2. PIPEWORK LEAKS AND BREAKS

2.1 DEFINITIONS

Leakage — Leakage results from a total localised loss of wall thickness in a pressurised component, either due to a stable (sub-critical) wall crack, or a degradation mechanism, such as the loss of wall thickness due to erosion-corrosion. A leak results in the loss of containment capability for the pressurised component without occurrence of a break in the pressure boundary.

: Note: leakage in the CPP [RCPB] via penetrations (such as the GMPP [RCP] shaft seals, control rod drive mechanism tubes or bolted flanges, is covered by the design rules discussed in Sub-chapter E.2.

Guillotine Break: A guillotine break refers to a break involving complete severance of a pipe.

Break Preclusion: Break (Rupture) Preclusion is a deterministic concept, which ensures by preventative measures (requirements on design, materials, product forms, manufacturing, quality assurance, analysis of fatigue crack growth) and surveillance measures (requirements on transient and water chemistry monitoring, leakage detection, in-service inspection) that rupture of a pipe can be discounted in safety studies.

Break (Rupture) Preclusion implies that pipework integrity will be maintained throughout the lifetime of the unit.

Leak before break: Leak before break describes the situation in which a leak occurs before a complete double-ended break of a component. Although not considered by itself as sufficient to demonstrate rupture preclusion, which is dependent on the component integrity, it can provide one element of the safety argument to limit the potential consequences associated with the loss of integrity, and provide information on the strength of the pipework.

2% Criterion: Breaks are not postulated to occur in qualified piping systems of more than 50mm nominal diameter (in accordance with the mechanical classification in Chapter C.2), which are in operation as high energy systems over service periods less than or equal to 2% of the unit service life.

High energy components: High energy components are components containing water or steam at pressures greater than or equal to 20 bar, or temperatures greater than or equal to 100^{0}C, under normal operating conditions. Components containing gas at a pressure above atmospheric pressure are always considered to be high energy components. All other components are considered to be moderate energy components.

2.2 FAILURE ASSUMPTIONS FOR HIGH ENERGY PIPEWORK

2.2.1 High Energy Pipework

2.2.1.1 Leak and breaks in small diameter pipework (≤ DN 50) [≤ NB 50]

For small diameter pipework (less than or equal to 50mm nominal diameter, (≤ DN 50) [≤NB 50]), there is no restriction in the assumed break location, i.e. breaks are assumed to occur at different places on the pipe.

As a result of the relatively low energy potential, secondary effects due to breaks are only analysed with respect to:

- loss of fluid relating to the function of the safety classified system (loss of pipework function);
- consequential damage to small diameter pipework or cables (e.g. pressure impulse lines) caused by jet impact forces and pipe whip;
- consequential damage to electrical and instrumentation and control equipment due to increases in pressure, humidity, temperature and radiation;
- flooding consequences.

2.2.1.2 Leaks and breaks for pipework (> DN 50) [> NB 50]

This section does not apply to pipework covered by the break (rupture) preclusion assumption.

Pipework failure effects discussed in Chapter C.4.2.5 below must be considered for all leaks and breaks in pipework with a nominal diameter >50mm, (>DN 50) [>NB 50]. Pressure wave forces due to rarefaction waves are only considered in the case of pipe breaks. For leaks, it is more realistic to consider steady state pressure forces.

<u>Leaks and Breaks in classified High Energy Pipework (RTHE) [HELB]</u>

Leaks and breaks in safety classified pipework (designed in accordance with mechanical or ESPN codes, as discussed in Chapter C.2) are postulated to occur at the following locations:

- at pipework terminations;
- in category 1 pipework:
    - o at intermediate locations where the usage factor is higher than 0.1, in combination with a variation amplitude higher than 2.4 Sm (see RCC-M code), where the variation amplitude is the sum of the primary and secondary stresses between two system conditions (calculated using equation (10) in paragraph B3653 of the RCC-M);

- at intermediate locations where the usage factor is lower than 0.1, in combination with a variation amplitude (as described above) higher than 3 Sm and a thermal expansion stress variation amplitude higher than 2.4 Sm. The thermal expansion stress, is based on the sum of the primary stresses and the secondary stress in the membrane, including flexing (outside of thermal flexing and thermal expansion) (equations (12) and (13) of paragraph B3653 of the RCC-M).

- in category 2 and 3 pipework:

  - at intermediate locations where the stress rate exceeds 0.8 (1.2 Sh + SA) (or equations (9) and (10) of NC or ND 3652 of ASME). The stress rate in category 2 pipework is calculated by the sum of equations (10) and (7) of paragraphs C3650 of the RCC-M. In category 3 pipework, similar stress criteria are applied by using equations (2) and (3) of the EN13480 standard.

  - if it is not possible to determine an intermediate location using the above approach or if a single break location is defined, two points of maximum stress with a 10% difference in stress intensity (or, if this difference is lower than 10%, with at least one bend between the two) should be chosen. If the pipe is straight, without stress concentrations and if all of the stresses are below the admissible level, only one location where the stresses are at their highest should be chosen.

It should be verified that the leak and break location chosen, represents bounding conditions in relation to the safety functions performed by the equipment located in the room under consideration. If sensitive areas are detected, additional measures must be taken (for example: analysis of the layout, further protection devices).

In the case of a guillotine break, the break size is usually assumed to equal to 2A (where A = cross sectional area of the pipe). If movement at the ends of the pipework is limited (for example, by a whip restraint or as a result of pipework stiffness), a smaller and more realistic break size may be chosen.

<u>Leaks and Breaks in non-classified High Energy Pipework (RTHE) [HELB]</u>

Leaks and breaks in non-safety classified pipework (neither mechanical or ESPN, according to Chapter C.2), are postulated to occur at varying locations, and the pipework failure effects discussed in Chapter C.4.2.5 are considered.

As a principle, the installation of non-classified high energy pipework in safety classified buildings (with the exception of the Nuclear Auxiliaries Building) is limited to the minimum extent reasonably practicable

2.2.1.3 Prevention of High Energy Line Breaks (RTHE) [HELB] and Leaks

If certain specific requirements are adhered to, catastrophic failures of pressurised pipework may be discounted in the deterministic approach used during the design of the equipment and surrounding structures. This concept is based on the following requirements:

a) Break (Rupture) Preclusion

In order to establish that the possibility of a pipe break can be ruled out from the safety assessment, the conditions discussed in Chapter C.4.2.3.1. below must be met.

The Break Preclusion concept applies to the Reactor Coolant System pipework (see Chapter E.2) and to the main steam lines (see Chapter J.5) between the steam generators and the fixed points downstream of the main steam isolations valves.

b) 2% Criterion

The 2% criterion may be applied to pipework of more than 50mm nominal diameter, (>DN 50) [>NB 50], designed in accordance with mechanical or ESPN codes, (see Chapter C.2).

Application of the 2% criterion requires the following to be met::

- application is restricted to qualified pipework (see Chapter C.2), that has:
    - high quality material characteristics, in particular toughness;
    - conservative limitation of stresses;
    - prevention of stress concentrations through optimum design;
    - assurance that optimised manufacturing and testing technologies have been applied;
    - consideration of operating fluid characteristics;
- limited period in which the systems experience high energy mode;
- negligible likelihood of crack propagation, because of reduced load cycling due to the systems limited operational use in high energy mode, i.e. the number of load cycles is relatively low compared to normally operating systems;
- good prediction of operating modes and anticipated stress levels, with the degree of fatigue notably being lower than 1;
- adequate surveillance provisions (e.g. non-destructive testing, pressure testing, integral visual inspections).

The following measures are considered within the context of the in-service inspection and operational surveillance:

1. Integral visual Inspection

Integral visual inspection can be generally performed during plant walk down reviews. These enable the condition of the pipework to be visually assessed (for pipework, the thermal insulation is removed).

The following should be verified:

- mechanical damage in general (e.g. bending, breaks, pipe movement);
- operation of support devices (e.g. free movement of the rollers, mounting positions of standard support devices, operability of spring hangers);
- indication of leaks;
- defects in threaded connections, measuring devices and impulse lines;
- vibrations, noise (e.g. cavitation).

2. Non-Destructive Testing

Internal and external surfaces of the weld area, and base material that is subject to high stress concentrations (e.g. pipe bends and elbows), may be examined.

The inspection of external surfaces can also be performed using surface crack detection methods (e.g. dye penetrant testing for austenitic steels, magnetic particle inspection for ferritic steels) and volumetric inspection techniques, using ultrasonic and radiographic inspection.

Some of the tests performed for the external surfaces, may not be possible for internal surfaces.

3. Pressure test

Pressure testing is required for pipework in accordance with design rules, codes and statutory or regulatory requirements.

Independent of these requirements, pressure testing may replace non-destructive testing in specific circumstances, for example, where a high level of radiation exists, or access is restricted.

The 2% criterion is applied to the following systems:

the main steam discharge lines downstream of the safety valves/isolation valves
the pressuriser discharge lines
The steam generator emergency feedwater system upstream of the first isolation valve

All of the above systems are used as standby systems for accident management.

The failure assumptions are shown in table C.4.2 TAB 1.

2.2.2 Assignment of failure assumptions to high energy piping systems

A summary of the failure assumptions assigned to high energy piping systems is shown in table C.4.2 TAB 2. In some cases, the match between the respective pipework sections and their associated supports will be examined further during the detailed design phase.

Some system specific requirements are listed below.

Reactor Coolant System pipework

The Break Preclusion concept is applied to the Reactor Coolant System pipework (see Chapter C.4.2.3 below). However, despite the application of this concept, a guillotine break of the Reactor Coolant System pipework is considered, (using realistic assumptions) as a basis for the design of the safety injection system and the containment, and for the environmental qualification of equipment. In addition, component stability is verified assuming a conventional static load of 2pA as the design basis for the pipework supports. These assumptions, adopted in addition to the application of break preclusion, are shown in table C.4.2 TAB 3.

Main steam lines

The Break Preclusion concept is applied to the main steam lines between the steam generators and the fixed points downstream of the Main Steam Isolation Valves (see Chapter C.4.2.3 below). However, despite the application of this concept, a guillotine break of this part of the main steam lines is considered, (using realistic assumptions), as a basis for the designs of the containment and the environmental qualification of equipment. In addition, component stability is verified using a conventional static load of 2pA as the design basis of the pipework supports. These assumptions, adopted in addition to the application of break preclusion, are shown in table C.4.2 TAB 4.

2.2.3 Specific requirements for shutdown conditions

For shutdown conditions, specific consideration is given to systems which are solely used in high energy mode, and systems which remain in high energy mode. In the shutdown plant state, as these present an increased risk of failure.

Breaks in pipework less than or equal to 50mm nominal diameter, (≤ DN 50) [≤NB 50], are postulated during conditions B and C (high energy operation) for the reactor coolant system and its connected pipework, up to the second isolation valve, classified as RCC-M category 1.

Beyond the reactor coolant system second isolation valve, the (RIS) [SIS] /(RRA) [RHRS] system trains which fulfil the RRA closed loop function, are only considered in high energy mode from a starting temperature of 120^{0}C, until the reactor coolant system pressure falls below 20 bar and the temperature drops below 100^{0}C. The connection temperature for trains 2/3 is less than 100^{0}C. Even though the (RIS) [SIS] / (RRA) [RHRS] is operated as a high energy system over service periods less than 2% of the unit's service life, the 2% criterion is not applied to (RIS) [SIS] / (RRA) [RHRS] pipework. Breaks in the main sections of this pipework (DN 250) [NB 250] are considered at locations inside the containment enclosure and in safeguard buildings 1 to 4 during reactor conditions C and D.

2.3 BREAK (RUPTURE) PRECLUSION

The break preclusion concept is applied to the main primary [1] and secondary [2] pipework. The implementation of this approach is described in Chapter E.2. and Chapter J.5 for the CPP [RCPB] and CSP [SSPB] respectively.

The conditions to be fulfilled for a pipe break to be discounted, are described below. These include defence in depth requirements for the consideration of leaks and breaks.

2.3.1 Requirements for break preclusion demonstration

The conditions to be fulfilled for a pipe break to be discounted, in accordance with Ref. [5], are associated with the objective of demonstrating that the pipework integrity will be maintained throughout the unit service life. These conditions originate from the Technical Guidelines (See Chapter C.1.2) or from Ref. [6], and provide the first two levels of a “Defence in Depth” safety approach.

For break preclusion the first two levels of Defence in Depth are; (a) damage prevention using good quality design and manufacture and; (b) operational monitoring, in order to prevent a loss of integrity. Both of these levels are described further below:

2.3.1.1 Design and manufacturing criteria

For design and manufacture, the quality is assured by the application of codes, verification of their application and final inspection of the results achieved.

2.3.1.1.1 Design requirements

a) A high level of quality is required in accordance with the design codes, behavioural analysis and choice of materials. Application of RCC-M level 1 requirements enables these design requirements to be satisfied. In particular:

1) Damage mechanisms considered.

   Assessment of the damage mechanisms must be comprehensive and continuous over the unit’s service life. This assessment must demonstrate that significant degradation caused by these mechanisms can be ruled out. The degradation mechanisms in which the kinetics cannot be reliably modelled or which could result in very long defects (or axisymmetrics) must be taken into consideration or ruled out.

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[1] The main (CPP) [RCPB] pipework comprises the hot legs, cross over legs (U bend), cold legs, including the connection weld to the vessels (reactor pressure vessel, GV [SG], GMPP [RCP]) and the forged connection nozzles, with the exception of the connection welds in the connection nozzles in connected pipework.

[2] The main (CSP) [SSPB] pipework comprises the main steam lines from the steam generators to the fixed points downstream of the Main Steam Isolation Valves, including the GV [SG] connection welds, the connection welds to the fixed points, including the forged connection nozzles, connection welds to the nozzles of the VDA [MSSS] isolation valve and the two main steam safety valves VVP [MSSV]. This does not include the connection welds for the nozzles associated with connecting lines, such as the bypass line for the steam isolation valve.

All potential degradation mechanisms are assessed when the pipework is designed. Periodic updating of these assessments is performed using operational plant experience feedback from other units, both nationally and internationally. The completeness of the degradation mechanisms considered is confirmed on the basis of this analysis. The following points are considered as a minimum:

- Fatigue. The assessment covers pipework fatigue for the operating conditions, thermal fatigue and vibratory fatigue;

  The usage factor must be lower than 1 for the unit full service life;

- Brittle fracture risk, including consideration of the effects of ageing; The risk of ductile fracture is ruled out as there is sufficient strength and ductility in the materials;

- Erosion-corrosion. The choice of materials should ensure protection against risks of this type. These mechanisms mainly affect carbon steel pipework systems containing water;

- Corrosion. The assessment primarily focuses on cracking by intergranular stress corrosion, and may refer to operational experience feedback, including control of the chemical composition of the system fluids under consideration;

- Erosion. The assessment may refer to operational experience feedback of similar installations.

2) Choice of materials

Material characteristics, stresses and combination of stresses and material properties, resulting from normal operation, design transients and earthquakes, must be considered.

As a general rule, the materials used are those already in use for similar pipework systems on operational nuclear units, characterised as having satisfactory performance.

However, other materials may be used provided the appropriate justifications are made.

The mechanical properties used are those defined in the RCC-M. Where the mechanical properties of materials are not discussed in the RCC-M, the materials use is justified, taking into account minimum values, with an adjustment made for the possible effects of thermal ageing.

b) Defect propagation, due to fatigue growth of a possible manufacturing defect (overlooked during the manufacturing inspections), where the defect is located at the point of highest stress, remains limited over the unit service life and the stability of the defect at the end of its service life is ensured under the most severe stresses.

c) Verification of the circuit robustness against fast fracture, taking into account possible defects.

A conventional approach is applied to demonstrate tolerance to potential defects of significant sizes, whatever their origin.

Two main methods may be used for verifying fast fracture resistance:

- application of screening criteria concerning material properties and temperatures in design transients,

- analysis of surface defects taking into account safety margins.

The objective of this analysis is to confirm that the defects which had not been detected at the end of the manufacturing process will not result in failures that affect safety.

Faults are postulated in circumferential in welds where:

- o Risk of defects which are difficult to detect are highest, at the end of the manufacturing stage,
- o Unfavourable combination of stresses and material properties exist.

The size of the relevant defects takes into account the manufacturing technology used, the performance of manufacturing inspections and the repair procedures used. In practice reference defects, are considered to be defects on the internal surface which are 20 mm long and 5 mm deep.

The propagation of these defects, under the effect of loads over the unit service life, as well as their stability at the end of their service life, is assessed in accordance with the RSE-M rules. An end of service life defect must remain stable even under the most severe stresses (earthquake, break in connected pipework). In practice, it is verified that the defect depth does not exceed one quarter of the thickness of the pipe.

In addition, propagation at the edge of an exceptionally long defect is verified to ensure that it remains limited and not vulnerable to instability in the large ligament. In practice, it is demonstrated that the defect depth does not exceed one quarter of the thickness of the pipework at the end of the service life.

d) The path is simple and short.

e) The number of welded joints is minimised.

2.3.1.1.2 Requirements relative to design verification

- The validity of the data and the assumptions relative to loads:

  Mechanical analysis take into account loads and load combinations specified in Chapter C.6 of the safety report. For loads which relate to earthquakes, the analyses are performed using the site specific design spectra. Possible significant dynamic effects caused by fluid forces in design situations are taken into consideration (e.g. on the secondary side: following rapid closure of steam valves, in RTGV [SGTR]). Specific attention is given to the ensure avoidance of waterhammer effects: it must either be demonstrated that the probability of waterhammer is very low, or that its amplitude is mechanically acceptable.

  Indirect causes of breaks, such as certain hazards will be analysed. Pipework not protected by buildings, and subject to the external hazards specified in the safety case, will also be analysed.

The possibilities of a hazard caused by pipe whip where the break preclusion procedure is not applied are also considered. In practice, pipework where the break preclusion principle is applied is that with the largest diameter and greatest thickness, and are thus not vulnerable to break from the effects of whipping of other smaller pipes. Nevertheless, large masses located on this pipework must be analysed to ensure that they are unlikely to damage the pipework subject to the break preclusion principle.

- Verification that the above design rules have been applied.

2.3.1.1.3 Manufacturing requirements

- Use of high quality materials, providing good toughness and strength, and which are not unduly sensitive to corrosion and erosion-corrosion degradation mechanisms.

- A high level of quality must be obtained via the specification of manufacturing procedures.

- Large diameter nozzles, as well as the RCV [CVCS] nozzle, will be extruded or integrally forged and not installed by welding in the pipework in question.

- Experimental samples are utilised in order to ensure that the mechanical properties of the materials and the welded joints comply with the minimum values assumed at the design phase. The provisions of RCC-M level 1 enable these requirements to be satisfied. They are supplemented where necessary by experiments to determine minimum values of properties necessary for the assessment which are not included in the RCC-M: technical qualification or material weld capability folder. This applies notably for the steel used in the steam lines.

- Experimental samples are utilised to verify the absence of significant ageing in the materials.

2.3.1.1.4 Requirements relative to manufacturing inspections

- The ability to inspect welds must be established.

- All welds must be inspected at the end of the manufacturing phase in order to demonstrate the absence of underfills and large defects. The size of these defects must be lower than that considered in the mechanical stability and integrity demonstrations.

- For ferritic steels, the manufactured thickness must be verified during acceptance inspections for defects and flaws.

2.3.1.2 Requirements relative to in-service monitoring

2.3.1.2.1 Operational monitoring

Generally, operational monitoring must be carried out to ensure the validity of assumptions made at the design stage, notably with regard to:

- stresses, by monitoring movements of possible auto-blocking devices, play in component supports, and vibration levels;

- Fatigue damage: in particular, by recording the transient history of the reactor coolant system and monitoring the main secondary system in areas subjected to major cyclical stresses;

- Additional instrumentation may be necessary on the lead unit to monitor certain complex local situations with major temperature differences and their associated durations;

- Corrosion: the chemistry of the fluids circulating in the relevant systems must be stringently monitored. The same applies, where appropriate, for external environmental conditions, notably to the risk of corrosion under insulation.

2.3.1.2.2 In-service inspection

The in-service inspection is one of the monitoring actions for the relevant pipework. It compliments design and production quality.

It must be demonstrated that the predictions of the risk of damage to pipework remain mainly within the on-site observations. It must also be demonstrated that no degradation appears which was unforeseen in the analysis of potential degradation mechanisms.

Accessibility and ability to inspect each point on the relevant pipework is required. In particular, provisions are made to enable volumetric inspection of all of the welds, and around those nozzles which are likely to develop degradation mechanisms. Transition welds must be able to be inspected by two different volumetric methods. Where it is proven that a single method can detect all degradation mechanisms which are likely to lead to a loss of integrity, the implementation of only one method is acceptable.

The in-service inspection complies with the requirements of French Regulations (Ref. [1] and Ref. [1]).

The detailed programme takes into consideration previous experience, available non-destructive testing techniques, and the result of the pre-service inspection (Complete Initial Visit). It is based on an assessment of the potential damage in the relevant systems. Those areas which are likely to be damaged must be identified in the maintenance manual, and be included in the in-service inspection programme. In-service inspection is implemented in those locations where the risks of in-service defects developing are the highest, based on operational experience feedback, the stress analysis (stresses or high usage factor, geometrical defects) and the construction specifics (type of materials and manufacturing procedures).

The in-service inspection must also cover the lower risk areas in terms of the defence in depth principle.

2.3.2 Requirements associated with the additional levels of defence in depth

A requirement of the additional level of defence in depth (a level which is independent of the previous levels) is to prevent and limit the consequences of an accident.

This level of defence in depth comprises two lines of defence:

- the first deals with the prevention and limitation of accidents which are postulated in the unit reference design (leak detection, RTHE [HELB] mitigation);
- the second consists of measures to deal with accidents which are not foreseen within the context of the reference design (LOCA 2A, RTV 2A).

The following measures are implemented, in accordance with the requirements described in B1.2, B1.3 and F1.2.1 of the Technical Guidelines (see Chapter C.1.2):

- **First line of defence:**

2.3.2.1 Postulated breaks

For those systems which meet the break preclusion requirements (conditions defined in Chapter C.4.2.3.1), guillotine breaks are not considered in the design analyses.

The mechanical design of the equipment, notably the demonstration of the integrity of the components and their internal structures, considered a possible break in any of the connected lines which do not meet the break preclusion requirements at their connection weld to the break preclusion system. The design of the backup and protection systems takes into consideration the same breaks. For these analyses, the leak rate is that which corresponds to the internal diameter of the connection, independently of the existence of any flow limitation devices inside the connection.

For the mechanical analyses of the primary system, the loads which result from a break in the largest primary connection are combined with those resulting from an earthquake.

It must be shown that failures in a bolted plug which may cause a break can be ruled out. Failing this, these breaks must be taken into consideration.

The analyses of postulated breaks are performed under rules given in Chapter P.0.

2.3.2.2 Postulated propagating defects

The objective of this analysis is to confirm the tolerance of the relevant pipework to propagating defects. Within the containment, the analysis is performed by comparing a critical defect with a defect which leads to a detectable leak under normal operating conditions. Outside the containment, an arbitrarily large defect is considered. Given the envisaged loads, the growth rates of propagating defects are necessarily very low and remain negligible in relation to leak detection delays.

Defects are expected to be circumferential in those welds where the combination of the restraint and material properties are least favourable. In order to estimate the leak rate in normal operating conditions, various loads (pressure, weight, thermal load) are considered and algebraically combined.

The break surface assessment considers an elliptical crack whose opening is assessed in accordance with the method described in Ref. [1] or by using a similar method.

The stability of the critical defect is calculated by taking into consideration the combination of the most severe loads in normal operation, combined with the forces due to the design basis earthquake and accident loads which are not attributed to an earthquake. For the assessment of the normal operating conditions attributed to an earthquake, the considered load is such that each component is the result of the sum of the absolute values of the individual loads and the SDD [DBE] spectrum.

Several methods may be used to carry out the mechanical analyses, among which:

- a formulation using the J criterion such as the EPRI Ref. [2]) or an equivalent formulation for determining the value of J and the dJ/da criterion for the stability analysis.

- a Gfr type formulation, as codified in the RCC-M, APPENDIX A16 “guide for leak studies before break and the associated defect sensitivity analyses".

The requirements which should establish the tolerance to large propagating defects, will be formulated at a later date.

2.3.2.3 Leak detection requirements

- A leak detection system must be installed to monitor leaks on pipework which is located in the containment enclosure.

- The leak detection system must have detection capability which enables reliable and sufficiently quick detection of a non-critical propagating defect.

- For the systems inside the containment enclosure, a hypothetical propagating defect, which is expected to be circumferential in the welds and is stable even in case of an earthquake, must lead to a detectable leak rate in normal operating conditions.

The leak detection requirements will be specified at a later date.

- **<u>Second line of defence:</u>**

2.3.2.4 Requirements relative to the consideration of breaks in terms of the defence in depth

In accordance with B1.2.3 of the Technical Guidelines, the leakage rate resulting from a conventional break in a section which is equal to 2 times that of the pipe area, referred to as a 2A break, is still considered, using realistic assumptions and appropriate criteria, for :

- demonstrating the existence of safety margins with regard to fuel cooling, including during the re-circulation phase;

- containment design;

- qualification of the equipment.

For each postulated break location a static force in the direction of the axis of magnitude 2PA (where P is the system’s operational pressure) is taken into consideration in order to verify the stability of the large components and to determine their support requirements.

In case of a guillotine break in a reactor coolant system primary loop, there is no transfer of mechanical damage to the unbroken loops. The reactor vessel is a fixed point. It is supported by a resistant mount which damps the forces. Each loop is surrounded by reinforced concrete walls which are thick enough to prevent damage to the unbroken loops or the containment.

On the secondary side, the potential for common cause failure between the main steam lines must be limited by sufficient separation of the lines. This requirement may be fulfilled by physical or geographical separation or by an installation which excludes impacts due to possible whip in the lines. Where common cause failure of two lines cannot be ruled out, reactor behaviour must be analysed using realistic assumptions.

In addition, a break in the largest connection (among all of the connections, including those covered by the break preclusion) on the steam lines outside of the containment is taken into consideration to verify the integrity of the:

- Steam line itself;
- Containment penetration.

2.3.2.5 Break analysis requirements for defence in depth

For thermohydraulic analysis and containment pressure and temperature calculations, calculations are performed for a 2A break using the realistic assumptions. Due to the implementation of break preclusion, it is considered that the probability of a guillotine break is actually very low. It is therefore analysed using the following best-estimate rules:

- Residual heat is defined by the SERMA curves;
- Main parameters are those appropriate to nominal values for operation (e.g. the initial condition is 100% nominal power);
- Aggravating factors or unavailability due to maintenance are not considered
- In the case of APRP [LOCA], the safety injection flow to the pipework which supplies the break is assumed to be lost;
- Manual actions of the operator are only taken into consideration after 30 mins have elapsed;
- Loss of external electrical sources is not considered;
- All instrumentation and control signals are assumed to be available;
- It is assumed that the geometry of the units inside the vessels and the fuel elements is preserved despite the initial decompression forces, so core coolability is not impaired;
- Acceptance criteria for the fuel are as follows:
    - o the fuel element temperature does not exceed 1200^0C;

- oxidation of the fuel element does not exceed 17%;
- the zirconium water reaction is limited to 1% of the mass of the fuel elements;

- the pressure and temperature inside the containment are determined to ensure that they do not exceed the assumptions considered in the mechanical design of the containment systems or the equipment qualification profile.

2.3.2.6 Protection in a RTV [MSLB] accident

Even though it is not required under the Technical Guidelines due to application of the break preclusion principles to the CSP [SSPB], an RTV-2A accident is studied using rules applicable to reference operating condition (PCC) studies. This accident study is described in Chapter P of this Design and Safety Report.

2.4 FAILURE ASSUMPTIONS FOR MEDIUM ENERGY PIPEWORK

Leaks are generally postulated for classified moderate energy pipework (DN > 50) (See Chapter C.2). Location of leaks is determined in accordance with Chapter C.4.2.3.2.1, and the leak rate equivalent to section A_L**,** calculated using the following formula:

$$A_L, = \frac{di \times s}{4}$$

Where di: internal pipe diameter

s: thickness of pipe wall

Breaks are postulated for small diameter pipework (DN > 50).

For non-classified moderate energy pipework, in accordance with Chapter C.2, there is generally no limit with regard to the size (up to break) and the location of the failures. However, based on the assessment of the material, fluid, in-service inspections, etc, failure assumption restrictions may be applied on a case by case basis, if necessary.

For moderate energy pipework, the effects of leaks and breaks are only to be considered for flooding, radiation risks and the loss of pipe functionality.

The moderate energy systems to be considered in the analysis are, for example, the fire fighting system, the liquid waste treatment system, the condenser extraction system, etc.

2.5 PIPEWORK FAILURE EFFECTS CONSIDERED

A summary of the pipework failure effects is provided in Chapter C.4.2 TAB 5.

During the design of the safety classified structures and mechanical, electrical and instrumentation & control system components, the effects of the following on the consequences of leaks and breaks are to be considered

For high energy pipework:

- Jet impact forces.
- Pipe whip.
- Reaction forces.
- Compression wave forces.
- Flow forces.
- Differential pressure forces.
- Pressure accumulation.
- Humidity.
- Temperature.
- Radiation.
- Flooding.

For moderate energy pipework:

- Flooding.
- Radiation.

Note: Pipework failure assumptions for the PCC-3/4 analyses are defined in Chapter P.

<u>Jet impact forces and pipe whip forces</u>

The consequences of jet impact forces, i.e. the thrust of the steam or water jet which escapes, and pipe whip which may have an impact on system safety classified pipework, mechanical, electrical and instrumentation & control components are considered during the design stage. The resulting loads on building structures are also taken into consideration.

Reaction forces

Reaction forces are the counteracting forces caused by the fluid escaping via the leak and / or caused by the fluid pressure at the break and acting on the break cross section. Reaction forces are taken into consideration for the design of safety classified equipment, equipment supports, support anchors and the associated building structures.

Pressure wave forces, flow forces

Safety classified components and their internal equipment (e.g. reactor pressure vessel internals, steam generator tubes) located in the systems considered are designed to withstand flow forces resulting from postulated leaks and breaks. In the case of transient blowdown conditions, the effects of pressure wave forces, including possible waterhammer effects, are taken into consideration.

Pressure wave forces (de-pressurisation wave forces) are forces which act on pipework sections between two bends and which occur from the blowdown compression wave transferred through the fluid from the break.

Differential pressure forces, pressure accumulation

In the event of a postulated leak or break in a high energy line with a temperature $\geq 100\ ^{0}C$, the mass and energy are released into the building. When it leaves the break compartment, the fluid is dispersed to other connected sub-compartments. The differential pressures occur due to the flow restrictions causing additional loads on the structures in the safety classified buildings. Also, pressure accumulation is taken into consideration for safety classified buildings (e.g. containment) with the exception of the nuclear auxiliaries building (BAN) (see Chapter C.1.1 Appendix 1/2 for the BAN).

The pressure accumulation in the sub-compartment is also taken into consideration during the design of the safety classified electrical and instrumentation & control system components.

Humidity, temperature, radiation

Safety classified electrical and instrumentation & control system components are designed to withstand temperature, humidity and radiation in the event of postulated leaks and breaks in the pipework. Humidity and temperature are only considered for pipework with a temperature ≥ 100°C. This is considered during the design of the areas which are subject to such loads.

Flooding

Safety classified mechanical, electrical and instrumentation & control components which must remain intact during a postulated leak/break are located above the maximum expected flood level.

The flood level is also considered during the design of the building structure.

2.5.1 Design principle for components used for reducing pipe breaks

Two types of restraints are provided to mitigate the consequences of pipe breaks where necessary:

a) Large gap restraints

Restraints with large gaps are used when the rupture may be associated with a large deflexion of the pipe.

b) Restricted gap restraints

Restricted gap restraints are installed where major pipework movements permitted by large gap restraints cannot be tolerated. The purpose of the restricted gap restraints is to limit pipework deflection, for pipework subject to jet impact loads (gap restraints) and to prevent collapse in the event of a postulated pipework break (multiple path restraints).

Each type of restraint is designed in the following manner:

Large gap restraints

The flexible restraints, that is, those with a U bar, are designed to operate in the elastoplastic range. The fastenings, such as the saddle, clevis pin, support bracket, the welded assemblies or anchor bolts are designed to operate in the elastic region

The maximum deformation of the U bar is limited to an acceptable value which is verified by an analytical method. Pipe whip restraints are designed for single use, for a constant blowdown force or an actual event. The minimum gap between the restraints and the pipework surface includes the thermal displacements and insulation thickness.

Gap and multiple path restraints

These restraints are designed for protection against pipe whip, using a load factor method static analysis. The force on the restraint is considered to be equal to the jet thrust load, multiplied by a dynamic load factor. A conservative dynamic load factor of 2 has been assumed.

2.5.2 Calculation techniques

The analysis of high energy line breaks may be performed in accordance with a modified dynamic method (pipe whip analysis) or by a simplified procedure, in order to verify the integrity of the main restraint components, main civil structures and to prevent secondary breaks resulting from broken pipework after an initial pipe break. The different acceptable methods for such an analytical approach for the assessment of pipework behaviour may be found in ANSI/ANS-58.2-1988.

The analytical design procedure for restraints is normally based on one of the following simplified methods:

Static analysis

The jet thrust force is represented by a conservatively amplified static load and the restraint is analysed statically. The amplification factor used to determine the magnitude of the forcing function is based on the choice of a conservative value as obtained by comparing the factors derived from a detailed dynamic analysis performed on comparable systems.

Energy balance analysis

The kinetic energy generated during the first quarter circle movement of broken pipework imparted to the pipework / restraint system through the impact is converted into equivalent strain energy. The pipework and restraint deformations are compatible with the level of absorbed energy. A constant thrust force is used in the energy balance analysis. It is taken as being equal to the initial pulse of the forcing function. However, a value below the initial pulse value may be used, if it is shown to be conservative in comparison to a standard dynamic analysis.

The thrust force for each postulated pipe break is determined by a permanent load function. The thrust force magnitude is:

$T = K . P. \ A$

Where:

T = thrust force.

P = system pressure prior to pipe break (design pressure).

A = pipe break area.

K = thrust coefficient.

The value of K is one of the following:

K = 1.26 for saturated or superheated steam, water or steam/water mixture,

K = 2.0 for non flashing, subcooled water.

2.6 ANALYSIS OF LOCAL EFFECTS

2.6.1 General points

The analysis of the consequential effects is performed taking into consideration the leak and break assumptions on high energy systems as defined in Chapter C.4.3.2 above.

The local effects are divided into compression wave forces and the effects on the systems caused by an increase in flow within the affected system and effects acting around the system:

- Jet impact forces;
- Reaction forces;
- Pipe whip.

In addition, spray effects from failures in low energy systems are considered for electrical components and instrumentation & control components, where unacceptable consequences could occur. Protective measures for these components are described in the form of conventional rules.

Compression wave forces and increased flow forces are only significant in case of sudden breaks or breaks of a large cross section, and are thus only analysed for such cases. This analysis must calculate the forces on the internal structures of components connected to the fluid system (e.g. forces on the reactor vessel internals in case of breaks in the pipework connected to the reactor coolant system). In addition, compression waves generate forces on the piping supports which are considered in the context of the reaction force analysis.

Jet impingement forces must be considered, in case of breaks and leaks, with respect to the consequential effects on neighbouring systems, components and structures. The resulting loads must be taken into consideration by ensuring that the loads are covered by the design or by providing appropriate protection measures, e.g. restraints or additional supports.

Reaction forces due to leaks or breaks acting on the relevant pipework supports must be taken into consideration for the calculations required for these supports.

Pipe whip must be considered, in case of breaks with respect to possible impact on neighbouring systems, components and structures.

With respect to the consequences on other pipework, it is assumed for pipe whip that :

- Breaks may occur in pipework with a diameter less than that of the pipework subject to whip;
- Consequential leaks may occur in pipework with a diameter greater than or equal to, and of a lesser wall thickness, than that of the pipework subject to whip.

The assumptions for consequential failure are shown in figure C.4.2 FIG 1.

2.6.2 Buildings to be considered

The local effects of failures in high energy lines in the following safety classified buildings must be analysed:

- Reactor building;
- Safeguard buildings, including the main steam and feedwater valve compartments;
- Fuel building.

2.6.3 Installation requirements relative to the avoidance of inadmissible consequential effects

Protection requirements must be defined for analysing the admissibility of local effects on adjacent systems in case of failures of high energy pipework. These protection requirements are based on the following design bases:

- In case of loss of the reactor coolant, the integrity of the containment including the pipework sections local to the containment penetrations, as well as the operability of the containment isolation valves, must be ensured in order to prevent the release of radioactivity outside the containment;
- Systems required to shutdown the reactor, maintain sub-criticality and remove residual heat must not be adversely affected by a pipework failure;
- A consequential failure in the small diameter impulse lines and cables of safety classified components is admissible if the resulting actions are not detrimental to safety or if the components are fail safe. If this is not the case, detailed failure analyses must be performed;
- As a general rule, the same protection requirements must be applied to the safety classified supporting systems as are applied to the safety classified systems themselves.

The protection requirements are important in case of high energy line failures. In certain instances, dispensation from these protection requirements is acceptable, where an appropriate justification is provided.

2.6.4 Integrity of radiological barriers

In case of pipework failure, the integrity of at least one of the following barriers is required:

- reactor coolant pressure boundary, including the steam generator tubes;
- containment.

Reactor Coolant Pressure Boundary (CPP) [RCPB]

The reactor coolant system isolation valves should be located as close as possible[3] to the reactor coolant system.

In order to prevent a consequential APRP [LOCA] in the case of a postulated failure in pipework connecting to the reactor coolant system, provision must be made for protection devices (e.g. fixed points).

Protection of the CPP [RCPB] is not the last line of defence and, as a result, this protection must be seen as a contribution to a defence in depth approach.

In case of failures in pipework not connected to the CPP [RCPB] e.g., failures in main steam lines or main feedwater lines, the isolation of the reactor coolant system must remain operable in order to ensure integrity of the CPP [RCPB].

Containment

When the containment function is required (release of reactor coolant inside the containment), integrity of the pipework sections which run through the containment up to and including the containment isolation valves must be ensured.

The containment isolation valves must remain operable.

For pipework which penetrates the containment, postulated failures between the isolation valve and the fixed points located beyond the valve require the protection of the:

- containment;
- pipework sections between the containment and the internal and external isolation valves, the fixed points beyond the isolation valves and the isolation valves themselves;
- power supply and the signal connection to the isolation valve.

However, if the initiating failure occurs in the area between the isolation valves, or close to them, one of the isolations is considered to be lost. In this instance, the penetration itself performs the containment function, as well as the pipework section outside containment, which must remain intact and leak-tight, i.e. there must no propagation of damage through the containment penetration.

The containment isolation valves are located as close[4] to the containment as possible.

An internal reactor building BR isolating component will be added to the RIS [SIS] system injection lines, which is specific to the internal BR containment isolation.

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[3] It is essential that there is a minimum distance in order to prevent potential damage resulting from the thermo-hydraulic stresses.

[4] For the RIS [SIS] system, the second isolation valve in the primary system is also the containment isolation valve. These valves are installed in dedicated valve rooms which are located between the primary loop protection wall and the containment.

In order to avoid pressurisation in the annulus between inner and outer containment buildings, the containment penetrations for high energy pipework containing fluid with a temperature of $\geq 100^0$C will be fitted with protection devices (e.g. double sleeved or guard pipework).

2.6.5 Preclusion of breaks resulting from consequential damage

Due to application of the break preclusion concept, breaks are discounted in certain high energy systems (see Chapter C.4.2.2.1.3, break preclusion).

Consequential damage to systems where the break preclusion principle applies must not occur due to other events.

2.6.6 Fulfilment of the required safety functions

In principle, the safety functions must be ensured using redundant means, segregated by divisional separation or by concrete structures for areas without divisions (see Chapter C.4.4 on Internal missiles). Certain specific installation requirements are described below, in particular in terms of local effects due to internal hazards (e.g. pipe breaks):

- In order to comply with the single failure criterion for the required RIS [SIS] trains, the APRP [LOCA] must be limited to one leg (hot or cold) of one reactor coolant system loop. In addition, the RIS [SIS] lines which do not inject into the break must remain intact;

- This also concerns consequential damage to the pressuriser spray lines (connected to the cold leg of loop 2 or 3). However, a break in a spray line may result in a simultaneous ARRP [LOCA] via the hot leg (connection of the pressuriser surge line) and the cold leg (connection of the spray line to loop 2 or 3). These cases are covered by the analyses of cold leg leaks and breaks;

- As a general rule, the pipework installation must be performed in a way which prevents consequential failures of the secondary system in case of a failure in the primary system and vice-versa;

- The isolating function of the secondary side must be ensured in a way which isolates the affected steam generator in case of failure in the main steam or feedwater system and all other secondary side leaks which cannot be isolated;

- Isolation of the affected pipework in case of a failure which can be isolated in the lines connected to the steam generators must be ensured (e.g. by fixed points which protect the isolation valves);

- A failure of secondary side pipework must not lead to simultaneous depressurisation of two steam generators, unless it is possible to demonstrate that this is acceptable from a safety perspective.

- Consequential failures between steam and feedwater pipework of the same steam generator must be avoided.

- Unacceptable consequential failures of the EVU [CHRS] system must be ruled out by using suitable installation (layout) provisions.

- In case of pipework failures with consequential damage to other pipework, the total fluid loss must remain within the limits of the global effects analyses.

2.7 ANALYSIS OF GLOBAL CONSEQUENCES

2.7.1 Flooding

(See Chapter C.4.8 - Internal flooding)

2.7.2 Harsh environmental conditions (increase in pressure, temperature, humidity, radiation and release of boric acid)

The qualification of the relevant electrical and instrumentation and control equipment must be performed such that the harsh environmental conditions resulting from the postulated failures can be supported even at the end of the unit's service life (consideration of ageing).

2.7.3 Pressure, Temperature, Humidity

Failure of pipework carrying hot water ($T \geq 100^0C$) or steam must be analysed taking into consideration the environmental conditions in the safety classified buildings.

Representative cases must be determined for the safety classified buildings listed below. The systems and components required to achieve the safety objectives must be designed so that they remain operational in case of an event which causes these harsh environmental conditions.

The following buildings must be analysed in relation to the effects of pressure, temperature and humidity:

- Reactor building;
- Safeguard buildings, including the main steam and feedwater valve compartments;
- Fuel building.

The systems and components of one division in the diesel generator buildings and the pumping station may be subject to failures caused by harsh environmental conditions, if the systems which cause these conditions are located in these buildings.

The propagation of the harsh environmental conditions from the non-safety classified buildings or from the nuclear auxiliaries building towards the safety classified buildings must be prevented using appropriate measures.

Reference should be made to Chapter C.4.8.1.2.2 for leak detection and the required grace periods for the implementation of countermeasures.

2.7.4 Radiation, release of boric acid

The global effects caused by radiation and the release of boric acid must be assessed for the required systems and components. Qualification of these components against radiation and boric acid release is required inside the containment and is described in the RCC-E.

2.7.5 Differential pressure forces for the building structures

The forces caused by differential pressure must be taken into consideration.

LIST OF REFERENCES

[1] Order dated 10 November 1999 relating to monitoring of the operation of the main primary system and of the main secondary systems for pressurized water reactors.

[2] Circular dated 10 November 1999 relating to monitoring of the operation of the main primary system and of the main secondary systems for pressurized water reactors.

[3] Computation of leak areas of circumferential cracks in piping for application in demonstrating leak-before-break behaviour. Nuclear Engineering and Design 135, 141-149, 1992.

[4] EPRI-GE handbook, “Advances in Elastic Plastic Fracture Analysis”. EPRI report NP 3607, 1984.

[5] RCC-M (see Chapter B.6)

[6] Examination of the break preclusion demonstration for main primary and secondary pipes from the EPR reactor project.
Correspondence DGSNR/SD5/FC/MFG n° DEP-SD5-0074-2006

TAB 1: FAILURE ASSUMPTIONS FOR THE SYSTEMS IN WHICH THE 2% CRITERION IS APPLIED

Systems	Failure assumptions	
	Back up (low energy)	Operation (low and high energy)
Back up system for accident control	Size of break equivalent to a DN 50 pipework breach treated as enveloping case	-
RCC-M classified systems used in normal operation in low and high energy modes	Size of break equivalent to a DN 50 pipework breach treated as enveloping case	Size of break equivalent to a DN 50 pipework breach treated as enveloping case

TAB 2: SUMMARY OF FAILURE ASSUMPTIONS FOR THE HIGH ENERGY PIPEWORK SYSTEMS (LINES WITH DN>50)

System	Respective Line in System Section	RCC-M Classification	Failure assumptions		Comments
			Breaks	Leaks	
Primary system	Main reactor coolant pipework	C	-	X	The local loads caused by leaks are practically negligible for the design; for additional assumptions See C.4.2.2
Main steam system	Main steam lines from the GV [SG] to the containment's fixed points	C	-	X	The local loads caused by leaks are practically negligible for the design; for additional assumptions See C.4.2.2
	Main steam lines from the containment's fixed points to the fixed points downstream of the main steam isolation valves.	C	-	X	The local loads caused by leaks are practically negligible for the design.
	Main steam lines downstream of the above mentioned section	NC	X	X	
	Main steam discharge lines downstream of the safety valves and the pressure reducing isolation valves	C	-	X	Failure assumptions for the accident control backup systems
	Heating lines	C	X	X	
Water supply system	Water supply lines from the GV [SG] to the water supply isolation valves	C	X	X	

C = Classified / NC = Non-classified

System	**Respective Line in System Section**	**RCC-M Classification**	**Failure assumptions**		**Comments**
			Breaks	**Leaks**	
Water supply system	Water supply, start-up and shutdown lines upstream of the water supply isolation valves	NC	X	X	
Pressuriser system	Expansion line	C	X	X	
	Pressuriser spray lines	C	X	X	
	Pressuriser discharge line	C	-	X	Failure assumptions for the accident control backup systems
Safety injection / Cooling of the reactor at shutdown	Lines between the main primary pipework and the first isolation valve	C	X	X	
	Lines between the first isolation valve and the second isolation valve	C	X	X	
	Accumulator injection lines between the accumulator and the second isolation valve towards the main primary pipework	C	X	X	
	Other RIS [SIS] /RRA lines (beyond the second isolation valve towards the main primary pipework)	C	X	X	Failure assumptions for the accident control backup systems and for the operating systems (for the section fulfilling the RRA function in a closed system)

C = Classified / NC = Non-classified

System	Respective Line in System Section	RCC-M Classification*	Failure assumptions		Comments
			Breaks	Leaks	
Chemical and volumetric control system with seal injection for the reactor coolant pumps	High energy pipework sections RCV [CVCS] charging lines towards the main primary coolant pipework, the pressuriser and the reactor coolant pumps Main reactor coolant system discharge pipework towards the HP reducing valve.	C	X	X	
	Other sections of pipework (low energy)	C	-	X	Only relevant for flooding
Emergency feedwater system	GV [SG] lines towards the non-return valves	C	X	X	
	Lines between the non-return valves and the isolation valves	C	-	X	Failure assumptions for the accident control backup systems
	Lines between the isolation valves and the emergency feedwater pumps	C	-	X	Failure assumptions for the accident control backup systems
	Other lines between the emergency feedwater supply tanks and the pumps (low energy)	C	-	X	Only relevant for flooding and the loss of pipework functionality

C = Classified / NC = Non-classified

System	Respective Line in System Section	RCC-M Classification	Failure assumptions		Comments
			Breaks	Leaks	
Steam generator purge system	Lines between the GV [SG] and two secondary side isolation valves	C	X	X	
	Lines downstream of the two secondary side isolation valves and the reducing tank	NC	X	X	
	Reducing tank	NC	X	X	The break is admissible because it is located in a separate compartment
	Lines in the containment from the reducing tank towards the water supply tank	NC	X	X	
	Containment isolation for the above mentioned line	C	X	X	
	Above mentioned line downstream of the external containment isolation valve	NC	X	X	
	Line from the reducing tank towards the exchanger	NC	X	X	
	Lines from the exchanger towards the containment isolation	NC	-	X	Only relevant for flooding
	Containment isolation for the above mentioned line	C	-	X	Only relevant for flooding
	Lines in backup building 4 and the nuclear auxiliaries building	NC	-	X	Only relevant for flooding in backup building 4. No analysis of the indirect failures in the nuclear auxiliaries building, (See C.1.1)

TAB 3:ASSUMPTIONS ADDITIONAL TO THE BREAK PRECLUSION PROCEDURE ON THE MAIN REACTOR COOLANT SYSTEM PIPEWORK

Effects		Postulated pipework failures
on	**from**	
RIS [SIS] Performance	Loss of coolant	Leak/break on the main primary pipework up to 2A break
Containment	pressure temperature	2A break on the main reactor coolant system pipework
Environmental qualification of equipment	flooding pressure temperature humidity radiation	2A break on the main reactor coolant system pipework
Primary components (with internal equipment and supports)	Dynamic effects of decompression	Guillotine break of all lines connected at the connection weld
Internal containment structures	Differential pressure temperature flooding	2A break on the main primary pipe Guillotine break of all lines connected at the connection weld
Main component supports	Co-linear 2pA force with the nozzle	“2PA” Force

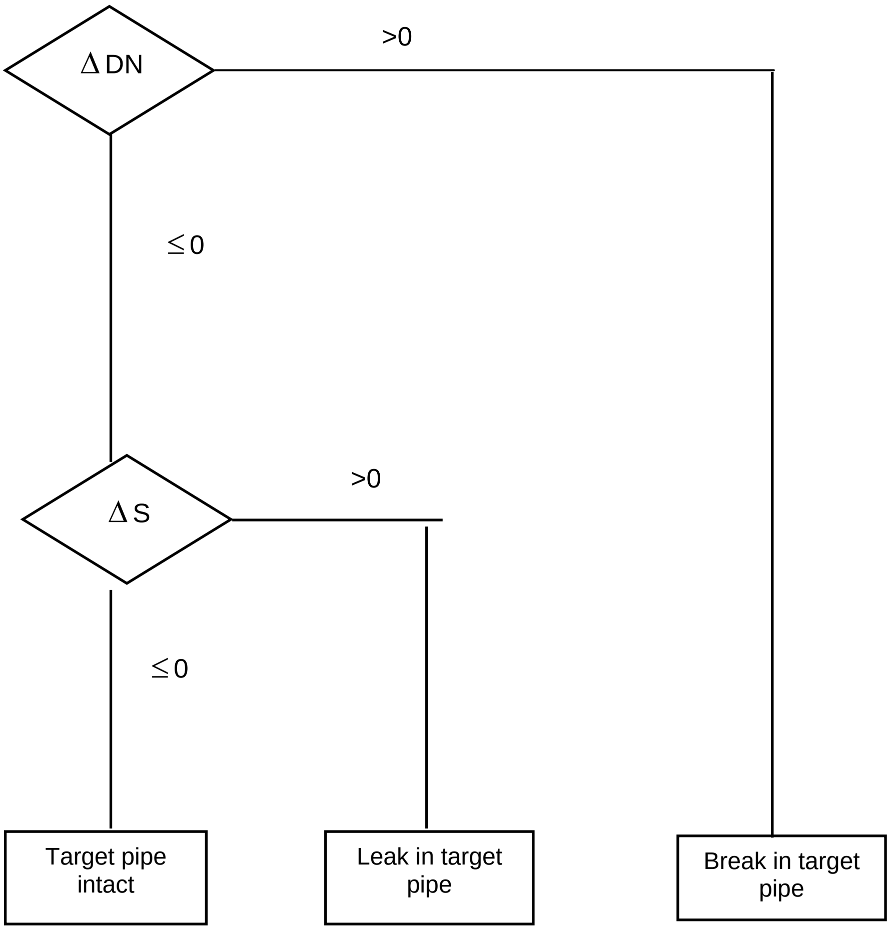
TAB 4: ASSUMPTIONS IN THE CONTEXT OF A BREAK PRECLUSION OF THE MAIN STEAM LINES IN THE CONTAINMENT

Effects		Postulated pipe breaks
from	**on**	
Additional assumptions despite the break preclusion		
Steam generator supports	Co-linear 2pA force with the nozzle	“2PA” Force
Containment	Pressure accumulation Temperature	2A break on a main steam line if it is not covered by a 2A break on the main primary pipe
Environmental qualification of equipment	Pressure Temperature Humidity	2A break on a main steam line if it is not covered by a 2A break on the main primary pipe
PCC4 events		
Steam generator with steam generator tubes and main steam line in the containment	Dynamic effects of decompression	Guillotine break in the areas without BP
GV [SG] tubes	Differential pressure between the primary side and the depressurised GV [SG]	Break in a main steam line downstream of the steam isolation valves
Internal containment structures	Differential pressure Temperature Flooding	Guillotine break in any other connected GV [SG] line, that is, APG [SGBS] and ASG [EFWS]
Behaviour of reactivity	Over-cooling transient	Break in a main steam line downstream of the steam isolation valves with pure steam discharge

TAB 5: EFFECTS OF PIPEWORK FAILURE (SUMMARY)

Effects from	Effects on
Jet impact forces	Building structures, components
Pipe whip	Building structures, components
Reaction forces	Building structures, components
Compression wave forces	Components
Flow forces	Components
Differential pressure	Building structures
Pressure accumulation	Building structures, electrical and control system equipment
Humidity	Electrical and control system equipment
Temperature	Building structures, electrical and control system equipment, components
Radiation	Electrical and control system equipment
Flooding	Building structures, components

FIG 1: POSTULATED SECONDARY FAILURES CAUSED BY PIPE WHIP



ΔDN. nominal diameter of the pipe subject to whip less the nominal diameter of the target pipe

ΔS thickness of the wall subject to pipe whip less the thickness of the wall in the target pipe