DESIGN OF A NUCLEAR DESALINATION FACILITY FOR BUSHEHR, IRAN[1]

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Abstract

Three options of coupling schemes were evaluated in order to integrate an MSF desalination plant of 200 000 m3/day with twin PWR units of 3728 MW(th) each for the Halileh Nuclear Power Station in Iran, which were under construction at the time of the investigation: (a) The exhaust steam from a backpressure turbine is fed to the brine heater; (b) The steam extracted downstream of a reheater of the NPP is fed to the brine heater; and (c) Hot water heated by the steam exiting the high pressure turbine of the NPP is fed to the brine heater. Technical and economic advantages and disadvantages of these three options are summarized.

Halileh Nuclear Power station near Bushehr, IRAN

A contract for a dual purpose desalting plant was awarded to the Consortium of Sasakura Engineering Co., Ltd., Mitsubishi Heavy Industries, Ltd. and Sumitomo Shoji Kaisya Ltd., Japan, by Atomic Energy Organization of Iran in 1977. The construction of the two PWR units of 3728 MW(th) and 1293 MW(e) each was started. An MSF desalination plant for 200 000 ton/day (6 x 33 552 t/d) with acid treatment was designed for integration with these PWR units. The design strategy was to keep the influence on the design of the nuclear power station as slight as possible. This was the largest nuclear desalination facility which was designed and contracted at the time.

Coupling of Desalination plant and Nuclear Power Station

The influence of the desalination plant on the design of the nuclear power station must be as slight as possible. The following options were investigated.

Description of the technical options

A) Generation of process steam in a secondary steam generator by means of main steam from the nuclear power plant and expansion of this process steam in a backpressure turbine. The exhaust steam is fed into the brine heater (Figure 1). During the periods of shutdown of the nuclear power station, an oil-fired auxiliary boiler takes over the steam supply of the backpressure turbine and the brine heater. The condensate of the main steam is fed back into the steam generators of the nuclear power station and the condensate of the process steam is returned into the secondary steam generator via a separate feedwater tank.

B) Via an extraction line branching off down stream of the reheater of the saturated steam turbine of the nuclear power station, superheated steam is conducted from the nuclear power station to the seawater desalination plant. In a reducing station with downstream injection-type desuperheater, the steam is throttled down to the saturated steam pressure which is required for the brine heater (Figure 2). By means of a condensate pump, the heating steam condensate is fed back into the nuclear power station, where it is introduced into the hotwell of the condenser after passing through a condensate cooler, through which a partial flow of the turbine condensate is routed parallel to the LP feedwater heaters.

[1] Although both the NPP and the MSF plant were not completed, the design experience appears valuable and is included here for the benefit of the readers.

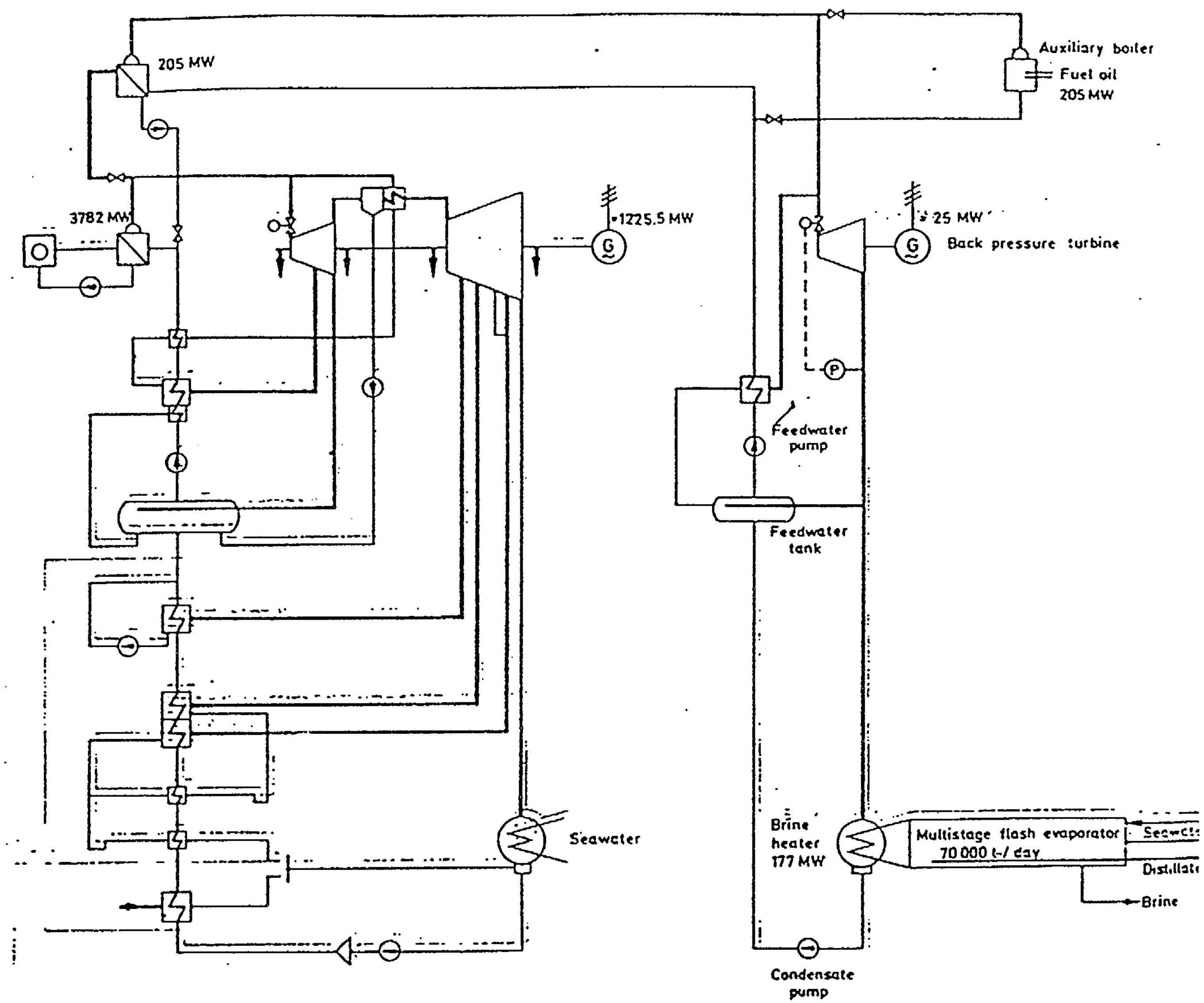

Fig. 1. Combination of a nuclear power plant (PWR) with a desalination plant (MSF) (Option A).

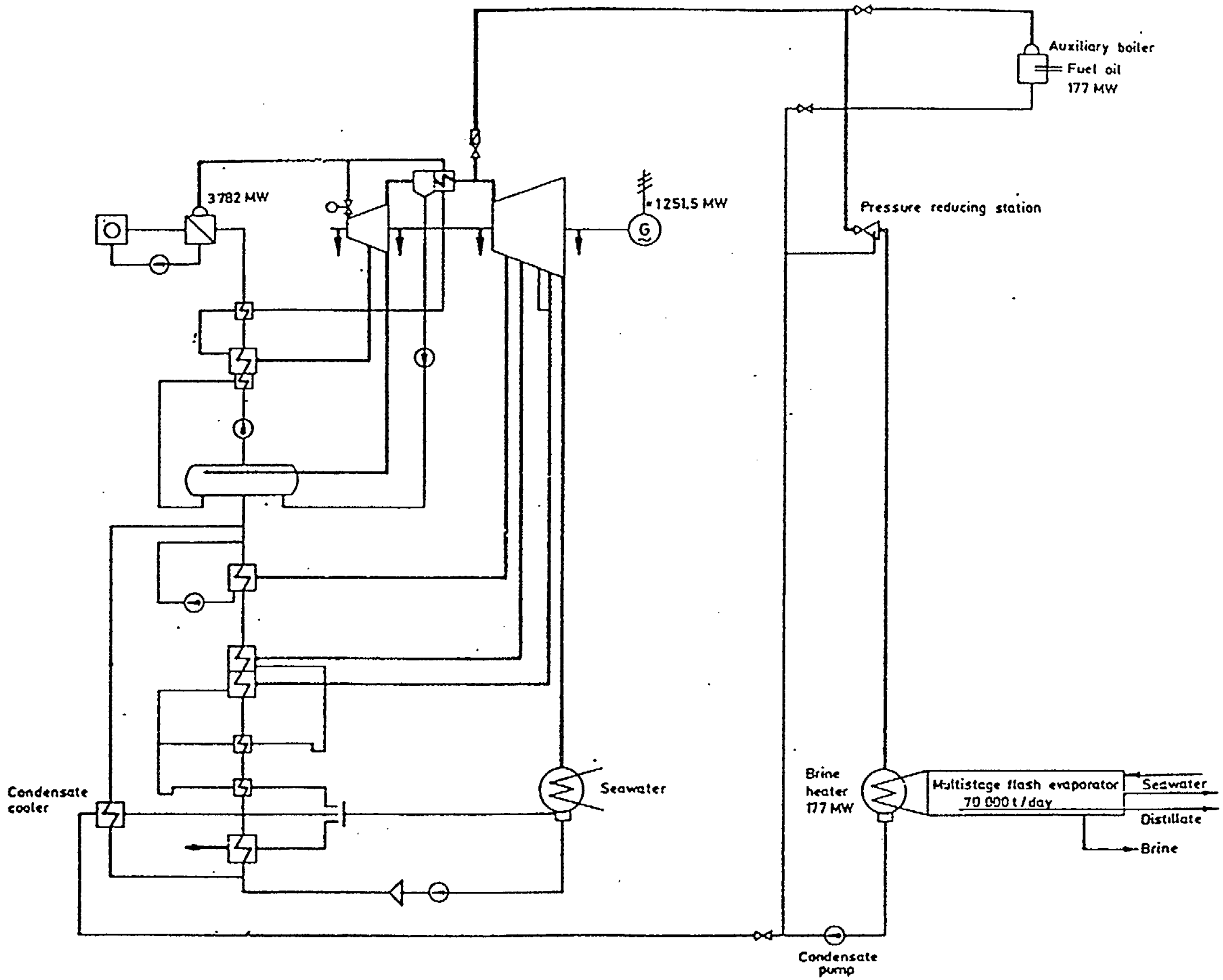

Fig. 2. Combination of a nuclear power plant (PWR) with a desalination plant (MSF) (Option B).

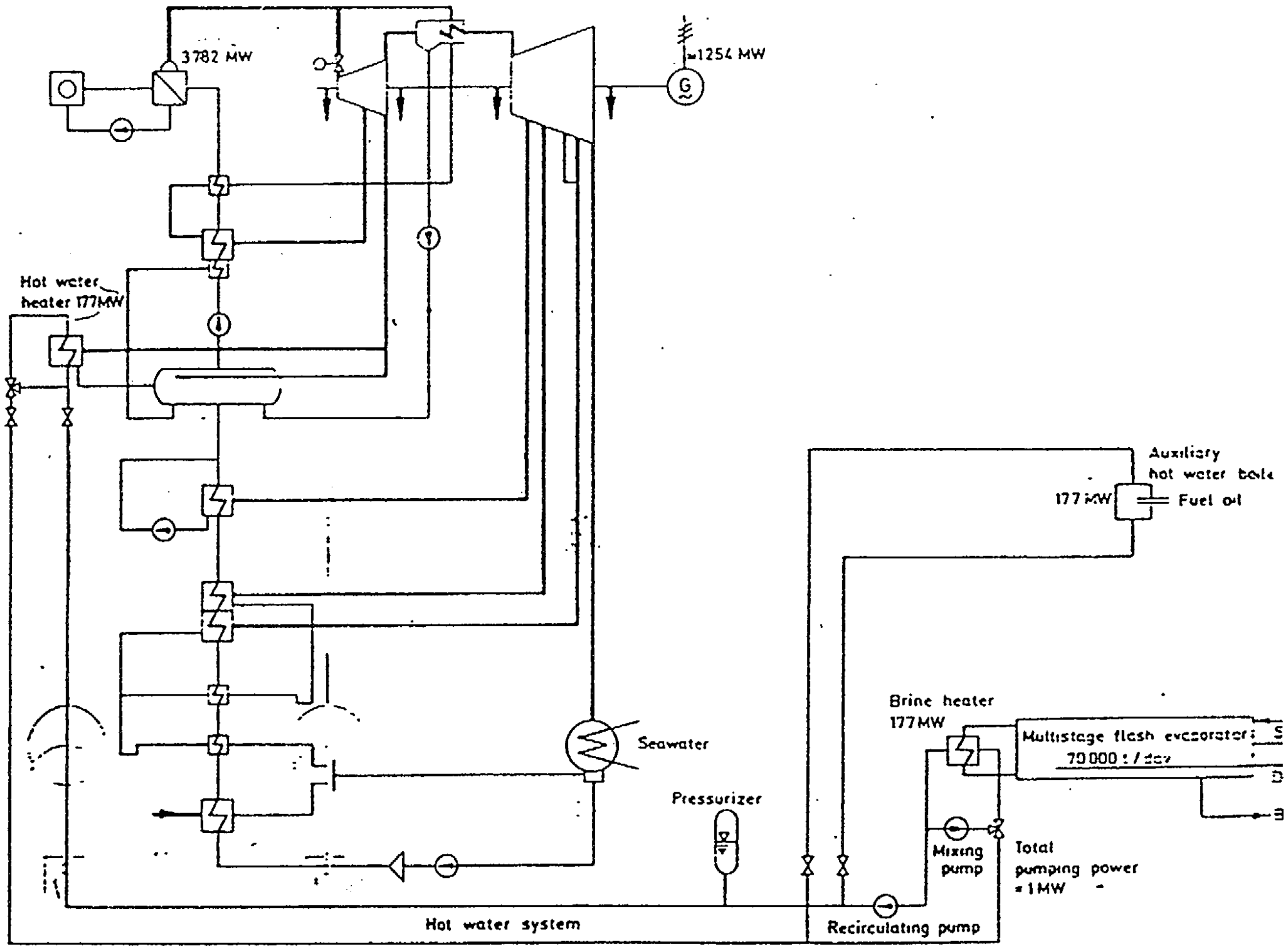

Fig. 3. Combination of a nuclear power plant (PWR) with a desalination plant (MSF) (Option C).

The steam of the nuclear power station will contain practically no radioactivity, because the steam generators will normally work without leaks. On top of these two radioactivity barriers, a pressure gradient from the brine to the process steam ensures that even in case of leakages no radioactivity can enter the brine and the distillate generated from it. An oil-fired auxiliary steam boiler supplies the heating steam for the brine heaters when the nuclear power station is shut down.

C) Heating the brine heaters by means of hot water which is heated in a hot water heater by steam exiting from the HP turbine (Figure 3). The pressure selected for the hot water system is higher than the pressure of the brine in the brine heaters and is also higher than the pressure of the steam in the hot water heater. If any leakages should occur, neither brine nor steam can penetrate into the hot water system and charge it with salt or make it radioactive. An oil-fired auxiliary hot water boiler takes over the heat supply of the seawater desalination plant when the nuclear power station is shut down.

Advantages and Disadvantages of the Solutions

A disadvantage of solution A is that the required large secondary steam generator cannot be accommodated in the turbine house without considerable design changes. This difficulty does not arise in the case of solutions B and C.

The installation, in the case of solution A, of a further small turbine-generator set with approximately 25 MWe also causes a complication as regards operation and maintenance which does not occur with solutions B and C. This complication is not justified for the relatively small amount of additional electric energy generated.

For solution A, steam at 10 bar is extracted when the turbine is at full load, whereas only 3 bar steam is required for the desalination process. The low efficiency of the small 25 MWe turbine generator set compensates fully for the throttling losses of solutions B and C.

The only occasion when the power/process heat combination of solution A is better than that of solution B and C is when the nuclear power station is operated at partial load below 50%. In this case the extraction steam pressure drops so far that it is necessary to use throttled main steam for solutions B and C.

The power supply of the seawater desalination plant is practically always assured by interconnecting to both nuclear power units Iran I and II. Even in the unlikely event of short shutdown period of both reactors, there is still power from the electrical grid available, which is in any case necessary for supply of start-up power to the nuclear power station.

There is also no essential difference between the two solutions as regards the reduction of power generation or the consumption of electric energy. In the case of solution B, the reduction of power generated in the nuclear power station is 2.5 MWe higher, but the hot water circuit in solution C has an additional energy consumption of approximately 1 MWe, which results in a partial compensation of the aforementioned disadvantage of solution B.

The initial expenditure for solution C is only slightly higher than for solution B, because the auxiliary hot water boiler is cheaper than an auxiliary steam boiler and the expenditure for the hot water circuit is thus almost compensated for. The remaining small difference is fully compensated for by the difference in power consumption (1.5 MWe).

In the case of the Halileh plant, the result of all aspects dealt with so far was that solution B (steam) and solution C (hot water) were practically equivalent. It is true that with the present level of technology it also appears perfectly possible to implement solution B, but the additional operating safety of solution C is a relevant point in its favour, particularly since this would be the first time that a combined NP and desalination plant of this type would be constructed.

In addition to this the operation of a hot water system is very simple. It corresponds to the operation of district heating plants which have often been constructed in connection with power stations.

Finally, it may be mentioned that, because of the large heat capacity of the hot water system, the dynamic behaviour of the nuclear power station and of the seawater desalination plant are almost disconnected, with the result that quick changes in one plant do hardly affect the other plant and can easily be controlled.

Because of the advantages described above, the decision was taken in favour of solution C with the hot water system. This solution would be the safest, simplest and most reliable one in operation.