the designer on ensuring the completeness of the testing during the time of PNR and in the stage of providing power were not properly used.

Another shutdown also took place at ROV-3 on 11/23/89 when the power unit was shut down by the action of AZ-1 because of an increase in pressure in PG-4 (parogenerator - steam generator) of more than 80 kgf/cm (with an open BRU-A). The reason the BRU-A was triggered was the closing of BZOK-4 because of the disconnection of 2 protection channels in the SAOZ SB 3. The disconnection of the 2 protection channels occurred during the planned inspection of the SB 3 channel while disconnecting sections of the VKh with the startup of DG-33 and the operation of the gradual start up of the SB mechanisms. Simultaneously there was an emergency switching off of the PTS for the ABP in channel 3 of the SB because of the false operation of RTS protection by the disappearance of condenser pulses.

In 4/7/89 a shutdown took place at KOL-3 because the ABP of SB channel 2 was switched off due to the false operation of current protection. Channel 2 of the SB was sent for repairs. After the AP was switched on for the output relays for protection of 2SB channel the false operation for protecting the SAOZ occurred because of the interruption of the GPK which resulted in the shutdown.

And the shutdown at YuUk-1 2/5/89 due to the action of AZ-1 as the result of the disconnection of the power supply control circuit of the SUZ (sistema upravleniya i zashchity - control and protection system) due to the unsteady operation of ABP in SB 3 channel. The fact that the SUZ power supply control circuit had been shut off by a worker was not found out because of the lack of signals in the design, the switched off position of the automatic supply (AP), and the disappearance of current on one of the inputs of the 2PP-18 direct current panel.

In two cases the pneumatic shut off unit was closed because of the formation of false signals in the control circuits which resulted in the unloading of the power units because of the switching off of GTsN 2. The reasons for the appearance of the false signals in the control circuits were:

7/12/89 BAL-3, internal damage of the BKL-UMz.N 6608;

1/5/89 KLN-1 damage to the control cable in the coil control circuits. The reason was poor installation.

In one case, BAL-1 9/20/89 the closing of the pneumatic cutoff unit in the oil system of the GTsN resulted in the unloading of the power unit to 50% because of the abrasion of the packing beneath of the piston of the reduction valve (Perst firm, FRG) which resulted in the leaking of the control air and a reduction in the pressure above the piston. The breakdown developed in a part of the shutdown of TG-1 because of the increase in the level in PG-3 as the result of the disruption in the operation of the algorithm for technological protection and interlocking.

Defects in the algorithm for technological protection and

interlocking.

Breakdowns in the operations of AES which are related with BZOK failures and which result in shutdowns of the power units occurred 8/9/89 at KhME-1 and 11.23/89 at BAL-3:

in the former breakdown the closing of the BZOK-2 took place spontaneously because of the presence of a progressive flaw on the flange of the vapor releasing unit for the piston space.

in the second - in the development of the breakdown because of a defect in the unit for the terminal closing switches (KVZ kontsevykh vyklyuchatelei zakrytiya - terminal closing switches) BZOK-3 did not receive the signal that the GTsN-3 was switched off which was the reason for the shutdown of the power unit due to the false triggering of the interruptive protection. The main reason for the maladjustment of the KVZ is the presence of vibrations of the steam ducts and BZOK in A-280. There is no information in the AES on the permissible level of vibration for the BZOK units. The technological interlocking of GTsN shutoffs ("one of one" scheme) is of low reliability.

2.3. Failures in the Safety System. Reasons.

2.3.1. Protective Safety Systems

There have been 15 equipment breakdowns in the protective SB (7 breakdowns in 1988), one of which resulted in an emergency state of the power unit with the breakdown of safe operating conditions. In 3 cases the failures of the protective SB systems resulted in unplanned shutdowns of the power units with a total production loss of 147.2 million kWh (see Tables 1, 2, 3, 4).

Of these breakdowns 9 are related with failures of the pumping equipment (systems for the emergency supply of boron,

emergency water level maintenance in the PG, emergency cooling). Of these 5 breakdowns occurred because the emergency pumping units of the protective SB were not switched on during testing of sections of reliable supply (NR) (nadexhnogo pitaniya - reliable supply) because of poor operation of VE-6 type switches. The reason is the low reliability and resource of the switch drive because of structural defects in the mechanical units and parts: shielding mechanism, drive wheel, connection spring (2 breakdowns) and also, predominantly, because of reductions in the control switch circuits because of electromagnetic interferences (3 breakdowns). See Table 7.

The producers developed measures designed to avoid failures in the mechanical parts. The measures propose a change in the technology of producing the drive parts of the switch, in the construction of the drive, and delivery to the AES, for the parts which fail most often.

Of the breakdowns 4 occurred because of failures in the low pressure pumping units in the system for the emergency supply of boron, and the emergency supply to the PG and as a result:

2/4/89, ZAP-2 - the failure of a pump for the emergency supply of boron due to structural defects in the bearings of the 4AZH1-800/8000YKhL4 and 4/13/89, ZAP-4 - failure of the pump for the emergency supply to the PG because of poor production of the butt packing for the pump (electric pump unit of the TsN-150-90-4KhLN TU 31-07-1507-82 z.N 4 type). In the other 2 breakdowns the failures happened because of repair personnel of the AES: 3/5/89, ZAP-2; 7/9/89 BAL-1 - poor quality in carrying out the repairs on the pump units for the emergency system for

supplying the PG, correspondingly emergency cooling.

In all 9 cases the failures occurred during tests of the SB, including in one case, 7/9/89, BAL-1 it led to the emergency state because of the breakdown in the conditions of safe operation as a result of being under repairs for more than 16 h.

In the period being considered there were 5 breakdowns with failures of the BZOK, BRU-A, including 2 failures of the BZOK which led to shutdown of the power units (8/9/89, KhME-1 and 11/23/89, BAL-3) see Table 6. The main reasons for the failure of BRU-A, BZOK are: poor quality of repairs (8/9/89 KhME-1), steaming up of the room, elevated vibrations of the PG's steam ducts (4/12/89 - BAL-3 11/23/89 - BAL-3, 3/18/89 KLN-2).

The breakdown which resulted in a shutdown of the powerunit occurred on 1/4/89, BAL-1. The shutdown occurred because of the false triggering of 2 protection channels in SB channel 2 (2SB) because of a defect in the insulation in the power supply cables the monitors for these precautions which showed up when water from the UAPT fire extinguisher fell onto the 2SB. The UAPT was triggered because of the steaming of the cable jacket of the 2SB and the false triggering of the monitors of the DIP-1 type fire alarms was the result of the poor quality of mounting the cable for 2SB.

CONCLUSIONS:

The equipment failures of the protective SB mainly occur because of:

1. Poor quality of repairs: ZAP-2 3/5/89, BAL-1, 7/9/89.

Spontaneous closing of BZOK-2 at KhME-1 8/9/89 because of a defect on the flange of the unit in the BZOK framing, culprit -

TsTsR -poor quality repair. The BZOK, BRU-A equipment (VES-6) was used without regard to operating requirements (steaming up of individual parts of the electrical circuit, elevated vibration of the steam ducts), (BAL-1, 12/3/89 and 11/23/89).

2. Poor finishing off of the units and parts of the 6 kV switches of the VE-6 (VES-6) type. There was also a number of failures of the VE-6 switches for unexplained reasons, primarily the appearance of electromagnetic interferences in the switch control circuits.

The defective construction of the bushing unit of the electric motor in the low pressure pumping unit of the emergency system for supplying boron (TsN150-110 type electric motor 4AZM1-800/6000 UKhL4)

2.3.2. Security Safety Systems

There were 34 breakdowns at AES (21 in 1988 including RDES-14) (reservnaya dizel'elektrostantsiya -reserve diesel power station) related with equipment failures in the security SB (OSB) (obespechivayushchikh SB - security SB): system for emergency electrical supply - 25 including the reserve diesel power station (RDES) - 17, uninterrupted supply unit -5-; technical water supply system OP - 9.

In 5 cases the failures in the security SB (the case when the ABP elements were switched off was discussed above) resulted in unplanned shutdowns of the power units with a total production loss of 50.0 million kWh or 20% of the production losses for AES with VVER reactors because of SB defects.

One failure occurred at NVO-2, 10/26/89 because the charging unit (PU) (podzaryadnogo ustroistva) was switched off because of a

defect in the relay for the switching on command which made it impossible to switch on the system for the emergency supply of boron for 20 minutes. This occurred because of a failure for general reasons and is classified as emergency conditions (p.2.2.2.4 PNAZG-12-005-87 - failure of all SB channels). The culprit was plant personnel, poor attention to the signaling panel of the BShchU (blochnyi shchit upravleniya - block control panel)

2.3.2.1. Reserve Diesel Power Plant

There were 17 breakdowns in RDBS equipment resulting in 16 failures and 1 emergency state for the power unit which is 27% of all of the SB failures in AES with VVER (VVER-1000 - 12 failures, VVER-440 - 5 DG failures).

One case occurred in the operation of the RDBS equipment upon demand: 12/19/89 at ZAP-5 in the process of the development of the breakdown the VA section was disconnected, the DG-1 automatically started up and the SB mechanisms were switched on but the DG's revolutions were 750 rpm which corresponded to $Hz = 42$ Hz (nominal frequency of revolution of the DG is 900 rpm, $Hz = 50$ Hz, DG type ASD-5600, Diesel 78G) The reason was the fracture of the torsion cylinder of the fuel supplying diesel pump, a part which was produced with a technological deviation which did not provide for a good quality assembling of the pump.

The remaining 15 breakdowns were exposed during testing of the SB. Events which are often repeated are failures which arise because of the defects in the activation system of the generator SBDG 6300-6MUZ (DG of the ASD-5600 type) This type of DG are found in the power units of VVER-1000 and RBMK-1500.

In 1989 there were 3 breakdowns due to defects in the RNR-5P

pressure regulators, blocks of rotating diodes. The failures occurred on 1/17/89, ZAP-4; 2/24/89, ZAP-3; 12/20/89, KLN-1. In the last case repair resulted in the destruction of the operating safety conditions of the power unit. An analogous case for the failure of the activation system for this type of generator occurred at KLN on 8/23/88 DG-3;

On 7/22/89 the DG-3 (GX-01) did not connect to the NP section during testing of the SB because of the failure of the VES-6 switch (Rovenski high voltage apparatus plant RZVA). The reason was the defective construction of the switch. This BES-6 failure again indicates the poor reliability of switches and the need for taking urgent measures to improve their quality.

In addition to 3 failures of DG because of defects in the generator's activating system, the remaining failures of the DG have the same character.

Because of the fault of the producers there were 9 equipment failures in RDES equipment:

- 1 case - the DG generator's switch (15D100 type) and the intersectional switch were not turned on - at KOL-3, 8/25/89 because of defects in producing the electrical units in the switch control circuits; the guilty party was the Kharkov electromechanical plant;

- 2 cases - 12/29/89 at ZAP-5, see above, and 12/13/89 at ROV-3 - failure of DG-31 because of the destruction of the spring in the high pressure fuel pump in the 13th cylinder - production defect;

- 3 cases - because of production defects in the activation system of the DG generator ASD-5600;

- 1 case - 10/28/89, ZAP-5, faulty logistics command unit (BKL) (bloka logicheskikh komand) in the command control circuit for switching on the DG in the 2nd series of the control system and lack of contact in the BKL joint; reliable connections were not provided in constructing the joints in the UKTS (unifitsirovannyi kompleks tekhnicheskikh sredst - unified group of technical media) columns and no recommendations were given on cleaning the joints;

- 1 case - 5/6/89, ZAP-2 - defective switch (type AK 63-3MGUZ) in the ShsN-2 KUAS-5600 DG ASD-5600 because of construction defects resulting in the need to repair the DG-1.

Failures caused by the producers occur as the result of structural defects in the system elements, poor quality production and assembly, the absence of requirements in the operating instructions on carrying out technical maintenance.

There were 7 breakdowns of the RDES due to AES personnel: YuUK-1, KhME-2; ROV-1, KOL-3.

On 10/31/89 during systematic testing of SB channel 2 after starting up the DG the MTZ was triggered. The reason was the improper connection of the electrical circuits to the protection for the reverse sequence.

On 12/13/89 a failure of the DG-21 occurred at ROV-2 during testing as the result of the wear of the electric motor's collector brush, the speed regulator, AES personnel ((TsTAM, ETs) - the clear cut boundaries were not determined for separating the plant's equipment in the DU DG system, there was no TO graph for the DG's speed regulators.

On 10/23/89 at KOL-3 the DG 3 SB channels failed because of

the AES personnel's failure to follow the technological regulations in part of the testing sequence of the SB before starting up the energy block after PPR. There was also an unsatisfactory organization of the supervisory AES personnel for carrying out the checks of the protection and interlocking of the power unit before start up and the requirements in the instructions 3,4-03 22 TO-86 on the control of the RDES guidance systems were not carried out.

Thus failures due to AES personnel occur because of poor organization and operational control on behalf of the supervisory personnel a breakdown in operating documentation.

There was one misfire of the DG on 7/18/89 at KhME-1 due to the fault of the AEP designers. The reason was that the DG was not prepared for automatic start up under the DG's operating conditions during systematic testing due to design defects in a part of the DG's control system. From 7//89 to 7/18/89 2 SB channels were in stand-by state but the possibility for automatic start up was excluded which is a breakdown in safe operating conditions according to the signals of the control SB. Two other SB channels were operative.

The failure of one channel in the system for emergency power supply for a time which exceeds that permitted by regulations classifies it as an emergency state according to VNIIAES (Vsesoyuznyi Nauchno-Issledovatel'skii Institute Atomnaya Elektricheskaya stantsiya - All Union Scientific Research Institute for Nuclear Power Plants) and PNAEG-12-005-87, p. 2.2.2.3.

It should be pointed out that, as compared with 1988, not a single case related with the failure of the butterfly valves in

the diesel's automatic control system was recorded at the RDES AES with a DG of the ASD-5600 type which indicates the efficiency of the measures adopted at the plants.

At the present time modernization of the system for supplying the oil to the drive bushing of the large auxiliary mechanisms (privoda krupnykh vspomogatel'nykh mekhanizmov - drive of the large auxiliary mechanisms)(PKVM) on the ASD-5600 is being carried out at the plant which optimizes the lubrication of the most loaded bearings in the first seconds of start up of the DG.

2.3.2.2. Commercial Water Supply Systems

There were 8 breakdowns recorded in AES (in 1988 - 4) related with failures of system equipment and 1 failure of the system's equipment occurred in the development of a breakdown due to other equipment in the AES (YuUK-2, 9/1/89, failure of the commercial water supply pump because of a breakdown in the power cable's insulation.

There were 7 breakdowns, or 78% of all of the system breakdowns, due to failures of the control valve (reguliruyushchego klapana)(RK) of the I68051-500-02 type.

In 2 cases these failures resulted in disruption of the safe operating conditions (p. 3.4.2. TRV-1000-1) ZAP-3, 12/6/89 and ZAP-5, 11/9/89. By comparison in 1988 2 cases of analogous failures of RK of this type were recorded in the investigation reports: 12/8/88, KhME-1 and 8/26/88, ZAP-2.

All cases of RK failures in 1989 took place at the Zaporozh AES (see Table 1). The reasons - the spontaneous separation of the rod from the control unit (plunger) because of the appearance of hydrodynamic vibrational stresses at low flow rates of

1000-1500 m/h. Six of the breakdowns were the result of construction defects (A reliable structure was not provided for the connections of the rod with the control unit. Earlier RK failures of this type took place in 1988 at KhME-1, 12/8/88, at ZAP-1, 6/4/88 and 5/13/88.

The measures taken by the producers to improve the reliability of the unit for attaching the rod to the control unit in 1988 did not give the desired results therefore the producers must take measures to improve the construction for this type of valve, taking into account the actual operating conditions at the AES.

On 4/28/89 during SB tests on the DG at KhME-1 the checkvalve (OK) (obratnogo klapana) jammed on the QF31D01 pump's pressure head; the reason was not determined. An analogous failure took place on 11/5/86 at BAL-1 with the QF21S06 OK because of a shift in the valve's axes. 12

In power units with RBMK there were no recorded failures in the commercial water supply systems.

Conclusions On Security SB:

1. Shut downs of the power units because of the unsteady operation and switching off of ABP elements take place because of the false triggering of SB precautions during power losses in individual protection channels, defects in the algorithm for technological precautions and interlocking.

2. DG failures take place because of faulty construction parts, poor quality production and assembly, the absence of requirements in the instructions for the operation and technical maintenance (TO) (technicheskomy obsluzhivaniyu - technical maintenance); due to the fault of personnel - improper assembly of

electrical circuits for protecting the generator, clear cut boundaries were not given for separating the equipment in the ETs and TsTAM plants in DG systems; violations of the requirements of technological standards in preparing the power unit for start up after PPR, (preventive maintenance and repair) and, on the whole, because of poor operating organization of the supervisory personnel in charge at the ALS.

3. Failures in the commercial water supply system OP in 78% of the cases occur as the result of construction defects in the rod-control unit connection of the control valve (RK).

2.3.3. Locating Safety Systems.

IN AES with VVER 10 breakdowns were recorded (in 1988 - 1), related with system equipment failures.

Three because of the unsanctioned closing of the pneumatic cut off unit in the GTsN's oil system and 1 false triggering of precautions for the power unit because of a pressure increase above the GO of more than 0.3 kgf/cm, which resulted in 2 shutdowns and 2 unloadings (because of the deviations of two GTsN) with an overall production loss of 49.82 million kWh (9/20/89, BAL-1; 9/19/89, KhME-1; 7/12/89, BAL-3; 1/5/89, KLN-1 respectively, see Table 1).

The closing of the pneumatic cut off units at BAL-3 on 7/12/89 and at KLN-1 on 1/5/89 occurred because of the appearance of false signals because of internal defects in the logical command blocks BKL-UM, Plant N 6608 and in the control cable in the coil control circuits.

The closing of the pneumatic shut off unit at BAL-1 on 9/20/89 resulted in the development of a shutdown of the powerunit

because of the increase in the level in the PG-3 as a result of the breakdown in the operation of the algorithm for the technological protection. The reason for triggering the pneumatic shut off unit was the maladjustment because of the aging of the packing material in the reducing valve in the coil's control system. Unsatisfactory carrying out the coil's TO.

One shut down at KhME-1 on 9/19/89 took place because of the activation of AZ-1 (avariinaya zashchita - emergency protection) by a false signal for a pressure increase of more than 0.3 kgf/cm above the GO when the hermetic valve TL 42SO2 for supplying the air under the casing was closed during systematic testing. The reasons for the false operation of the protection was the defect in the algorithm for the technological protection of the obstruction.

Six breakdowns were related with failures of the pump units in the sprinkler system TQ 11 (21, 31) DO1, (3/17/89, KhME-1; /3 21189, ZAP-2; 8/7/89, ZAP-3; 1/14/89, ZAP-4; 4/1/89, ZAP-4; 5/20/89, ZAP-4) including 4 breakdowns which happened because the pump units to the sections for reliable supply were not switched on because of breakdowns in the operation of VE-6 type switches. The reasons for the failure of the switches are the same as in the breakdowns which are related with the pump units of the protective SB and 2 breakdowns occurred as the result of the low operating levels of the pumping equipment because of the defective organization of the operation. As an example we cite the failure of the sprinkler pump on 8/7/89 at ZAP-3 during tests because of the overheating of the 3rd bearing to 99°C. The failure was the result of the lack of proper control of the oil level in the pump

crank case; there are no marks on the pump oil gauges for the minimum permissible level in the crankcase. Such failures may be the reasons for the appearance of general failures. An analogous failure of the sprinkler system took place at ZAP-4 on 4/1/89. A low operating level for the SB mechanisms.

Conclusions:

Equipment failures for the localizing SB occur mainly because of:

1. False triggering of the pneumatic cut off unit in the GTsN oil system in all 3 cases occurred because of the appearance of false signals in the coil's control circuits because of: hidden defects because of the use of elements in the BKL which do not correspond to the requirements of the operating conditions for the UKTC, poor mounting of the control cable.

2. The poor organization of the operation, the lack of requirements in the instructions in operating the pump units as to the quality and level of the oil in the crank case for pumps of the type TsNCA 700-140 (N13.35.00.00PS) 8/7/89, ZAP-3; 4/1/89, ZAP-4).

The conclusions about the sprinkler pump failures because the switches of the VE-6 type did not turn on are considered under the subheading "precautionary SB."

3. BREAKDOWNS IN THE OPERATION OF THE SAFETY SYSTEM WITH RBMK REACTORS

In 1989 7 breakdowns were recorded at AES with RBMK reactors or 10% of all breakdowns due to failures of safety system (SB) equipment. In comparison there were 5 in 1988. Moreover 2 breakdowns happened in 1 power unit of the Bilibinsk AES which has another type of reactor. Of all of the breakdowns 2 resulted in emergency states and 7 in failures (Tables 1, 2) of the power unit

One breakdown which happened on 11/18/89 at SMO-1 resulted in an unplanned shutdown of the power unit with a production loss of 149.2 million kWh and a downtime of 150.0 h. The breakdown was related with the appearance of cracks in the welded joint in the Du200 duct of the SPiR and SAOR junction at a distance of 8 m from the branch into the SAOR collector. In operation of the SAOR the defect in the welded joint could lead to a disruption of the conditions for emergency cooling. Reasons - the preliminary cross tightening of the duct in the region of the welded joint, bending of the duct because of insufficient heat compensation, and poor quality of the weldings because of a breakdown in technology and poor control over the welded seam.

All of the breakdowns that happened in power units with RBMK in 1989 were of the same character except for 3 which were related with the false triggering of the SLA 10 system, 10/11/89 and 12/21/89, LEN-4.

Distribution of the breakdowns with respect to the safety systems:

Protective SB:

4 breakdowns - 5/14/89, IGN-2; 11/18/89, SMO-1; 4/24/89, 5/28/89, BIL-1;

security SB:

2 breakdowns because of DG failure (1 during use 5/22/89, KUR-4; and 1 during testing 5/11/89, IGN-2);

locating SB:

3 breakdowns SLA (11/10/89 and 12/21/89 LEN-4).

In 1989 there were:

2 independent SB equipment failures (5/22/89, KUR-4; failure of the DG-1 because of improper adjustment of the relay in the DG's control circuit; 5/14/89, IGN-2; failure of the catch in the SAOR pump's recirculation line because of a defect in the flow monitor);

2 failures for general reasons (5/14/89 IGN-2; catch failure on the SAOR pumps' pressure head because of the improper adjustment of the clutch limiting the moments of the catches' electric drives; 10/10/89 LEN-4 because of the hermetic loss for the compressed air duct there was a loss in the efficiency in the emergency locating units LEN-3,4).

On 5/14/89, IGN-2 6 of the 8 catches on the NSAOR pressure head did not open during the complex testing of the SAOR's efficiency; 2 of the catches only opened partially (TN16S01,02, TN17S02, TN27S01, 02, TN26S02, TN17S01, TN26S01). This made it impossible to feed water from the NSAOR to the MPTs loop. In addition to these catches the TN53D01 catch in the NSAOR recirculation line did not close because of the absence of a signal from the flow monitor. The failures of the catches which

connect the NSAOR to the KMPTs were due to the common reason of the improper adjustment of the clutch for limiting the electric drive's momentum. The RTs personnel did not carry out measures mentioned previously which were developed on the basis of the conclusions of the previous test of the SAOR p. 3.4 act N 1-13/459 from 10/29/88. An analogous event occurred on 7/17/88 at IGN-2. The control values on the NSAOR pressure head were in the closed state during operation on power because of the disruption of the technological standards by the RTs personnel which meant that water could not be supplied to the KMPTs during operation of the pumps on demand (act N 2JGN-0-7/19/88). Because of this order of repetition of the events it can be concluded that the organizational state for the operation of SB at the IGN AES is unsatisfactory, there is no control over carrying out the requirements of the operating documents and of measures instituted on the basis of results of preceding tests of the SAOR, a low level of worker's discipline.

Because of leaks in the armature and pulse tubes of the KMPTs on 5/33/89 at KUR-2 there was a pressure increase in the dense-stable boxes (PPB) (plotno-prochnykh boksakh) triggering an AZ-5. The high speed catches (BDZ) (bystrodeistvuyushchie zadvizhki) of the water tanks (GB) (gidroballonov) and PEW opened up. The DG-1,2,3 started up. The DG-1 did not connect to the section for reliable supply (NP) (nadezhnogo pitaniya). The reason for the failure of DE-1 on demand was predominantly the improper adjustment of the time control relay for the start up period (KZ-1) (kontrolya zapuska) in the DG's control circuit (type 12 ZV40/48 + S2445-12) which caused the switching off of the

activation for the generator and then for the diesel. Prior to the occurrence of the breakdown one subsystem of SAOR NOAP-21,22 was under repair and KUR-4 was being operated under non-design conditions. Removing one of the SAOR subsystems for repairs for SB constructions according to principle 3 by 50% is a gross breakdown in the safety conditions for operating the power unit. The culprit was the AES personnel who allowed the improper adjustment of the relay in the DG control circuits and also the removal of the NOAP subsystem for repair without determining the proper and necessary safety measures as well as the design and construction units of the AEP and p/ya A-7291, A-1758 which did not provide technical means for determining the flow in the PPB, the lack of standards on the permissible flow in the PPB for the operation of the power units on power.

On 5/11/89 at IGN-2 there was a short circuit and the triggering of a differential protection of the DG during tests of the DG-10 because of a latent defect in mounting the circuit cable which developed under operating conditions (water entering the trough in the high water period and the lack of observation capacity).

Three interruptions in the operation of LEN-3,4 occurred because the emergency locating unit (BLA) (bloka lokalizatsii avarii) was out of operation because of false triggerings of the start up system of the BLA siphons:

11/10/89, because of defects in the circuit which carries the air under conditions of using an non-design pneumatic valves of the A96347 type, Du 150. In this case the spontaneous opening of the valve and the start up of the siphons takes place with a loss of

pressure in the air conducting system because of the damage to the air duct for supplying the tanks of the BLA or with a power loss to the electromagnets of the pneumatic distributors. The damage to the air duct for supplying the BLA tanks was due to the fault of AES personnel who ignored the requirements for safety in carrying out ground operations (side by side with the actual ducts) using shrew-like techniques.

12/21/89 at LEN-4 because of the overfilling of the water seals (GZ) (gidrozatvorov); the culprit - AES personnel who allowed the overfilling of the GZ. There was no reduction in power or shutdowns of the energy blocks. In all 3 cases the false triggering of the BLA system resulted in the non-design operation of the power units during the time the BLA efficiency was restored (10 h). The first two breakdowns of the commission are classified as emergency states and the breakdown on 12/21/89 was classified as a failure, citing the notice on the change in the Technological standard verified by the MAEP SSSR. This notice was not cleared with the Gospromatomnadzor SSSR, construction and design organizations which is a breakdown in the requirements of the Technological standard on the operation of power units with RBMK-1000 reactors p. 3 and therefore the notice authorizing the operation of power units without SLA is invalid and the breakdown must be classified as an emergency state.

Two breakdowns occurred at BIL-1 during the PPR which were classified as failures. On 4/24/89 during tests of ASPOV there was a jamming of the reverse valve in the 4th loop. The reason was the accumulation of corrosion production - the culprit AES personnel. On 5/28/89 during adjustment there was a jamming of

the auxiliary valve IPK-1V, of the type V-573, DU 20, produced in 1978 and put to use in 1981, intermediate repairs - 1988, culprit - TsTsR personnel.

Measures For Improving Safety

From 1986 to 1989 VNII AES, along with the plants carried out a series of studies on improving the reliability of DG-40 which are installed in one line of the KUR and Cher and in the LEN AES. Produced and distributed to all interested organizations, the technical solution which suggests improving the degree of automation for the operation of diesel loop after shutdown, pumping the oil out of the diesel's crank case under stand by conditions and also a modernization of the SGD 16-69-6 generator with the aim of lowering the thermal loads on the rotor when operating at power during the summer.

CONCLUSIONS

Breakdowns in the operation of AES with RBMK reactors due to equipment failures basically occurred for the following reasons:

nonfulfillment of the requirements of the operating documents by the AES personnel; poor worker discipline (5/14/89, IGN-2, 5/22/89, KUR-4);

poor quality of repairs (5/28/89, BIL-1);

breakdown in the welding technology; lack of control on the welded joint; poor installation of the control cable (1/18/89, SMO-1, 5/11/89, IGN-2);

insufficient development of the construction solutions for the air supply systems - false triggering of the start up system for the BLA siphons, 11/10/89, LEN-4 because of the use of a

non-design valve A96374 and the common duct for supplying the BLA tanks with compressed air for 3,4 energy blocks.

TABLE 1

BREAKDOWNS IN AES OPERATION DUE TO SB EQUIPMENT FAILURES AND SB EQUIPMENT
 FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down-time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
1	YuUK-1	2/5/89 on power	0	4.9	6.6	ABP, unsteady operation during switching	Constant operation	Analogous breakdown in ABP PTS on 2/17/87 Act N42
2	YuUK-2	9/1/89 on power	0	-	-	NTVO - 2 insulation breaks	"	
3	YuUK-2	10/31/89 on power	0	-	-	DG - false operation of MTZ	Testing	Improper switching on of the current circuits to protect reverse sequence
			3	4.9	6.6			
4	BAL-1	1/4/89 on power	0	18.35	13.5	Steaming up of the cable shaft room of 2SB and start of UAFT 2SB	False Triggering	
5	BAL-1	7/9/89 PPR	AS	-	-	TQ22 D01, increase in temperature p/sh N3	Testing	
6	BAL-3	7/12/89 on power	0	14.94	-	Pneumatic Armature control and protection circuit	False Triggering	In oil system of GTSN
7	BAL-1	9/20/89 on power	0	7.28	1.25	Pneumatic Armature control and protection circuit	False Triggering during development	"
8	BAL-1	4/12/89 on power	0	-	-	A failure occurred in KV during operation of BRU-A TX80S05 because of high level of vibration in PG-4 steam duct	Operating on demand	

TABLE 1

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FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES, Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down-time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
9	BAL-3	11/23/89 on power	0	72.27	56.9	Because of defect in KVZ BZOK-3 there was no signal to switch off GTsN-3 resulting in triggering false interruption protection	Operating on demand	KVZ BZOK failure because of elevated vibration in duct and on BZOK
			5 OT + 1 AS	112.84	71.65			
10	KhME-1	3/17/89 on power	0	-	-	VES-6 TQ21D01 did not switch on	Testing	The main reason the switch did not turn on was a breakdown in the kinematic circuit
11	KhME-1	4/28/89 on power	0	-	-	Jamming of the OBK in the pump in VF system (QF31D01)	"	
12	KhME-1	6/8/89 PPR	0	-	-	Start up failure for DG-1 due to maladjustment of pneumatic head	"	Assembling defect PNR
13	KhME-1	6/9/89 PPR	0	-	-	VES-6 of the TQ12D01 pump did not switch on	"	
14	KhME-1	7/15/89 PPR	0	-	-	Start up failure of DG-1 due to leaks of compressed air through inlet nut	"	
15	KhME-1	7/18/89	0	-	-	Start up failure for DG, defect in control system	"	
16	KhME-1	9/19/89 on power	0	18.54	15.9	False triggering of precaution pressure elevation above housing of 0.3 kgf/cm	"	

BREAKDOWNS IN AES OPERATION DUE TO SB EQUIPMENT FAILURES AND SB EQUIPMENT

FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES, Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down-time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
17	KhME-1	8/9/89 on power	0	56.62	52.6	Spontaneous closing of BZOK -Flaw in mounting framework of BZOK	False triggering	
18	KhME-1	9/1/89 on power	0			BZOK-5 did not close due to interlocking as level in PG4 increased	Oper-ating on demand	During develop-ment of break-down
			9	75.16	68.5			
19	KLN-1	1/5/89 on power	0	9.06	-	Spontaneous closing of pneumatic out-off mounting in QTSN-K3 oil system in control circuits	False Triggering	
20	KLN-1	12/20/89 on power	AS	-	-	Failure of DC's activating system	Testing	
21	KLN-2	1/18/89	0			BRU-A-2 did not close because feed robot was "knocked out"	Oper-ation on demand	
				9.06				
22	ROV-3	4/9/89 on power	0	15.43	17.0	Failure of ABP in SB3 due to mal-adjustment of power thyristor	Constant Operation	
23	ROV-3	11/23/89 on power	0	11.506	12.0	Failure of ABP SB3 due to false operation of PTS protection	"	
24	ROV-3	12/13/89	0	-	-	Failure of DG-31 due to defect in TNVD	Testing	

TABLE 1

BREAKDOWNS II: AES OPERATION DUE TO SB EQUIPMENT FAILURES AND SB EQUIPMENT

FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES, Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down-time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
25	ROV-2	12/13/89 on power	0	-	-	Failure of DG-21 due to defect in speed control	Testing	
			4	26.93	29.0			
26	ZAP-2	1/10/89 on power	0	-	-	Failure of control valve in VF system operation spontaneous disconnection of control unit	Constant	Use of non-design joint pins and nuts in repairs 8/26/88
27	ZAP-2	2/4/89 on power	0	-	-	Failure of TQ23D01 due to defect in power meter bushing	Testing	
28	ZAP-2	2/25/89 on power	0	-	-	Failure of TZ13D01 due to defect in VES-6 switch	"	
29	ZAP-2	2/11/89 on power	0	-	-	Failure of TQ31D01 due to defect in VES-6 switch	"	
30	ZAP-2	4/3/89 on power	0	-	-	Failure of control valve in VF system	Constant Operation	
31	ZAP-2	3/2/89 on power	0	-	-	Failure of TX30D01, oil leak	Testing	
32	ZAP-2	3/5/89 on power	0	-	-	TX30D01 failure, oil leak	By-pass of equipment	

BREAKDOWNS IN AES OPERATION DUE TO SB EQUIPMENT FAILURES AND SB EQUIPMENT

FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES, Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down-time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
33	ZAP-2	5/6/89 on power	0	-	-	DC-1 sent for repair because of failure of AK 63-ZMKGUZ in ShSN-2 shaft of KYAS-5600	Equipment inspection	
34	ZAP-2	4/16/89 on power	0	-	-	Failure of TQ23D01 because VES-6 did not switch on	Testing	
35	ZAP-2	2/24/89 on power	0	-	-	Failure of DC due to defect in activating system	"	
36	ZAP-2	3/18/89 on power	0	-	-	Failure of ASP's control system	"	
37	ZAP-3	8/7/89	0	-	-	Failure of TQ31D01 - elevation in temperature of 3rd bushing	"	
38	ZAP-3	12/6/89 on power	0	-	-	Failure of control valve in VF 1SB system	Constant Operation	
39	Z	1/17/89 on power	0	-	-	Failure of DG due to defect in activation regulator	Testing	
40	ZAP-4	1/14/89 on power	0	-	-	Failure of TQ11D01 in VES-6 switch's control system	"	
	ZAP-4	4/1/89 on power	0	-	-	TQ21D01 because of increase in temperature of 3rd bushing	"	
42	ZAP-4	4/13/89 on power	0	-	-	Failure of TQ20D01 - leak in seal	"	
43	ZAP-4	4/28/89 on power	0	-	-	Failure of TX30D01 due to VES-6 defect	"	

TABLE 1

BREAKDOWNS IN AES OPERATION DUE TO SB EQUIPMENT FAILURES AND SB EQUIPMENT

FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES, Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down-time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
44	ZAP-4	4/29/89 PPR	0	-	-	Failure of control valve in VF system	Constant Operation	
45	ZAP-4	5/20/89 on power	0	-	-	Failure of TQ11D01 due to interference in VES-6 control circuits	Testing	
46	ZAP-4	7/22/89 on power	0	-	-	DC CX-01 did not connect to section due to VES-6 failure	"	
47	ZAP-4	8/27/89 on power	0	-	-	Failure of control valve of VF system leak in weld seam	Constant Operation	Dynamic action on RK
48	ZAP-5	10/11/89 on power	0	15.8	15.75	ABP failure due to inverter defect	"	
49	ZAP-5	10/28/89 on power	0	-	-	Start up failure DG-3 due to control system defect	Testing	BKL defect in control circuit of DC switch on command
50	ZAP-5	11/9/89 on power	0	-	-	Failure of control valve in VF system	Constant Operation	
51	ZAP-5	12/29/89 shutdown	0	-	-	Independent failure of DC due to break in fuel pump	Operation on demand	
52	ZAP-5	4.12.89	0	-	-	Failure of control valve of VF system		
			27	15.8	15.75			

TABLE 1

BREAKDOWNS IN AES OPERATION DUE TO SB EQUIPMENT FAILURES AND SB EQUIPMENT
 FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES, Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down- time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
53	HVO-2	10/26/89 on power	AS	-	-	Failure of VPU, dis- charge AB inability to start emergency system to add boron	Constant Operation	
54	HVO-2	8/10/89 on power	0	-	-	Independent failure of ODG-4 due to defect in frequency control	"	
				1 OT + 1 AS				
55	KOL-3	4/7/89 on power	0	2.4	5.4	Disconnec- tion of APB 2SB due to false oper- ation of protection currents	"	
56	KOL-3	8/25/89 on power	0	-	-	Failure of DG because generator and section switch did not turn on for general reasons AP ShchPT	Testing	Defects in switch solenoid circuit
57	KOL-3	10/23/89 on power	0	-	-	DG 3SB failure due to im- proper pos- ition for start up relay	"	
58	KOL-4	3/16/89	0	-	-	Failure of DG due to defect in air starting system	"	
59	KOL-4	7/25/89	0	-	-	"	"	
				5	2.4	5.4		

BREAKDOWNS IN AES OPERATION DUE TO SB EQUIPMENT FAILURES AND SB EQUIPMENT

FAILURES OCCURRING IN BREAKDOWNS DUE TO OTHER AES EQUIPMENT

No.	AES, Block	Date of breakdown, State of Block	Record category	Production Loss, million kWh	Down- time h	Equipment causing breakdown (Failure)	State of System Equipment	Remarks
1	2	3	4	5	6	7	8	9
60.	KUR-4	5/22/89 on power	0	-	-	Independent Operation DG-1 failure due to a defect in control system	on denabd	
			1					
61	LEN-4	10/10/89 on power	AS	-	-	False triggering of SLA due to design errors	False triggering of the system	
62	LEN-4	10/11/89 on power	AS	-	-	"	"	
63	LEN-4	12/21/89 on power	0	-	-	"	"	
			1 OT + 2 AS					
64	SN-1	11/18/89 on power	0	149.2	150.0	Flaw in SPIR-SAOR duct	Constant Operation	Poor quality of welding during assembly
			1	149.2	150.0			
65	IGN-2	5/11/89 on power	0	-	-	DG Failure Action of DF2- grounding (hidden cable defect	Testing	
66	IGN-2	5/14/89 PPR	0	-	-	Failure of cladding on delivery conduit of NSAOR	"	
			2					
67	BIL-1	4/24/89 PPR	0	-	-	Jamming of ASPOV's OBK system	"	
68	BIL-1	5/28/89 PPR	0	-	-	Jamming of IPK valve	"	
			2					
Total			68	396.1	346.9			39

TABLE 2

SB BREAKDOWNS IN 1989 BY AES BY QUARTERS

No.	Name of AES	For 1988	Block 1				Block 2				Block 3				Block 4				Block 5				Total No Breakdowns
			Quarter I	Quarter II	Quarter III	Quarter IV	Quarter I	Quarter II	Quarter III	Quarter IV	Quarter I	Quarter II	Quarter III	Quarter IV	Quarter I	Quarter II	Quarter III	Quarter IV	Quarter I	Quarter II	Quarter III	Quarter IV	
AES With VVER Reactors																							
1	Balakov	3	1	1	2																	6	
2	Zaporozh	7				6	3			2		1	1									4	
3	Kalinin	1	1			1	1	1				1	1	2	5	2			1			27	
4	Khmel'nits	5	1	3	5																	3	
5	Yu.Ukraine	1	1						1	1												9	
6	N.Veronezh	3							1													3	
7	Rovenski	2							1										1			2	
8	Kol'skii	6							1			1		2								4	
											1	1	1	1								5	
Total for VVER		28																					59
ES With RBMK And Other Types of Reactors																							
9	Kur'sk	1																	1			1	
10	Chernobyl	1																	1			-	
11	Leningrad																					-	
12	Smolensk					1															3	3	
13	Ignalinsk	3							2													1	
14	Beloyarsk																					2	
15	Bilibinsk																					-	
Total for RBMK		5																					9
Total		33																					68

TABLE 3

ENERGY PRODUCTION LOSSES AND TYPES OF BREAKDOWNS IN THE
OPERATION OF SB FOR 1989

No.	AES Name Block	Production Loss 1988	Production Loss		Total Downtime h	Emergency State	Failures	
			Shutdown/ Shutdowns	mil kWh Unloading				
AES With VVER Reactors								
1.	Balakov		3/97.9	1/14.94	4/112.8	71.65	1	5
2	Zaporozh	1/12.9	1/15.8		1/15.8	15.75		27
3	Kalinin			1/9.06	1/9.06		1	2
4	Khmel'nits	1/6.44	2/75.16		2/75.16	68.50		9
5	Yu. Ukraine		1/4.9		1/4.9	6.60		1
6	N. Voronezh						1	1
7	Rovenski	2/35.83	2/26.93		2/26.93	29.0		4
8	Kol'skii	2/9.11	1/2.4		1/2.4	3.4		1
Total for VVER		6/84.28	10/223.1	2/24.0	12/247.09	196.9	3	56
AES With RBMK Reactors								
9.	Kursk	1/65.96						1
10	Chernobyl							1
11.	Smolensk		1/149.2		1/149.2	150.0		1
12	Leningrad						2	1
13.	Ignalinsk							2
14	Beloyarsk							2
15	Bilibinsk							2
Total for RBMK		1/65.96	1/149.2		1/149.2	150.0	2	7
Total		7/130.24	11/372.3	2/24.0	13/396.29	346.9	5	63

TABLE 4

NUMBER OF SB BREAKDOWNS BY AES

AES 1652		Safety System					Total
Productive		Emergency Power System	Water Supply System	Locating			
Control Mech. & Elec. Circuit Equipment		Control Mech. & Elec. Circuit Equipment inc. RDEC	inc. RDEC	Mechanical and Electrical Equipment	Mechanical and Electrical Equipment		
AES With VVER Reactors							
Balakov	3	1					
Zaporozh	1	5	3/2	5/4	7	2	
Kalinin	-	1	-	1/1	-	5	
Khmel'skii	2	1	2/2	1/1	1	1	
Ukraine	-	-	1/1	1/0	1	2	
N. Voronezh	-	-	-	2/0	-	-	
Rovenski	-	-	2/1	2/1	-	-	
(Flock 3)	-	-	1/0	2/1	-	-	
Kol'skii	-	-	2/2	3/2	-	-	
Total for VVER	7	8	10/8	15/9	9	10	
AES With RBMK and Other Types of Reactors							
Kursk	-	-	1/1	-	-	-	
Chernobyl	-	-	-	-	-	-	
Leningr. d	-	-	-	-	-	3	
Smolensk	-	1	-	-	-	-	
Ignalinsk	1	-	-	1/1	-	-	
Beloyarsk	-	-	-	-	-	-	
Belobinsk	-	2	-	-	-	-	
Total for RBMK	1	3	1/1	1/1	0	3	
Total for AES	8	11	11/9	16/10	9	13	
						68	

DISTRIBUTION OF SB BREAKDOWNS BY TYPES OF POWER BLOCKS

TABLE 5

Type of AE;	SAFETY SYSTEMS							Total
	Protection		Security					
	Control Circuits	Mech & Elec. Equipment	Emergency Power Supply		Water Supply System		Locating	
			Control circuits Including RDEC	Mech. & Elec. Equipment Including RDEC	Mechanical and Electrical Equipment	Mech & Elec. Equipment		
VVER-440	-	-	3/2	5/2	-	-	8	
VVER-1000	7	8	7/5	10/7	9	10	51	
RBMK-1000	-	1	1/1	-	-	3	5	
RBMK-1500	1	-	-	1/1	-	-	2	
EGP	-	2	-	-	-	-	2	
Total	8	11	11/8	26/13	9	13	68	

TABLE 6

TRIGGERING (THE OPERATION) OF THE SB BY QUARTERS
AES WITH VVER REACTORS

	Triggerings, (operation)												No. SB Triggerings per Power Block					
	SB l/f*				Including DG				BRU-A					BZOK				
	I	II	III	IV	I	II	III	IV	I	II	III	IV		I	II	III	IV	
Balakov	1	1/1	1/0					1	1					3				$n_{SB}^{**} = 20$ trig/block
	2									1				2	1			
	3	1/42/11/0	1/0	2				1	1	1		2	1			1		
Zaporozh	3	0/1																$n_{SB}^{**} = 0.6$ trig/block
	4		0/1															
			1/1				1				1					1		
Kalinsk	1	1/0									1							
	2							1										
Khmel'nits	1	0/1	1/0						1	1				1	2			$n_{SB}^{**} = 1.0$ tr-g/block
Yuzh Ukraine	2		0/1	0/1										1				$n_{SB}^{**} = 0.6$ trig/block
Novo- Voronezh	4		0/1	0/1			1											$n_{SB}^{**} = 0.6$ trig/block
	5		0/1									1						
Rovenski	3	0/1		0/1														$n_{SB}^{**} = 0.33$ trig/block
Xol'skii	3	0/11/0			1													$n = 0.25$ trig/block

*l/f - False/Actual SB triggerings

** n_{SB}^{**} Numer of actual SB triggerings/block/year

TABLE 7

TRIGGERING (THE OPERATION) OF THE SB BY QUARTERS
AES WITH REMK REACTORS

AES. Block	Triggerings (Operation)													
	SB 1/f				DG				GPK					
	I	II	III	IV	I	II	III	IV	I	II	III	IV		
Kursk 4 blocks		0	1			1				1				$n_{SB} = 0.25 \text{ trig/block}$
Chernobyl														
Leningrad 4 blocks				3										
Smolensk 2 blocks				0				1						$n_{SB} = 0.25 \text{ trig/block}$
Ignalinsk 5 blocks				0				1						$n_{SB} = 0.25 \text{ trig/block}$

*1/f - false/actual Sb triggerings

** n_{SB} - number of actual SB triggerings/block/year

INDEPENDENT SB EQUIPMENT FAILURES

No	AES, Unit Date	Brief Description of Event
1	KAL - 2 1/18/89	The BRU-A-2 did not open up in the standby state because of loss of power in the control circuit.
2	BAL - 1 4/12/89	During operation of the BRU-A (TKh80S05) the casing of the terminal switches (KV) of the valve drive cracked. As a result there was a "knock out" of the robot for disconnecting the BRU-A drive. The reason - high vibration level of the steam duct from PG-4. An analogous breakdown occurred on 1/16/89. In addition the TKh80S05 was put into the closed state.
3	BAL - 3 11/23/89	Because of a defect in the steam supply valve in the BZOK-2 framework and the subsequent burn out of the valve's electric motor because of steaming, the BZOK-2 shut down for several minutes resulting in premature switching off of the GTsN-2. In addition there was a failure of BZOK-3 because of a defect in the terminal switch. As a result of this the signal was not given for switching off of the GTsN-3 which was the reason for the breakdown - triggering interruptive protection of SB 1 and the shut down of the power unit.
4	KhME - 1 9/1/89	Failure of BZOK-4 (TKh80S06), which did not close by interlocking as the PG-4 level increased due to a defect in the framework cladding.
5	YuUK - 2 9/1/89	Because of the false operation of protection during switching off GTsN-4 the NTVO-2 was disconnected - a break in the insulation of the bolt cable connection to the electric motor because of overvoltage.
6	ZAP - 5 12/29/89	In the development of the breakdown the DG's failed to start up due to the failure of the fuel supply pump.

7.	NVO - 4 8/10/89	In developing the breakdown the ODG-4 failed because of the drift in the frequency adjustment of the monitor for the frequency regulator.	
8	KOL - 3 4/7/89	The ABP of 2SB was disconnected because of the false operation of the current protection, triggering the precautions SAOZ 2SB, start up of DG 3QV and 3QX. The IPK cover of PG-1 was not closed.	
9	KOL - 3 8/25/89	While the power units are on power it became necessary to repair one of the three independent commercial water supply systems. In testing 2 other SB channels the DG did not start up; the generator and section switches failed because of the failure of their control circuits. 2 SB channels failed (for commercial water and emergency power). A breakdown in safe operating conditions.	
TOTAL FOR VVER		9 independent failures including failures in carrying out equipment functions.	8

SB EQUIPMENT FAILURES FOR A COMMON REASON AND REPETITIVE FAILURES

No.	AES, Unit Date	Brief Description of the Event
1. Failures for general reasons		
1.1	NVO - 2 10/26/89	Because of the spontaneous switching off of the VU (failure of the switch control relay) there was an extensive discharge of the storage battery which was the reason the system for the emergency addition of boron (5 pumps) could not be started up. Culprit-AES personnel
1.2	KOL - 3 8/25/89	In testing the SB there was a failure in the DG's section and generator switches due to a defect in the switch control circuits (supply robot for ShchPT), culprit - EMZ (electromagnetic plant), Khar'kov.
2. REPEATING FAILURES		
2.1	Failures of the I68051-500-02 control valve	
2.1.1.	ZAP - 2 1/10/89	Spontaneous separation of the rod from the regulating unit, 8/26/88 because of a construction defect in the unit for attaching these parts (TsKBA) and the subsequent poor repair work on the valve by the TsTSR personnel who did not observe the requirements of the factory design (the designed pin was not replaced) combined with the high mineral content of the water
2.1.2.	ZAP - 2 4/3/89	Spontaneous detachment of the rod from the regulating unit.
2.1.3.	ZAP - 3 12/6/89	"
2.1.4.	ZAP - 4 4/29/89	See Paragraph 2.1.2
2.1.5.	ZAP - 4 8/27/89	"
2.1.6.	ZAP - 5 4/12/89	"
2.1.7.	ZAP - 5 11/9/89	"
	TOTAL	7 RK failures or ~12% of SB failures in AES with VVER

- TABLE 9 (CONT.)
- 2.2 Pump and DG failures for the SB during tests due to failure of VE-6 type switches
- 2.2.1. ZAP - 2
2/11/89 The TQ31D01 did not connect to the section of the sprinkler pump because of the failure of the VES-6 switch. Reason predominantly the appearance of electromagnetic interferences in the control circuits of the switches.
- 2.2.2. ZAP - 2
2/25/89 The pump for the emergency supply of boron TQ13D01 did not turn on. Reason - failure of the VES-6 because of a defect in the mechanical part of the catch, destruction of the floor covering in the KRU-6, absence of TsZ requirements for the floor covering.
- 2.2.3. ZAP - 2
3/12/89 The pump for the emergency feed of the PG, TKh30D01, did not turn on primarily because of the appearance of breakdowns, the board assumes the appearance of electromagnetic interferences in the BKL circuits.
- 2.2.4. ZAP - 2
4/16/89 Failure of pump for emergency supply of boron to turn on, TQ23d01. Probable reasons - defect in the plug connection of the secondary circuits, the circuit connecting the switch with relay cut off case and failure of the elements of the kinematic drive circuit. Culprit - RZVA
- 2.2.5. ZAP - 4
1/14/89 Failure of the TQ11D01 sprinkler pump. Main reason - interferences in the VE-6 switch control circuits (see 2.2.1)
- 2.2.6. ZAP - 4
4/28/89 Start up failure of pump, TKh30D01.
- 2.2.7. ZAP - 4
5/20/89 TQ11D01 did not switch on (see 2.2.1)

2.2.8.	ZAP - 4 7/22/89	The DG-3 did not connect to the section because of a construction defect in the switch drive.
2.2.9.	KhME - 1 3/17/89	Failure of pump TQ21D01. Possible reason - breakdown in mechanical part of the switch.
2.2.10	KhME - 1 6/9/89	The emergency cooling pump TQ12D01 did not turn on due to the failure of the VES-6 switch. Reason not established.
<hr/> TOTAL		10 failures of VE-6 type switches including 6 failures in which reason was determined and 1 in which it was not.