PAPER NO. 4.10.

HOW TO HANDLE STATION BLACK OUTS

Frigyes Reisch
Swedish Nuclear Power Inspectorate
S-10252 Stockholm

Station black out is defined as the loss of all high voltage alternating current at a nuclear power site. An international study was made to survey the practices in the different countries. The best way to handle station black out is to avoid it therefore briefly the normal off site and emergency on site power supplies are discussed. The ways in use to enhance nuclear power plants using Boiling Water Reactors or Pressurized Water Reactors to cope with a station black out are discussed in some detail.

RESUME

Comment traiter la perte complète des alimentations électrique externe-interne dans une cetrale nucléaire.

La perte complète des alimentations électrique externe-interne est definie comme le manque de tout le courant alternatif de haute tension dans un site nucléaire. Un rapport international a été preparé pour étudier les pratiques de certains pays industriels. La meilleure méthode de traiter la perte des alimentations électrique externe-interne est l'eviter, pour cela la normale alimentation électrique externe et les sources de secours électriques internes sont discutées brièvement. Les methodes qui sont employées pour renforcer les centrales nucléaires - qui utilisent les réacteurs avec l'eau bouillante ou les réacteurs avec l'eau sous pression - pour élucider la perte complète des alimentations électrique externe-interne sont discutées dans certain detail.

HOW TO HANDLE STATION BLACK OUTS

1. Introduction

During this conference and also in the litterature (1), (2) the high reliability of the normal off-site and emergency on-site electrical power supplies has been described in details.

However high reliability does not mean certainity i.e. that electricity is always available at a nuclear site. Therefore studies (3), (4) were made to examine the nuclear power plants capacities to withstand the simultaneous loss of all external and internal power sources.

Every nuclear power plant can survive unharmed the deprivation of its electrical sources for a limited time. Further there is equipment in use which enhance the possibilities to keep a reactor cooled much longer time than the original design allows would a station black-out occur.

Some aspects of the normal off-site and emergency on site power sources will be discussed before introducing the different solutions which increase the time a nuclear station can stand a station black-out.

2. Normal off-site and emergency on-site power supplies.

Most of the world's nuclear power plants are using two high voltage connections to the grid as normal off-site power supply and two diesel generators as emergency on-site power supply (see Figure 1). The causes of the loss of high voltage off-site power supply is divided into the following groups
- failure at the plant itself
- grid failure
- severe weater conditions

Statistics has shown that one loss of off-site power supply occured per 10 years and reactor. This figure varies widely from site to site nevertheless probably as an average value can be expected for the future. With more then 500 reactors in operation and under construction quite a few loss of off-site power occur every year at nuclear sites.

The backbone of the emergency power supply is the diesel generators. The causes of their failures are divided into the following groups
- hardware
- operation
- support system
- external

Diesel generators are tested often, therefore there is plenty of data to make statistics. As an average a diesel generator fails to operate two times out of 100 demands. An average repair takes about 8 hours. Using the statistical values the range of unavailability of the emergency on-site power is estimated to be of 10^{-4} to 10^{-2} per demand.

According to analyses the range of frequency of station black-out is estimated to be of 10^{-5} to 10^{-3} per year. Until now about 4.10^{3} reactor years are accumulated and 2 station black-outs were reported.

The best way to handle a station black-out is to avoid it. This can be done by improving the reliability of the off-site and on-site power supplies. The major factors are as follows
- training of the personal
- redundency and
- diversity of the on-site and near by power sources.

Should a station black-out occur, every effort should be made to recover the normal and emergency power supplies as soon as possible.

3. How to handle a station black-out.

Every nuclear power plant can stand unharmed a station black-out for a short time even without additional cooling water because the heat capacity of the coolant in the reactor vessel can absorb the residual heat for a while without the core beeing uncovered. The duration depends on the past history of the core. However many PWRs and BWRs have equipment facilitating core cooling for a longer time in spite of a station black-out. For both reactor types however there are some prerequisities which are inevitable to cope with a station black-out of longer duration, these are:
- trained personal
- sufficient battery capacity
- sufficient water storage capacity
- sufficient compressed air capacity

3.1 Pressurized Water Reactors ability to cope with station black-out

The classical PWR design contains one steam turbine driven auxiliary feed water pump, see Figure 2. Granted the earlier mentioned prerequisites are provided such a station can stand a station black-out for several hours. However, make up water is not supplied to the primary system. If a primary leak occurred the situation could quickly deteriorate.

Therefore some stations are equipped with one more turbine generator feeding the electrical motor of a high pressur pump which inject water to the seals of the reactor coolant pumps thus compensating for an occasional loss of primary coolant. The same generator charges the batteries too, see Figure 3. This configuration can endure station black out for much longer time than the original design.

Some PWRs got no steam driven auxiliary feed water pumps. Those stations are equipped with emergency feed water pumps driven directly by diesel engines and located in an emergency feed water building, see Figure 4.

3.2 Boiling Water Reactors ability to cope with stations black-out.

The older type of BWRs are equipped with an isolation condenser, see Figure 5. As long as feed water is supplied to the shell side the residual heat is removed. However there is no replanishment of the primary water.

This is taken care of at the later design, see Figure 6. Here a steam turbine driven high pressure pump can take suction either from the condensate storage tank or from the suppression pool and inject water into the reactor thus taking care of the core cooling and compensate for an occasional primary leakage.

An example of up dating an older BWR is given in Figure 7. There are originally installed redundant steam turbine driven high pressure core spray pumps, however they are booster coupled with electrical motor driven pumps connected to the safety buses, thus they cannot be used during a station black-out. Lately an electric motor driven high pressure coolant injection pump was installed, the motor is the only object connected to a dedicated diesel generator, this pump together with a steam turbine driven auxiliary feed water pump assures core cooling at a station black-out event.

4. Conclusions

Nuclear power plants can stand a station black-out. However the duration they can cope with depend on the preparations made previously to meet such an eventuality.

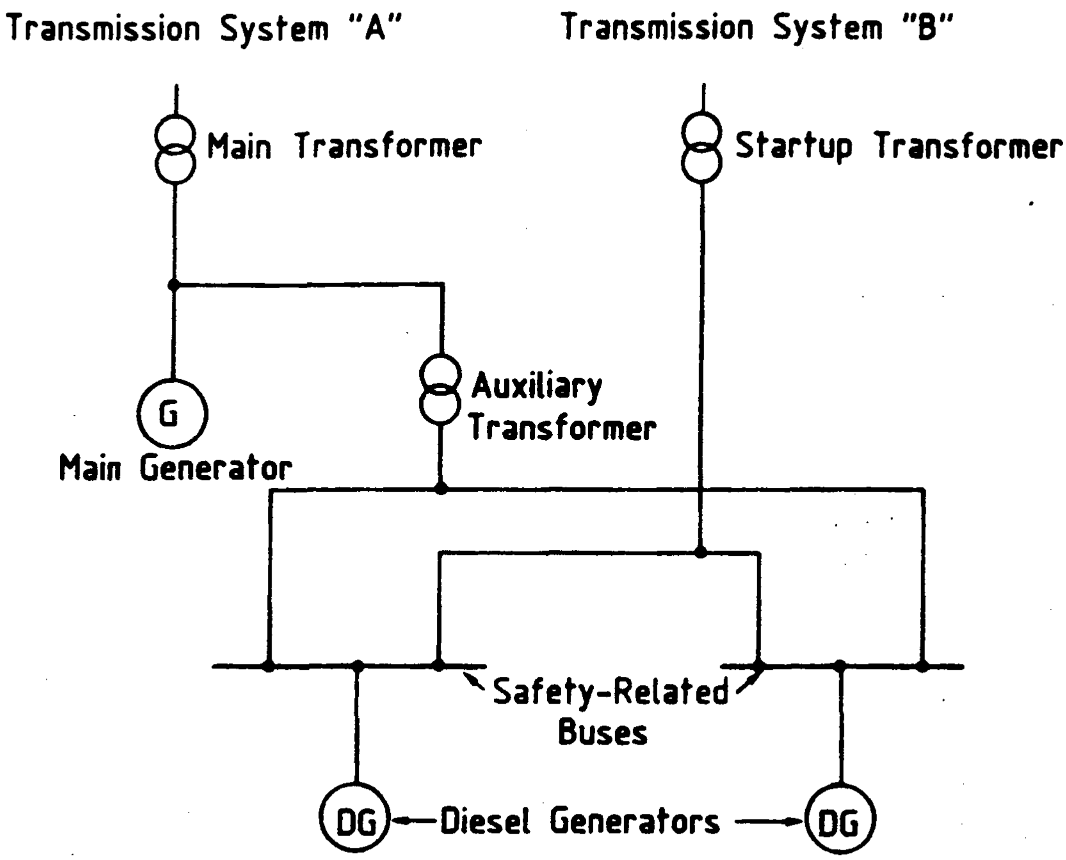
References:

1) NRC, Evaluation of Station Blackout Accidents at Nuclear Power Plants. NUREG 1032. NRC Washington DC USA, Jan 1985

2) Reisch, F. "Sweden's December 1983. Grid Collapse and the Nuclear Power Plants' Responses". Nuclear Safety, vol. 26, No 2, p 153, March-April 1985.

3) IAEA, Safety Aspects of Station Blackouts at Nuclear Power Plants, TECDOC -332, IAEA, Vienna, March 1985.

4) Reisch, F. "Coping with Station Blackout". Nuclear Engineering International, October 1985.



(a)

Figure 1.

Simplified diagram of nuclear power plant normal high voltage off-site and emergency on-site AC electrical power supply

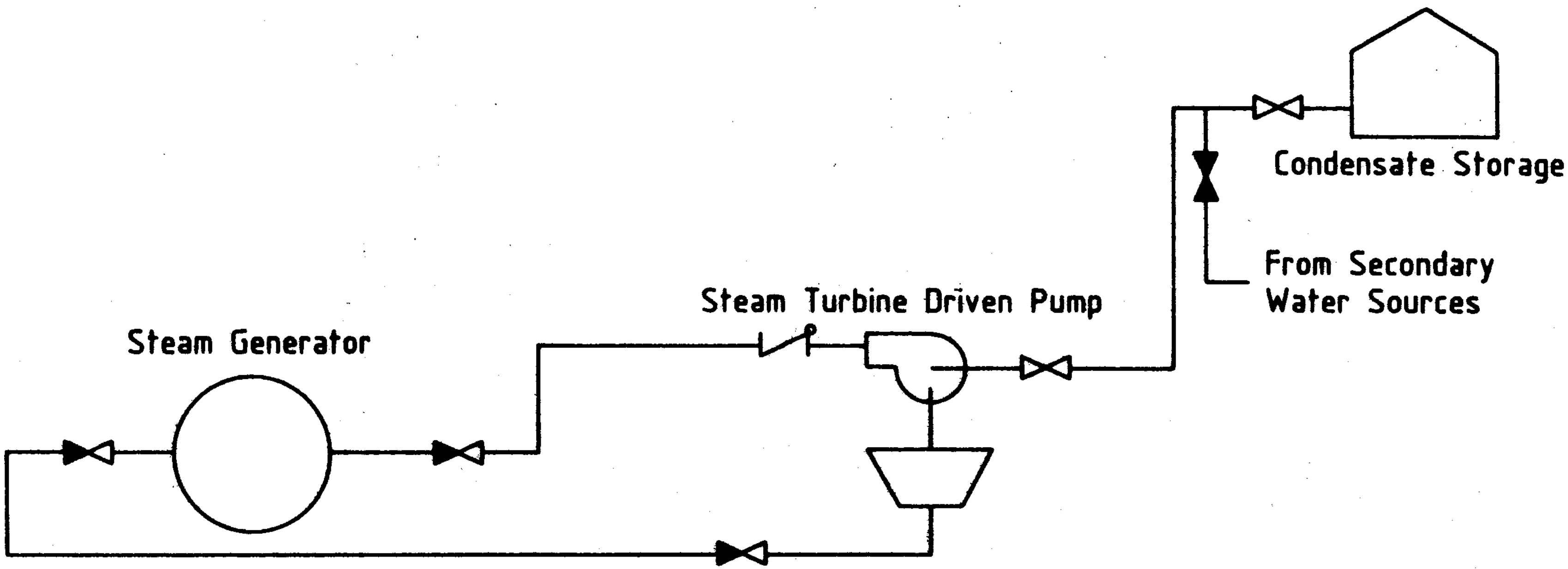


Figure 2

Simplified flow diagram of steam turbine driven auxiliary feedwater system for pressurized water reactor

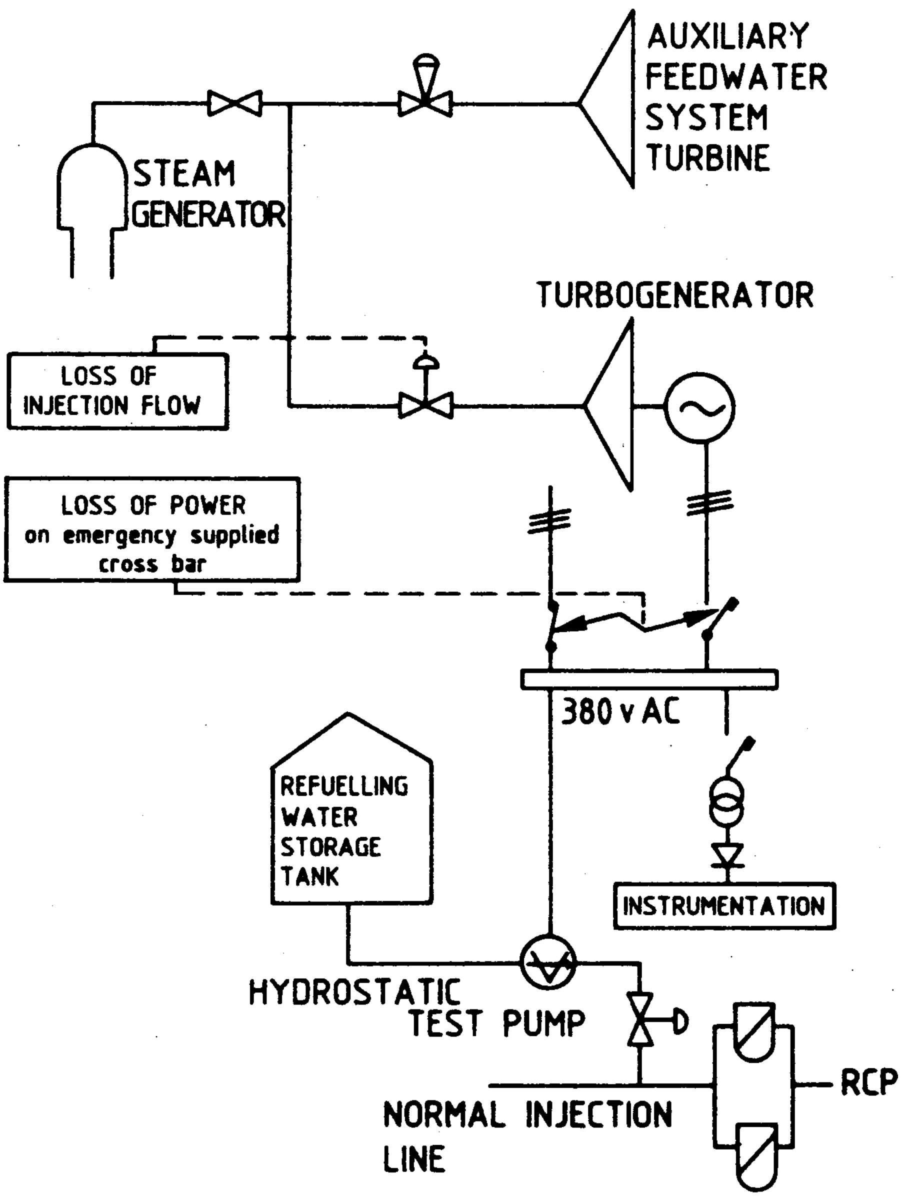


Figure 3

Simplified flow diagram of PWR with two steam driven turbines

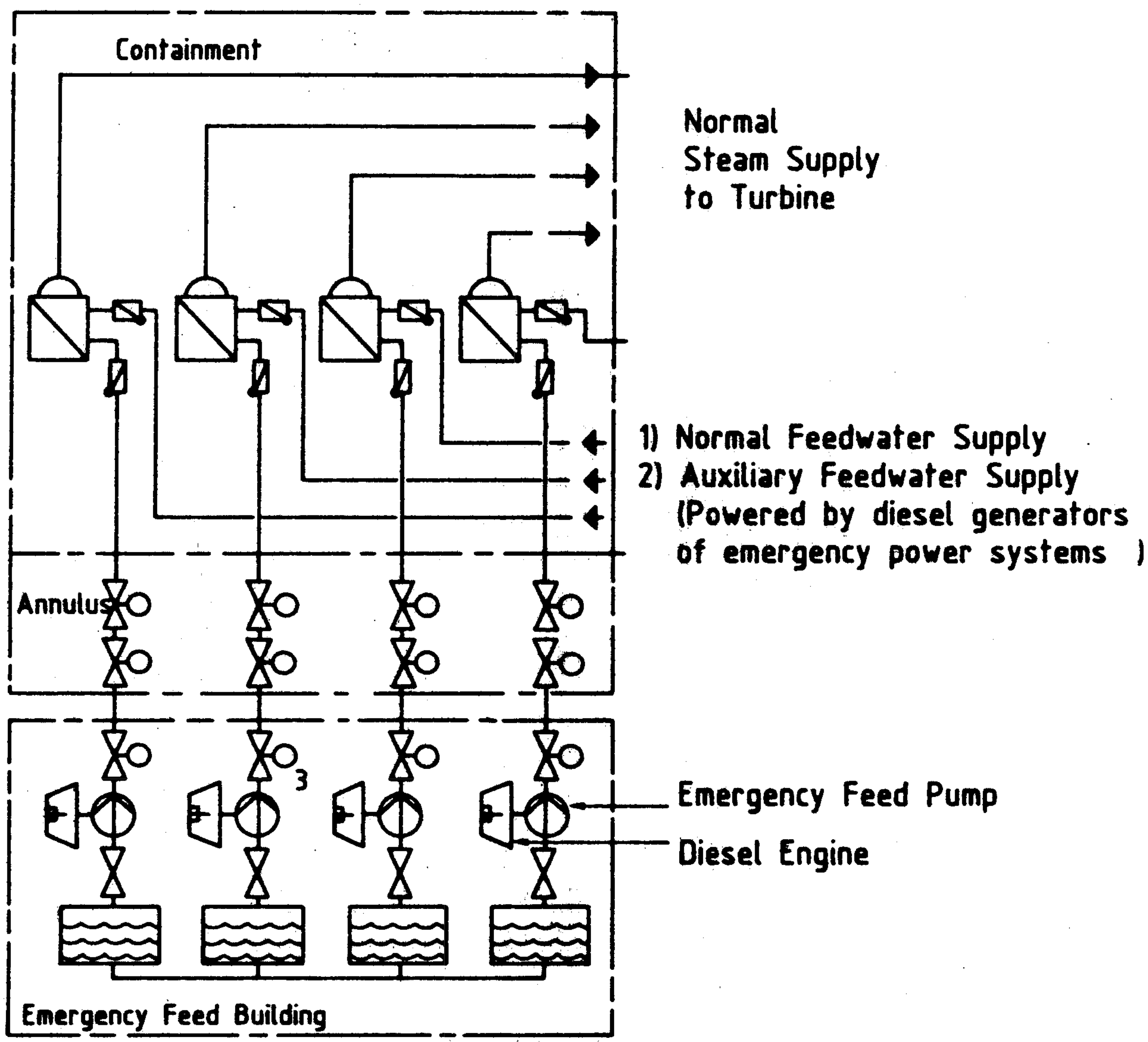


Figure 4

Simplified flow diagram of PWR plant with emergency feed building

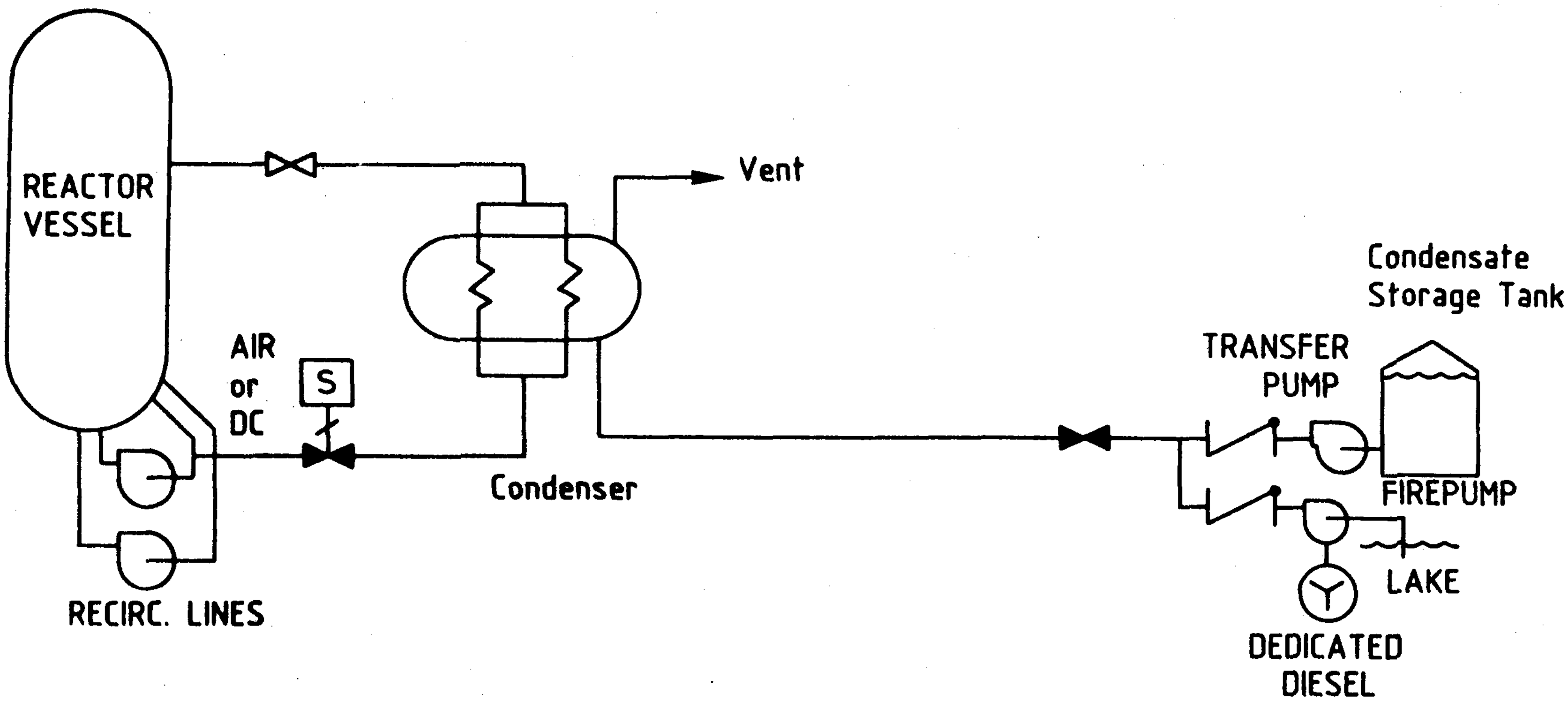


Figure 5

Simplified diagram of typical isolation condenser design for boiling water reactor

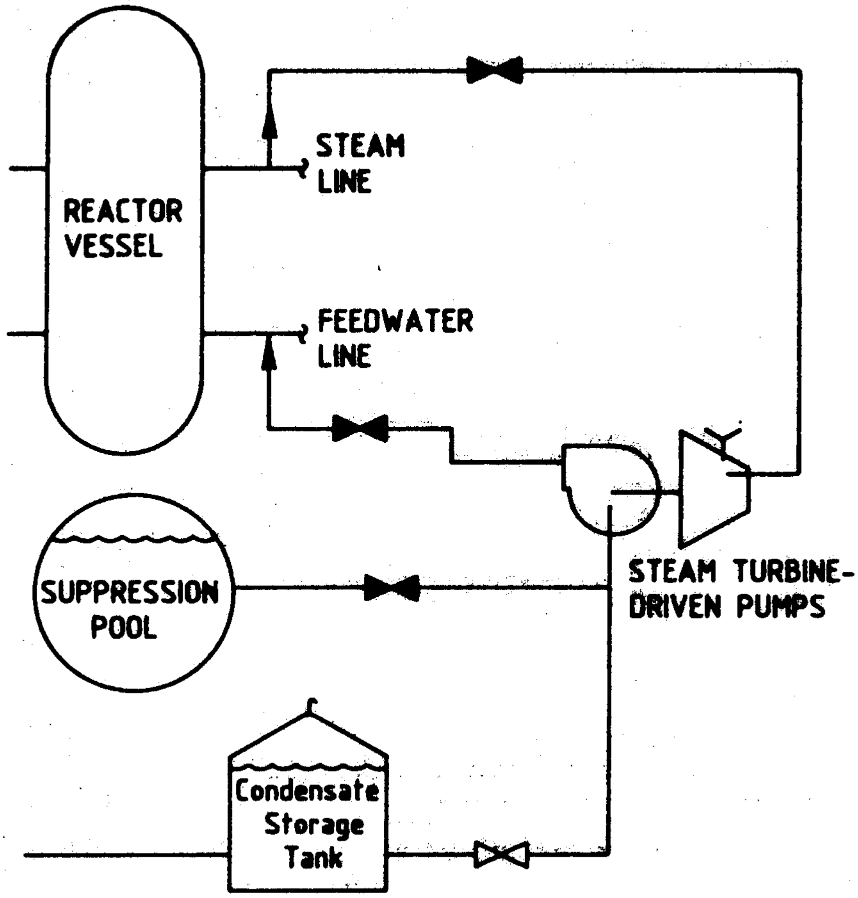


Figure 6

Simplied flow diagram of steam turbine driven high pressure coolant injection system for BWR

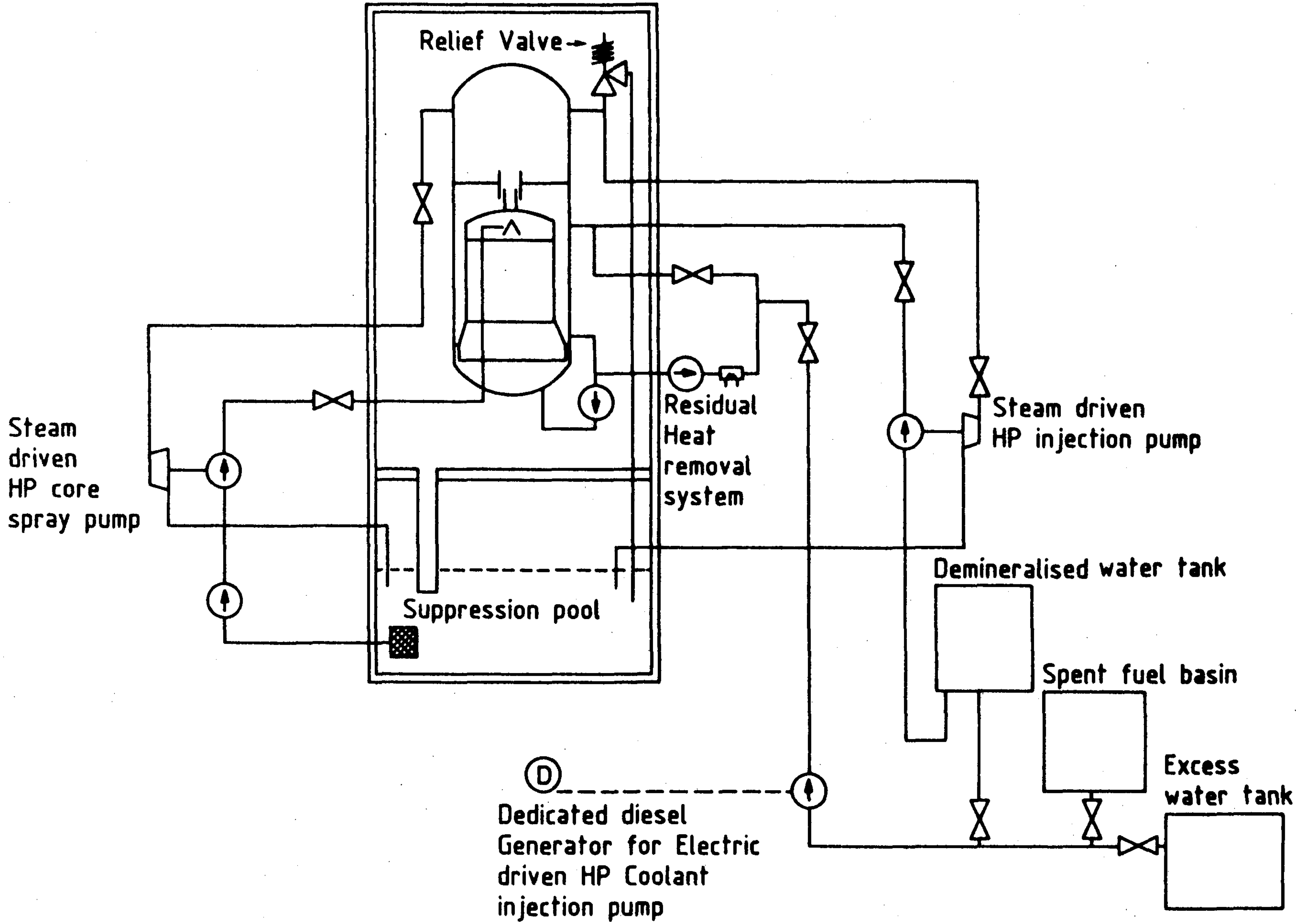


Figure 7
Example of BWR core cooling systems including systems independent from AC busbars