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CONTAINMENT BYPASS AND LEAKTIGHTNESS

Report by an NEA Group of Experts

October 1995

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COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS (CSNI)

PRINCIPAL WORKING GROUP ON
CONFINEMENT OF ACCIDENTAL RADIOACTIVE RELEASES (PWG4)

CONTAINMENT BYPASS AND LEAKTIGHTNESS

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with the support of the

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FOREWORD

Containment bypass and leaktightness is an important topic. The purpose of this report, prepared by CSNI's Principal Working Group on the Confinement of Accidental Radioactive Releases (PWG4) and its Task Group on Containment Aspects of Severe Accident Management (CAM), is to present a "snapshot" of the situation regarding the reliability of the containment isolation devices. The report, drafted by Mr. F. Robledo (CSN, Spain), covers the following aspects: containment leaktightness control, operational experience, reliability of containment isolation devices, detection methods, containment bypass, conclusions and recommendations. It focuses on light water reactors and core damage accidents at full power.

Efforts have been made to be practical, and to establish links between theoretical studies and real plant criteria.

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LIST OF ACRONYMS

DF	Decontamination Factor
FRIPP	Forsmark Ringhals Post Accident Project
ILRT	Integrated Leakage Rate Test
LLRT	Local Leakage Rate Test
PASS	Post Accident Sample System
PRISE	Primary to - Secondary leakage accidents
SGTR	Steam Generator Tube Rupture

CONTENT

1.- INTRODUCTION

The containment building is the last barrier to prevent the release to the environment of the fission products generated in case of a core damage accident. Therefore, an assurance of the containment leaktightness during the course of a core damage accident is critical to the plant safety. This report analyzes the reliability of the containment isolation devices, i.e., their capability to maintain the containment leakage rate below the allowable limits in the safety analysis; the probability of severe accidents resulting in containment bypass as well as a review of the installed measures to detect unacceptable leaks in the containment isolation devices during a core damage accident. This report focuses on light water reactors and core damage accidents at full power.

2.- CONTAINMENT LEAKTIGHTNESS CONTROL

The control of the containment leaktightness is mainly carried out by the containment leakage rate testing program. The main objective of this program is to guarantee that throughout the operating cycle, the containment leakage rate holds below the allowable limits in the safety analysis. The containment leakage rate testing program consists of two kinds of tests: local leakage rate tests (LLRT) and the containment integrated leakage rate test (ILRT).

This program is not the unique method to assure the containment leaktightness during the normal operation of the plant. There exist alternate methods to detect gross leakage during normal operation: the subatmospheric containment, inertization, to keep the containment at slight overpressurization or underpressurization, low pressure test during normal operation, the methods shown in NUREG-1273 (Ref.1), and the administrative controls to assure the closure of the local manual containment isolation valves. NUREG-1273 analyzes the efficiency of these methods and concludes that the alternate methods cannot completely replace the current containment leakage testing program, because of the low pressure and the lack of accuracy in comparison with current tests. However, these alternate methods have an advantage over the current program: the speed of detection. For alternate methods, the time to detect a leak ranges from one day to several weeks, whereas the current program detects the leak from 6 to 12 months in average. The installation of an on-line containment leaktightness monitoring system is being considered for some future LWR.

This report focuses on LLRT and ILRT in present LWR, so that a more detailed description of these tests is made.

2.1.- LOCAL LEAKAGE RATE TESTS (LLRT)

The LLRT objective is to assure the leaktightness of the containment isolation devices that may become potential leakage pathways after a LOCA. These containment isolation devices are: equipment hatches, personnel airlocks, electrical penetrations, blind flanges, expansion bellows and containment isolation valves.

Table I shows some characteristics of the local leakage rate testing programs in several countries. It can be seen that significant differences exist. The main differences focus on the number of containment isolation valves submitted to LLRT, test pressure and frequency. These issues are analyzed in more detail below.

2.1.1.-<u>Containment isolation devices submitted to LLRT</u>

As table I shows, there is no uniformity in the scope of the LLRT program. The containment isolation valves belonging to the feedwater lines in BWR are not submitted to LLRT in all the plants. As far as PWR is concerned, in some designs, all the containment isolation valves are leak tested, except for those valves belonging to the secondary system, whereas in other designs a reduced number of containment isolation valves are leak tested, only those belonging to the containment ventilation systems.

2.1.2.-<u>Medium and pressure</u>

LLRT are carried out with air, nitrogen or water. The use of air or nitrogen as test fluid is recommended for several reasons:

i) These test fluids represent most closely the containment environment after a LOCA.

ii) There are no reliable correlations to extrapolate water leakage rate test results to an equivalent air leakage rate test results.

iii) LLRT carried out with air or nitrogen are more conservative than the corresponding water LLRT.

From table I, test pressure ranges from 10 mbar up to pressure above DBA pressure (full pressure). Two reasons, mainly, underlie on this wide range of pressures. The first reason is that the design of some containment isolation devices impedes LLRT at full pressure. The second reason is the credit given to the reliability to extrapolate low pressure leakage rate test results to full pressure leakage rate test results (see chapter 2.2.3). Test pressure should be applied to the containment isolation devices in the same direction that would occur after a LOCA. Testing in the reverse direction is discouraged because the results are not always conservative.

2.1.3.-Fluid test temperature

Typically, LLRT are carried out at room temperature. The influence of the temperature in the containment leakage rate test results is analyzed in chapter 2.2.4.

2.1.4.-Containment isolation valve closure

Closure of containment isolation valves for LLRT shall be accomplished by normal operation and without adjustments.

Some valves fix better after being pressed against the seat for some hours. This issue arises from the question of the convenience of a "waiting period" before the LLRT. This practice is discouraged because the containment integrity is required from the beginning of an accident.

2.1.5.-Frequency, " as found" and "as left" LLRT.

Table I shows a great variety in LLRT frequency. It ranges from once in three days (typical frequency for seals in personnel airlocks opened oftenly) up to once in four years. Typical LLRT frequency is every outage for refuelling. This frequency is shortened when the containment isolation devices show recurrent failures in previous LLRT as well as their safety significant is relevant. That is the case of the personnel airlock. The recurrent failures found in past LLRT - mainly, because of its frequent openning during normal operation - and its great importance for the safety resulted in more frequent LLRT. Also, LLRT may be made less frequently when the component shows a good performance. That is the case of some electrical penetrations.

In order to obtain an accurate measure of the leaktightness of the containment isolation devices during the operating cycle, two LLRT should be carried out for each containment isolation device: the "as found" leakage rate and the "as left" leakage rate. The "as found" leakage rate is defined as the leakage rate prior to any needed repairs or adjustments to the leakage barrier being tested. The "as left" leakage rate is defined as the leakage rate following any needed repairs or adjustments to the leakage barrier being tested. The "as found" leakage rate provides a measure of the containment isolation devices leaktightness during the operating cycle. In some countries, the "as found" leakage rate is measured only when the ILRT is to be carried out, i.e. three times in ten years. In other countries the "as found" leakage rate is measured with the same frequency as the "as left" leakage rate, i.e., each shutdown for refuelling.

USNRC may change during 1995 its regulations on containment leakage testing program (ref. 27, 28). NUREG-1493 (ref. 29) provides the technical basis for this change. The new regulations shall be based on the performance of the containment isolation devices from the leaktightness point of view. According with these new regulations, containment isolation valves may be leak tested up to once in five years, assuming that two consecutive periodic "as found" local leakage rate tests meet the acceptance criteria. Containment airlocks shall be leak tested once per two years, and the door seals shall be leak tested within 7 days after each containment access. For access more frequently than once every 7 days, door seals may be leak tested once per 30 days during this time period.

2.1.6. <u>Uncertainties in the measurement process.</u>

This section addresses briefly the issue of the role of the uncertainties associated with the leak rate measurement of the containment building. For the LLRT, the uncertainties in the leak rate measurement affect only a few plant specific cases, e.g. when several containment isolation devices are tested simultaneously. Because the study of the uncertainties in the LLRT measurements is a specific case of the more general issue of the uncertainties associated with the measurement process in the ILRT, it will be discussed in section 2.2.6.

2.2.- INTEGRATED LEAKAGE RATE TESTING (ILRT).

ILRT measures the overall leakage rate of the containment building. The main objective of this test is to find leakage pathways undetected by LLRT. In addition ILRT is a check of the LLRT. Some characteristics of this test are exposed below.

2.2.1.-Method

In order to measure the overall leakage rate of the containment building, it should be assumed that the air behaves as an ideal gas. By measuring temperature, dew point and pressure of the containment, the mass of gas inside the containment may be calculated. This mass decreases linearly along the time. This decrease is the leakage rate.

2.2.2.-Frequency

Table II shows the time intervals to carry out the ILRT in several countries. Test frequency ranges from every outage for refuelling up to once in 10 years, the most typical frequencies are 3 times in ten years or once in 4 years. Belgian and French plants carry out ILRT once in ten years because these plants are also tested at low pressure, up to Δp=60 mbar, during normal plant operation. The objective is to detect, instead of a containment liner degradation, any gross leak from misaligned valves, unintentional left open valves, flanges or instrument connections. These tests allow to detect leaks with an equivalent diameter of 1 cm. at Δp=60 mbar. These tests are performed after each cold shutdown of more than fifteen days. Ref. 2 provides additional information on these tests.

As it was explained in chapter 2.1.5. USNRC may change its regulations on containment leakage rate testing program. According with these new regulations, ILRT may be carried out up to once per ten years, assuming that two consecutive periodic "as found" ILRT meet the acceptance criteria.

2.2.3.-Pressure

This is a very controversial issue. As Table II shows, test pressure varies with the countries, ranging from 0,5 bar up to the full pressure. This variety in the test pressure stems from the different technical opinions about the reliability to extrapolate low pressure leakage rate test results to full pressure leakage rate test results.

Some experts think that there exist reliable correlations to extrapolate low pressure leakage test to a greater pressure (Ref.6). Other experts think that these correlations do not exist. (Ref.7,8).

2.2.4.-Temperature

ILRT is run at room temperature. Probably, here lies the main test conservatism. Table III shows the results obtained in a research program carried out in Carolinas Virginia Tube Reactor in 1971 (Ref.9). For this decommissioned nuclear power plant, the resulting environment conditions after a DBA were:

Pressure : 21 psig.
Temperature : 33,3°C.

Table III clearly shows that the containment leakage rate decreases as the temperature is increased. One additional test was run at the DBA conditions, i.e., the above mentioned pressure and temperature plus the corresponding steam mass. Test result was 0,260%/day, providing an additional verification to the earlier conclusions.

Table IV shows the results of the experimental program carried out in CSE in 1970 (Ref. 7). Table IV verifies the aforementioned conclusions. In addition, in these experiments, the leakage rate was measured for several individual containment penetrations including: blind flanges, cap, valves and a drilled hole of 0,076 cm. in diameter (equivalent to a leakage rate of 4000 l/min at room temperature). In all the cases, the greater the test temperature, the lower the leakage rate. In the case of the hole, a detailed examination after the test revealed that it was plugged with the debris generated during the drilling process.

2.2.5.-Duration

The full pressure ILRT may be run in eight hours with the present instrumentation. This time is increased at lower test pressures. In addition, a stabilization period is necessary before conducting the test. One reason is that one should allow the conditions in the containment (temperature, humidity, ...) to become stable so as to increase the accuracy of the measurements. Another reason is that when there is a pressure change in the containment the concrete structure take some time to come in equilibrium. Concrete contains air, and some hours are needed for this air to reach the same pressure as in the containment. If an ILRT is performed inmediately after the containment has been at a higher pressure, the air coming out of the concrete could mask a containment leak.

2.2.6. Uncertainties in the measurement process.

The study of the uncertainties associated with the measurement of the overall containment leak rate during the ILRT is an important issue, but it is beyond the scope of this report. Nevertheless, it will be briefly addressed below. Although significant progress was made in the past on the adequacy of the instrumentation associated with the ILRT (ref. 5), there exist still a great number of variables that affect the accuracy of the measurement of the overall containment leak rate during the ILRT, e.g. the mouisture content of the air, the number of dry-bulb sensors, the stability of the containment atmosphere conditions, etc.

It must be born in mind that the measurement methods used in power plants are not really a scientific measurement of the leak rate, but rather a verification that the real leak rate is below the criterion (La), with a specified confidence level. It is therfore possible to "measure" a leak rate when in fact the containment is practically leaktight. This is acceptable because the goal of the ILRT is not to have an accurate knowledge of the leak rate, but to demostrate that the containment meets its leaktightness limit.

Generally an ILRT is performed after completing the LLRT. The results of the "as left" LLRT typically fall in the range from 6% to 15% of the allowable containment leak rate defined in the safety analysis (La). Howerver, the overall containment leak rate measured in ILRT generally falls in the range from 10% La up to 75% La, 50% La being a typical value, Therefore, the containment leak rate measured during the ILRT may be considered as an upper bound of the real containment leak rate.

3.- OPERATIONAL EXPERIENCE

In this chapter some of the problems related with excessive leakage rate found during the execution of the containment leakage test program are exposed.

3.1.- EXCESSIVE LAKAGE RATES FOUND WITH ILRT.

Following, some of the leakage pathways found during ILRT running are described

- U.S.A.

NUREG/CR-3549 (Ref.7) provides the following examples:

- One ILRT failed due to excessive leakage through two holes that had been inadvertently drilled in the liner.

- During one ILRT, leakage was found in the reactor building differential pressure switches resulting from rupture diaphragms. The diaphragms had been incorrectly designed for a pressure less than the DBA pressure.

- Nine ILRT failed due to excessive leakage from penetrations or valves that previously were subjected to local leak testing.

USNRC IE Bulletin No. 78-09 (Ref. 8) shows that inadequate drywall head closures in BWR resulted in ILRT failures.

USNRC IE Information Notices 86-16, 88-73, 92-20 (Ref. 9, 10, 11) show that an inadequate local leakage rate test program resulted in ILRT failures, because of the LLRT were carried out in the reverse direction.

- FRANCE.

IRS-N° 1288. GO (Ref.15) shows that some corrosion problems in the liner were found in some of the 900 MWe unit containments. In Bugey-4, these problems were found during the ILRT in 1990. Since that time, all EDF 900 MWe units have been scrutinized for this issue. The findings were some corroded parts and a few holes in the lower part of the liner (truncated region, beneath the dead concrete layer at the bottom of the reactor containment). According to an EDF safety study, the observed damage is not subject to aggravation under the mechanical stresses resulting from an accident, and in no case should yield an accidental radioactivity release into the environment. Nevertheless, all 900 MWe units are checked and fixed, when appropiate, to make them fully comply with the design requirements; methods include concrete injection, repair of holes and corroded parts, fixing and protection of the seals between the liner and the covering dead concrete layer. As of March 1995, nine units are fully repaired, and the works on the twenty-five remaining units are due to be completed by the end of 1997.

- BELGIUM.

CSNI Report 179 (Ref. 2) shows the following ILRT failures:

- Doel 2, September 1986. At 0,5 bar overpressure, an open valve was discovered on the personnel airlock and was closed.

- Tihange 2, July 1981: At 2,7 bar overpressure the equipment hatch began to leak. This hatch is bolted from outside and is therefore not autoclave. It was discovered that the torque used for the bolts was too low.

- Tihange 3, July 1984: At 0,4 bar overpressure, an open line was discovered on the equipment hatch. This line had been used previously for some tests and had been inadvertently left open.

- SWEDEN.

In 1993, during the ILRT carried out in Barseback-2, the containment leaked in excess of specified limit by a factor of 2. The investigations revealed corrosion holes in the steel liner due to poor workmanship during the building of the containment. The corroded parts of the liner were replaced.

Unintentionally left open isolation valves in small pipes have been found a couple of times during ILRT's.

- SPAIN.

In 1981, in Ascó 1, a PWR Westinghouse design, the containment pressurization for ILRT was stopped at 0,5 bar to carry out a visual inspection. This inspection revealed several drills in the liner.

In 1986, in "Santa María de Garoña", a BWR-4 with Mark I type containment; a gross leakage was detected through a containment isolation valve belonging to Post Accident Sampling System (PASS) and a moderate leakage was found through one personnel airlock penetration out of service. The cause of these leaks are described below. Containment isolation valves belonging to PASS were not local leak tested; the personnel airlock in this plant cannot be overall leak tested at full pressure, only at 1/6 of this pressure and it was the first time that ILRT was run at full pressure.

In 1986, in "José Cabrera", a PWR Westinghouse design, during the pressurization for the ILRT at a pressure between the half and full pressure, a great leakage was detected in the connection box of the personnel airlock. The leakage came from a defective electrical cable inside the containment.

In other plants, in two occasions, the air space between the two containment isolation valves belonging to the containment ventilation system was partially pressurized during the ILRT running.

- ITALY

Trino Vercellese showed leakage from the ventilation isolation valves during ILRT running.

Caorso showed leakage through several containment isolation valves including those belonging to the "Primary Containment Air Purge" systems during the ILRT run in 1986.

3.2.- EXCESSIVE LEAKAGE FOUND WITH LLRT

There are a great number of cases in which the "as found" leakage rate of the containment isolation devices is in excess of the allowable limits. Below a brief description is provided for the cases that potentially have a greater impact in the safety.

3.2.1.-<u>Containment purge and vent valves</u>

These penetrations provide a direct pathway between the containment and the environment. Therefore, the leaktightness assurance is very important for the safety. In some countries, these containment isolation valves are leak tested every 3 to 6 months. This high frequency stems from the recurrent LLRT failures found in these valves.

3.2.2.-<u>Containment personnel airlocks</u>

Because of the great size of these mechanical penetrations as well as their frequent opening in many plants, the leaktightness of these penetrations is relevant for the safety. In some countries, these containment personnel airlocks are overall leak tested once per six months and the door seals are leak tested when the airlock is opened for personnel entry into the containment. The recurrent LLRT failures found in the past is the reason for this high frequency.

3.2.3.-MSIV in BWR

In BWR plants, the main steam lines provide a direct pathway between the reactor pressure vessel and the environment. This fact shows their significant role for the safety. The recurrent failure found during the LLRT in these valves forced, in some countries, the installation of one specific system to provide an additional assurance of their leaktightnes: the Main Steam Isolation Valves Leakage Control System. Nevertheless, the problems to maintain the leakage rate in these valves below the allowable limits continue, so that additional measures are being studied to solve this problem. The problems to hold the leaktightness of these valves come from several causes: seat damage, inadequate dimensioning of pieces of the valves, etc.

3.2.4.-Feedwater valves in BWR

These lines provide also a direct pathway to the environment. The containment isolation devices for these lines are, typically, two check valves. These valves have a double safety function. On the one hand, they have to assure the water leaktightness of the reactor coolant system at the operating pressure. For this purpose, the hard seat is very suitable. On the other hand, they have to maintain the containment leaktightness during a LOCA. In these accidents, containment pressure ranges from 0,8 bar up to 3,5 bar overpressure and the fluid is air or nitrogen plus steam. In order to pass the LLRT under these conditions, soft seat is more suitable. To accomplish these two safety functions, several measures have been taken: to install hard seat in one containment isolation valve and soft seat in the other one; to increase the corrective maintenance for the hard seat valves; to relax the leaktightness requirements for the LLRT. Every solution has advantages and drawbacks. The first one allows to comply with the double safety function but the single failure criterion is not totally fulfilled. The soft seat increases the possibility for water leakage and poses significant potential for degradation under normal operating conditions. The second solution arise dose problems and may be necessary to dedicate significant resources for corrective maintenance. In addition, this increase in corrective maintenance resources does not always assure total air leaktightness during normal operation. The third solution assures the water leaktightness, but the air leaktightness may be impaired.

3.2.5.-Penetrations that bypass the secondary containment in BWR.

The design of some BWR includes containment penetrations that bypass the secondary containment. The loss of the leaktightness of these penetrations in case of LOCA results in a very strong radiological impact. In addition, their allowable leakage rate is very small, therefore, the assurance of their leaktightness is a very significant issue for the safety.

3.2.6.-Service air penetrations.

In many cases, the service air lines are made of carbon steel. The great humidity of the service air generates a great quantity of debris from carbon steel corrosion. These debris damage the containment isolation valves seats with the corresponding safety problem.

3.2.7.-Electrical penetrations.

Electrical penetrations show a much better performance for leaktightness than the remaining containment isolation devices. As an example, the NUREG-1273 (ref. 1) shows that 33 out of 2192 (1,5%) failures in containment isolation devices come from electrical penetrations.

4.- RELIABILITY OF THE CONTAINMENT ISOLATION DEVICES

This section tries to provide a method to assess the reliability of the containment isolation devices in case of accident with the reactor at full power. This method may be divided in the three steps described below.

4.1.- RELIABILITY OF THE CONTAINMENT ISOLATION DEVICES AGAINST CONTAINMENT ISOLATION SIGNALS.

This step calculates the probability of failure of a valve to close, if a containment isolation signal occurs. This probability may be calculated by probabilistic safety analysis (PSA) techniques. The PSA carried out in the Spanish plants show a failure probability around 1E-3 to 1E-2. For Swedish PWR, the total probability of a containment isolation valve not to close at a LOCA less than 5 cm^2 is assumed to be 0,015. The corresponding probability at a 60 cm^2 is 0,01. These probabilities are based on statistics, being one substantial contributor the unintentionaly left open valves. For German plants, the failure probability of containment isolation valves is about 2E-5 for ventilation valves. The other isolation valves have a failure probability of 1E-6 to 1E-7. All these numbers show a high reliability.

Some containment isolation devices are locked closed during the normal operation and only can be local manually actuated. The probability to leave unintentionally opened these devices should be included in this step. A precise quantification of this probability was not found in the literature reviewed for this report. Nevertheless, NUREG-1273 (Ref. 1) reports that only 130 out of 2189 (6%) events analyzed were due to unintentionally left open some containment isolation devices. The aforementioned probabilities for Swedish PWR show an upper bound for unintentionally left open containment isolation valves.

4.2.- RELIABILITY OF THE CONTAINMENT ISOLATION DEVICES FROM THE LEAKTIGHTNESS POINT OF VIEW.

Assuming that the containment isolation devices are closed in case of accident, the next step is to calculate the probability that the leakage rate of the containment isolation devices is higher than the allowable values. This issue is strongly plant specific. The aforementioned probability has been calculated in several works. Ref. 2 provides an excellent review of a significant number of them. One of the most complete works in this area is NUREG-1273 (Ref.1), whose main results are shown in Table V. These results were obtained by taking data from the containment leakage test program results of many plants. Because of the plant specific characteristics of this issue, the results shown in Table V should not be applied to a particular plant. Instead, these results show that a significant number of plants need improvement in the field of the containment isolation devices leaktightness.

The assurance of the containment isolation leaktightness depends on characteristics that are very plant specific:

i) Design plant features; i.e., the number and size of penetrations that communicate the containment with the environment.

ii) Containment isolation devices design features. Similar containment isolation devices show a different behaviour in different plants. For example, some containment purge valves or containment personnel airlocks show high leakage rates in some plants but not in other plants.

iii) Type of containment. Mark I type containment is unaccessible in normal operation because it is inerted, but in other plants the entrance to the containment is frequent in normal operation.

iv) Management issues; i.e., resources dedicated to the maintenance; efficiency of the maintenance in the past.

v) Problems found during the running of ILRT, described in section 3.1., are very different.

4.3.- RELIABILITY OF THE CONTAINMENT ISOLATION DEVICES AGAINST SEVERE ACCIDENT LOADS.

On this issue the following aspects should be considered.

- The capability of the containment devices to withstand the pressure, temperature, radiation fields and deformation loads resulting from a severe accident. The main information to analyze this situation comes from the experiments. A quick reading of the experimental results sponsored by USNRC, shows that the usual isolation devices have great safety margins and can withstand the loads resulting from severe accidents. The extrapolation of these experimental results to older containment isolation devices may be uncertain. Nevertheless, the following points should be taken into account:

  i) Some containment isolation valves with elastomer seals can maintain their leaktightness against severe accident loads, but when the pressure and, above all, the temperature descend, may lose their leaktightness (Ref. 13).

  ii) A strong hydrogen explosion may damage electrical cables in the containment with the potential to exacerbate the accident (Ref. 14).

  iii) Calculations carried out for Mark III containments show some potential for high temperature failure in drywall mechanical penetrations (Ref. 15).

  iv) It seems, that some electrical penetrations can withstand the severe accident loads but their capability for electrical current conduction may be hampered (Ref. 16).

v) Experiments carried out in Japan (Ref.17,18) show the following results:

a) Electrical penetration assemblies including alumina module is expected to withstand the loads from a severe accident.

b) Silicone-rubber gaskets maintain their leaktightness up to 225°C and five times the containment design pressure.

vi) Experimental results obtained by CISE in Italy, show that irradiation by deposited aerosols impaired elastomer seal leaktightness.

- In some severe accident sequences there exist containment isolation valves that can unintentionally open during the accident progression, with the corresponding increase in the containment leakage rate. This is the case of the containment isolation valves belonging to the scram system in some BWR designs (Ref.22). In case of a Station Blackout, the scram system with nitrogen tanks have valves with fail safe in open mode. This means that when the battery capacity is exhausted (after at least 2 hours) only the check valves in this system would stop activity release but with a considerably larger leakage.

- The capability of the closed loops outside the containment to maintain their leaktightness during a severe accident is a matter of special concern. These loops belong, usually, to safety systems and their containment isolation devices are: one or two containment isolation valves with the backup of the own closed loop. In some cases, these containment isolation devices are leak tested with air during outage for refuelling, in other cases leakage rate tests are carried out with water and, finally, in other cases no leakage rate tests, as such, are carried out, instead, the closed loop leaktightness is monitored during normal operation because these loops are continuously pressurized.

- Because of the leaktightness requirements for water testing are less stringent than the corresponding air testing, and some of these penetrations are in contact with the containment atmosphere during a severe accident, they can leak above the allowable values in current safety analysis. This issue is addressed in more detail in chapter 4.5.

In addition, some of these closed loop may transport containment water in the long term of a severe accident, arising concerns about their capability for leaktightness in the long term. This issue is treated in chapter 4.4.

- Some containment penetrations are located in the lowest part of the containment. If the reactor pressure vessel fails in a severe accident, these penetrations may be attacked by the corium. This was the case in some modern Swedish BWR plants. Protective measures were therfore installed to protect these penetrations to prevent containment failure (Ref. 20).

- In France, during the studies devoted to the analysis of the consequences of the basemat melt-through by the corium, it appeared that, in the 900 and 1300 MWe standard basemats, direct pathways to the atmosphere of early releases, not filtered by the ground (basemat auscultation, draining systems), were found.

  For the N4 standard, these pathways were eliminated at the design stage. For the 900 and 1300 MWe files of reactors, various arrangements are under study or already implemented, covered by the general term of U4 procedure, aimed at suppressing or mitigating the presence of these pathways (Ref. 21).

4.4.- CONTAINMENT LEAKTIGHTNESS IN THE LONG TERM OF A SEVERE ACCIDENT.

By long term is understood, in this chapter, the period of time ranging from one day up to five years after the onset of a severe accident. Several issues related with the long term aspect of a severe accident have been analyzed in the Swedish FRIPP (Forsmark Ringhals Post Accident Project) project (Ref. 22). The more relevant conclusions obtained in the FRIPP project concerning with the containment leaktightness in the long term after a severe accident are summarized below.

FRIPP studied one Swedish BWR (Forsmark 1) and one Swedish PWR (Ringhals 3) during a time interval ranging from 1 day up to 5 years after the initiating event. The scenario chosen was the total loss of AC power as initiating event, including steam driven auxiliary pumps. In this accident sequence the core melts through the bottom of the reactor vessel.

In order to minimize uncontrolled leakage from the containment, the environmental consequences and the radiation exposure to the staff at the plant after the severe accident, the following recommendations are given by FRIPP:

- The water level in the containment should be maintained between two predetermined levels.

  A minimum level is required to achieve coolability of the core debris in the bottom of the containment and to fulfill operational conditions for the containment spray pumps.

  If filtered containment venting had to be activated in the long term, the water level should cover the lower part of the reactor vessel in order to reduce the releases to the environment.

  A maximum water level is required not to be exceeded to prevent the water leakages from some containment penetrations.

- The temperature in the containment should be less than 100°C.

- The pH should be between 10 and 10,5. The last two recommendations are thought to minimize the corrosion rate in stainless steel in the containment.

  FRIPP provides also insights on the leaktightness of the closed loops outside of the containment as it is exposed below.

  In order to remove the heat in the containment after a severe accident, it should be actively cooled, otherwise filtered containment venting should be activated. To avoid this, Forsmark 1 needs active cooling for five years and Ringhals 3 for one year. In Forsmark 1 the filter is activated after 10 hours if the active cooling stops one week after the start of the accident. If active cooling stops after one year, the release through the filter will occur after one month. In Ringhals 3, the filter is activated after 4 days, if the active cooling stops after one week. This cooling is effected through the use of systems having closed loop outside the containment.

FRIPP estimates as 0,5 m^3/day the water leakage from the closed loops outside the containment in Forsmark 1. For Ringhals 3, the estimated leakage from the closed loops outside the containment is 158 m^3 of water in 5 years.

This data have been obtained based on experiences from the testing of valves during maintenance. FRIPP points out that degradation of penetrations due to radiation and corrosion will gradually cause an increased leak rate, but it is not possible today to achieve reliable values of water leakage in the long term.

4.5.- RELEASES FROM THE FILTERED CONTAINMENT VENTING VS. RELEASES FROM CONTAINMENT BY DIFFUSE LEAKAGE.

Some plants are equipped with filtered containment venting to prevent the containment failure by slow overpressurization in case of a severe accident. Typically, filtered containment venting is activated at containment design pressure. This chapter addresses the comparison between the radioactive material released by the activation of the filtered containment venting within 24 hours after the onset of a severe accident with the radioactive materials released by gas leakages from the containment penetrations in 24 hours after the accident. Ref. 19 provides the details of the summary exposed below. The paper analyzes the problem for a Swedish BWR, the accident sequence is a total blackout of all AC current and the calculations were made with MAAP 3.0 code.

Table VI, shows the results. The first column shows the radioactive products released during the first 24 hours by diffuse leakage. The containment leakage rate assumed in the calculation is greater than the allowable in the current safety analysis, mainly because some containment isolation valves are leak tested with water but during the severe accident analyzed are in contact with the containment atmosphere. The main contribution for the values in this column is the gas leakage from the reactor pressure vessel system piping, bypassing the containment. The second column shows the radioactive products released when the filtered containment venting is activated assuming the design decontamination factor (DF); i.e. 100. The third column assumes a best estimate value for DF: close to 10^{+4} for iodine (excluding organic iodine) larger than 10^{+4} for Cs.

5.- DETECTION METHODS

This section focuses on the methods to detect leak paths from the containment isolation devices in case of an accident. The containment leakage test program described in Section 2, intends to provide enough guarantee that the containment isolation devices will hold their leaktightness during an accident. Nevertheless, this program cannot guarantee totally this function. Therefore, additional measures should be available to the operational crew to take corrective actions after the onset of the accident. These procedures only exist already in France, where the U2 procedure has been implemented.

The U2 procedure (Ref. 2) addresses the search for and the processing of leakages from containment isolation devices after an accident that involves fuel damage or reactor coolant system failure.

Currently, four distinct actions to recover or to improve the containment leaktightness are operational on 900 MWe. units.

If a significant radioactivity level is detected at the stack (greater than Level 1 or greater than level 2 during a time lapse T1), actions aim at isolating the contaminated areas and at putting an end, when feasible, to the leakage, once its origin has been detected by an instrumentation channel designed for the purpose; such a channel is dedicated to provide the activity flow rate at specific places in the ventilation ducts of the Nuclear Steam Supply System.

If a very high level of activity is detected in the containment (dose rate greater than Level 3) - which means a failure of the two first barriers, i.e. the fuel cladding and the primary system boundary, - all the containment penetrations are checked, and identified failures, if any, are repaired so as to limit radioactivity releases into the environment.

If a high level of activity is detected in the primary coolant (dose rate greater than Level 4), the penetrations in contact with the highly contaminated primary water are isolated except for those of the safeguard systems, because the former circuits, external to the containment building, are not dimensioned for a degraded fuel accident; the reactor is then brought to the depressurized cold shutdown state. Nevertheless, there is a possibility of using the Nuclear Sampling System to monitor the primary coolant activity by making local adaptations to ensure the reinjection of the samples into the containment after analysis.

If a high level of activity (dose rate greater than Level 5) is detected above the sumps of the auxiliary buildings, there is a tightness defect in a safeguard system; in this case, an intervention team tries locally to put an end to the leakage, when feasible. Injection to the Liquid Waste Treatment System is closed and the operator may reinject the sump water into the reactor building.

6.- CONTAINMENT BYPASS

In this section three potential situations resulting in containment bypass are described: V-sequences, severe accidents induced by a steam generator tube rupture and steam generator tube rupture induced by a severe accident.

6.1.- V SEQUENCES.

V Sequences are defined as unisolable rupture of a low pressure coolant injection system outside the containment caused by failure of the set of valves that normally isolate the reactor coolant system from the low pressure system.

Table VII shows the contribution to the core damage frequency of this sequence in several plants. This frequency ranges from negligible up to 12%, a low contribution, but the radiological consequences from these sequences are very significant because of the inefficiency of the containment mitigation systems.

6.2.- SEVERE ACCIDENTS INDUCED BY STEAM GENERATOR TUBE RUPTURE.

Table VII shows the contribution to the core damage frequency from the severe accidents whose initiating event is the rupture of one steam generator tube. It is remarkable the high contribution to the core damage frequency in Loviisa plant, 40%. This number deserves a more detailed explanation. Because of the horizontal steam generator design, the Loviisa PSA includes three sequence classes under the tittle "Primary -to- secondary leakage accidents (PRISE)": single tube rupture, multiple tube rupture and large PRISE accident (break area 90 cm^2). The total contribution to the core damage frecuency from PRISE accidents is around 40% as table VII shows. It is foreseen that after several modifications, including extensive plant changes, to be completed at Loviisa 1 in 1996 and at Loviisa 2 about two years later, the contribution of PRISE will be around 2,4%. For the remaining plants, this contribution ranges from negligible up to 12,5%, a low contribution to core damage frequency.

6.3.- TEMPERATURE INDUCED STEAM GENERATOR TUBE FAILURE BEFORE VESSEL BREACH.

In the case of a severe accident with high pressure in the reactor coolant system of a PWR, natural circulation in the hot leg may be established. This phenomenon happens during the in-vessel phase of the severe accident and results in the transfer of a part of the energy generated during the core damage to the hot leg of the reactor coolant system, pressurizer surge line and steam generator tubes. The corresponding heating of these metallic structures may result in their failure before the vessel breach. In the case of pressurizer surge line or hot leg failure, the containment building can still confine the fission products. But, if the steam generator tube fails, the containment is bypassed. The probability of temperature induced steam generator tube failure before vessel breach during these kind of severe accidents was analyzed by an expert panel during the making of NUREG 1150 (Ref. 23).

In order to analyze this probability, the expert panel considered a TMLB' sequence with the reactor coolant system pressure near the PORV set point. The three experts agreed that the thermohydraulics conditions that drive the steam-generator tube failure also drive the hot leg failure.. The expert panel concluded that, assuming defective steam generator tubes, their failure probability is low. Assuming non defective steam generator tubes, their failure probability decreases significatively.

Temperature-induced steam generator tube rupture and hot leg creep rupture are, in reality, competing phenomena to provide a mechanism of natural depressurization in high pressure sequences. Therefore, it is uncertain whether one phenomenon will occur (Ref.27) prior to the other. Recent plant-specific calculations performed with MAAP 3.B (and SCDAP/RELAP 5 (Ref. 28) for the two-loop Beznau plant show that the NUREG-1150 assessment is rather conservative with respect to temperature induce steam generator tube rupture. Recent and detailed SCDAP/RELAP 5/MOD 3 analysis of the Surry plant response to a TMLB' transient without operator actions has been performed (Ref. 26). The steam generator tubes were assumed to be free of defects in all calculations. Given that assumption, failure of the steam generator tubes would not be expected because the circulating steam loses a significant amount of energy before reaching the steam generators, leaving the tubes relatively cool.

One exception is "José Cabrera" NPP. Because of this PWR has only one loop, MAAP calculations show a very high probability of temperature-induced steam generator tube failure in sequences with high pressure in the reactor coolant system.

7.- CONCLUSIONS

This report analyzes the capability of the containment isolation devices, installed in light water reactors, to maintain the containment leakage rate below the allowable limits considered in the safety analyses during the course of a severe accident with the reactor at full power, the probability to bypass the containment during a severe accident and the methods to detect unacceptable leakages in the containment isolation devices during the accident.

The most effective way to assure the containment leaktightness in case of a severe accident, is the containment leakage rate testing program. This program consists of two kind of tests: local leakage rate tests (LLRT) and integrated leakage rate test (ILRT). LLRT measures the leaktightness of the containment isolation devices, whereas ILRT measures the leaktightness of the overall containment building, providing a check for LLRT. Other alternate methods (slight under or overpressurization, inertization, low pressure test under operation, etc.) have not replaced the current containment leakage rate testing program. Although these alternate methods allow a more rapid speed of detection for the loss of the containment leaktightness, they do not have the reliability of the current containment leakage rate testing program, because of the low pressure and the lack of accuracy. For some future reactors, the installation of an on-line containment leaktightness monitoring systems is being studied. Also, it should be beared in mind that the containment leakage rate in case of severe accident is different in comparison with the case of a DBA. This issue shall be clarified later.

Operational experience shows that few problems have been detected during ILRT running. However the LLRT program shows that a significant number of containment isolation devices, specially containment isolation valves, lose their leaktightness during the operational cycle.

LLRT and ILRT programs are not uniform in the different countries. As far as LLRT program is concerned, the main differences lie in test pressure, frequency and number of containment isolation devices submitted to these tests. Regarding to ILRT program, the main differences lie in test pressure and frequency.

On the capability of the containment isolation devices to maintain their leaktightness in case of a severe accident, this issue may be divided in three aspects:

I) Reliability of the containment isolation devices against containment isolation signals. PSA techniques allow to calculate the failure probability of the containment isolation system, if a containment isolation signal occurs. Typical values for the failure probability of the containment isolation system range between 1E-2 to 1E-3, i.e. a high reliability.

II) Assuming that the containment isolation devices are closed in case of an accident, the next step is to assure their leaktightness. This issue is strongly plant specific, because it is influenced by design plant features, containment isolation devices design features, containment type, management issues and the diverse nature of the problems found during the ILRT. According with the works carried out in this area, a significant number of plants need improvement in this area.

III) Reliability of the containment isolation devices against severe accident loads. Experimental results from research programs, show that typical containment isolation devices have, in general, great safety margins to withstand the pressure, temperature, radiation and deformation loads resulting from a severe accident. Nevertheless, their failure can not be ruled out. Therefore a plant specific analysis is needed.

Leaktightness of closed loops is a safety concern, both in the short term and in the long term. By short term is understood, in this report, the period of time elapsed from the onset of the severe accidents through the first 24 hours, assuming the failure of any recovery actions taken. By long term is understood, the time elapsed from the first 24 hours after the onset of the severe accident through five years. In the short term, the leaktightness of the closed loops may be a problem because their isolation devices, in many cases, are not leak tested or are leak tested with water, whose requirements are less stringent than the requirements of the tests with air. The assurance of the leaktightness of closed loops in the long term is a very uncertain issue, because these closed loops have to recirculate water containing radioactive and corrosive products, in order to cool the containment.

Swedish FRIPP project has analyzed the containment leaktightness in the long term of a severe accident. In order to minimize the leakage rate from the containment in the long term of a severe accident, the following recommendations are provided: to maintain the water level between two predeterminated levels, the temperature in the containment should be less than 100°C and the pH should be between 10 and 10,5.

The release from the containment by diffuse leakage is of the same order of magnitude as the release from the filtered containment venting.

Very low attention has been paid, up to now, to the detection methods of leakage pathways from containment isolation devices after a severe accident. These methods only exist in France, where the U2 procedure has been implemented.

Three severe accident sequences resulting in containment bypass are analyzed: V-sequences; severe accidents induced by steam generator tube rupture and temperature-induced steam generator tube rupture before vessel breach in sequences with high pressure in the reactor coolant system.

The contribution of V-Sequences to the core damage frequency ranges from negligible to low (12%); although the radiological consequences from these sequences are very significant because of the inefficiency of the containment mitigation systems.

The contribution of severe accidents induced by steam generator tube ruptures to the core damage frequency range from negligible to low (12%), with the exception of Loviisa plant (40%). This plant is planning extensive plant changes whose implementation will result in a contribution to the core damage frequency from PRISE around 2,4%.

The probability of temperature-induced steam generator tube rupture before vessel breach in sequences with high pressure in the reactor coolant system is very low when the tubes are intact. Assuming degraded tubes, the probability is low. One exception is "José Cabrera" plant. This PWR has only one loop, and MAAP calculations show a very high probability for this phenomenon.

8.- RECOMMENDATIONS

The capability of the containment isolation devices to maintain their leaktightness in case of a severe accident plays an important role in nuclear safety. The research on severe accident phenomenology carried out in the last few years has paid a lot of attention to the early containment failure modes. Once these phenomena are reasonably well understood, mitigation measures may be adopted. Taking it in mind, the assurance of the leaktightness of the containment isolation devices is also relevant for plant safety. The containment leakage rate test program results show that the containment leakage rate allowed in safety analysis is exceeded frequently during the operational cycle of the plant. Therefore, attention should be paid to the following issues:

a) Causes of excessive leakages in the containment isolation devices.

b) Consideration of detection and plugging methods for excessive leakages in containment isolation devices after the onset of a severe accident. These detection and plugging methods could be specifically developed for the existing plants or could use the existing capabilities of the plants. Operating procedures for severe accidents, should face the use of these detection and plugging methods.

c) Analysis of the behaviour of some containment isolation devices in the long term of a severe accident.

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TABLE I (1/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **BELGIUM** PLANT **DOEL 3**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	NO	-	-
Door seals	YES	Pa(1)	. 40 months . After use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	NO	-	-
Door seals	YES	Pa	After use (2)
Electrical Penetrations	YES	Pa	40 months/ 24 months(3)
Mechanical Penetrations	YES	Pa	40 months/ 24 months(3)
Other	-	-	-
Electrical Penetrations	YES	Pa	Continuous pressurization verified each month.
Mechanical Penetrations Ventilation Valves	YES	Pa	24 months/ 40 months (3)
MSIV	N/A	-	-
Feedwater Valves (BWR)	N/A	-	-
Other	YES	Pa	24 months/ 40 months (3)

(1) Pa = peak pressure in case of DBA.

(2) Air space between seal pressurized at pressure > Pa after accident.

(3) 40 months for leaks ending in secondary containment.
24 months for leaks bypassing secondary containment.

TABLE I (2/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **BELGIUM** PLANT **TIHANGE 3**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	NO	-	-
Door seals	YES	Pa(1)	After each use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	Pa	10 years
Door seals (2)	YES	3 bar	6 months After each use
Electrical Penetrations	YES	Pa	10 years
Mechanical Penetrations	YES	Pa	each refuelling
Other	-	-	-
Electrical Penetrations	YES	Pa	Continuous pressurization verified every 18 months.
Mechanical Penetrations Ventilation Valves	YES	Pa	18 months
MSIV	N/A	-	-
Feedwater Valves (BWR)	N/A	-	-
Other	YES	Pa	18 months

(1) Peak pressure in case of DBA.

(2) Air space between seals connected with secondary containment.

TABLE I (3/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **FINLAND** PLANT **LOVIISA 1 AND 2**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	Pa(1)	6 MONTHS
Door seals	YES	3,5 bar abs	AFTER EACH USE
Electrical Penetrations	NO(2)	-	-
Mechanical Penetrations	NO(2)	-	-
Other	-	-	-
Personnel airlocks Overall	YES	Pa	6 MONTHS
Door seals	YES	Pa	AFTER EACH USE
Electrical Penetrations	NO(2)	-	-
Mechanical Penetrations	NO(2)	-	-
Other	-	-	-
Electrical Penetrations	YES		10 YEARS
Mechanical Penetrations Ventilation Valves	YES	>Pa(3)	12 MONTHS
MSIV	-	-	-
Feedwater Valves (BWR)	-	-	-
Other	YES	>Pa(3)	12 MONTHS

(1) Pa ≡ peak pressure in case of DBA

(2) During overall test

(3) Pa=1,7 bar.abs. Test pressure between 1,7 to 2 bar. abs.

TABLE I (4/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **FINLAND** PLANT **TVOI,II**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	2 bar abs	After each use
Door seals	NO	-	-
Electrical Penetrations	NO(1)	-	-
Mechanical Penetrations	NO(1)	-	-
Other	-	-	-
Personnel airlocks Overall	YES	Pa(2)	After each use
Door seals	NO	-	-
Electrical Penetrations	NO(1)	-	-
Mechanical Penetrations	NO(1)	-	-
Other	-	-	-
Electrical Penetrations	YES		
Mechanical Penetrations Ventilation Valves	YES	>Pa(3)	12 MONTHS
MSIV	YES	>Pa(3)	12 MONTHS
Feedwater Valves (BWR)	YES	>Pa(3)	12 MONTHS
Other	YES	>Pa(3)	12 MONTHS

(1) During overall test

(2) Pa= 3,7 bar abs. peak pressure in case of DBA

(3) Test pressure 4,7 bar abs.

TABLE I (5/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **FRANCE** PLANT **900 MWe PWRs**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	-
Door seals	YES	4(bar)g	Each refueling (1)
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	0,3(bar)g	(4)
Dynamic seals (2)	YES	4(bar)g	Each refuelling.
Electrical Penetrations (static)	YES	0,3(bar)g	(4)
Static Seals (3)	YES	0,3(bar)g	(4)
Other (vacuum breakers)	YES	4(bar)g	Each refuelling
Electrical Penetrations			
Mechanical Penetrations Ventilation Valves	YES	4(bar)g	Each refuelling
MSIV	N/A	-	-
Feedwater Valves (BWR)	N/A	-	-
Other	YES	4(bar)g	Each refuelling

(1) Before openning and after closing.
(2) Door seals, flap seals, interlock shaft penetration seals.
(3) Door view ports, plugs allowing the mounting of dynamic seals.
(4) Before commissioning. Periodically, only when dynamic seals are not provided with test taps.

TABLE I (6/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **FRANCE** PLANT **1300 MWe PWR P4**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	-
Door seals	**YES**	**3,8(bar)g**	**Each refue-ling (1)**
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	**YES**	**0,3(bar)g**	**(4)**
Dynamic seals (2)	**YES**	**4(bar)g**	**Each refue-lling.**
Electrical Penetrations (static)	**YES**	**0,3(bar)g**	**(4)**
Static Seals (3)	**YES**	**0,3(bar)g**	**(4)**
Other (vacuum breakers)	**YES**	**4(bar)g**	**Each refue-lling**
Electrical Penetrations			
Mechanical Penetrations Ventilation Valves	**YES**	**4(bar)g**	**Each refue-lling**
MSIV	**N/A**	-	-
Feedwater Valves (BWR)	**N/A**	-	-
Other	**YES**	**4(bar)g**	**Each refue-lling**

(1) Before openning and after closing.
(2) Door seals, flap seals, interlock shaft penetration seals.
(3) Door view ports, plugs allowing the mounting of dynamic seals.
(4) Before commissioning. Periodically, only when dynamic seals are not provided with test taps.

TABLE I (7/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **FRANCE** PLANT **1300 MWe PWRs P'4**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	-
Door seals	YES	4,2(bar)g	Each refue-ling (1)
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	0,3(bar)g	(4)
Dynamic seals (2)	YES	4,2(bar)g	Each refue-lling.
Electrical Penetrations (static)	YES	0.3(bar)g	(4)
Static Seals (3)	YES	0.3(bar)g	(4)
Other (vacuum breakers)	YES	4,2(bar)g	Each refue-lling
Electrical Penetrations			
Mechanical Penetrations Ventilation Valves	YES	4,2(bar)g	Each refue-lling
MSIV	N/A	-	-
Feedwater Valves (BWR)	N/A	-	-
Other	YES	4,2(bar)g	Each refue-lling

(1) Before openning and after closing.
(2) Door seals, flap seals, interlock shaft penetration seals.
(3) Door view ports, plugs allowing the mounting of dynamic seals.
(4) Before commissioning. Periodically, only when dynamic seals are not provided with test taps.

TABLE I (8/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **GERMANY** PLANT **PWR AND BWR**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
<u>Equipment hatch</u> Overall	**During ILRT**	**1,5 bar abs.**	**4 years**
Door seals	**YES**	**Vacuum 0,02 bar**	**1 year**
Electrical Penetrations	**YES**	**Idem**	**1 year**
Mechanical Penetrations	**YES**	**Idem**	**1 year**
Other	-	-	-
<u>Personnel airlocks</u> Overall	**During ILRT**	**1,5 bar abs.**	**4 years**
Door seals	**YES**	**Vacuum 0,02 bar**	**1 year**
Electrical Penetrations	**YES**	**Idem**	**1 year**
Mechanical Penetrations	**YES**	**Idem**	**1 year**
Other	-	-	-
Electrical Penetrations	**YES**	**Vacuum 0,02 bar**	**1 year**
<u>Mechanical Penetrations</u> Ventilation Valves	**YES**	**Vacuum 0,02 bar**	**1 year**
MSIV (BWR)	**YES**	**Vacuum 0,02 bar**	**1 year**
Feedwater Valves (BWR)	**YES**	**Vacuum 0,02 bar**	**1 year**
Other Containment isolation valves (1)	**YES**	**Vacuum 0,02 bar**	**1 year**
Blind flanges	**YES**	**Vacuum 0,02 bar**	**1 year**
Pipe penetration chambers	**YES**	**1,5 bar N_2**	**Permanent**

(1) Not all the containment isolation valves are leak tested, for example, the containment isolation valves belonging to the secondary system in PWR. Example of containment isolation valves leak tested are: vacuum relief valves, service air; desmineralized water, etc.

TABLE I (9/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **ITALY** PLANT **TRINO VERCELLESE**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch (1) Overall	**YES**	**150 mm Hg**	**6 months or 20 opennings**
Door seals	-	-	-
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks(2) Overall	**YES**	-	**6 months or 20 opennings**
Door seals	-	-	-
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	
Electrical Penetrations	**YES**	**(3)**	**(4)**
Mechanical Penetrations Ventilation Valves		**Pa(5)**	**1 year**
MSIV		-	-
Feedwater Valves (BWR)		-	-
Other		**Pa**	**1 year**

(1) Principal airlock
(2) Emergency airlock
(3) Some during ILRT (see table II). Remaing from 1.4 bar abs up to 5 bar. abs.
(4) From 6 month up to 3 times 10 years.
(5) Pa = Peak pressure in case of DBA.

TABLE I (10/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **ITALY** PLANT **CAORSO**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	Pa(1)	Every refueling
Door seals	-	-	-
Electrical Penetrations	-	-	-
Mechanical Penetrations			
Other			
Personnel airlacks Overall	YES	Pa	Every refueling
Door seals	-	-	-
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	< Pa(2)	Every refueling
Mechanical Penetrations Ventilation Valves	YES	Pa	Every refueling
MSIV	YES	1/2 Pa	"
Feedwater Valves (BWR)	YES	Pa	"
Other	YES	Pa	"

(1) Pa = 4,07 Kg/cm^2 abs.
(2) Test pressure 3,1 Kg/cm^2 abs.

TABLE I (11/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **JAPAN** PLANT **TYPICAL PWR (1)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	3,6 Kg/cm^2g	Every refueling
Door seals	YES	"	"
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	3,6 Kg/cm^2g	Every refueling
Door seals	YES	"	"
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	3,6 Kg/cm^2g	Every refueling
Mechanical Penetrations Ventilation Valves	YES	3,6 Kg/cm^2g	Every refueling
MSIV	-	-	-
Feedwater Valves (BWR)	-	-	-
Other	YES(2)	3,6 Kg/cm^2g	Every refueling

(1) 4 loops PWR and dry containment.

(2) Except the closed system in Containment Valves and Sealed lines by water.

TABLE I (12/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **JAPAN** PLANT **TYPICAL BWR/5**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	3,85 Kg/cm^2 abs	Every refueling
Door seals	YES	"	"
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	3,85 Kg/cm^2 abs-	Every refueling
Door seals	YES	"	"
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	Partially (1)	3,85 Kg/cm^2	Every refueling
Mechanical Penetrations Ventilation Valves	YES	3,8 Kg/cm^2 abs.	Every refueling
MSIV	YES	"	"
Feedwater Valves (BWR)	NO	-	-
Other	YES	-	-

(1) Testable portion only

TABLE I (13/32)
LLRT CHARACTERISTICS IN SEVERAL COUNTRIES

COUNTRY: NETHERLANDS PLANT: BORSELLE

Type of containment isolation devices	Remarks	Are leak tested?	Test pressure in overpressure	Frequency
Equipment airlock	Is tested every fourth year within de overall ILRT and is tested ever year twice integrated as airlock (seals and penetration included)	Yes	LLRT: 550 MMH_2O IIRT: 2 bar	twice a year
Personnal airlock	Is tested every fourth year within de overall ILRT and is tested ever year twice integrated as airlock (seals and penetration included)	Yes	LLRT: 550 MMH_2O IIRT: 2 bar	twice a year
Emergency airlock	Is tested every fourth year within de overall ILRT and is tested ever year twice integrated as airlock (seals and penetration included)	Yes	LLRT: 550 MMH_2O IIRT: 2 bar	once a year
Electrical penetrations	Is tested every fourth year within the overall ILRT and is tested every year, except the year of the ILRT, as separate penetration.	Yes	He-leakagestest in period between ILRT's and as ILRT: 2 bar	once a year every fourth year
Mechanical penetrations including hot and cold line penetrations	Is tested every fourth year within the overall ILRT and is tested every year, except the year of the ILRT, as separate penetration.	Yes	He-leakagestest in period between ILRT's and as ILRT: 2 bar	once a year every fourth year
Containment isolation valves	Are tested every fourth year within the ILRT	Yes	Every year special valve test. ILRT:2 bar	once a year every fourth year
Blindflanges	Are tested every fourth year within the ILRT	Yes	ILRT: 2 bar	every fourth year
Other	Are tested every fourth year within the ILRT	Yes	ILRT: 2 bar	every fourth year

TABLE I (14/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SPAIN** PLANT **"JOSE CABRERA"**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	-
Door seals	-	-	-
Electrical Penetrations	YES	Pa(1)	Every refueling
Mechanical Penetrations	YES	Pa	"
Other	-	-	-
Personnel airlocks Overall	-	-	-
Door seals	-	-	-
Electrical Penetrations	YES	Pa	Every refueling
Mechanical Penetrations	YES	Pa	"
Other	-	-	-
Electrical Penetrations	YES(2)	Pa	Every refueling
Mechanical Penetrations Ventilation Valves	YES	Pa	Every refueling
MSIV	N/A	-	-
Feedwater Valves (BWR)	N/A	-	-
Other	YES	"	"

1) Pa = peak pressure in case of DBA.

(2) A number of them are tested during ILRT.

TABLE I (15/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SPAIN** PLANT **"SANTA MARIA GAROÑA"**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	-
Door seals	YES	Pa(1)	Every refueling
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	~1/6 Pa	Every refueling
Door seals	-	-	-
Electrical Penetrations	YES	Pa	"
Mechanical Penetrations	YES	Pa	"
Other	-	-	-
Electrical Penetrations	YES	Pa	Every refueling
Mechanical Penetrations Ventilation Valves	YES	Pa	Every refueling
MSIV	YES	"	"
Feedwater Valves (BWR)	YES	"	"
Other	YES	"	"

(1) Pa ≡ Peak pressure in case of DBA.

TABLE I (16/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SPAIN** PLANT **ALMARAZ, ASCO, VANDELLOS**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
<u>**Equipment hatch**</u> Overall	-	-	-
Door seals	YES	Pa(1)	Every refueling
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
<u>**Personnel airlocks**</u> Overall	YES	Pa	6 months
Door seals	YES	Pa	After each use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	Pa	Every refueling
<u>**Mechanical Penetrations**</u> Ventilation Valves	YES	Pa	Every refueling
MSIV	-	-	-
Feedwater Valves (BWR)	-	-	-
Other	YES	Pa	Every refueling

(1) Pa = peak pressure in case of DBA.

TABLE I (17/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SPAIN** PLANT **COFRENTES**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	-
Door seals	YES	Pa(1)	Every refueling
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	Pa	6 months
Door seals	YES	Pa	After each use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	Pa	Every refueling
Mechanical Penetrations Ventilation Valves	YES	Pa	Every refueling
MSIV	YES	Pa	"
Feedwater Valves (BWR)	YES	Pa	"
Other	YES	Pa	"

(1) Pa = Peak pressure in case of DBA.

TABLE I (18/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SPAIN** PLANT **TRILLO**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	1 year
Door seals	YES	0,8 bar abs	1 year
Electrical Penetrations	YES	1,5 bar abs	4 years
Mechanical Penetrations	YES	0,8 bar abs	1 year
Other	YES	1,5 bar abs	4 years
Personnel airlocks Overall	-	-	-
Door seals	YES	0,8 bar abs	1 year
Electrical Penetrations	YES	1,5 bar abs	4 years
Mechanical Penetrations	YES	0,8 bar abs	1 year
Other	YES	1,5 bar abs	4 years
Electrical Penetrations	YES	1,5 bar abs	3 penetrations for refue-ling(1)
Mechanical Penetrations Ventilation Valves	YES	0,8 bar abs	1 year
MSIV	-	-	-
Feedwater Valves (BWR)	-	-	-
Other	-	-	

(1) Some Spare electrical penetrations during refueling also tested.

TABLE I (19/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SWEDEN** PLANT **BARSEBÄCK; OSKARSHAMN,1,2**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	0,45 MPa	1 year
Door seals	YES	0,45 MPa	1 year
Electrical Penetrations	YES	Continously pressurized	
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	0,45 MPa	1 year
Door seals			
Electrical Penetrations	YES	Continously pressurized	Checked each month
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	-	-	-
Mechanical Penetrations Ventilation Valves	YES	0,45 MPa	3 months-1 year
MSIV	YES	0,45 MPa	1 year
Feedwater Valves (BWR)	YES	0,45 MPa	1 year
Other	YES	0,45 MPa	2-4 years

TABLE I (20/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SWEDEN** PLANT **RINGHALS 3/4**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	0,465 MPa	6 months
Door seals	YES	0,465 MPa	6 months
Electrical Penetrations	YES	0,465 MPa	3 years
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	0,465 MPa	6 months
Door seals	YES	0,465 MPa	6 months
Electrical Penetrations	YES	0,465 MPa	3 years
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	-	-	-
Mechanical Penetrations Ventilation Valves	YES	0,465-0,565 MPa	1 year
MSIV	N/A	-	-
Feedwater Valves (BWR)	N/A	-	-
Other	YES	0,465-0,565 MPa	1 year

TABLE I (21/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SWEDEN**

PLANT **FORSMARK 1-3**
OSKARSHAMN 3

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	0,38 MPa	Each openning
Door seals	YES	0,38 MPa	Each openning
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	0,38 MPa	Each openning
Door seals	YES	0,38 MPa	Each opening
Electrical Penetrations	NO	-	-
Mechanical Penetrations	NO	-	-
Other	-	-	-
Electrical Penetrations	NO	-	-
Mechanical Penetrations Ventilation Valves	YES	0,38 MPa	1 year
MSIV	YES	0,38 MPa	1 year
Feedwater Valves (BWR)	YES	0,38 MPa	1 year
Other	YES	0,38 MPa	1 year

TABLE I (22/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SWITZERLAND** PLANT **MÜHLBERG**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	YES	2,7 bar abs	1 year
Door seals	-	-	-
Electrical Penetrations	YES	"	"
Mechanical Penetrations	YES	"	"
Other	-	-	-
Personnel airlocks Overall	YES	1,4 bar abs	1 year
Door seals	-	-	-
Electrical Penetrations	YES	-	-
Mechanical Penetrations	YES	-	-
Other	-	-	-
Electrical Penetrations			
Mechanical Penetrations Ventilation Valves	YES	0,8 bar abs	1 year
MSIV	YES	1,2 bar abs	"
Feedwater Valves (BWR)	NO	-	-
Other	YES	2,7 bar abs	"

TABLE I (23/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SWITZERLAND** PLANT **LEIBSTDAT**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	**YES**	**2 bar abs**	**1 year**
Door seals	-	-	-
Electrical Penetrations	**YES**	**2 bar abs**	**4 years**
Mechanical Penetrations	**YES**	**1,68/2,05 bar abs**	**1 year**
Other	-	-	-
Personnel airlocks Overall	**YES**	**2,0 bar abs**	**1 year**
Door seals	-	-	-
Electrical Penetrations	**YES**	**2,5 bar abs**	**4 years**
Mechanical Penetrations	**YES**	**1,68/2,05 bar abs**	**1 year**
Other	-	-	-
Electrical Penetrations			
Mechanical Penetrations Ventilation Valves	**YES**	**1,68/2,05 bar abs**	**1 year**
MSIV	**YES**	"	"
Feedwater Valves (BWR)	**YES**	"	"
Other	**YES**	"	"

TABLE I (24/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SWITZERLAND** PLANT **BEZNAU I,II**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch(1) Overall	-	-	-
Door seals	-	-	-
Electrical Penetrations	YES	2,6 bar abs	1 year
Mechanical Penetrations	YES	2,6 bar abs	"
Other	-	-	-
Personnel airlocks Overall	YES	1,21 bar abs	1 year
Door seals	-	-	-
Electrical Penetrations	YES	-	4 years
Mechanical Penetrations	YES	2,6 bar abs	1 year
Other	-	-	-
Electrical Penetrations			
Mechanical Penetrations Ventilation Valves	YES	2,0 bar abs	1 year
MSIV	-	-	-
Feedwater Valves (BWR)	-	-	-
Other			

(1) Personnel airlock too.

TABLE I (25/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **SWITZERLAND** PLANT **GöSGEN**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment hatch Overall	-	-	-
Door seals	**YES**	**Δp=1 bar**	**1 year**
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other (1)	**YES**	**2 bar abs**	**1 week**
Personnel airlocks Overall	-	-	-
Door seals	**YES**	**4,9 bar abs**	**1 year**
Electrical Penetrations	**YES**	**Δp=10 mbar**	**4 years**
Mechanical Penetrations	**YES**	**0,5 bar abs**	**1 year**
Other	**YES**	**0,5 bar abs**	**1 year**
Electrical Penetrations			
Mechanical Penetrations Ventilation Valves	**YES**	**Δp=20 mbar**	**1 year**
MSIV	-	-	-
Feedwater Valves (BWR)	-	-	-
Other			

(1) Sump and drain line.

TABLE I (26/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **USA** PLANT **ZION (WESTINGHOUSE PWR)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment Hatch			
Overall	YES	324 kPa abs	Every 24 months
Door seals	YES	"	Every 24 months
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks			
Overall	YES	324 kPa abs	Every 6 months also, after each opening, unless performed within the previous 6 months
Door seals	YES	ΔP > 17 kPa	Within 72 hours after use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	324 KPa abs	Every 24 months
Mechanical Penetrations	YES	324 kPa abs	Every 24 months
MSIV	-	-	-
Other	-	-	-

TABLE I (27/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **USA** PLANT **SURRY (WESTINGHOUSE PWR)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment Hatch Overall	-	-	-
Door seals	**YES**	**310 kPa abs**	**Every 24 months**
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	**YES**	**310 kPa abs**	**Every 6 months also, after each opening, unless performed within the previous 6 months**
Door seals	**YES**	**310 kPa abs**	**Within 72 hours after use**
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	**YES**	**310 KPa abs**	**Every 24 months**
Mechanical Penetrations	**YES**	**310 kPa abs**	**Every 24 months**
MSIV	-	-	-
Other	-	-	-

TABLE I (28/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **USA** PLANT **SEQUOYAH (WESTINGHOUSE ICE CONDENSER)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment Hatch Overall	-	-	-
Door seals	YES	83 kPa abs	Every 24 months
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	83 kPa abs	Every 6 months also, after each opening, unless performed within the previous 6 months
Door seals	YES	83 kPa abs	Within 72 hours after use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	83 KPa abs	-
Mechanical Penetrations	YES	83 kPa abs	Every month
MSIV	-	-	-
Other	-	-	-

TABLE I (29/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **USA** PLANT **WATERFORD (CE PWR)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment Hatch Overall	NO	-	-
Door seals	YES	303 kPa abs	Every 24 months
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	303 kPa abs	Every 6 months also, after each opening, unless performed within the previous 6 months
Door seals	YES	303 kPa abs	Every 6 months. If opened, tested twice
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	303 KPa abs	Every 24 months
Mechanical Penetrations	YES	303 kPa abs	Every 24 months
MSIV	NO	-	-
Other	-	-	-

TABLE I (30/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **USA** PLANT **PEACH BOTTOM (BWR MARK I)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment Hatch Overall	YES	339 kPa abs	Every 24 months
Door seals	YES	"	Every 24 months
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	339 kPa abs	Every 6 months also, after each opening, unless performed within the previous 6 months
Door seals	YES	"	Within 72 hours after use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	339 kPa abs	Every 24 months
Mechanical Penetrations MSIV	YES	172 kPa abs	Every 24 months
Feedwater valves	-	-	-
Other	-	-	Every 3 months

TABLE I (31/32)

LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **USA** PLANT **LASALLE (BWR MARK II)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment Hatch Overall	-	-	-
Door seals	YES	273 kPa abs	Every 24 months
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	273 kPa abs	Every 6 months also, after each opening, unless performed within the previous 6 months
Door seals	YES	Δp > 70 kPa	Within 72 hours after use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	273 kPa abs	Every 24 months
Mechanical Penetrations MSIV	YES	273 kPa abs	Every 18 months
Feedwater valves	YES	"	Every 24 months
Other 1.Vent and purge isolation valves flanges 2. ECCS isolation valves in hidrostatically tested lines	 YES YES	 " "	 Every 18 months Every 18 months

TABLE I (32/32)
LLRT CHARACTERISTIC IN SEVERAL COUNTRIES

COUNTRY **USA** PLANT **GRAND GULF (BWR MARK III)**

CONTAINMENT ISOLATION DEVICE	LEAK TESTED	TEST PRESSURE	FREQUENCY
Equipment Hatch Overall	NO	-	-
Door seals	YES	Δp = 79 kPa	Every 24 months
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Personnel airlocks Overall	YES	ΔP= 79 kPa	Every 6 months also, after each opening, unless performed within the previous 6 months
Door seals	YES	"	Within 72 hours after use
Electrical Penetrations	-	-	-
Mechanical Penetrations	-	-	-
Other	-	-	-
Electrical Penetrations	YES	ΔP = 79 kPa	Every 24 months Those with continuous leak monitoring system every 36 months.
Mechanical Penetrations MSIV	YES	"	Every 18 months
Feedwater valves	YES	"	Every 18 months
Other 1. Purge supply and exhaust valves with resilient seals.	YES	"	Every 3 months

TABLE II (1/2)

ILRT PRESSURE AND FREQUENCY

COUNTRY/PLANT	TEST PRESSURE (1)	FREQUENCY
BELGIUM	BETWEEN 1/2 Pa AND Pa	10 YEARS
FINLAND		
LOVIISA 1,2	Pa	4 YEARS
TVOI, II	Pa	4 YEARS
FRANCE		
900 MWe PWRs	4 (bar) g	1st REFUELLING/10 YEARS
1300 MWe PWRs P4	3,8 (BAR) g	Idem
1300 MWe PWR-P'4	4,2 (bar) g	Idem
GERMANY	1,5 bar abs	1st REFUELING/4 YEARS (2)
ITALY		
TRINO VERCEL-LESE	1/2 Pa	3 IN 10 YEARS
CAORSO	Pa	3 IN 10 YEARS
JAPAN		
TYPICAL PWR	1,8 (Kg/cm^2) g	1 IN 3 YEARS
TYPICAL BWR/5	3,85 bar abs	EVERY REFUELING OUTAGE
NETHERLANDS		
BORSSELE	2,0 bar abs.	ARS
DODEWAARD	2,0 bar abs.	(3)
SPAIN		
AMERICAN PLANTS	Pa	3 IN 10 YEARS
GERMAN PLANT	1,5 bar abs	4 YEARS
SWEDEN		
BARSEBÄCK	0,3 MPa	3 IN 10 YEARS
RINGHALS	0,283 MPa	3 IN 10 YEARS
FORSMARK	3 bar	3 IN 10 YEARS

TABLE II (2/2)

ILRT PRESSURE AND FREQUENCY

COUNTRY/PLANT	TEST PRESSURE (1)	FREQUENCY
SWITZERLAND		
MÜHLBERG	2,7 bar abs.	4 YEARS
LEIBSTADT	1,68 bar abs.	4 YEARS
BEZNAU I, II	2,0 bar abs.	10 YEARS
GÖSGEN	2,0 bar abs.	4 YEARS
UNITED STATES	Pa (4)	3 in 10 YEARS

(1) Pa = DBA pressure

(2) Preoperational tests:
One test at 1,5 bar abs.; another test at design pressure.

(3) Depending on results previous ILRT according to next table:
0,000 ≤ leak rate ≤ 0,375 every 3 years
0,375 < leak rate ≤ 0,422 every 2 years
0,422 < leak rate ≤ 0,472 every 1 year

(4) A reduced number of plants run the test at 1/2 Pa.

TABLE III

TEST RESULTS FROM THE EXPERIMENTS CARRIED OUT IN CVTR (1)

PRESSURE (psig)	TEMPERATURE (° C)	LEAKAGE RATE (% / day)
21	19,4	0,371
21	25,0	0,315
21	63,3	0,122
21	90,6	Undetectable (2)

(1) Results with very low steam content in the containment atmosphere.

(2) To check the accuracy of the measure, a calibrated leakage rate 0,16 ± 0,02 % / day was imposed. After that, it was measured 0,14 ± 0,02% / day.

TABLE IV

TEST RESULTS FROM THE EXPERIMENTS CARRIED OUT IN CSE.

PRESSURE (psig)	TEMPERATURE (° C)	LEAKAGE RATE (% / day)
34,8	23,9	0,471
34,8	121	0,147
22,8	23,9	0,417
23,5	106	0,268
8,8	23,9	0,226
8,9	80	0,108

TABLE V

PROBABILITY OF LOSS OF CONTAINMENT LEATIGHTNESS IN CASE OF ACCIDENT.

LEAK RATE	BWR	PWR
1 < La < 10	0,1	0,31
10 < La < 100	0,04	0,08
La > 100	0,01	0,07

La : Containment leak rate allowable in safety analysis.

TABLE VI

RADIOACTIVE RELEASED BY DIFFUSE LEAKAGE AND BY ACTIVATION OF THE FILTERED CONTAINMENT VENTING. (1)

RADIONUCLIDE	DIFFUSE LEAKAGE	FCVS (DF DESIGNED)	FCVS (BEST ESTIMATE) (DF)
NG	1,4	Not calculated	Not calculated
I	1,5 E-2	2,2 E-2	2 E-3
Cs	1E-3/1E-4	2,3 E-2	2,3 E-4

(1) Values in % of initial core inventory.

TABLE VII (1/2)

CONTRIBUTION TO CORE DAMAGE FREQUENCY FROM V-SEQUENCES AND SEVERE ACCIDENTS INDUCED BY STEAM GENERATOR TUBE RUPTURE

COUNTRY/PLANT	TYPE	SGTR	V-SEQUENCES
BELGIUM			
DOEL 3	PWR	6,6%	7,3%
TIHANGE 2	PWR	1,9	10,2%
FINLAND			
LOVIISA 1,2	VVER	40%(*)	
FRANCE			
900 MWe	PWR	4,7%	
1300 MWe	PWR	4,3%	
GERMANY	PWR	4%	NEGLIGIBLE
ITALY			
TRINO VERCE-LLESE	PWR	12,5%	12,2%
JAPAN			
TYPICAL	BWR-5	-	NEGLIGIBLE
TYPICAL	PWR	NEGLIGIBLE	NEGLIGIBLE
NETHERLANDS			
BORSELLE	PWR	1,80%	1,43%
SPAIN			
JOSE CABRERA	PWR	2,4%	0,95%
Stª Mª GAROÑA	BWR	-	NOT CALCU-LATED
ALMARAZ	PWR	4,91%	2,53%
ASCO	PWR	10,2%	NEGLIGIBLE
COFRENTES	BWR	-	NEGLIGIBLE
VANDELLOS II	PWR	2,1%	NEGLIGIBLE

TABLE VII (2/2)

CONTRIBUTION TO CORE DAMAGE FREQUENCY FROM V-SEQUENCES AND SEVERE ACCIDENTS INDUCED BY STEAM GENERATOR TUBE RUPTURE

COUNTRY/PLANT	TYPE	SGTR	V-SEQUENCES
SWEDEN			
RINGHALS 3,4	PWR	10%	-
SWITZERLAND			
MÜHLBERG	BWR		2%
LEIBSTADT (1)	BWR		NEGLIGIBLE
BEZNAU I, II	PWR	10%	2%
GOSGEN (1)	PWR	NEGLIGIBLE	NEGLIGIBLE
UNITED STATES			
ZION	PWR	NEGLIGIBLE	NEGLIGIBLE
SEQUOYAH	PWR	3,0% 4,0% (**)	1,1% < 1% (**)
SURRY	PWR	4,5%	4,0%
PEACH BOTTOM	BWR MARK I	-	-
GRAND GULF	BWR MARK III	-	NEGLIGIBLE

(1) Preliminary results
(*) This value includes from single tube rupture up to large PRISE.
(**) Based on recent Individual Plant Examination.

APPENDIX

List of Members of the
CSNI-PWG4 Task Group on
Containment Aspects of Severe Accident Management
(September 1995)

Belgium	Mr. Benoît De Boeck (AVN) Dr. Jean Snoeck* (Tractebel)
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