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GERMAN PATENT 1575 25: APPARATUS FOR LOCALIZING DISTURBANCES IN PRESSURIZED WATER REACTORS (PWR)

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(89) see (31) and (33)

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(54) APPARATUS FOR LOCALIZING DISTURBANCES IN PRESSURIZED WATER REACTORS (PWR)

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(57) The invention according to CS-PS 177386, entitled "Apparatus for increasing the efficiency and passivity of the functioning of a bubbling-vacuum system for localizing disturbances in nuclear power plants with a pressurized water reactor", concerns an important area of nuclear power engineering that is being developed in the RGW member countries. The invention solves the problems of increasing the reliability and intensification during the operation of the above very important system for guaranteeing the safety of the standard nuclear power plants of Soviet design. The essence of

the invention consists in the installation of a simple passively operating supplementary apparatus. Consequently, the following can be observed in the system: first an improvement and simultaneous increase in the reliability of its function during the critical transition period, which follows the filling of the second space with air from the first space; secondly, elimination of the hitherto unavoidable initiating role of the active sprinkler-condensation device present; thirdly, a more effective performance and subjection of the elements to disintegration of the water flowing from the bubbling condenser into the first space; and fourthly, an enhanced utilization of the heat-conducting ability of the water reservoir of the bubbling condenser. Representatives of the supplementary apparatus are autonomous and local secondary systems of the sprinkler-sprayer without an insert, which spray the water under the effect of gravity.

PATENT CLAIMS

1. Apparatus for increasing the efficiency and passivity of the operation of the bubbling-vacuum system for localizing disturbances in atomic power plants (APP) with a water-water reactor, installed in a system for limiting the consequences of mishaps at APP according to the Author's Certificate CS-PS 177,386, characterized in that it consists of passive autonomous (26) or of passive local (27) subsystems of sprinkler-sprayers, installed at sites of the first space (2), switched by means of a connecting conduit (28) through automatic isolating valves (29) and/or through check valves (30) to flutes (11) and/or water traps (31), where the sprinklers of the existing active condensation apparatus (19) are switched from the upper groups of flutes (11) and the corresponding water traps (31) also by means of the connecting conduit (28) through a cutoff check valve (32), completely independently or jointly with passive autonomous subsystems (26).

2. Apparatus according to claim 1, characterized in that the passive local subsystem of the sprinkler-sprayers (27) when switched to the 3-12 m higher water trap (31) is comprised of sprinkler-sprayers with a low resistance and of the non-insert type.

3. Apparatus according to claims 1 and 2, characterized in that the passive local subsystem, located in the vertical shaft part of the first space (2), i.e., opposite the flutes (11) of the bubbling condenser, consists of sprinkler-sprayers (27), located in planes perpendicular to the longitudinal direction of the flutes (11), the axis of which is oriented obliquely upward to the flutes (11), forming an angle of 30-60° with respect to the horizontal plane.

4. Apparatus according to claim 1, characterized in that the automatic isolating valve (29) is equipped with a servo-drive (33).

5. Apparatus according to claim 1, characterized in that the water trap (31) for collecting water from the near upper group of flutes (11) is created by a flat or contoured continuous sheet, equipped in the bottom with apertures or connecting pieces for connecting the conduit (28).

6. Apparatus according to claim 1, characterized in that a cutoff check valve (32) is located in the connecting conduit (28) near the point of its introduction into the delivery conduit (20).

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APPARATUS FOR INCREASING THE EFFICIENCY AND PASSIVITY OF THE FUNCTION OF THE BUBBLING-VACUUM SYSTEM FOR LOCALIZING DISTURBANCES IN A WATER-WATER REACTOR OF ATOMIC POWER PLANTS (APP)

The Author's Certificate is dependent on AC No. 177368 - Czechoslovakia

Application date: June 4, 1979 (PV 3844-79)

Author's Certificate 209238 of August 26, 1981.

The invention concerns an apparatus for increasing the efficiency and simultaneously enhancing the passivity of the functioning of a bubbling-vacuum system for localizing disturbances in APP with a water-water reactor. The function of the localizing system will in a radical and basically new manner assure the radiation safety of the power production of an entire generation of standard two-circuit medium-power APP of Soviet design without a containment shell. The apparatus according to the present invention intensifies, precisely defines and consequently improves the functioning of the entire above basic safety system, protected in Czechoslovakia by Author's Certificate No. 177368 under the title, "System of limiting the consequences of mishaps at atomic power plants".

The current development and the state of the art of the bubbling-vacuum system for localizing disturbances are currently determined by the design solution used for the standard APP unit with a water-water reactor with an electric power of 440 MW, the actualization of which was already begun in the USSR and other countries of the Socialist camp. A description of the basic equipment of the

said system and the explanation of its functioning are contained in the specification of AC No. 177368. The disadvantages of the current solution of the system examined are that its heat-removing capacity is not fully utilized and that a relatively very important basic initiating role is given the active sprinkler subsystem within the frame of the given, exclusively strategic safety-assuring system, the reliability network of the equipment, in the middle of which it finally ends with the emergency reserve of motor oil in the tanks of the Diesel generators. It is evident from the patent claims for the the AC No. 177368 and also from the planning materials available that assurance of the goal, namely, the quickest possible achievement of post-mishap evacuation in the hermetic space in which the atomic source of steam or the first APP circuit is located, with the aid of the functioning of the system examined, is linked with the relatively rapid and impetuous functioning of the active sprinkler subsystem, i.e., with the functioning of the active condensation apparatus, represented by the sprinkler pump. Besides, a potentially critical or weak point during the function of the said system can be the creation and achievement of a relatively small, but inversive difference of pressure after completion of the bubbling and subsequent equalization of the pressures in the spaces above and below the flutes of the bubbling condenser for the purpose of obtaining a mass discharge of water from the said flutes. It is provided that the rate of condensation of steam in a steam-air mixture, which will continue, in particular, on a large surface of the flutes of the bubbling condenser, will be greater than the rate of steam generation under the action of the accumulated and

excess and possibly also reactive Zr-H_2O of the heat of the atomic steam source, as a result of which the assumed pressure conditions arise after some time and cause an automatic displacement or inflow of a substantial majority of the water from the said flutes. Thus, a strong cascade of water of only part of the disintegrated water flow arises inside of the high intake shaft of the bubbling condenser, causing a further contact condensation of steam in the steam-air mixture present here, as a result of which the required rapid reduction in the post-mishap excess pressure occurs in the entire hermetically sealed space, namely, to half its value. The residual excess pressure is continuously reduced under the action of a further condensation of the steam in the steam-air mixture due to the continuing operation of the now switched-on active sprinkler subsystem. The residual excess pressure ceases in the period between 10 and 15 minutes after the mishap occurs. With the aid of the subsequent functioning of the sprinkler pumps, an evacuation is created and maintained by periodically switching on and off the said pumps at the required intervals over a prolonged period of time. In spite of the positive calculated indices and the presence of very good results of the individual verifying experiments with bubbling condensation on models of the bubbling condenser, it should be noted that while it is impossible to definitively exclude the potential possibility of failure of the entire said, conceptually new system for assuring safety during a projected and even more so, an unanticipated mishap, during which an excessive formation of hydrogen would also be observed, in any APP of the given generation. Prior to the execution of a controlled slow, but from the standpoint of

the parameters a full-fledged pre-exploitation verification of the complex functioning of the first feasible bubbling-vacuum system of localizing mishaps in an APP, it must be assumed that (1) the danger of blocking or reducing the productivity of the condensation surface below that of the steam generation of the water in the mishap first circuit in the period after the completion of bubbling, namely, as a result of a possible extreme local increase in the partial pressure of air with a possible admixture of hydrogen in front of the flutes of the bubbling condenser. In the given case, there would be no inflow or reverse displacement and discharge of water from the flutes and, consequently, no rapid drop in the post-mishap excess pressure in the hermetic first space. The excess mishap pressure would be primarily liquidated only by the active sprinkler subsystem, here during approximately twice the time. Secondly, in spite of the relatively high reliability, determined by the substantial excess, i.e., the double reserve in the active sprinkler subsystem, there is still a certain risk of failure during its startup and operation, as a result of which the existence of a residual post-mishap excess pressure is possible in the hermetic first space during the passing out of service of the active sprinkler subsystem, during which there would be leaks of radioactive medium into the surrounding medium. The above are the basic shortcomings of the current solution of the bubbling-vacuum system of localizing mishaps.

The above shortcomings of the said safety-assuring system are diminished in the case of the arrangement of the supplementary apparatus according to the present invention, consisting of passive

autonomous or also passive local subsystems of sprinkler-sprayers, placed at points in the first space in which after the completion of bubbling there is a minimum air concentration or a maximum steam partial pressure, connected by means of a linking conduit through automatic isolating valves and/or through check valves to the flutes and/or to the water traps, where sprinklers having an active condensation apparatus, functioning as a result of this also in the case of a possible failure of the sprinkler pumps, are also connected from the upper groups of flutes and the corresponding water traps also by means of a linking conduit through cutoff check valves completely independently or jointly with passive autonomous subsystems of sprinkler-sprayers.

The characteristic advantages of the supplementary apparatus protected here, besides a reduction in the above shortcomings, are also the other basic ones given below: first, liquidation of the mishap excess pressure in the hermetic first space, i.e., in the series of the hermetic compartments of the reactor building and the corresponding spaces of the bubbling condenser - in calculating a more complete utilization of the heat or heat-removing capacity and potential energy of the water from the flutes - is practically completely assured by the very essential equipment operating here with an increased passivity, i.e., a bubbling condenser, during a considerably reduced period of time. Secondly, it is possible to reduce the initially quite rigorous requirements on the productivity of the active sprinkler subsystem, above all, the requirements on the productivity of the sprinkler pumps and, as a result of this, on the power of the Diesel generators that constitute the system of

assuring the electric power supply. The productivity of the sprinkler pumps need not be subsequently deducted from the requirement of as rapid as possible elimination of the residual excess pressure and the creation of a vacuum, and from the milder requirement of prolonged maintenance or regulation of a moderate vacuum. Thirdly, the relatively rapid startup of the sprinkler pumps can be delayed by an interval of time that corresponds to a several-minute discharge of water from the flutes and the water traps of the bubbling condenser, which takes place through passive, autonomous and also through passive local subsystems of sprinkler-sprayers, and it is also possible through sprinklers of the existing active condensation apparatus, through which, however, water from the bubbling condenser flows out up to the moment of startup of the sprinkler pumps. Fourthly, as a result of the arrangement of supplementary high-reliability passive sprinkler subsystems, the insertless sprayers, which disintegrate the water substantially better from the standpoint of thermokinetics and hydrodynamics, the quantity of water sprayed per second in the hermetic space is increased, and also the "temperature approximation", which results in a substantial reduction in the time interval during which a complete vacuum is achieved, as a result of which the potential possibility of reducing the requirements on the tightness of the system of hermetic spaces, which is difficult to achieve in view of their disjointed nature and geometry, arises. Fifthly, initiation of the beginning of placing the passive sprinkler subsystems in service is derived, for example, from the established given pressure, or the unambiguously determined value of the absolute pressure in the second space, i.e., in the corresponding

air sampler, as a result of which the obvious, but analytically and experimentally difficultly attainable actions are excluded, in particular, the influence of the damage site, the influence of the form and orientation of the crack in the primary conduit, their variation under the action of the reactive discharge forces, etc. - and, consequently, also the substantial randomnesses and, as a result of this, also the time differences during the functioning of the entire existing system of localizing mishaps. Sixthly, the initiation passive autonomous sprinkler subsystem, connected through an automatically opening isolating valve, is located near the presumed sites of damage, consequently, in the most advantageous space from the standpoint of thermokinetics. Its increased efficiency is apparently determined thereby, as a result of which the minimum possible time constant will be obtained for the equalization curve and the subsequent turnover of the pressure difference under and above the flutes of the bubbling condenser. Seventhly, by means of the arrangement of the local subsystems of the sprinkler-sprayers, oriented obliquely upward with a slope to the bubbling condenser, in comparison with the perforated sheet steel of the water traps used to date, the following are obtained: an improved decay of the water, increase in the residence time of the water drops in the space, in which case also as a result of the cascade discharge of part of the water through the lower-lying water traps, increased use of the space of the bubbling condenser sprinkled with water by the sprayers, an increase in the turbulence of the whirling motion of the steam-air mixture, located at the "dead" sites between the individual levels of the bubbling condenser at the wall, beyond which are the chambers or air

samplers. All the said factors positively influence the process of energy and mass transfer between the media and materials interacting here. Eightly, after evaluating all the above advantages on the basis of their verification prior to exploitation, it is possible to predict either a decrease in the existing system of localizing mishaps and consequently a drop in its value, or an increased protection of the surrounding medium of future APP of the given generation on which the improved system of localizing mishaps in the sense of the present invention will be used.

The basic layout of the supplementary apparatus and its connection to the existing bubbling-vacuum system for localizing mishaps is depicted on the attached drawing. Figure 1 shows the conventionalized scheme of the modified set of arrangements for reducing the pressure in the hermetic spaces, which arises as a result of mishaps in the primary conduit. The following are shown: (1) hermetically sealed shell, (2) limiting first space, which contains, in particular, (3) the reactor, (5) the primary conduit, (6) the steam generator, and (7) the circulating pump. By means of the channel (8) the first space (2) is connected with the second space (9). The bubbling condenser is located in the shaft part of the channel (8); it consists of the water-filled flutes (11), above which the cabinet (13) is located, from which moist air can flow through the check valve (18) into the second space (9). The active sprinkler condensation apparatus (19) is located in the first space (2); it is connected with the aid of the pressure conduit (20) to the sprinkler pump (21), usually equipped with the unnumbered check value used here. The sprinkler pump (21) draws water first from

the tank (22) and after its emptying from the sump (23), in which case the said water is first cooled on a heat-exchanger (24), and is then purified on an ion-exchange filter (2). Only the new supplementary apparatuses are given, some of which are the object in the claim of a specific protection. These are, namely: the passive autonomous subsystem of sprinkler-sprayers (26) and the passive local subsystem of sprinkler-sprayers (27), variously connected by means of the connecting conduit (28), on which the automatic isolating valve (29) with servo-drive (33), the check valves (30) and the cutoff valve (32) are installed. The improved water trap (31) can also be assigned to the new supplementary arrangement. The function of the existing set of arrangements, i.e., right up to the ion-exchange filter (25), is given in the specification for the Author's Certificate No. 177368, so it is not necessary to give it here. The function of the protected supplementary arrangement is as follows. Shortly before completion of the first stage of the mishap, i.e., prior to equalization of the pressures in the first space (2) and in the second space (9), the startup impulse (+P) is given; it is designated by a dotted line, and opens with the aid of the servo drive (33) the automatic isolating valve (29), as a result of which a discharge of water occurs from the highest-lying flutes (11) and its gravitational spraying with the aid of the passive autonomous subsystem of sprinkler-sprayers (26) and/or the opening of the cutoff check valve (32) with the aid of the sprinkler condensation apparatus (19). An intense contact condensation of the discharged steam occurs precisely in the space from which the air disappeared, which rapidly causes an initiation reduction in the pressure in

the entire first space (2) and consequently a subsequent inflow and discharge of water from the flutes (11) on the cabinet (15). Water is fed into all the sprinkler subsystems depicted through the water trap (31), constructed together with the cabinet (15) for taking the entire water volume from one horizontal group of flutes (11), and through the connecting conduit (28). With the aid of these subsystems, the water is subjected to decay and to spraying in the form of drops in the first space (2), a component part of which is also the channel (8), which consists of a horizontal corridor part and a vertical shaft part. As a result of this organization of the condensation of the steam liberated during a mishap by means of all the water suitable for use from the sufficiently highly placed flutes (11), a sudden and substantially increased drop in the pressure of the steam-air mixture occurs in the first space (2). The rapid transition to evacuation, or only to maintenance of the mode of the slight vacuum obtained in the first space (2) is also the effect of the reliable functioning of the sprinkler pump (21) here. It should also be noted that the startup impulse (+P) can be replaced or linked with a repeated opening of the check valve (18).

The preliminary considerations were used in a specific design solution of the bubbling-vacuum system of localizing mishaps in a standard APP with two water-water reactors having a heating power of 2 x 1375 MW. Each of the reactors has its localization system, represented by a bubbling condenser containing 1400 t of water in flutes arranged in 12 levels. After inversion of the difference in pressures between the steam-water mixture under the flutes and the moist air above the flutes, 1170 t of water heated to ca. 57°C

from the prior bubbling suddenly flows out. The capture and disintegration of 600 tons of the said water through the perforated plate steel of the water traps into fine streams are provided for of this amount, which according to calculations should lead to a pressure drop in the hermetic first space from a value of ca. 0.19-0.195 MPa to a value of ca. 0.14 MPa. As a result of a simple conversion for the utilization of all the water flowing from the flutes again proposed here, we obtain the value of a "final quasi-static" absolute pressure within the limits of 0.0878-0.0925 MPa, which indicates the real potential of rapidly obtaining the appropriate evacuation only with the aid of the bubbling condenser itself.

It can be assumed that after a more detailed calculation-model verification and subsequent evaluation of the above advantages of the said improved bubbling-vacuum system of localizing mishaps will have great expectations for a rapid introduction and dissemination not only in Czechoslovakia, but also in the pertinent foreign countries.

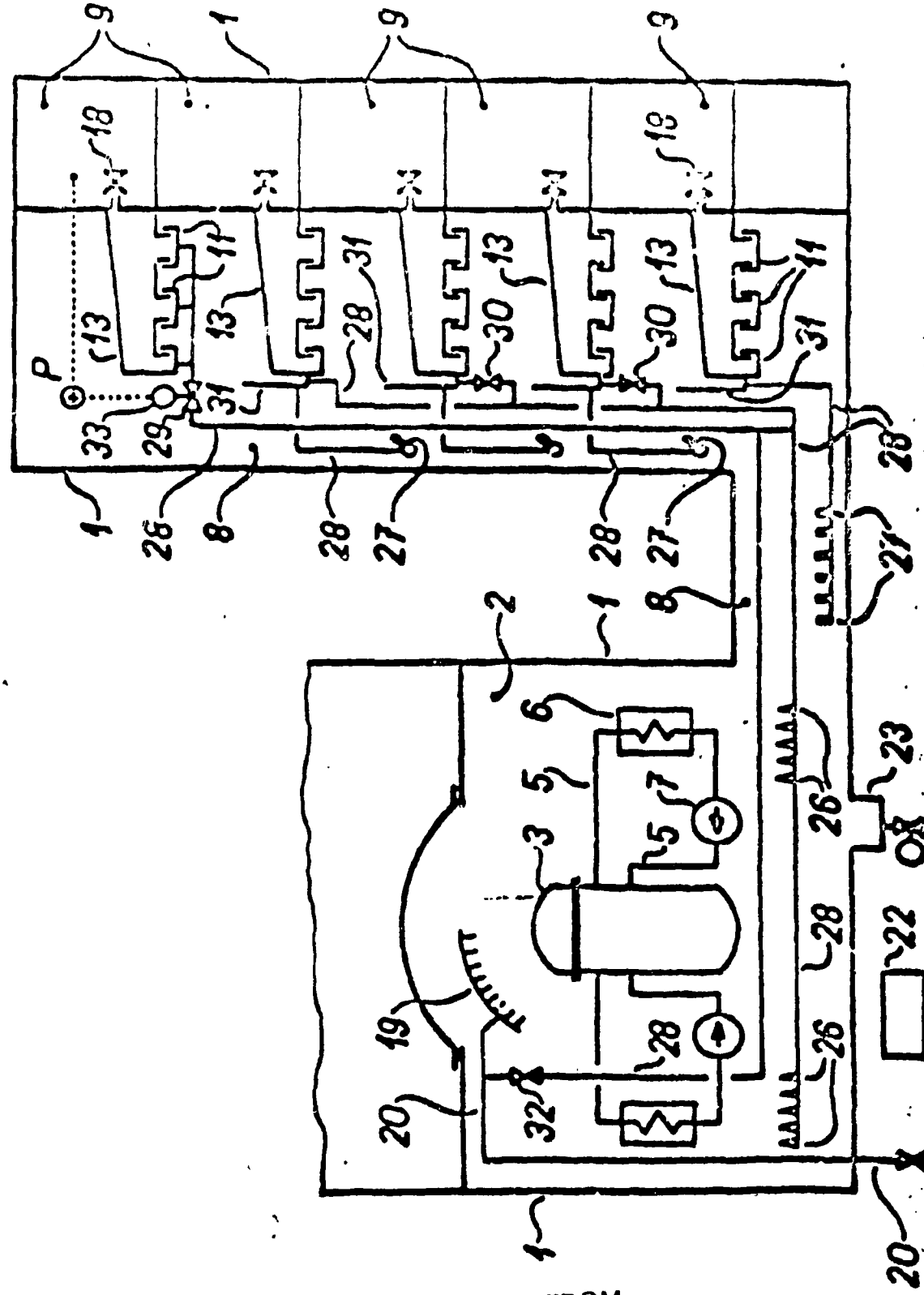

FIG. 1
Figure 1