NUCLEAR SAFETY DIRECTORATE - BUSINESS MANAGEMENT SYSTEM		
TECHNICAL ASSESSMENT GUIDE **HEAT TRANSPORTER SYSTEMS**		**T/AST/037** ISSUE 001
Approved By: *B J Furness*	B J Furness	Issue Date: 10/05/99
Open Government Status: Fully Open		Review Date: 10/05/02

1. Purpose and scope

1.1 This Assessment Guide is intended to support the Safety Assessment Principles[1] and to provide general guidance on the main issues to be addressed by nuclear inspectors in the assessment of safety submissions relating to the provisions for the transport of heat generated from a variety of sources, and transmitted through intermediate hot bodies to an ultimate heat sink. The Guide applies to all systems that contribute to the safe transport of heat, by absorbing heat, by accumulating heat, by conveying heat, by providing power or by supplying fluids to act as a medium for the transport of heat including applications in both power reactors and nuclear chemical plant.

1.2 The Guide is broadly applicable both to new plant throughout the design, construction and commissioning phases, and to existing operating plant originally built to standards applicable at the time of their design. Because of development in safety standards, existing plant may not comply in every respect with current standards. Where this is the case other factors such as the age of the plant and projected lifetime may be taken in to account in demonstrating ALARP. For power reactors the Guide covers the heat transport role of the reactor coolant system (RCS), the transport of heat to the energy converter (eg turbo-generators) and finally the removal of residual heat to an ultimate heat sink, together with a range of auxiliary and intermediate heat transfer systems. For nuclear chemical plant, the Guide addresses the requirement to provide or remove heat from the relevant stages in the particular process to ensure that an energy balance is maintained and controlled at an acceptable level.

1.3 The Guide does not extend to the detailed design, categorisation, qualification or specification of individual components or systems, particularly in relation to their ability to perform their safety function. What it does do is consider the duty identified for safety related components or systems, in the broad terms of the safety functional requirements intended by incorporation of a component or system into the overall design of heat transport systems for nuclear installations.

1.4 As for all guidance, inspectors should use their judgement and discretion in the depth and scope to which they employ this guidance. Comments on this guide, and suggestions for future revisions, should be recorded on the appropriate registry file.

2. SAPs addressed

2.1 Safety assessment principles P243 to P259 in reference 1 are relevant to heat transport systems.

2.2 For power reactor applications, the RCS (see **Table 1**) and its associated systems (see **Table 2**) have the primary safety objective of ensuring that the fuel in the core is cooled by an appropriate coolant for all operational states and identified fault conditions. In addition, an intact RCS including its integral components and features, should act as a barrier to limit the loss of heat transport fluids and radioactive inventory, particularly by way of a release to the atmosphere.

2.3 The majority of additional power reactor heat transport systems (see **Table 3**) are present to ensure that all other sources of heat generation are cooled sufficiently to ensure that the safety systems they serve are capable of performing their safety function under all operational and identified fault conditions, eg residual heat removal system. However, where background or trace heating is required, heat transport systems may also be required to perform this function.

2.4 In the case of nuclear chemical plant, the heat transport systems are generally present to ensure that appropriate quantities of heat are supplied or abstracted to maintain the required process conditions, and ensure that the plant operates and performs its safety function in the necessary range of plant states considered in the design.

2.5 The treatment given to heat transport systems in the SAPs, should not be regarded as necessarily complete. The specific principles are intended to address issues of particular significance relating to the adequate provision of systems to control and regulate the heat flows within the nuclear application.

2.6 Additional or related issues not directly addressed in the SAPs may be of equal importance in specific circumstances and these aspects of a thorough nuclear safety assessment may need to be identified and considered by the experienced and qualified nuclear assessment inspector.

3. Relationship to licence and other relevant legislation

3.1 Licence Condition (LC) 14: Safety Documentation - The safety case for the plant, including the justification of heat transport aspects, is produced and assessed by the licensee under this condition, which also requires documentation to be submitted to HSE on request.

3.2 Licence Condition (LC) 15: Periodic Review - The adequacy of the safety case, including heat transport aspects, should be reviewed against the current operating conditions and statutory requirements to ensure that there has been no significant change (eg increase in fouling, tube plugging etc sufficient to invalidate the safety case).

3.3 Licence Condition (LC) 19: Construction or Installation of New Plant - The design of the heat transport system should be considered at an early stage, and appropriate testing should be carried out to ensure that the systems meet the design specification.

3.4 Licence Conditions (LC) 20 and 22: Modification to plant - Such modifications should be assessed to ensure that they do not impact adversely on the design heat transport capability of the plant.

3.5 Licence Condition (LC) 21: Commissioning - Appropriate commissioning tests should be carried out to ensure, for example, that design criteria have been met.

3.6 Licence Condition (LC) 23 and 24: Operating Rules and Instructions - These will be required, for example, in respect of availability of heat transport systems.

3.7 Licence Condition (LC) 25: Operational Records - These may include, for example, records of temperatures, pressures and flow rates of heat transport fluids.

3.8 Licence Condition (LC) 27: Safety Mechanisms, Devices and Circuits - The suitability and sufficiency of the heat transport systems should be assessed to comply with this condition.

3.9 Licence Condition (LC) 28: Examination, Inspection, Maintenance and Testing - It is expected that heat transport system components such as pumps, valves and heat transfer surfaces would form part of the licensee’s site-wide arrangements under this licence condition.

4. Advice to assessors

4.1 General

1) It is particularly important in nuclear applications to ensure, so far as is practicable, that safety related equipment will perform its function safely and with an adequate reliability despite the potential for the occurrence of a significant number of identified faults and/or hazards. This objective may be achieved by the adoption of a number of different plant and equipment provisions, together with the use of techniques to evaluate the adequacy of the specified measures.

2) In assessing the fitness for purpose of safety related plant, and particularly the ability to perform a primary safety function, a number of issues relating to the safe transport of heat are of major significance and need to be considered. A distillation of the more important criteria to judge the acceptability of specific safety related provisions in this respect are briefly discussed in the following text, and covered in more detail in Appendix I.

3) Heat transport systems are primarily provided to ensure, so far as is practicable, that heat flows for specified processes are controlled and remain in balance including flows both within and across the overall system boundary. Where heat flow is not balanced, within acceptable limits, there is the possibility of heat accumulation within the system boundary, having the potential to provide a serious challenge to the integrity of the plant. Such a situation may be caused by the occurrence of normal process variations, a malfunction, or a fault/hazard, and may result in a release of radiation to the atmosphere in the event that the containment barriers or plant safety limits are breached. The likelihood of such a potential release needs to be assessed so that tolerability of the various outcomes associated with the operation of the installation can be judged. In addition, any risk to the workers within the site boundary needs to be considered and predictions judged against appropriate criteria. These matters are considered in greater detail in **Appendix 1**, in the SAPs, and also in assessment guide T/AST/030.

4) In addition to this probabilistic treatment of the risk arising from the design of an installation, attention should be paid to the appropriate codes, standards and methods used in specifying the deterministic plant design. Frequently, deterministic design criteria contain unquantified pessimisms, since they develop from the safe operation of plant without the need for a precise knowledge of an actual design capability. However compliance with accepted codes or standards is often a useful indicator of a basically sound design. In any assessment of heat transport systems for nuclear application any reliance on these possible contributors to the plant design and specification process need to be established.

4.2 Identification of Heat Loads

A primary requirement in any assessment of the heat transport provisions at nuclear installations, requires the identification of all forms of heat load likely to affect a particular process. This assessment is best achieved by the licensee and should include identified heat sources and sinks, together with any energy conversion processes, designed or inherent, which have the potential to affect the heat balance throughout the process. Compilation of a schedule of such heat loads may then be useful in demonstrating the cooling requirement of a process and the level of cooling margin present in the measures provided to perform this function.

4.3 Maintaining Cooling Capability

1) Most often the process cooling medium is an appropriate fluid, which has the potential to leak from its containment and mix with the surroundings. The consequences of this occurrence need to be considered, in terms of possible adverse reactions with the surroundings generating additional heat, the system ability to maintain its cooling function and any possible radiological consequences.

2) Where the heat transport fluid is pressurised water or steam, successful cooling may depend on the fluid pressure being kept within an acceptable range related to saturation temperatures. It should be ensured that this range can be maintained by the pumps delivering feed

water and by the valves controlling the discharge pressure and that the heat removal system can withstand the fluid pressures and temperatures generated.

3) Where there is doubt about the cooling capability of a faulted heat transport system, or its reliability, alternative measures should be provided to back-up the primary provision in the event that the safety function requires it. In some circumstances where a particular heat transport system contributes fundamentally to plant safety, then it may be prudent to provide back-up systems regardless of predicted plant reliability and performance. Particular examples of heat transport systems with important safety functions are discussed further in Appendix 1 and in the supporting references.

4.4 Monitoring Coolant Provision and Condition

1) Loss of coolant in a heat transport system has the potential to allow local heat accumulation which may challenge a system safety function and may dramatically increase the risk from the plant. To guard against excess coolant loss, safety systems should include a means of monitoring coolant levels to facilitate early detection of reducing levels.

2) On detection of coolant loss, reserve supplies of coolant should be available to provide make-up or an alternative cooling provision. Such measures should be capable of responding in the time scales required to prevent rapid progression of a routine make-up requirement or a fault scenario. In some applications it may be necessary to provide separate safety systems to provide appropriate cooling provision in the short term and in the longer term.

3) Where routine leakage, let-down, by-pass, evaporative loss or overflow can occur adequate provision needs to be made to collect the extraneous coolant, and measures taken to allow reuse if possible and safe storage if not. Where possible, coolant inventory should be adequately monitored, in order to control the total quantity of coolant resident in a safety system.

4) Where coolant is recycled, the licensee should ensure

that plant is provided to maintain the condition of the coolant within specified limits of performance. These limits should be identified by the licensee, documented and included in the procedures developed to ensure that the nuclear facility functions within specification.

5. Appendix 1 - Technical Guidance

5.1 General

1) The assessor is advised that the following sections should be considered in the assessment of the heat transport aspects of a safety case. The safety aspects described may not be totally comprehensive and may not be applicable in all circumstances. The assessor will need to utilise expertise, experience, appropriate advice and engineering judgement in the consideration of each particular safety case.

2) In order to limit potential releases of radioactivity to workers and the public to as low as is reasonably practicable from a nuclear installation, it may be necessary to set appropriate design limits to provide defence in depth against an intolerable radioactive release. In general terms this requires provisions to prevent:

i) overheating of the fuel elements or an excess of alternative sources of process heat, chemical heating or nuclear heating;

ii) loss of integrity of any primary barriers or pressure containment;

iii) loss of integrity of any intermediate barriers or additional containment provisions.

iv) loss of safety significant equipment.

1) In deciding what constitutes a tolerable potential release of radioactivity to workers and the public, guidance should be obtained from the SAPs, and particularly T/AST/030.

2) To reduce the risk of an unacceptable release of radioactivity to workers and the public, it is likely that the design of heat transport systems will need to possess a number of important features which are intended to improve system reliability and enhance the safety functional performance of the plant. These characteristics are likely to include a number of the following:

v) appropriate level of inherent system and functional reliability;

vi) satisfactory performance against the single failure criterion;

vii) inclusion of appropriate levels of redundancy into the safety system;

viii) incorporation of diverse equipment into redundant trains where possible;

ix) segregation of redundant trains of equipment where possible;

x) ensure functional independence where necessary;

xi) inclusion of principles of a fail-safe design;

xii) provision of auxiliary safety system back-up;

xiii) appropriate safety categorisation/ classification of plant and equipment;

xiv) employ robust provisions for faults and hazards.

1) These aspects of safety system functional performance are covered in detail in other Assessment Guides.

2) In order to assess the adequacy of heat transport provisions, it is necessary to identify potential heat sources and sinks within the system boundary. Heat loads and design temperature limits should be

considered. Consideration of heat flows within a system should address the necessary range of commissioning, operational and identified fault conditions which might make demands on the heat transport systems. It may also be prudent, at an early stage, to consider any particular heat transport requirements relating to decommissioning the facility.

3) Where a quantitative assessment of the heat flows within a system is required, it should be ensured that the system capabilities are specified on the basis of a suitably pessimistic consideration, with appropriate allowances for uncertainties included in the calculational route.

4) In many locations of safety significance on a nuclear installation (eg, the main control room) the local environmental conditions are controlled by the heating ventilation and air-conditioning control system (HVAC). This system acts primarily on the air supply to a location and as part of its function will supply or extract heat as required. In any fault or accident scenario, this will often result in removal of heat from the internal atmosphere via an intermediate heat exchanger to a heat transport system exchanging heat with an UHS. For locations of primary safety significance, the heat transport function of the HVAC will need to have a high level of reliability, which will usually require the design to display many of the characteristics described in para. 4.1(3).

5.2 Power Reactors

1) The main source of heat within a nuclear power reactor results from the nuclear reaction taking place within the reactor core. The rate of this reaction is varied by adjustment of the appropriate control features which are present to impinge directly on the parameters which govern the rate of heat liberation from the nuclear fuel within the reactor core (see the assessment guide on fuel and core design). After a reactor is shutdown decay heat continues to be produced at a decreasing rate.

2) In addition, heat can be supplied from a range of other sources including heat created by mechanical work, heat supplied by chemical reactions, heat supplied by nuclear reactions outside the core (eg fuel route, etc), internal

energy released as heat and heat supplied by energy conversion processes.

3) For power reactors (with a few exceptions such as boiling water reactors) the primary means of heat abstraction from the reactor coolant system is the heat exchanger, which transfers heat from the primary to the secondary circuit. To maintain a stable process for converting the feedwater supplied to the heat exchanger into steam to be then transmitted to the turbo-generator for power production, requires that the heat flows throughout the systems are balanced and controlled. Heat production, heat dissipation and heat conversion to mechanical work and ultimately electrical energy should be sufficiently balanced and controlled so that the safe limits of the design (eg temperature, pressure, allowable stress) are not exceeded during both normal and fault conditions. The precise means of ensuring that the heat flows are maintained sufficiently in balance depends upon the specific mode of operation or fault condition prevailing at a given time. However to satisfy the intention of a defence in-depth approach to safe heat transport, prudent provision for redundancy, diversity and independence etc, within the design, is required (see para. 4.1(3) and T/AST/036).

4) The provisions for ensuring plant safety, particularly in fault conditions where the primary provisions for adequately controlling heat flows may not perform their design safety function as intended, will essentially be the provision of back-up heat sinks or heat removal systems to ensure adequate cooling at all points in the process. To achieve this, all of the potential heat sources or points of potential heat accumulation as may occur throughout the heat transport systems need to be identified. This having been done, measures should be provided to ensure that sufficient safety systems are in place to be confident to an acceptable level, that sufficient cooling capacity is available to provide a robust design displaying defence in depth.

5) Ultimately, all heat not converted in the energy conversion process or absorbed by the surroundings, needs to be exchanged with a final heat sink to prevent unacceptable temperature rises in the plant. The general

requirement for this heat sink, is that it has a sufficiently large heat capacity not to be significantly affected by the absorption of heat from the relevant processes so that its thermal properties and conditions remain essentially independent of the particular or related nuclear process. Such a heat sink is usually referred to as an ultimate heat sink (UHS). Two common forms of UHS are, substantial bodies of water (rivers, lakes or the sea) and also the atmosphere.

6) Clearly the role of the UHS is essential in maintaining the heat flows under adequate control throughout the relevant processes, since without it heat may accumulate at a point in the thermal cycle not designed to withstand it. For this reason it is sometimes considered necessary for nuclear safety reasons, to make a redundant provision for heat transfer to an ultimate sink by using both water cooled and air cooled safety systems.

7) In addition to heat transfer achieved through the provision of heat transport systems as part of the design, heat transfer will also occur by fundamental natural processes. These include heat conduction, convection and radiation, coolant phase changes and potential removal of heat by the allied process of mass transfer. It is unlikely that the contribution to the overall transfer of heat from these processes will be substantial by comparison to the systems incorporated into the design, but their role may be of safety significance particularly in a fault situation, and should therefore be considered.

5.3 PWR Reactor Types

1) For the PWR reactor the primary means of heat transport from the heat source (nuclear fuel), is the reactor coolant system (RCS). In this case it is essential that the chemical and thermal properties of the coolant are maintained within specified limits to ensure that fuel clad temperatures do not exceed safe levels. Application of the plant design features mentioned in para. 4.1(3) require the provision of measures to ensure a high level of system reliability to reduce the likelihood of the system capability being exceeded for all operating modes and identified fault conditions. This is achieved primarily by including adequate provisions to promote system

performance including control of flow direction within the RPV, coolant make-up, let-down and excess heat abstraction from supporting safety systems to ensure safe heat dissipation.

2) Such provisions are also required for non-power producing operational modes, and in this case the heat accumulated in the RCS and the residual heat from the fuel will also need to be controlled at an acceptable level. These operational modes are unavoidable, and consequently the systems provided to perform this function are of prime importance in ensuring adequate cooling and therefore require high levels of system functional reliability.

3) Where the overall structure of the primary circuit has suffered a significant challenge to its integrity a loss of coolant accident (LOCA) may result and therefore a separate means of providing essential cooling both in the short and long term needs to be present and each of these provisions will need to possess an adequate level of reliability whilst demonstrating a robust deterministic design basis. The need for provisions to perform emergency core cooling stems from the requirement to remove heat rapidly from the reactor core on loss of full function of the primary cooling capability provided by the RCS.

4) Abstraction of heat from the primary circuit by means of the heat exchanger (steam generator) may prove necessary in a non-generation mode if the heat transport systems linked to the primary circuit cease to remain in balance, particularly during possible fault conditions. To achieve this, the secondary circuit must remove heat at appropriate rates, and provision needs to be made to allow for the possibility of loss of either the means of heat conversion (turbo-generator/condenser) or the feedwater delivery components of the primary circuit. These requirements imply provisions for main and auxiliary feedwater supply to the heat exchangers and a facility to dispose of (dump) excess steam by-passing the heat conversion process, which for some sequences may not be functional.

5) Where a breach in the primary circuit pressure

retaining boundary occurs, the environment within the reactor containment may be heated significantly. Under these conditions, systems will be required to assist in the removal of the excess heat from the containment and to reduce the concomitant pressure rises and to mitigate the prevailing fault conditions and possibly help in any accident management strategy. Such a role may be provided by local water spray systems which are able to absorb heat from the immediate surroundings affected by the fault. Routine provision for heat removal from containment will also be required to adequately dispose of excess process heat absorbed by the surroundings.

5.4 Gas Cooled Reactors

Many of the principles discussed in the preceding general text and that on PWRs will also apply in the case of gas cooled reactors, although the precise nature of the provisions provided to address these principles may be quite different. In addition to the common issues, there are also a number of issues relating to heat transport systems which are specific to gas cooled reactors, and some of these are as follows.

5.5 Steel Reactor Pressure Vessel Stations (RPV)

1) The early Magnox stations in the UK incorporated welded steel RPV's as the primary pressure boundary retaining the primary coolant. A feature of the design of these stations is that they were considered to be robust enough to withstand a rapid depressurisation of the RPV, with subsequent loss of much of the primary heat transport medium. Such an event has immense significance for the safety systems intended to provide adequate heat transport in the absence of a significant quantity of the primary coolant and a breach in the pressure retaining boundary.

2) Following a rapid depressurisation by loss of the primary coolant, with the consequential risk of radioactive release, the licensee must demonstrate that the remaining plant and equipment will continue to provide adequate cooling of the fuel and core both in the short and long term, following the operation of the safety shutdown equipment. The cooling must be sufficient to

adequately remove both decay heat generated in the fuel and the possible exothermic heat of reaction between graphite and air if air ingress to the core occurs. The precise conditions that are likely to prevail in the reactor following a rapid depressurisation are extremely complex and these issues are more fully addressed in the assessment guide on transient analysis of accidents (T/AST/007 refers).

3) On gas cooled reactors, the heat exchangers (boilers) again have a role of fundamental importance in removing heat from the primary circuit (RCS). The importance of this role is reflected in the high level of reliability required for this function. To this end, both main and auxiliary feedwater supplies are included to provide redundancy in the system design. However, the original systems included at the Magnox stations did not have sufficient diversity and so these stations have been provided with diverse tertiary boiler feedwater systems. These provisions facilitate the transport of heat away from the primary circuit in the event of combined failure of both the main and auxiliary feedwater supplies to the main heat exchanger (boiler/steam generator).

4) The steel RPV stations generally have provision for heat transfer away from the external surfaces of the RPV and its attachments to ensure that locations on and around the vessel do not accumulate too much heat. This system is usually designed to provide cooling air by a system of ducts and dampers to convect heat away from the vessel. The role of such systems is of particular importance on steel RPV stations, to ensure that the vessel maximum and minimum temperature requirements are complied with (T/AST/016 refers).

5.6 Concrete Reactor Pressure Vessel Stations

1) For the concrete RPV stations many of the requirements contained in the preceding sections also apply in principle to the heat transport systems employed on these stations. However there are some specific requirements for these vessels which are considered in the following text.

2) The concrete RPVs each have a gas tight steel liner

which provides a seal for the primary coolant retention. During operating and fault conditions the liner will generally become hot and a separate heat transport system is provided to maintain the liner temperature within acceptable limits. It is essential that these systems display the appropriate level of reliability and this will probably include some of the characteristics described in para. 5.2(6). In addition, temperature limits are frequently specified for the concrete containment and any cooling provisions will need to ensure compliance with these limits.

3) Transport of heat away from the core by coolant leakage through the liner may be of significance for concrete RPV's, particularly if excessive heating of the pre-stressing tendons etc, is possible. The heat transport provisions for this aspect of these reactors should be designed to prevent this problem becoming of safety significance.

5.7 Nuclear Chemical Plant

1) For nuclear chemical plants, many of the safety requirements discussed in the preceding general text and that on power reactors may also apply, although the specific plant provisions to achieve a safety function may be quite different.

2) On nuclear chemical plant, the supply or abstraction of heat from the process is the primary function of the heat transport provisions, in that there is no requirement for power production by heat conversion as in the turbo-generator of a power reactor. However, there may be a variety of mechanisms whereby heat can be produced or accumulated at a number of points in a process during operation and identified fault conditions, and these need to be considered in the design and assessment of heat transport systems for such plant.

3) For each process involved at a nuclear chemical facility, potential heat sources and sinks should be identified and recorded in a schedule of heat loads for the plant. The potential for exothermic chemical reactions should be considered and minimised by design as far as is reasonably practical. The list translates to a

requirement for adequate heat transport systems to maintain the heat loads under control within the design temperature limits at all points in the process. Passive heat transport systems (eg radiation or natural convection) are preferable to active systems (eg forced convection).

4) In assessing the heat loads, and particularly so in the case of nuclear chemical plant, the potential for internal energy, accumulated in the reactants or stored material, being released as heat if the appropriate conditions prevail, should be included in the heat transport calculations. Where the potential exists for large quantities of additional heat being available from a source, appropriate measures should be considered to ensure that potential heat liberation is reduced to acceptable levels within the capacity of the heat transport systems provided.

5) Where heat-generating nuclear materials are intended to be stored, a record of the items retained in the store and the cooling requirements of the stored material needs to be maintained. The quantity and arrangement of such material also needs to be considered in relation to the heat transport systems provided to ensure that temperature limits are maintained within acceptable levels, bearing in mind that it may be difficult to isolate a storage facility or its safety systems. The systems provided should have the capability to ensure acceptable temperatures throughout the material retained in the store, for all operational and identified fault conditions for the complete duration of the anticipated storage period.

6) Prior to plant modification or decommissioning activities being undertaken on a nuclear chemical facility, a re-evaluation of the potential heat loads should be undertaken to ensure that the provisions for safe and adequately controlled heat transport will remain sufficient throughout the process to be undertaken.

6. References

1. Safety Assessment Principles for Nuclear Plants (1992).
2. IAEA Requirements on the Safety of NPPs: Design. (Draft).

3. 50-SG-D6-IAEA Safety Guide - Ultimate Heat Sink and Associated Heat Transport Systems for NPPs.
4. 50-SG-D13-IAEA Safety Guide - Reactor Coolant System and Associated Systems for NPPs.
5. 50-SG-D14-IAEA Safety Guide - Design for Reactor Core Safety in NPPs.
6. 10-CFR-50 - Code of Federal Regulations - USA Code for NPP Design Compliance.

TABLE 1

MAIN POWER REACTOR COOLANT SYSTEM COMPONENTS

The following listings give typical examples of the main components and equipment comprising the reactor coolant systems for various reactor types.

PWR

(a) Reactor vessel and primary circuit, with the closure head assembly;

(b) Reactor vessel internals (other than fuel assemblies and core support structures) necessary for the proper flow of the primary coolant, such as the core barrel;

(c) Reactor coolant side (tube side) of the steam generators;

(d) Reactor coolant pumps including the first stage seals;

(e) Pipes that, together with the tube side of the steam generators and the reactor coolant pumps, constitute the coolant loops:

- a hot leg between the reactor vessel and the steam generator of each loop,

- a crossover leg between the steam generator and the pump of each loop,

- a cold leg between the pump of each loop and the reactor vessel;

(f) Pressuriser with its relief valves, safety valves and piping connecting it to the coolant loop piping;

(g) Pipes bypassing the steam generators and the reactor coolant pumps and used for measuring the temperature of each loop;

(h) Reactor vessel appurtenances such as control rod drive mechanism pressure housing;

(i) Auxiliary systems connected to a loop up to and including the isolating devices;

(j) Components such as valve actuators and pump drives associated with (a)-(i).

MAGNOX/AGR

(a) Reactor vessel and primary circuit, with all internal insulations, external removable closures and fuelling machine when connected to a channel;

(b) Primary coolant pressure retaining parts of reactor vessel penetrations provided for the transfer of feed steam and services through the pressure boundary;

(c) Reactor coolant circulators and seals;

(d) Gas baffle assembly including core supporting structure;

(e) Reactor core channel extensions provided to segregate core inlet and outlet gas (guide tubes);

(f) Reactor moderator and associated equipment;

(g) Connections to the gas processing plant and secondary shutdown, reactor auxiliary and instrumentation systems up to and including the isolating devices;

(h) Reactor coolant safety relief valves and their connections to the reactor pressure vessel;

(i) Main boilers, reheaters and decay heat removal boilers located within the pressure boundary;

(j) Components such as valve actuators and pump drives associated with (a)-(h).

TABLE 2

REACTOR COOLANT SYSTEM - ASSOCIATED SYSTEMS

Associated Systems

(1) Systems directly associated with the RCS and which perform functions such as:

- emergency core cooling (by pumped or passive means);
- residual heat removal;
- reactor coolant chemical and inventory control including reactor coolant clean up;
- transfer of mass and heat and conversion to steam by the main stream and feedwater system or emergency feedwater system (for direct cycle designs this is limited to those portions of the systems not included in the RCS);
- transfer of heat by intermediate cooling loops from systems containing reactor coolant to the ultimate heat sink;
- containment cooling systems;
- transfer of heat from moderator.

(2) The systems connected to the RCS or to those systems listed in (1) above such as:

- drain lines (including seal leakage lines);
- safety or relief valve discharge lines up to and including any associated equipment;
- instrument lines;
- sample lines;
- surge lines;
- fill and vent lines;
- relief tanks.

TABLE 3

HEAT TRANSPORT SYSTEMS CONNECTED TO AN ULTIMATE HEAT SINK

(1) Circulation of sea water once through heat exchangers.

(2) Circulation of fresh water (or stored water) once through heat exchangers.

(3) Recirculation of water through a spray pond.

(4) Recirculation of water from a lake or reservoir or large pond.

(5) Evaporation of heat in steam generators.

(6) Dry cooling towers.

(7) Wet cooling towers with make-up facility, or wet/dry tower combinations.

(8) Conduction, convection or radiation from structures.

(9) Condensing systems.

(10) Spray systems.

(11) Forced convection through heat exchangers.

(12) Containment cooling systems.

(13) RPV cooling systems (external).

(14) Trace heating provisions (eg frost protection).