REACTOR BUILDING INTEGRITY TEST AT GENTILLY 2

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INTRODUCTION

Since commissioning of Gentilly 2, the containment integrity has to be demonstrated to the safety authority every three years for the three major components : the reactor building, the air locks, the containment valves. The method used is a pressure test at 124 kPad. Because of the original design and the numerous modifications to the systems needed for the test, it has to be done during a planned outage. This activity requires at least 7 days and it costs 350 000 $ whatever the results.

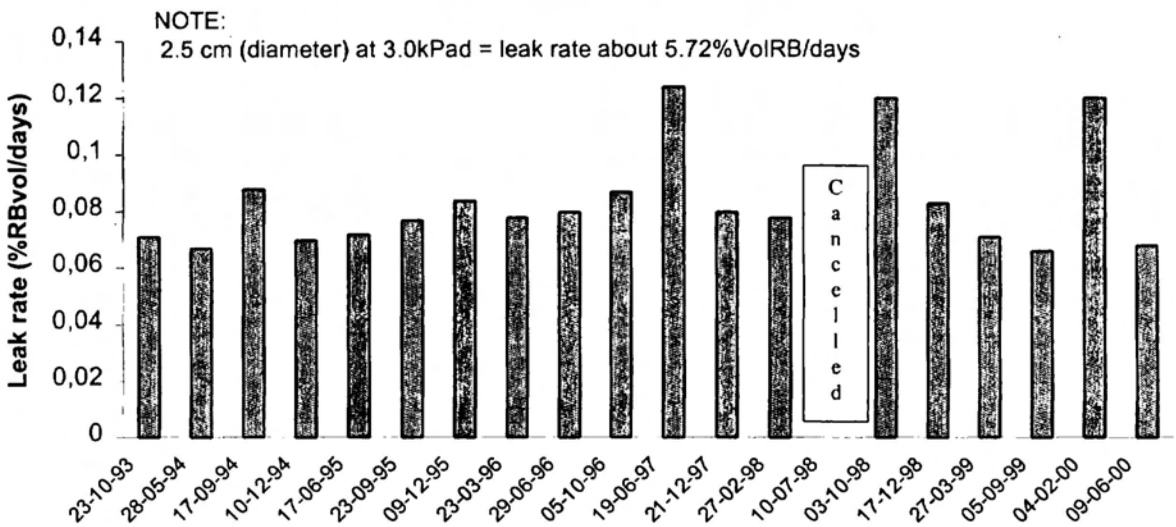
Also, when coming back to power after the outage, the probability of a containment breach is very high because of the number of operations done on the systems like the preventive and corrective maintenance activities and the test. This higher containment breach probability and the impossibility to test containment while on power, had justify the Safety Authority to ask Gentilly-2 to develop a test allowing to confirm the containment stability while restarted. From 1987 to 1989, Hydro-Québec has invested time and money to develop this test, the TCM method, and from 1990 to 1991, it was commissioned. So now in Gentilly 2, we are having high pressure test every three years and three integrity test (low pressure test at 100% power), with the TCM method, every year from which one about two or three weeks from the planned outage restart.

HISTORIC

In November 91, the Containment Integrity Test was executed with the reactor at 3.5% full power. We considered the test successful even though the results were inconsistent. This inconsistency was due to the behavior of many systems being at an unstable stage (because of the reactor's low power) and due to the extreme sensitivity of our instruments. From that experience, we decided to go ahead with a containment integrity test at 100% full power which gave more stability to the environment of the R/B (temperature, moisture, pressure, etc...)

The first test performed at 3.0 kPad with the reactor at 100% full power was done in October 92. This test permitted us to discriminate some operations which affect the environment inside the reactor. For example, a transfer of service water heat exchangers has produced a temperature upset in the R/B which consequently produce a pressure upset . Following that test, twenty (20) containment integrity tests were executed with the reactor at 100% full power and sixteen of them were successfully performed.

Low pressure test results

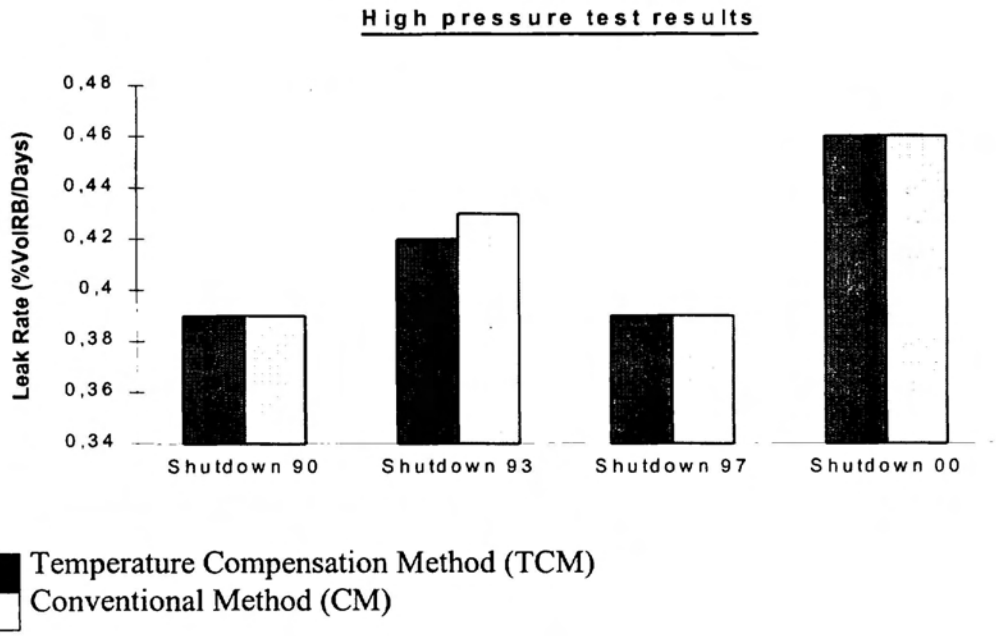


The integrity test was developed originally to ensure the containment integrity, to make sure for example that no valve remained open. For that reason, the acceptance criteria for this test is not the result of a scientific study but simply on an engineering judgment. So the criteria correspond at 3.0 kPad to a 2.5 cm (diameter) equivalent orifice through the reactor containment wall. Now if we are looking at the data on the above chart, the similarity within the result shows clearly the containment integrity. With these results, we are ensuring ourselves that the containment is within it normal operation configuration and it has not degraded between high pressure test. For the results of June 19 1997, October 3 1998 and February 4 2000, it demonstrates an increase in the results in an order of 37 %. This increase could be explained by numerous factors but not by a significant containment deterioration. The results are still within the acceptance criteria. The July 10 1998 test was cancelled.

TCM FEATURES

General Description

The Containement Integrity tests at Gentilly-2 (with the reactor at 100% full power) are done at a pressure of about 3.0 kPad because of operations reasons. The Safety Shutdown Systems #1 ad #2 get actived, among other factors, if the différential pressure of the R/B is greater or equal to 3.45 kPad. Still, our test, which is based on the temperature compensating method, can be used at any pressure. In fact, the temperature compensating method is also used for the R/B pressure test which is done at 124 kPad



The similarity between the results of the conventional method and the temperature compensation method is conclusive, the temperature compensation method could also be used at high pressure.

The Temperature compensating method is unique and convenient for many raisons, which have all been proven true and reliable. Here the most important :

- It can be applied at any test pressure ;
- It can be applied with the reactor at 100% full power ;
- No need for several temperature points and no need correction for temperature upset due to a temperature tubular network ;
- A more representative dew point due to a moisture tubular network.
- Very fast time response, specially at high pressure test.

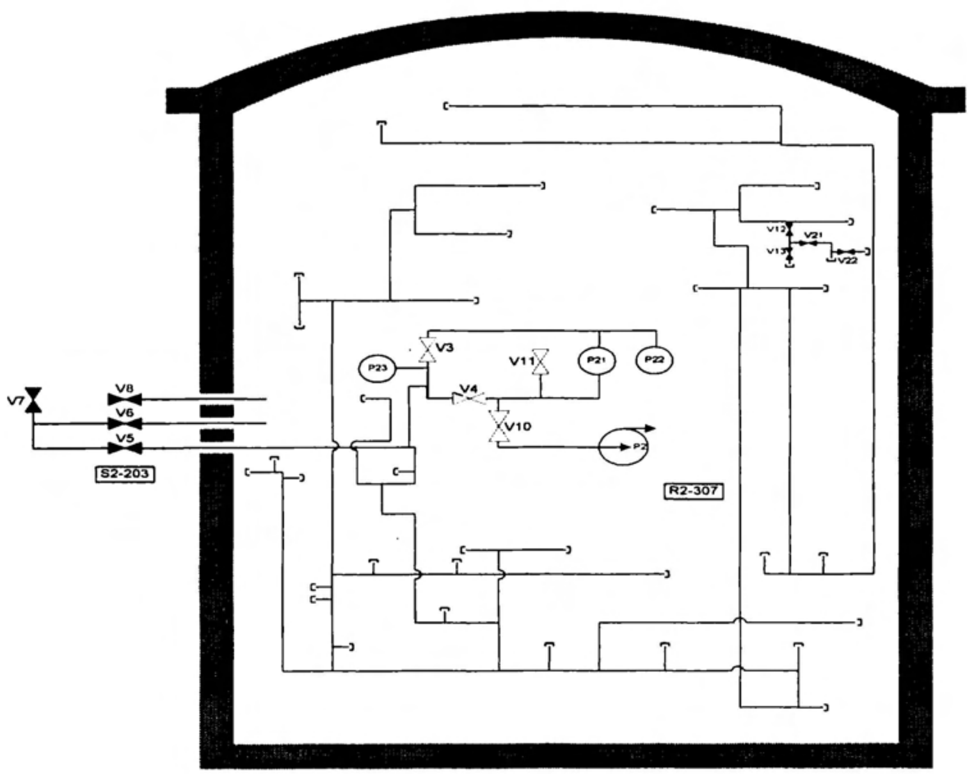
Temperature Tubular Network (reference volume)

The principle of this test is based on the ideal gas law. That is, when a confined mass of air in a airtight reference volume (temperature tubular network) is itself contained in another fixed volume of air, the differential pressure is independent of temperature. However, the geometry of the reference volume must be such that the two volumes are characterized by the same temperature without delay. We may then conclude that any change of differential pressure between the temperature compensation network and the R/B internal pressure is related to :

1. Leak rate of R/B
2. A variation of water vapor pressure for which a correction is initiated to cancel the error
3. An addition of some gas within the R/B which we may introduce a correction factor, by calculating the change cause by this phenomena.

The temperature tubular network is a airtight copper network installed inside the reactor building. It travels the R/B for 0.75 km in such a way that the volume of air in the tubing in one room is proportional to the volume of air in that room. So the network represents quite accurately the temperature in the overall R/B. Of course, the path of the network avoids hot and cold sources.

Temperature compensation network (TCN)



Also, some crucial verification must be done before each test to assure the validity of the network, such as : the network must have passed with success the airtight test and the network must be at the same pressure than of the R/B at the beginning of the measure (differential pressure = 0 kPad). Consequently, almost all changes in the differential pressure between the network and the R/B are attributed to the R/B leak. The other changes are related, like we saw, to the variation of water pressure or an addition of some gas within the R/B (ex : the heat transport storage gas system.).

Than, to confirm the leak tightness of the temperature compensation system, a vacuum pressure test is done on the system two weeks before the integrity test. We need two weeks because it takes about five days with our pump P2 to reach almost a perfect vacuum. After five days, the vacuum is about 10 mTorr. The system is then isolated and it's leak tightness is evaluated after some time. It is considered tight if the vacuum lost is lower then 20 mTorr/hr. We then keep the system under vacuum until the test. This way, we make sure that the system is appropriate by a daily check of the vacuum lost.

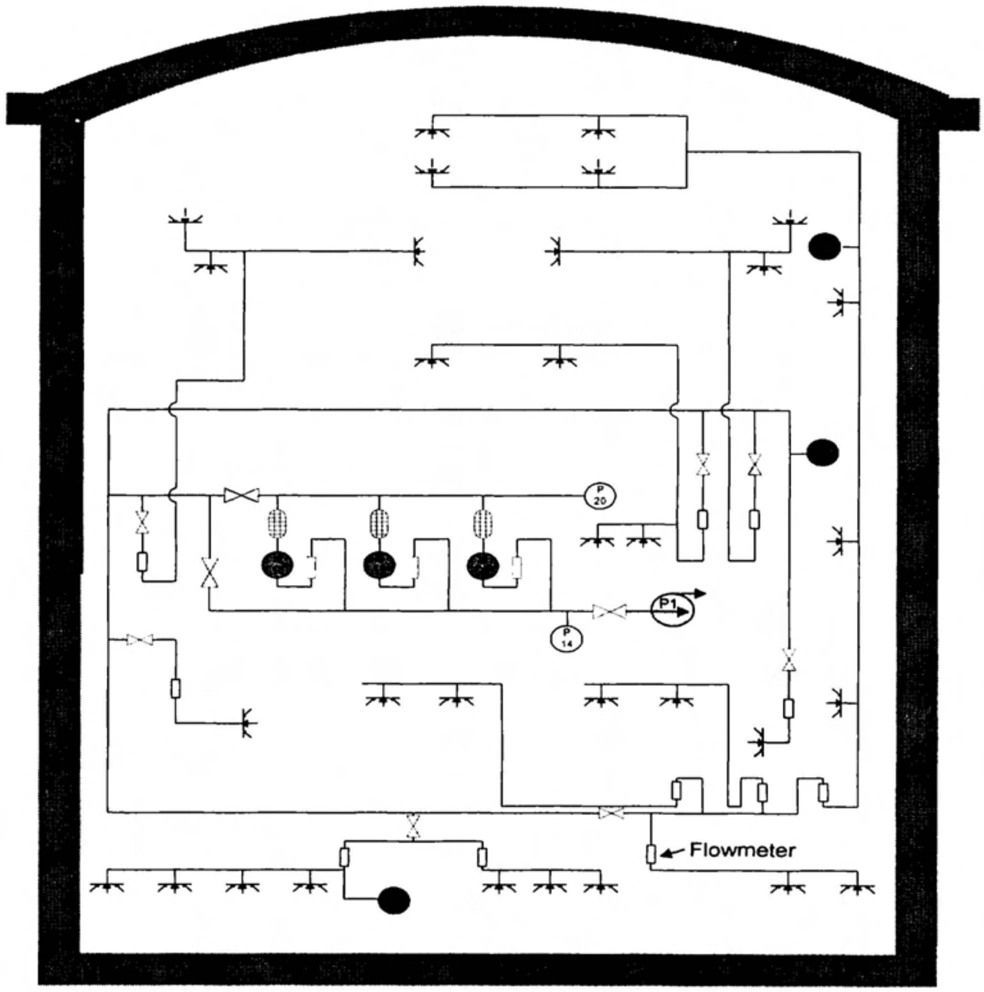
Also to have a 0 kPad differential pressure at the beginning of the measure, the tubing system is open to the R/B atmosphere while the building is pressurized. To achieve this V5 and V6 are open in the service building. After pressurizing the R/B, that takes about 50 minutes plus a stabilization period of 2 hours, the two valves are closed and a full measurement is taken, that takes about 8 hours.

Moisture tubular network

Six hundred seventy meters (670 m) of copper tubing is the moisture tubular network. There are thirty two (32) opening on the network from which air is pumped up to three hygrometer. The diameter of each 32 orifices are proportional to the volume of the room from which we pump the air. Those opening are distributed through eleven (11) predetermined zone. In fact, each zone has a predetermined flow, adjusted by its dedicated flow meter, which was calculated with respect to the volume of air to be sucked up. Therefore the dew point read by the hygrometer is very representative of the overall dew point inside the R/B.

Evidently, the humidity network doesn't have to be as tight as the temperature one because of it's use. The leak tightness is verified only to make sure that, during the measurement, the air that is pumped in, is sample through the 32 orifices of this system. So to test the leak tightness, all the valves upstream of the orifices are closed before starting the vacuum pump. While reaching -95kPad, the pump is isolated. If a leak of more then 1 kPad within 20 minute is seen, the system is considered as not available and a leak search is then initiated. The leak tightness test is done one week before the integrity test. A verification of the sample flow is also done with the flow meters installed on the system.

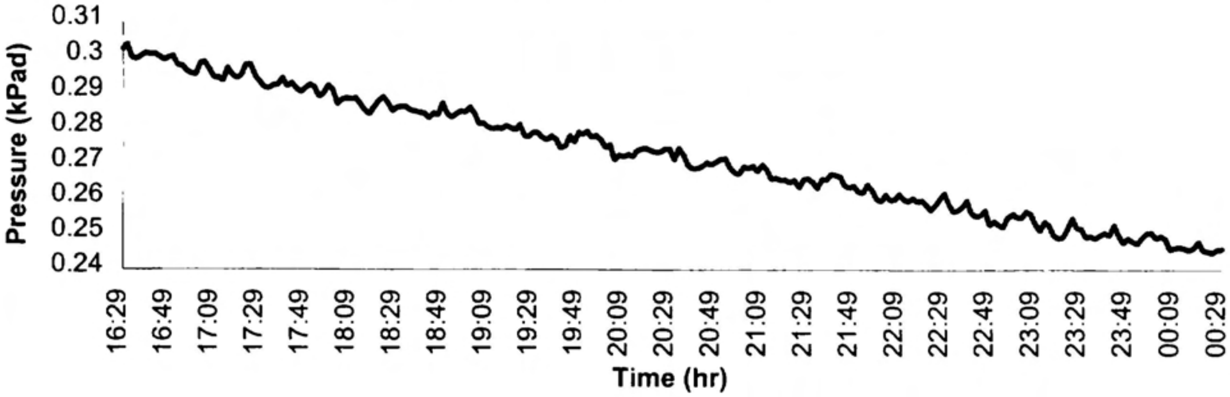
Humidity network



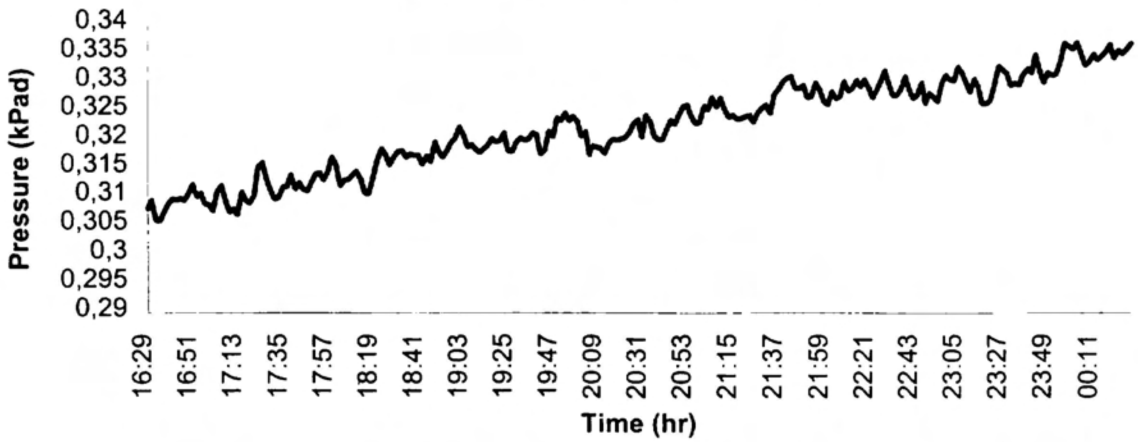
The humidity network has been design to provide a good sampling of the dew point during the measure, it is an essential parameter for the calculation of the leak. Indeed the variation of water partial pressure in the reactor building has an impact on the differential pressure between the R/B and the temperature network.

During the integrity test, the R/B is box up, the R/B ventilation and vapor recovery system are shutdown and because of the lack of tightness of some systems containing light water or heavy water, the water partial pressure increase. This increase generates pressure build up during the measurement and is creating a decrease of the leak rate.

Graphic 1
Differential pressure (TCN/RB)



Graphic 2
Differential pressure (TCN/RB)



These two graphics are showing well the effect of the partial water vapor pressure. Graphic 1 shows that the effects of this increase is more important then the R/B leak rate, considering it's negative slope. Indeed the reference of the pressure transmitter, that gives the R/B -TCN differential pressure, is the R/B pressure, so to have this negative slope, the pressure in the R/B has to increase. The graphic 2 shows the differential pressure between the R/B and the temperature network after correction for the water partial vapor pressure. That shows the depressurization from the reference of the transmitter and consequently the depressurization of the reactor. Finally, it is this lost of pressure from the R/B over time that will gives us the R/B leak rate. Also note that graphic 1 and 2 take into account a compensation for the incoming gas, the response time of the network and the increase of heavy water concentration into the R/B. Nevertheless for the test done in September 1999, these three correction factors were negligible which means that graphic 1 and 2 are representative of the water vapor impact on the measurement in the R/B.

Correction.

After the compensation for the humidity variations, the other corrections to be considered within the calculation within the MCT computer program are :

- Correction for the temperature network response time.

  The temperature compensation network might have a response time to adjust to temperature changes. To be able to implement a correction for the response time involve by the imperfect thermal conductivity of the copper and to be able to calculate it, we must know the average temperature of the R/B for each data sample taken. We then use the perfect gas equation and the absolute pressure of the tubular network to calculate the average temperature in the R/B and than the change rate. During commissioning, test have been performed inside the R/B by stopping/running LAC's which have been useful to calculated the correction to applied

- Correction for gas system leaks

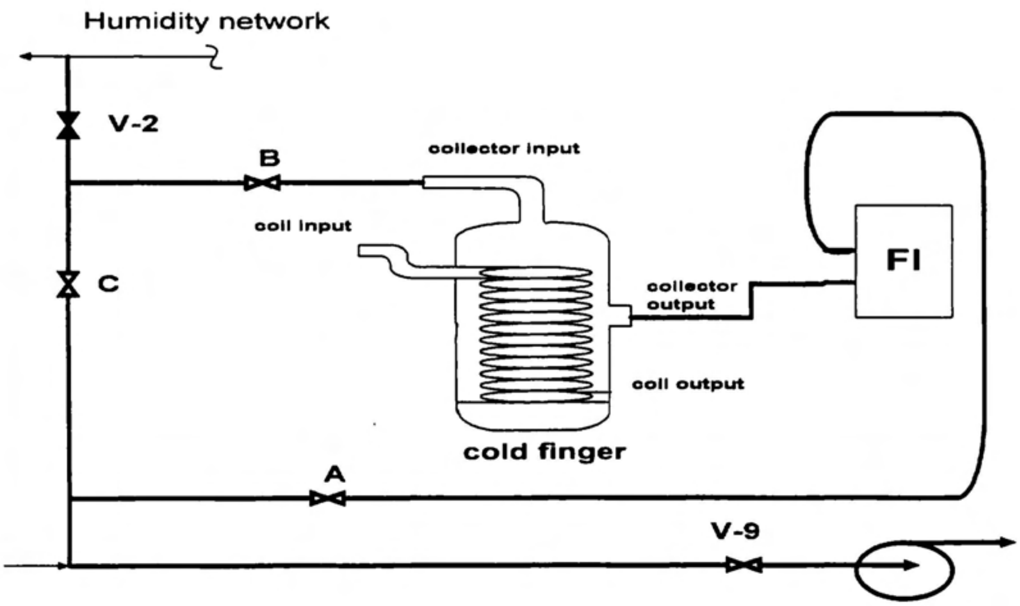
  During an integrity test, the reactor power is close to 100% F.P., this implies that all systems, including the gas systems,, except the instrument air system and the cover gas for the reactor shield, are within their normal operation configuration. These systems are :

  - moderator cover gas system
  - CO2 gas annulus system
  - Heat transport gas storage system
  - Liquid zone control gas system
  - SDS #2 poison injection system

  These systems are not isolated neither de-pressurized during the integrity test. Being under positive pressure, these will most likely leak and let gas go into the R/B atmosphere and by doing so, it will induce an error into the reading of the differential pressure readout between the temperature tubular network and the R/B. A compensation should be done. Basically, the compensation is to evaluate the volume of gas leaked from every system and to evaluate the partial pressure of these gas leak within the total R/B pressure.

- **Correction for heavy water within the R/B atmosphere**

  Like we saw earlier, our moisture transmitters measures the dew point of moisture of the R/B. The dew point, which serves to calculate the vapor pressure, is thus the most important factor to be measure after the differential pressure between the temperature tubular network and the R/B. But there is a percentage of heavy water in the moisture found in the air of the R/B due to some minute leaks essentially found on the heat transport system. The R/B being confined during our tests, the percentage of D_2O increases linearly during that period, unless another leak emerges during the test. A test done in December 1994, during which an important leak of D_2O existed, gave a leak rate of the R/B much higher than the previous tests. We therefore asked ourselves : Does D_2O have an effect on vapor pressure calculated as if it were exclusively light water (H_2O) ? Indeed , for the same value of dew point, two component with different physical properties will have a different vapor pressure , So, the vapor pressure equation used should not only depend on the dew point value but also on the composition of the gas detected on the mirror of the hygrometer. Then to determine the gas composition or to simply define the heavy water concentration within the R/B atmosphere, we use an instrument call Cold Finger . This instrument is made of a glass container with a glass coil tubing inside. It is connected in parallel into the humidity network through a by-pass. This container is immerge in an isopropanol solution with dry ice to condense the humidity that contain the air sample that continuously flow through it. The sample composition is analyzed by technicians in the chemistry laboratory. This method is simple, not expensive, and does not need processing of the sample after being taken. It doesn't allow us to have a continuous follow up of the sample composition. We need to have a sample taken at the beginning of the measurement and at the end. The slope between the two results is allowing to predict the evolution in time of the he D_2O concentration within the air of the R/B during the test.



Instrumentation air regulation system

The instrument air for the reactor building is normally supply by three large tanks. These three tanks, installed in the R/B are maintained under pressure by a set of three compressors connected in parallel and are installed in the S/B. This means that to maintain the appropriate pressure within these tanks, the air is taken from the S/B and carried into the R/B. There is a continuous supply of air into the R/B. To make sure that no air transfer is done into the R/B during the leak

rate measurement, instrument air system is isolated from the R/B and an air regulation system with three smaller compressor are used.
The three small compressors are located inside the R/B. This way, it could supply the R/B instrument air with R/B air, there is no air flow inside. The regulation system is used to make sure that the internal R/B pressure is influenced as little as possible by the on and off cycling of the three small compressors. So the regulation system while taking the measurement keeps constant the tank internal pressure. There is still some small pressure cycling (in the order of 1 kPa related to the internal pressure of 800kPa), These small cycles could generate a small error on the leak rate evaluation, this error could be calculated.

One pressure transmitter send a signal to the data acquisition system. These data will be used only to follow-up the system behavior during the leak rate measurement, it is not use for calculations.

Reactor shield cover gas (nitrogen)
Contrary to the other system, the reactor shield cover gas system has no instrumentation to allow the evaluation of the gas lost in time. This system is then isolated and depressurized at the beginning of the test. This way we ensure that there will be no gas leak into the R/B atmosphere during the measurement from this system.

Errors associated to the leak rate calculation and validation

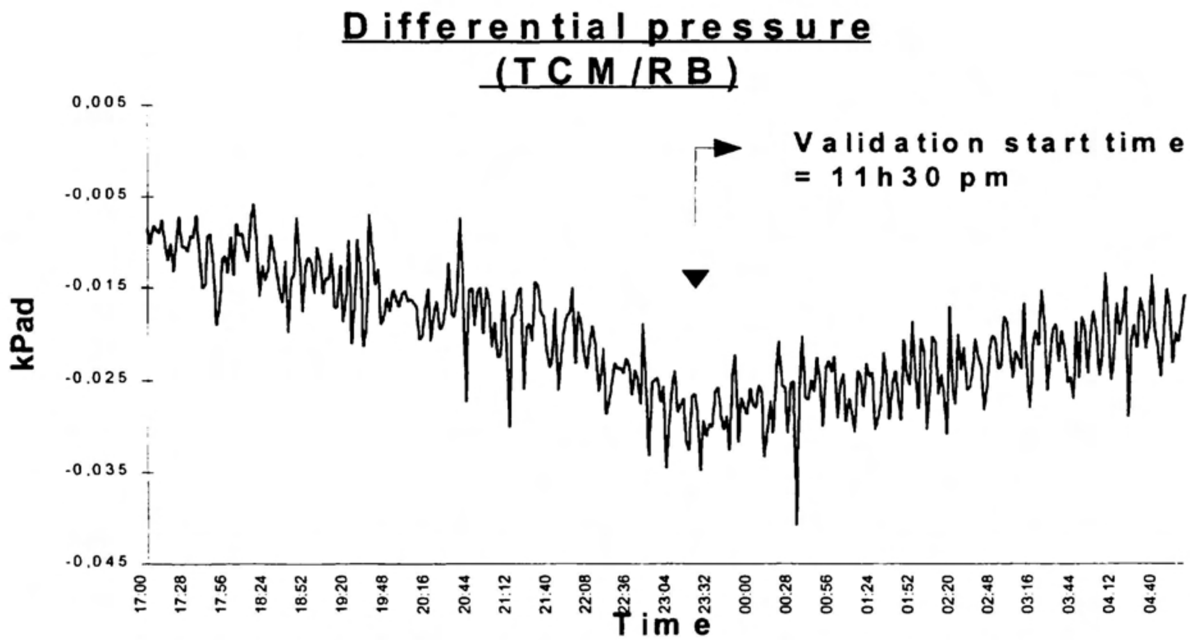
There are different kinds of errors which are taken into account to calculate the leak rate of the R/B as the statistic error, the systematic errors and the instrumental errors.

- The calculation of the statistical error for the leak is done to evaluate the amplitude of the spurious differential pressure changes in relation to the regression strait line.
- The systematic errors imply more factors such as : the temperature tubular network representativeness and air tightness, the correction for the responding time, the correction for the moisture variation and the correction for normalization.
- The instrument errors are the uncertainties associated to each instrument and their transducer

Also, to have an idea for the precision of the temperature compensation method, we use at Gentilly 2 a validation period by creating a known leak.

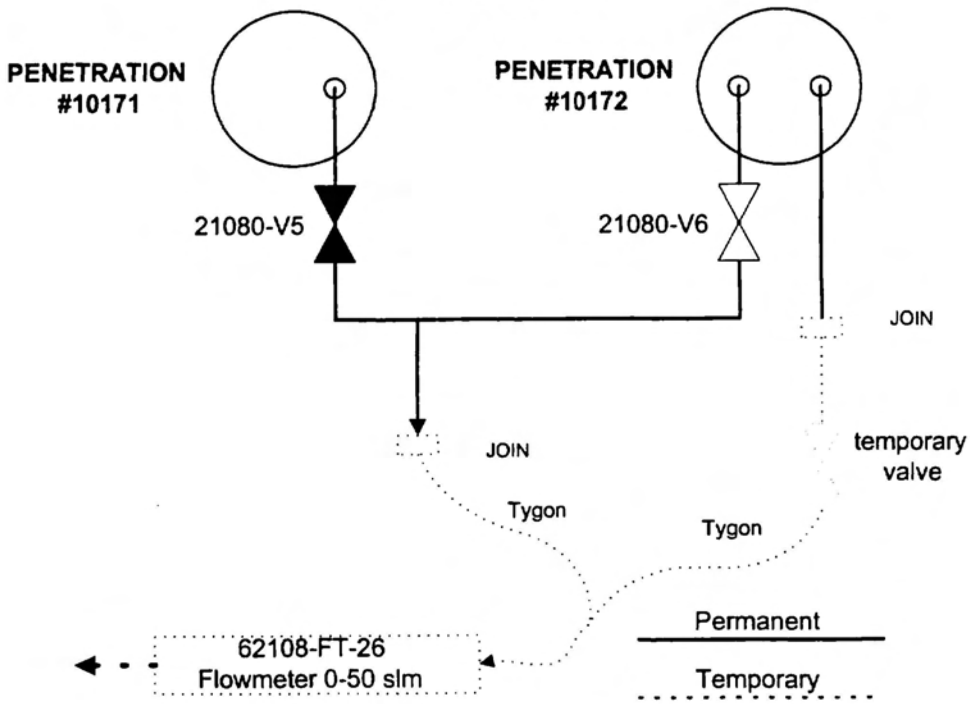
After the period of time (8 hours) used to calculate the unknown leak of the R/B, a known leak, ≈35 slm, is created. Then, a new period of time (4 hours) measures the new R/B leak rate which will now include the unknown and the known leak rate. The difference between the results measured during those two periods [(unknown + known) - (unknown)] should be close to the known leak measured by a high precision flow meter. This procedure allows a validation of the methodology, software and instruments of the temperature compensation method system. environment. The difference between the value calculated with the computer and registered on the flow meter for a sample leak is about 10% on average. This difference could be reduce if we were using a longer validation period because there are small changes in the flow with time. But the first objective for this validation is not to provide a quantitative check for the methodology precision but to give us an idea for the interaction of the temperature compensation method with the environment. This way it is easy to justify or not the calculated leak rate within the 8 hours measurement period.

The sensitivity of pressure transmitter (the one measuring the differential pressure between the temperature network and R/B) being so great, we can easily identifies on its graph, at which time the unknown leak was measured with the time the known leak was created and measured.



To create the leak, we open the temporary valve 21080-V6. The leak tightness of the temperature network is maintained by keeping 21080-V5 closed. With the temporary valve and V6 open and a 3 kPad pressure in the R/B, we have a flow out of about 35 slm at the flow meter. The air passing through the flow meter is then sent to the 40 liters monitor and then to the evacuation stack.

VALIDATION



Instrumentation

Every 15 seconds, data from each instrument is archived in the TCM computer. The precision of the instruments is very high, within the order of 0,04% of the full scale. Also during the integrity test, many instruments are use to make the calculation for the gas system, the leak rate, or to provide other data to make easier the analysis of the test.

Here they are.

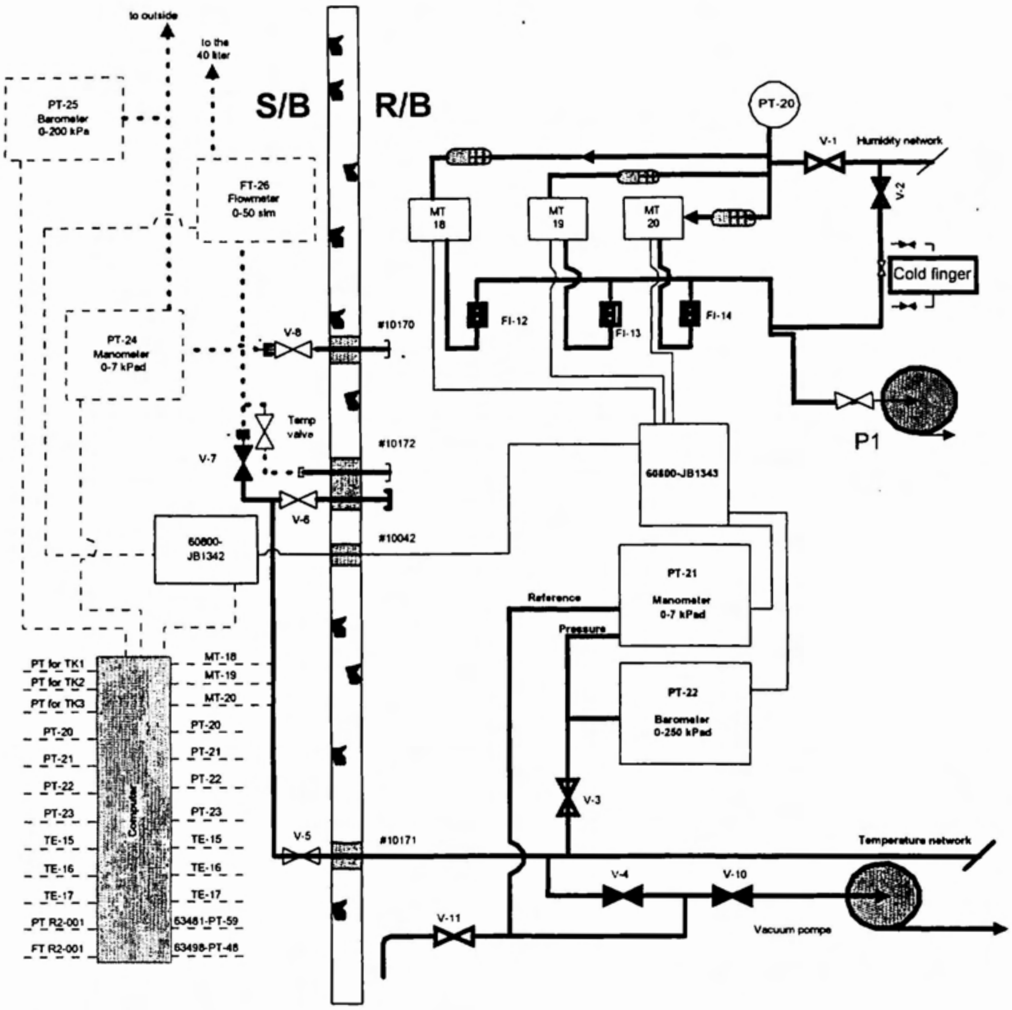
Calculation for the leak rate of the gas system.
PT-3,LT-13a, allowing the measurement of the leak from the moderator cover gas system
PT-59, LT80a, allowing calculation of the leak rate from the liquid zone control cover gas
PT48, allowing calculation of the leak rate from the annulus gas system
PT-21, allowing calculation of the leak rate from the SDS#2 cover gas system
PT10, LT-14c, allowing the calculation of the leak from the HTS cover gas

Calculation of the leak rate
PT-21, give the differential pressure between the temperature network and the R/B. This is a basic element of the leak rate calculation
PT-22, give the absolute pressure of the temperature network, This pressure is used to determine the average R/B temperature which is a basic element for the time response compensation
PT_24, Give the R/B differential pressure. This instrument is use to determine the R/B absolute pressure and to make sure we will not triggered the SDS#1 and SDS#2 systems.

PT_25, Give the atmospheric pressure. It is use to determine the R/B absolute pressure
MT-18.19,20 one of these three dew point meter is giving us the R/B dew point to make the vapor pressure calculation
RTD15, 16, 17, To ''calibrate'' the measure of the temperature given via the absolute pressure of the temperature network, the software will use the first datum read by three transmitters which are installed on the moisture tubular network.PT-20, give the internal pressure of the R/B air sampling system. This measurement allow us to compensate the partial pressure of water vapor with the dew point measurement . This compensation is necessary because the sampling system is at a slightly lower pressure (about 9kPa) then the R/B because the sampling pump keeps running during the integrity test.

<u>Instrument for other data</u>
FT-26, flow meter to account for the leak generated buy opening the temporary valve and V 6 during the validation period.
PT-1,2,3, Pressure transmitter for each instrument air tank. This data acquisition is use only to ensure that the air pressure within the tanks is maintained constant, the data is use in any calculation. the data is not use in any calculation.
PT-23, vacuum gage that allow to make sure the temperature compensation network is leak tight. This transmitter is off during the integrity test.
PT-27, allow us to follow up the pressure within the spent fuel transfer room. the data is not use in any the calculation.
FT-27, allow us to determine the leak rate between the R/B and the spent fuel room.

Temperature compensating method



Intervention plan

At Gentilly for every integrity test we use a procedure prepared by the system engineer and approved by operation. This procedure describe the operations and the sequence. Here is an overview of the procedure, it gives a good idea of the integrity test.

Step 1, Duration 3.5 hours

- Validation of the tightness of the two airlock seals, R/B side
- Dew point meters cleaning
- Reactor shield cover gas system isolation

Step 2, Duration 3.5 hours

- Alignment of the piping use to pressurize the R/B
- Reactor stability test
- Commissioning of the three temporary compressors

Step 3, Duration 0.5 hour

- Manually triggering the R/B containment
- Stop the R/B ventilation system
- Stop the R/B air dryers

Step 4, Duration 0.5 hour

- Opening all R/B internal doors
- Final R/B inspection

Step 5, Duration 1.0 hour

- Pressurize the R/B
- Prepare for the first Cold Finger

Step 6, Duration 2.5 hours

- Install the first Cold Finger on the humidity network
- Close V% and V, the temperature network is isolated
- Measurement period for the first Cold Finger

Step 7, Duration 8.5 hours

- Removal of first Cold Finger for analysis
- R/B leak rate measurement

Step 8, Duration 4.0 hours

- Prepare for the second Cold Finger
- Validation of the leak rate measurement

Step 9, Duration 2.0 hours

- Installation of the second Cold Finger
- Measurement period for the second Cold Finger

Step 10, Duration 0.5 hour

- Removal of second Cold Finger
- Instrument air system back to normal service condition
- Dry out and depressurize the R/B
- R/B Containment, ventilation and airlocks back to normal service condition

Step 11, Duration 2.0 hours

- Complete the return of all system to normal service condition
- R/B accessible

Total duration of the integrity test is approximately 29 hours.

Advantages and Disadvantages of the method TCM

Advantages

- It could be done at any test pressure
- It could be done with the reactor at 100% power
- no need for several temperature measurements and correction for temperature upset related to the temperature tubing network
- a more representative dew point because we use a moisture tubing network
- allows us to evaluate the R/B leak tightness within 30 hours
- allows more frequent evaluation of the R/B leak tightness

Disadvantages

- Atmospheric pressure is an disadvantage because is an independent factor which affect directly the differential pressure of the R/B. Thus, it affects the calculation of the normalized leak rate of the R/B but not in a considerable manner. What it can affect more dangerously is the operation of the plant since the differential pressure of the R/B could get to 3.45 kPad. Indeed the SDS#2 system by design will trigger if a pressure differential of 3.45 kPad is reached. Because of the noise related to some instrument, the error margin, and the cost to the production lost related to a poison injection, the uppermost pressure for the integrity test is limited to 3.2 kPad within the R/B by the operation shift supervisor. But a prevision of the atmospheric pressure furnished by the environment ministry permit to set a point to which the R/B will be pressurized for at the end of the test, the R/B differential pressure will not be over 3.2 (maximum differential pressure of the R/B accepted by the operation group).

- Despite what we observe during a R/B pressure test at full pressure, the pressure drop related to a leak during a low pressure test is extremely small. For an example, the pressure drop during the high pressure test during the 2000 shutdown was 0.65 kPa compared to 0.033 kPa during the integrity test done four weeks later.

Pressure drop related to test pressure

Pressure test kPa	Pressure Drop kPa
124	0.65
3	0.033

It is easily seen that the pressure drop will be difficult to measure. The precision of the instruments will warrant the reliability of the results. The cost of the instruments needed for the integrity become significant.

- The increase of the R/B contamination level during an integrity test is also more significant than during an high pressure test because of the normal operation configuration of the system. Two major inconvenience is related to this increase.

  1.During the installation and the removal of the second Cold Finger, the person responsible for the operation will have to use radiation protection equipment, as filtering mask, white coverall, to limit the absorption of contaminated heavy water.

  2.In the case of a large atmospheric pressure drop, the shift supervisor would request to depressurized the R/B by the opening of two containment valves till the pressure is back to 3.0 kPad. This operation is authorize only if the R/B internal contamination is less then 500 MPD. For this atmospheric contamination level, the release equivalent to the R/B volume will be 250 Ci, which is equivalent to 0.1 % MPL per week. But because the venting will be stopped when the pressure will reach 3.0 kPad and because the dryer will be under operation for this period , the release will be less then the mentioned value. This means that the test could be stopped because of an atmospheric pressure drop but also because the R/B internal contamination may reach the upper limit. But since we begin using this temperature compensation method, no test were stopped because of the R/B internal atmospheric contamination. The level normally reached is 90. Only one test reached 300 MPD, because we had a minor HTS leak

Conclusion

Hydro-Quebec, Gentilly 2, devoted many years in studying and researching for a convenient and reliable containment integrity test. Following those years, test were done to make the fine tuning of the method. In fact, all the containment integrity test done brought practical experience which was needed to make the results more representative of the containment leak rate. But of course, the two permanent networks, sensitive instruments, a good software and the trained staff were the key to the success of the Containment Integrity Test.

However, all that energy spent was worthed it. Based on the results obtained from the tests accomplished at 3.0 kPad with the reactor at 100% full power, we concluded that the temperature compensation method is an efficient and reliable method.

Finally, the two major advantages in using the temperature compensation method are :

1. We ensure the integrity of the R/B at shorter period (3 times a year) and also three of four weeks after a shutdown where the probability of having a breach are higher. The integrity is then a tool to improve the Gentilly 2 safe operation.
2. The 20 last integrity test are providing interesting data. We believe that this year, we will be in a position to give to the Safety Authority a document that is demonstrating that with this method (MTC), the leak rate result stability and the confidence in the result justify to increase the period for the high pressure test to five or six years. This frequency reduction for the high pressure test would the translate for Gentilly 2 in a saving of a lot of money.