SEP 2 3 1993

MEMORANDUM FOR: Distribution

FROM: Moni Dey, Senior Task Manager
Engineering Issues Branch
Division of Safety Issue Resolution
Office of Nuclear Regulatory Research

SUBJECT: TRIP REPORT FOR MEETING WITH SWEDISH NUCLEAR POWER INSPECTORATE AND VATTENFALL ENERGISYSTEM (UTILITY) TO DISCUSS APPROACHES TO CONTAINMENT TESTING

I met with the Swedish Nuclear Power Inspectorate (SKI) and Vattenfall AB (Operator of Ringhals 1, 2, 3, 4 and Forsmark 1, 2, 3) on July 14, 1993 to obtain information regarding their approaches to containment testing and experience with an On-Line Containment Integrity Monitoring System. A list of attendees is enclosed. The purpose of the meeting was to obtain design and implementation information, including the rationale for changes in approaches to containment testing. The information obtained at this meeting and others provided as a follow-up will be utilized towards formulating options for the Performance-Based Containment Testing Regulation currently being developed in the "Marginal to Safety" program. Data obtained from the Swedes are presently being analyzed by S. Cohen and Associate and Battelle Columbus Labs, that are providing technical assistance to the staff, to develop value impact analyses of rulemaking options including the use of on-line monitoring.

Based on similar approaches adopted in France and Belgium, Vattenfall AB has proposed three modifications to SKI on containment testing:

1. Extension of the "Type A" integral containment test to once in every 10 years based on historical test data that indicate that "Type A" tests do not reveal any new information beyond that obtained by local leak rate tests regarding leaktightness of the containment, and only provide information regarding the structural integrity of the containment. The interval of Type A tests can be established to confirm the structural integrity of the containemnt.

2. Conduct of local leak rate tests of penetrations and isolation valves based on failure and performance history since many isolation valves and penetrations have not failed leak rate tests over the last 10 years of operational history.

3. Implement an on-line monitoring system (designed by EdF, France) to provide a gross check of containment integrity following a cold shutdown.

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1/1

Vattenfall AB is presently conducting tests of the on-line monitoring system and analyses of historical test data to provide justification of the modified testing scheme to SKI. They expect to implement the proposed revisions by early 1994. SKI agreed to provide NRC data and documents that will be submitted by Vattenfall AB to support testing modifications in Items 1 and 2.

Details of the design and tests conducted to date of the on-line containment integrity monitoring system were provided by Vattenfall AB (see attached slides presented by Gustaf Lowenheim, papers from EDF, France; Association Vincotte, Belgium; and demonstration test results of the Belgian system, "Laborelec"). Vattenfall AB has tested both the Belgian and French systems which are similar and has decided to adopt the French system based on the availability of technical support from the vendors. Background documents of earlier studies that lead to modification of European containment testing practices were also provided and are attached.

The on-line monitoring system measures the flow of air into the containment atmosphere from leakages of the compressed air system, temperature and humidity in the containment building, and calculates the leakage rate. The system is claimed to be capable of measuring leakages of about 0.1 to 0.4 percent volume per day (equivalent to a hole of about 1/2 in. in diameter). The system is intended to check for gross leakages following cold shutdowns.

The French Sexten System has been installed and tested at the Ringhals Nuclear Power Station, Units 2 and 3 at an approximate cost of 2.5 Million SEK/Unit ($0.4 Million/Unit). Results of these tests will be provided to the NRC when the tests are completed later this year. Vattenfall AB has encountered some problems determinining weighting functions for the temperature sensors in the containment due to large temperature fluctuations from some sensors, weather pressure variations, and load follow operations during the tests. They anticipiate resolving these problems and successfully completing the tests. The problems encountered by Vattenfall AB were not expected by the system vendors, EDF, France. To date, the system has been successful in detecting small leaks through the purge valves and radiation monitoring system.

As a result of conflict with vacation periods in France and Belgium, similar meetings at those countries were not possible in July and have been planned for October 1993.

Representatives of SKI and Vattenfall AB were very helpful and open in their discussions regarding their approaches and experiences. They have agreed to keep the NRC informed of their efforts and findings.

ORIGINAL SIGNED BY

Moni Dey, Senior Task Manager
Engineering Issues Branch
Division of Safety Issue Resolution
Office of Nuclear Regulatory Research

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MDey:jf
09/23/93

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Attendees of Meeting on
On-Line Containment Integrity Monitoring System
Stockholm, Sweden
July 14, 1993

SKI

Dr. Wiktor Frid
Lars Berglund

Vattenfall AB (Utility)

Gustaf Lowenhielm
Dag Djursing
Bengt Svegner
Lars Fredlund

NRC

Moni Dey, RES

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~~Doy~~
Xkee CY
thanks

PRESENTED BY
GUSTAF LOWENHIELM
VATTENFALL AB

PURPOSE

*GET A BETTER FOLLOW-UP OF CONTAINMENT LEAKAGE
- ON-LINE AND "AS-RUN" CONDITION

*CONTAINMENT AIR TEST SUPPORTED BY NEW SYSTEM

*IMPROVED
-IA SUPPLY MEASUREMENT
-TEMPERATURE SENSORS

*POSSIBILITY TO SHORTEN OUTAGE PERIOD

PROBLEMS
DURING COMMISSIONING

* WEATHER CONDITIONS - HIGH/LOW PRESSURE VARIATIONS

* LOAD FOLLOW

* TEMPERATURE SENSORS TOO CLOSE TO RCP

* IA TOO LEAK TIGHT (5 → 20 DAYS)

PLANT DEFICIENCIES

* LEAKS ETC IN APD SYSTEM (CONTAINMENT AIR WAS RELEASED TO STACK AFTER MONITORING)

* PURGE AIR VALVES LEAK RATE 1-5 Nm3/h BELOW 0,04-0,07 barö, TIGHT AT HIGHER PRESSURE

COST

APPR 2,5 MSEK/UNIT (0,4 MUSD/UNIT) 400K

FINANCED BY LONGER CAT TEST INTERVALS

ACCEPTANCE CRITERIA

< 5 Nm3/h NORMAL CONDITION

5-15 Nm3/h IDENTIFY AND CORRECT WITHIN LIMITED TIME

>15 Nm3/h INFORM SKi, ACTION PLAN

List of equipment

The test equipment used to measure the leakage rate of nuclear containments during operation includes :

- 34 temperature gauges,
- 4 hygrometry gauges,
- 1 containment pressure sensor,
- 1 atmospheric pressure sensor,
- 1 data acquisition and processing system consisting of :
    - . 1 acquisition unit,
    - . 1 laser printer,
    - . 1 think-jet printer,
    - . 1 RS232 link cable,
    - . 1 HPIB link cable.
- 1 ICADS (Instrument Compressed Air Distribution System) flow meter
- 1 100 Ω precision resistor for calibrating the resistance measurements.

Automatic printing

Procedure carried out every 1/4 hour

The following data are printed on the ThinkJet printer :

- the number of the reading in the current cycle,
- the time in hours and minutes,
- the pressure in the containment,
- the partial steam pressure,
- the mean temperature in the containment,
- the ICADS flow rate,
- the leak rate over the last 4 hours with an estimation of its uncertainty,
- the variation in the volume of air corrected by the ICADS contributions since the beginning of the cycle.

Procedure carried out every 8 hour assessments

If more than 5 valid points (dP8h, Lr8h) are available :

- the Lr60 and Lr0, and their uncertainties, Ulr60 and Ulr0, are printed out on the ThinkJet printer,

- the valid measurements (dP8h, Lr8h) and invalid measurements (dP8h, Lr8h) are printed out on the ThinkJet printer,

- the points (dP8h, Lr8h), with the Lr60, Lr0, and uncertainties, are plotted with the date and time of the first reading (HP-Laserjet).

THE MEASUREMENT SYSTEM

Acquisition system

The SEXTEN SYSTEM measurement equipment at Ringhals consists of the same type of equipment as provided for SEXTEN 2 EDF. This enables both systems to evolve simultaneously.

The equipment used is as follows :

- an HP 75000 B acquisition unit, equipped with 6 relay boards (8 resistance channels or 16 voltage channels), a voltmeter, a disk drive, a 20 MB hard disk, and an I BASIC processor ;

- a laser printer, connected in RS 232 to the HP 75000, used as a plotter ;

- a thinkjet printer for real time printing and other messages, recorded in HPIB.

The program is written in I BASIC. It is executed by the I BASIC processor installed in the HP 75000.

Temperature gauge

- Precision upon installation :
  . Respect the third of the standard DIN 43760, which, for a platinum gauge PT100 at 0°C, gives : 100 Ω ± 0,04 Ω or 0°C ± 0,1°C.

Hygrometry gauge

LiCl-type hygrometry gauges are used. They must therefore be regenerated for recalibration and to fulfil the precision requirements. it is recommended not to have air speeds in excess of 1 m/s.

- Precision after recalibration or upon installation :
  . acceptable error of ± 1°C on absolute dew-point temperature Td
  . acceptable error of ≤ 0,75 mbar over a variation of 5 to 20 mbar of Hm

Containment pressure sensor

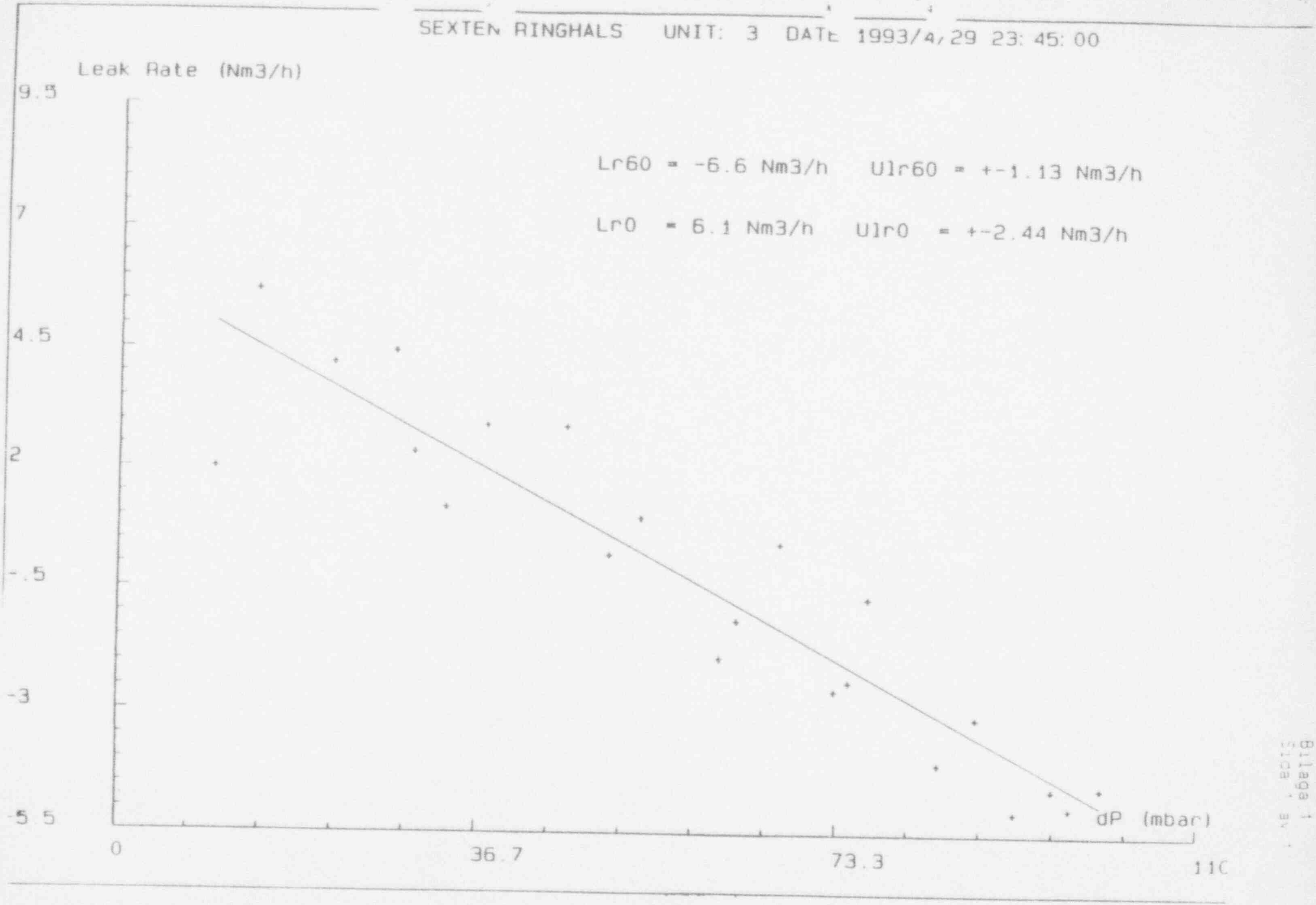
- Precision after recalibration or upon installation :
  . acceptable error of ± 1 mbar at absolute pressure Pc
  . error ≤ 0,1 mbar over variation of 950 to 1050 mbar of Pc

Atmospheric pressure sensor

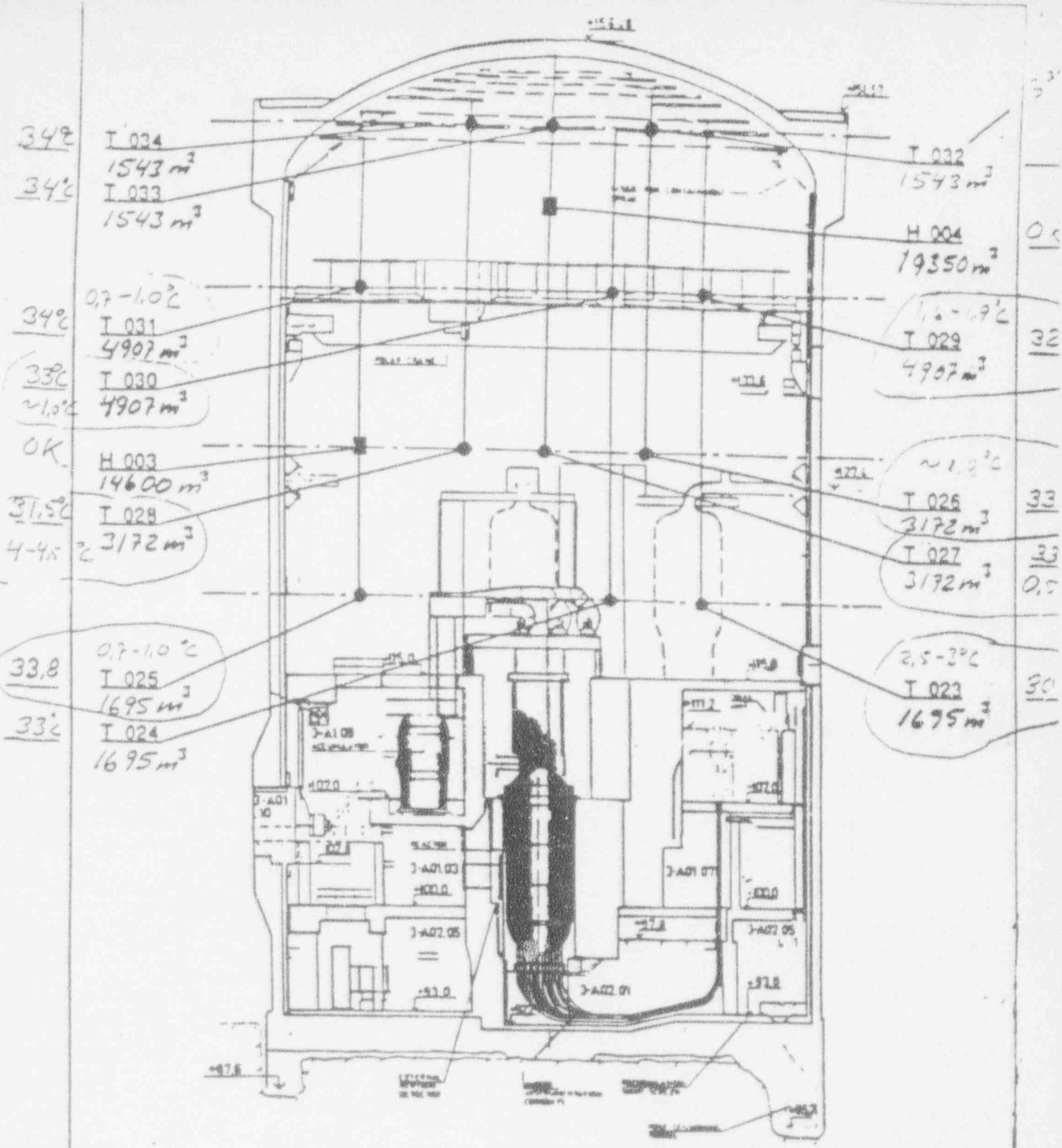
- Precision after recalibration or upon installation :
  . acceptable error of ± 1 mbar at measured atmospheric pressure Pa

Mass flowmeter

- Precision during one year of operation :
  . Error of ± 0.5 Nm^3/h on the ICADS flow

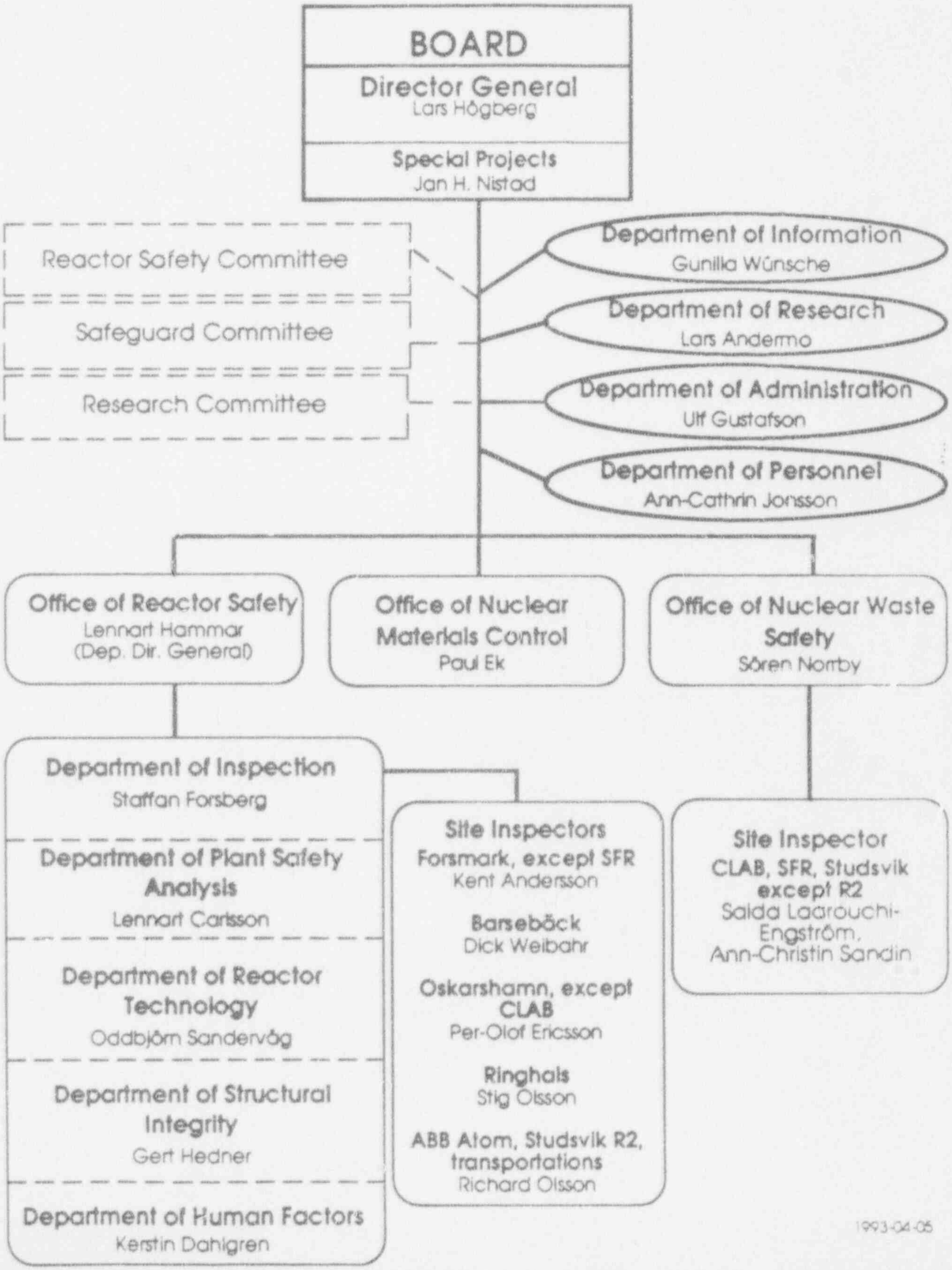

SEXTEN RINGHALS UNIT: 3 DATE 1993/4/29 23:45:00
Leak Rate (Nm3/h)
Lr60 = -6.6 Nm3/h Ulr60 = +-1.13 Nm3/h
Lr0 = 6.1 Nm3/h Ulr0 = +-2.44 Nm3/h
9.5
7
4.5
2
-.5
-3
-5.5
0
36.7
73.3
110
dP (mbar)

Bilaga 1



RINGHALS - GAUGES LOCATION					
GAUGE	CAT ref.	Loc. level	GAUGE	CAT ref.	Loc. level
T 023	K506	120 m	T 029	K509	140 m
T 024	K546	120 m	T 030	K549	140 m
T 025	K526	120 m	T 031	K529	140 m
H 003	K527	130 m	H 004	K544-545	145 m
T 026	K502	130 m	T 032	K505	150 m
T 027	K542	130 m	T 033	K545	150 m
T 028	K522	130 m	T 034	K522	150 m

SKi ORGANISATION SCHEME



1993-04-05

March 89

CONTINUOUS MONITORING OF CONTAINMENT LEAKTIGHTNESS

THE SEXTEN SYSTEM

[redacted] GERMAIN - [redacted] JANNETEAU

[redacted]

Direction des Etudes et Recherches

6, quai Watier

78400 CHATOU

FRANCE

Ringhals use The Sexten System 2.
BS

1 - INTRODUCTION

The containment leaktightness is essential to the safety of PWR nuclear power plants. This was illustrated by the Three Mile Island accident where the containment efficiently played its part in preventing the release of radioactive materials to the atmosphere.

The containment leaktightness is usually checked before the unit is started and, then, periodically by performing integrated leakage rate tests. In France, these tests are carried out before the plant startup/ during the first refuelling and, after, every ten years unless a degradation in the containment leaktightness is detected. In this case, tests are performed more frequently. The leeaktightness is checked at a pressure corresponding to the Lost of Coolant Accident that is at a 4 bar gauge pressure.

In France, it was decided to check the containment leaktightness on a permanent basis by installing a continuous monitoring system, the SEXTEN, working during the unit operation.

This system has now been installed in all the French PWR units. It has, on several occasions, revealed leaktightness defects in the containment of working units.

2 - HISTORY

The first containment leakage rate tests in an operating unit were performed in 1980. The results of these tests are shown in Figure 1. The solid line curve (dM/M) describes the modification of the air mass in the containment versus time.

During the first phase, the system recorded a decrease in the air mass corresponding to a leakage rate of 21 Nm^3/h at a 52 mbar positive pressure. The plant radiation monitoring system once closed, the SEXTEN system measured an air ingress into the containment of about 6 Nm^3/h (phase 2). During phase 5, once the plant radiation monitoring system and the service compressed air distribution system were closed, the containment leakage rate at a 33 mbar positive pressure was 0 Nm^3/h. In conclusion, the test system detected a leakage through the plant radiation monitoring system and an undesired air inleakage into the containment through the service compressed air distribution system.

This first test, therefore, demonstrated that integrated containment leakage rate could be measured during unit operation with an accuracy sufficient to detect leakage problems that may occur on this type of component.

Following these tests, in 1981 and 1982, another containment was instrumented and measurements were recorded for approximately one year. This test was used as a basis to define a simplified measurement instrumentation which served as a reference to build a prototype monitoring system, called SEXTEN (Surveillance en Exploitation du Taux de fuite des Enceintes = In Service Monitoring of Containment Leakage Rate). Three of these prototypes were installed in power plants in order to be perfected and validated.

In [redacted] it was decided that all EDF PWR units would be equipped with [redacted]

At present, the containment leaktightness in French units is being continuously monitored by the SEXTEN system.

3 - OPERATING PRINCIPLE

Leakage detection in containments is based on the fact that the pressure inside the containment is succesively under or above atmospheric pressure. Actually, the gauge pressure inside the containment goes up and down (ref. figure 2) due to the air from the instrument compressed air distribution system (ICADS) being consumed by the air-operated valves in the reactor building. The air drawn from outside is released in the containment where the pressure slowly rises. When the pressure reaches a set limit, the operator quickly depressurizes the containment, and a new pressurization cycle begins.

When there are leaks, these may be detected during the positive or negative pressure periods in the containment by assessing the gas mass balance in this containment.

This gas mass is measured by the absolute method. This method is widely used for containment leakage-rate tests.

It consists in measuring the average partial steam pressure and the absolute containment air pressure. The dry air content of the containment can then be calculated.

The slope of this quantity variation is equal to the integrated containment leakage mass flow.

The containment leakage rate can be measured by subtracting the ICADS air flow rate injected into the containment from the integrated containment leakage mass flow.

[redacted] consists in finding an instrumentation capable of [redacted] measuring the average temperature and the average partial [redacted], especially when these quantities exhibit large [redacted], which happens quite often inside the containment of an [redacted]

The choice of the location of the various sensors and of their weighing for the computation of average values is essential to have accurate measurements.

For instance, Figure 1 shows that the average temperature varies by approximately 1°C and the partial steam pressure by some 5 mbars during phase 2. A disruption can be seen on the curve of the dry air mass (dM/M) versus time, but the error level remains low.

As a pressurization cycle lasts some 20 days (900 MW units), an average leakage rate and an average gauge pressure in the containment can be measured every day.

Curves such as those in Figure 3 are obtained. By analyzing these curves, a precise diagnosis of the containment leaktightness can be made.

To characterize the containment leaktightness a criterion was defined for the containment leakage rate at a positive pressure of 60 mbars (Qf60). In France, in 900 MW units, the containment leaktightness is considered adequate when Qf60 is below [redacted]

4 - CHARACTERISTICS OF THE SEXTEN

Several problems likely to affect the containment leaktightness or the operator of some circuits can be detected with the SEXTEN system. These are :

- leaks of the components contributing to the containment leaktightness,

- leaks of the systems running across the containment,

- undesired gas inflow (air, nitrogen).

SEXTEN can be used, once it has detected a problem, as an aid to identifying the defective circuit or component. Indeed, thanks to the real-time plotting of the evolution of the gas mass inside the containment, the way the closing of systems or the repair of components affect the integrated containment leakage rate can be clearly seen (ref. example in Figure 1).

For a 900 MW unit containment (free volume of about 50 000 m^3), the average uncertainties with the SEXTEN system are :

- [redacted] over a [redacted] measurement period for the containment integrated leakage rate,

- [redacted] for the assessment o[redacted] over a pressurization cycle in the containment.

[redacted] 4 hours of measurements to confirm the development, [redacted] 5 Nm^3/h leak.

The instruments used in the SEXTEN system are given in Figure 4.

The system, strickly speaking, consists of a processing unit, a data logger, a printer and a plotter. A SEXTEN system can monitor two containments simultaneously. The following sensors are used :

- 1 absolute-pressure tranducer in each containment,

- 10 temperature sensors in each containment,

- 2 moisture-content sensors in each containment,

- 1 flowmeter on the instrument compressed air distribution system (ICADS) in each containment,

- 1 atmospheric-pressure transducer.

- 1 flowmeter on the instrument compressed air distribution system (ICADS) in each containment,

- 1 atmospheric-pressure transducer.

[redacted] At the operator's request, the evolution of the gas mass inside the containment can be plotted in real time when leaks are looked for.

5 - RESULT ANALYSIS

The SEXTEN system confirmed that leakage problems may sometimes occur in the containment of operating units. The leaks are generally located in the circuits running across the containment, for instance in the plant radiation monitoring system, the nuclear island vent and drain system, the containment sweeping ventilation system and the containment atmosphere monitoring system.

The SEXTEN detects these problems and helps the operator to locate the leaks.

[redacted]

[redacted]

[redacted]

6 - CONCLUSIONS

The tests performed from 1980 to 1982 demonstrated that the [redacted] rate [redacted]

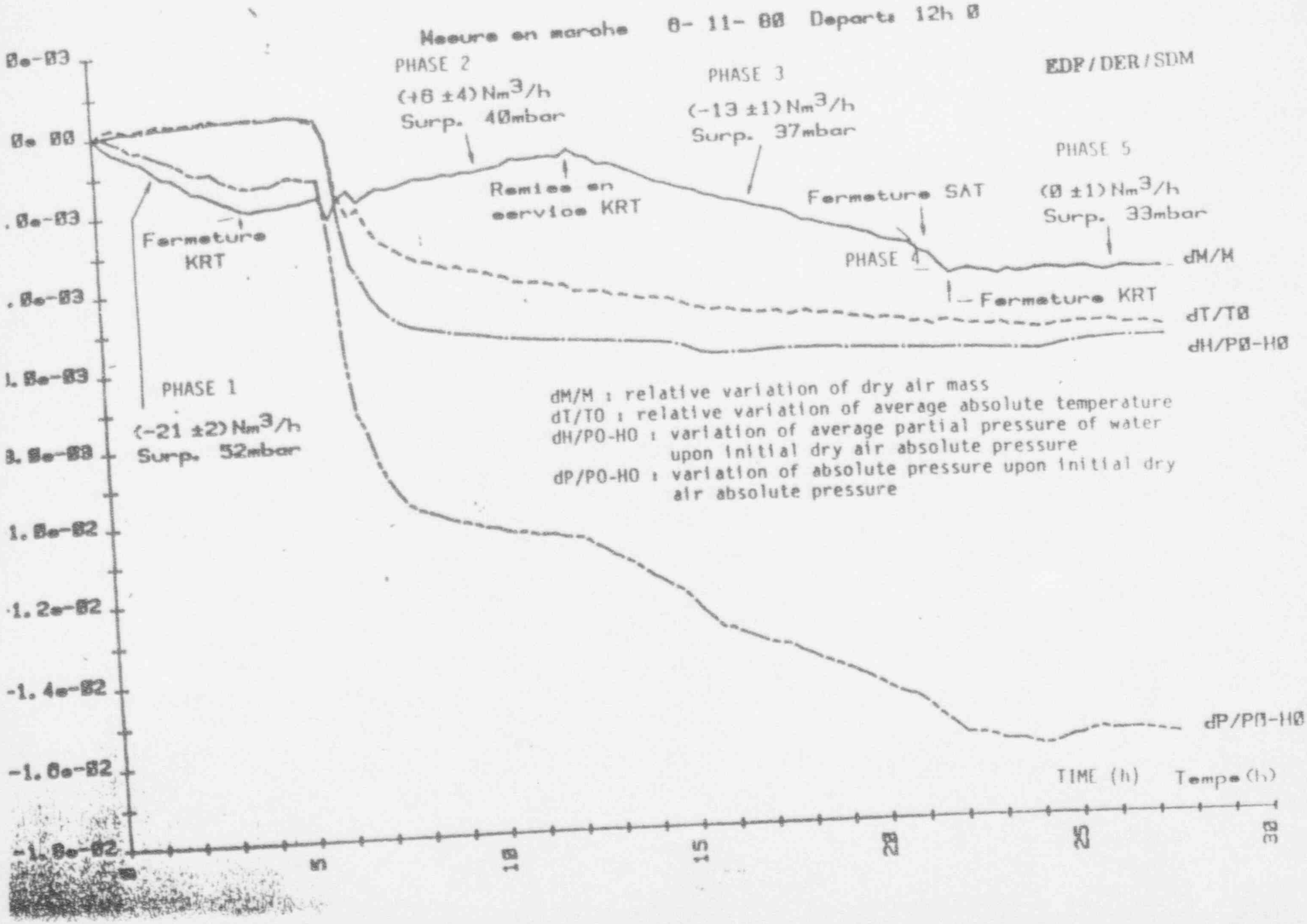
A continuous monitoring system of the containment leaktightness, called SEXTEN, has been developed by EDF. This system has been installed in all French PWR units.

This system detected some leakage problems likely to occur on certain circuits running across the reactor building connected to the containment air.

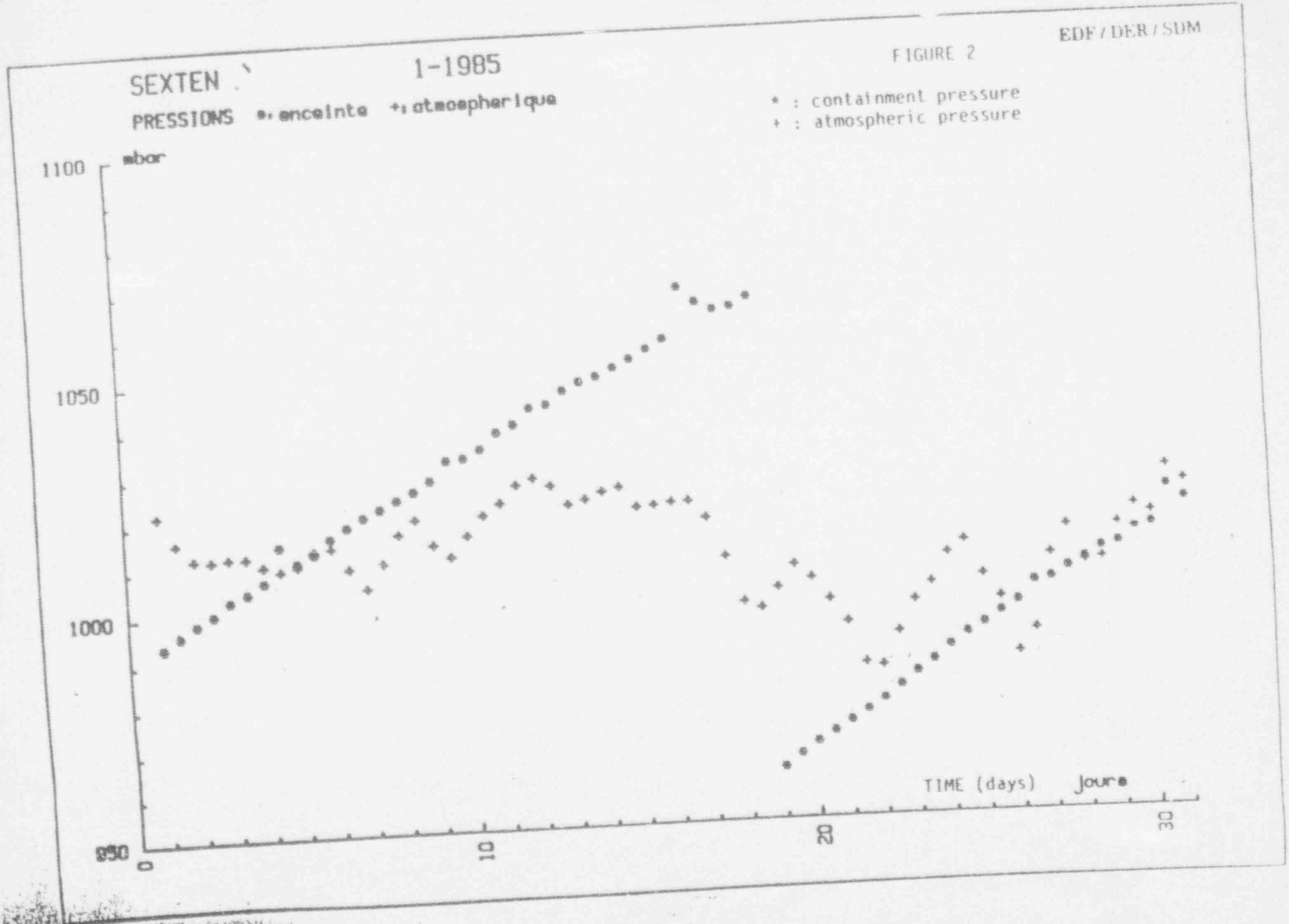
This continuous monitoring complements the tests performed to measure the leakage rates at the LOCA pressure and improves the unit safety by contributing to an adequate containment leaktightness.

LIST OF FIGURES

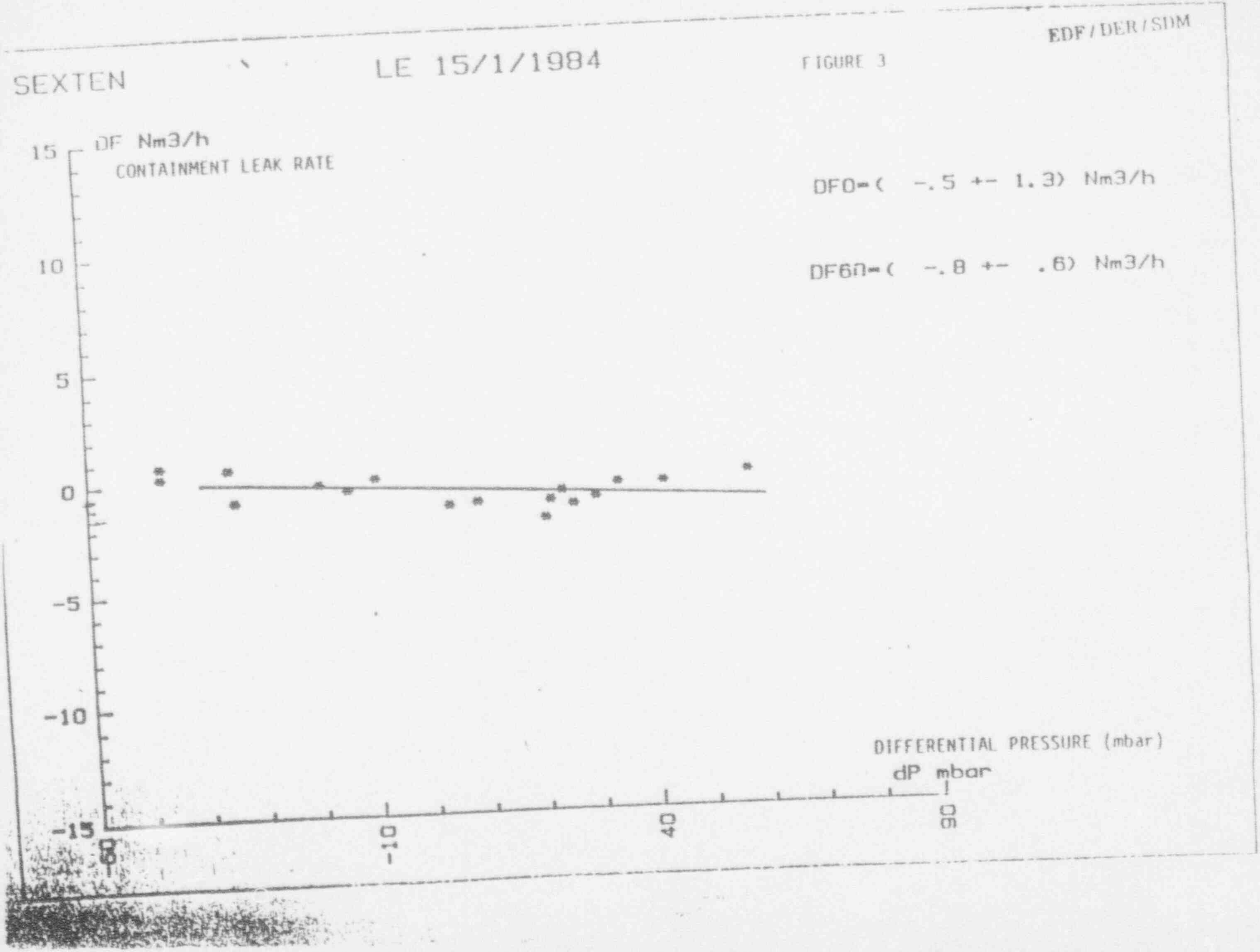
FIGURE 1



Mesure en marche 8- 11- 88 Depart: 12h 0
EDF/DER/SDM
PHASE 1
(-21 ±2) Nm3/h
Surp. 52mbar
Fermeture KRT
PHASE 2
(+8 ±4) Nm3/h
Surp. 40mbar
Remise en service KRT
PHASE 3
(-13 ±1) Nm3/h
Surp. 37mbar
Fermeture SAT
PHASE 4
Fermeture KRT
PHASE 5
(0 ±1) Nm3/h
Surp. 33mbar
dM/M
dT/T0
dH/P0-H0
dP/P0-H0
dM/M : relative variation of dry air mass
dT/TO : relative variation of average absolute temperature
dH/PO-HO : variation of average partial pressure of water upon initial dry air absolute pressure
dP/PO-HO : variation of absolute pressure upon initial dry air absolute pressure
0e 00
1.0e-02
-1.2e-02
-1.4e-02
-1.6e-02
TIME (h) Temps (h)
5
10
15
20
25
30



EDF / DER / SDM
FIGURE 2
SEXTEN
1-1985
PRESSIONS *: enceinte +: atmospherique
* : containment pressure
+ : atmospheric pressure
mbar
1100
1050
1000
950
TIME (days) jours
0
10
20
30


EDF/DER/SDM
SEXTEN
LE 15/1/1984
FIGURE 3
DF Nm3/h
CONTAINMENT LEAK RATE
DF0=(-.5 +- 1.3) Nm3/h
DF60=(-.8 +- .6) Nm3/h
15
10
5
0
-5
-10
-15
DIFFERENTIAL PRESSURE (mbar)
dP mbar
-60
-10
40
90

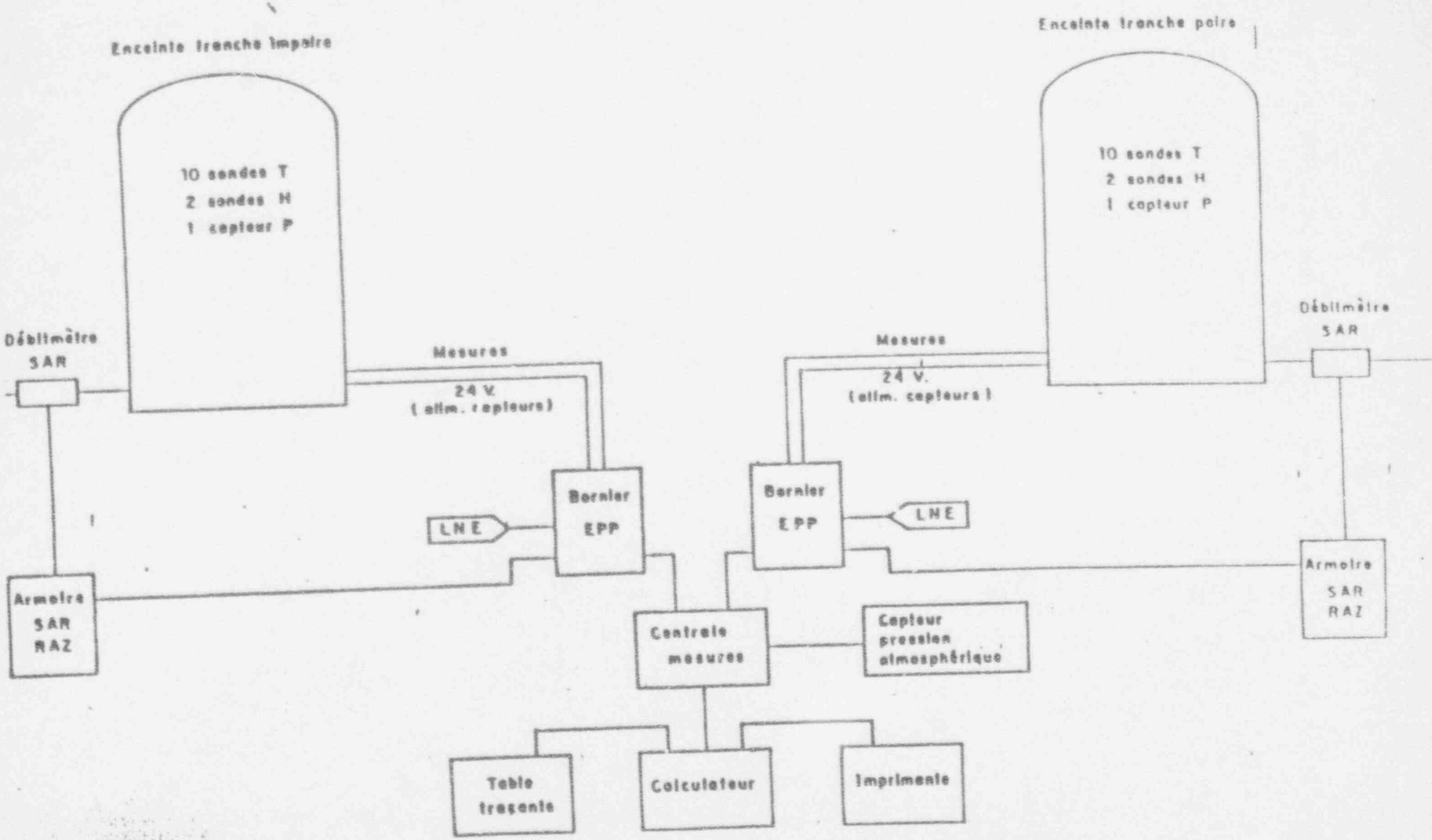


Figure 4 : Schéma du SEXTEN . Diagram of the SEXTEN system

CONTAINMENT LEAKAGE RATE

TESTING METHODOLOGY

B. CENTNER

26.11.1[illegible]

CONTENTS

1. INTRODUCTION

After ten years of Belgian PWR commercial operation, at the request of the Belgian Licensing Authority, a task force was set up to analyze the results gained from Containment Leak Rate Testing (CLRT) experience.
The task force included representatives from :

- Vinçotte (Licensing Authority)
- Utilities (EBES and INTERCOM)
- Architect Engineer (BELGATOM)

The analysis has evidenced that some aspects of the U.S. methodology, applied so far in Belgium, could be modified in order to reach a better trade-off between plant safety and operation requirements, through "on-line low pressure" tests. Additionally, the new methodology significantly reduces plant outage requirements.

2. PEAK PRESSURE TEST (P_a)

It was considered that, after the containment preoperational leakage rate test performed at peak pressure P_a to measure a leakage rate L_{am}, it should not be considered as mandatory to perform periodic peak pressure tests. Indeed the main reasons are :

- lack of representativity of P_a pressure versus the effective pressure in the containment after an accident
- risks of fire and of damaging components in the containment
- fast duration considerably lengthened

3. REDUCED PRESSURE TEST (P_t)

3.1. US Regulations

The 10 CFR50 - Appendix J - 1983 imposes to perform leak test at a reduced pressure (P_t) at least equal to half the peak pressure and measure a leakage rate L_{tm}.

"The leakage characteristics yielded by measurements L_{tm} and L_{am} establish the maximum allowable test leakage rate L_t of not more than L_a (L_{tm}/L_{am}). In the event L_{tm}/L_{am} is greater than 0,7, L_t is specified as equal to $L_a(P_t/P_a)^{1/2}$".

From the test data analysis it appeared that the measured values of L_{tm} and L_{am} are :

- affected by errors which become greater as the actual leak rate becomes smaller, which is generally the case,
- the ratio (P_t/P_a) is expected to change during the containment lifetime,
- the ratio $(P_t/P_a)^{1/2}$ is not conservative for laminar flow rates along the leak paths

The acceptance criterion L_{tm} < 0,75 L_t was then analyzed to improve accuracy and conservatism.

3.2. New acceptance criterion

Based on extensive testing and validation programs performed with the research laboratory of the Belgian utilities LABORELEC experienced in such testing, another acceptance criterion was proposed :

$$L_{tm} \leq 0,75 \frac{P_t}{P_a} L_a$$

where :

L_{tm} : measured leakrate at P_t

L_a : maximum allowable leakage rate at P_a

0,75 : corrective factor to cover a potential containment tightness degradation between two consecutive leak tests (§ 6).

The hereabove relationship, which is independent from the leakage rates measured during the preoperational leakage rate test, deals with the laminar flow type along the leak paths and leads to the greatest leakage rate variation versus pressure changes.

Note : This relationship does not account for threshold leaks. However experience indicates that the latter can be neglected.

3.3. Frequency

The containment leak test at P_t is performed once every ten years.

3.4. Conclusions

High pressure tests may replace peak pressure tests provided that :

- the acceptance criterion is derived from the ratio of the effective pressures P_t/P_a
- Pressure P_t is at least equal to $\frac{P_a}{2}$

Although there is no theoretical justification for the factor 2, it appears advisable to test the containment at a pressure which

a) is not too different from the peak pressure.

b) leads to a reasonable accuracy of the leak measurement

c) limits the interval of leakage rate extrapolation.

4. USE OF TWO INDEPENDENT TEST METHODS

In Belgium, the integrated CLRT are performed using both absolute method and comparative method (reference vessel method).
These two methods are totally independent and their results can be used for their mutual validation. It results therefrom that it is not always necessary neither to carry on the test during 24 hours, nor to perform the calibrated leak test to verify the accuracy of the leakage rate measurement.

4.1. Duration criterion

If each of both measurement techniques provides, over a period of at least 8 hours and with at least 30 consecutive measurement points, a leakage rate which meets the acceptance criterion given in section 3.3, the test can be stopped.

4.2. Concordance criterion - Verification test

It is not necessary to perform a verification test (i.e. calibrated leak) if, at the end of the test period, the difference between the measured leakage rates derived from each method, over the last 8 hours, is lower than :

$$0,25\ L_t - 0,1\ L_{tm}$$

where : - $L_t = \frac{P_t}{P_a} L_a$

- L_{tm} is the mean value of the two leakage rates

- Factor 0,25 L_t is derived from ANSI/ANS-56.8 - 1981 criterion § 3.2.6

- Factor 0,1 L_{tm} implies a better concordance between the measured leakage rates by both methods, when the actual leakage rate is close to the acceptance criterion.

In this case, it is more suitable to have the confidence that the leakage rate is accurately measured, rather than in the case where the leakage acceptance criterion is largely met.
Indeed, from the safety standpoint, the higher the actual leakage rate is, the more accurate the measurement must be.
The hereabove concordance criterion is thus consistent with both the accuracy of the measurement techniques and the safety goal.

5. <u>CALIBRATED LEAK TEST</u>

If one method only is used for reduced pressure tests, or if the concordance criterion is not met (§ 4.2), it is mandatory to perform a calibrated leak test (or an equivalent test).

5.1. For peak pressure tests, the acceptance criterion is defined in the ANSI/ANS - 56.8 - 1981 :

$$|L_o + L_{am} - L_c| \le 0,25\ L_a$$

where :

L_o : calibrated leak
L_{am} : measured leak before introducing the calibrated leak
L_c : composite leak after superimposition of the calibrated leak.

To use the above criterion, the following condition should be met :

$0,75\ L_a \leq L_o \leq 1,25\ L_a$

5.2. For reduced pressure test ($P_t < P_a$), the proposed new acceptance criterion, derived from § 5.1, is :

$$|L_o + L_{tm} - L_c| \leq 0,125\ L_t + 0,125\ L_o$$

with . $\frac{P_a}{2} \leq P_t \leq P_a$

. $Lt = \frac{P_t}{P_a} L_a$

. $Max\ (0,75\ L_{tm}\ ;\ 0,1\ L_t) \leq L_o \leq 1,25\ L_t$

The hereabove criterion has the following advantages

- easy application
- L_o dependent
- close to ANSI criterion when L_o is close to L_t.

<u>Notes</u> : Lo shall not be lower than 0,1 L_t, so as to remain measurable

Factor 0,125 has been arbitrarily chosen to 50 % of the original ANSI criterion.

6. <u>EXTRAPOLATION OF THE LEAKAGE RATE BETWEEN TEST AND ACCIDENT CONDITIONS</u>

According to the law chosen to characterize the flows in the containment leak paths, different ratios are obtained between leakage rate in test and accident conditions.

For example, flows through nozzles (most conservative assumption at LOCA peak temperatures and pressure lead to increase the flow at test temperature and peak pressure by a factor of about 1,4. The acceptance criterion should then read as :

$$L_{am} \leq \frac{0,75}{1,4} L_a = 0,54\ L_a$$

Corrective factor 0,75 from 10 CFR50 - Appendix J - does not cover the leakage rate extrapolation to LOCA peak temperature. This factor only covers a potential containment tightness degradation between two consecutive tests.
However, for the radiological assessment, the containment is assumed to leak at L_a value during the first 24 hours and at $\frac{L_a}{2}$ afterwards (Regulatory Guides 1.3/1.4), although the containment pressure is rapidly reduce.
This conservative assumption being taken into account, it is not necessary to introduce any additional extrapolation factor in the acceptance criterion given in section 3.

7. LOW PRESSURE TESTS (containment tightness on-line monitoring)

7.1. Principles

Experience shows that the reactor containment liner does not give rise to tightness problems.
Major sources of leaks are containment isolation valves and penetrations.
These are periodically tested with a frequency consistent with 10 CRF 50 - Appendix J - requirements (type B and C tests).
Therefore, as a complement to the high pressure test methods, other methods have been developed to perform tests at pressures below $P_a/2$, the objective being then to detect instead of a

containment liner "natural degradation", any gross "localized" leak instead of a containment liner leak such as misaligned valves or left open valves, flanges or instrument connections or a faulty operation such as, for instance, an inadvertent drilling through the containment liner.

Experience shows that these gross localized leaks can be easily evidenced by continuous containment on-line monitoring during plant operation.

The principle of this measurement is the following :

during normal operation, the pressure in the containment building tends to increase due to compressed air leaks from pneumatically operated equipments.

By monitoring the compressed air makeup to the containment, it is thus possible, with appropriate measurements and a calculation code, to correlate the theoretical atmosphere pressure increase versus the measured one.

The containment leakage rate can be derived from the discrepancies between these values.

The calculation code developed for these low pressure tests take into account the temperature and moisture variations during the tests. The code has been validated by the experimental results.

The measurements are performed within the pressure range - 40 mbars to + 60 mbars.

One or both techniques (absolute method and reference vessel method) can be used for these tests.

After the completion of the leak test, a verification test can be performed by superimposition of a leak through a calibrated orifice (ex : 3/8", 1/2", 1",...)

7.2. Accuracy of the method - Acceptance criterion

7.2.1. Accuracy

Experience has shown that, for an effective containment pressure of 60 mbars, the detection limit is lower than 5 STPm3/h (typical

values of 1 m3/h (STP) have been measured for tight containments).
For indicative purpose, an orifice of 3/8" leads to a leak equal 17 Nm3/h at 60 mbar effective pressure.

7.2.2. Acceptance criterion

The following criteria have been set up by the Belgian Licensing Authority :

$Q^{*}_{f,60} \leq 5$ Nm3/h	- Normal condition -
5 Nm3/h $< Q_{f,60} \leq$ 17 Nm3/h	- A search of the leak location to be undertaken.
$Q_{f,60} >$ 17 Nm3/h	- Cold shutdown after one month if the leak cannot be located and isolated.

(*) $Q_{f,60}$ = containment leakage rate at 60 mbars effective pressure
(Nm3/h)

Note : $N_{m3/L}$ = 5 Nm3/h at STP conditions.

The Belgian PWRs, a leakage rate of 17 Nm3/h corresponds, at containment room temperature, to 70 times L_a extrapolated to 60 mbars.
Physically it also corresponds to the flow rate through a hole of 1 cm diameter in a thin plate and effective pressure of 60 mbars

7.3. Frequency

A low pressure test is performed after each cold shutdown longer than 15 days.

The test is to be carried out only when steady state conditions (temperature, moisture) are reached inside the containment atmosphere and not later than one month after reaching 260° C (500° F) in the reactor coolant.

7.4. Test duration

The experience gained so far indicates that such tests can be easily performed in less than 72 hours (§ 7.5).

7.5. Experimental results

Containment tightness on-line monitoring (or low pressure tests) are routinely performed in Belgium PWRs since 1985.
This section reports typical results obtained so far.

7.5.1. Example 1

Figure 1.1 illustrates the containment absolute pressure increase rate in a "tight" containment.

Figure 1.2 illustrates the evolution of the pressure difference between the containment atmosphere and the reference vessel.

Figure 1.3 shows the record of the regulation air make-up to the pneumatically operated equipments located inside the containment (≈ 29 STP m^3/h).

Figure 1.4 illustrates the evolution of the containment (*) leakage rate, in function of the difference between the

---

(*) Note : for convenient purpose, the square root of the pressure difference has been used instead of the pressure difference itself. Negative values of $\sqrt{\Delta P}$ correspond to ingress leaks.

containment pressure and the atmospheric pressure, obtained by the "absolute method".

For Δp = 0 mbar, the theoretical value of the leak $Q_{f, 0 \text{ mbar}}$ should be equal to 0 $STPm^3/h$.
The measured value is 2,4 $STPm^3/h$ (accuracy limit of the method).

For Δp = 60 mbar (or $\sqrt{\Delta p}$ = 7,7 mbar), the measured leakage rate after the drift correction is :

$$Q_{f, 60mbar} - Q_{f, 0mbar} = 1,0 \; STPm^3/h.$$

These results are given for a 95 % confidence level and are corrected for containment temperature and moisture variations during the test.
The $Q_{f, 60 \text{ mbar}}$ standard deviation is equal to 1,34 $STPm^3/h$.

Figure 1.5 illustrates, under the same conditions as above, the evolution of the containment leakage rate obtained by the "reference vessel method" :

$Q_{f, 60 \text{ mbar}}$ = 0,7 $STPm^3/h$

$Q_{f, 60 \text{ mbar}}$ standard deviation = 0,73 $STPm^3/h$

7.5.2. Example 2 (Figure 2)

The purpose of figure 2 is to illustrate the sensitivity of the method, when calibrated orifices are opened during the leakage rate test.

The results obtained by the absolute method are summarized hereafter (95 % confidence level) :

Size of the orifice (")	$Q_{f,60\ mbar}$ (STPm^3/h)
0	2
3/8	17
3/4	89

The method enables thus to easily detect leaks through one orifice as small as 3/8" (10 mm diameter).
The corresponding leakage rate (17 STPm^3/h) is far above the accuracy limit of the method (2-5 STPm^3/h).

8. CONCLUSIONS

The major features of the new methodology are :

- reduced pressure test frequency : tests at P_t are performed once every ten years, in conjunction with containment tightness on-line monitoring (see below)

- reduced pressure tests duration : if two independent methods are available, the verification test is no more required, provided that the concordance between both methods meets the acceptance criterion.

- the use of an acceptance criterion independent from the preoperational test results and based on a conservative extrapolation law

- a greater confidence in the reactor containment integrity thanks to "in-service low pressure tests"

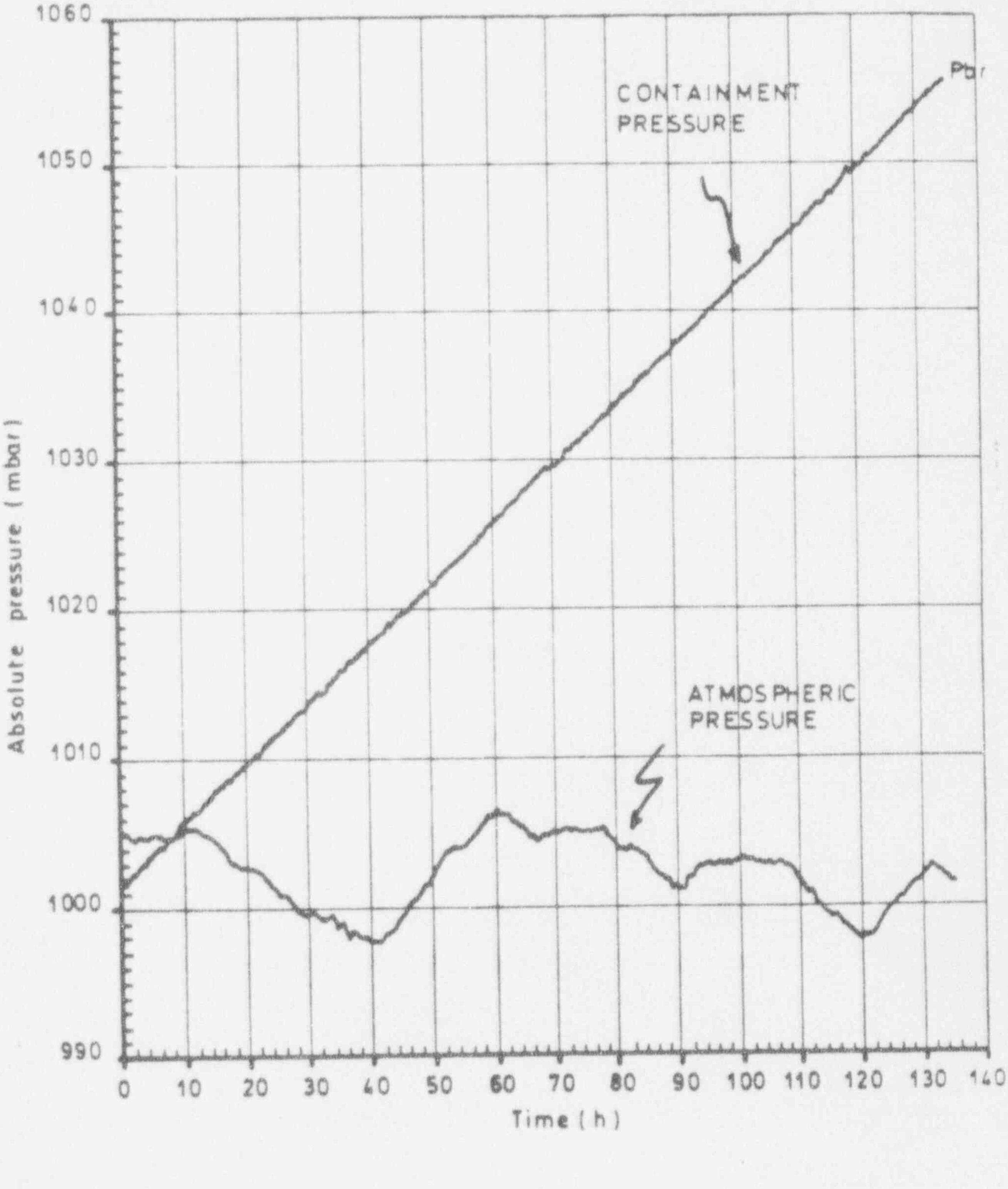
- significant reduced plant outages.

CONTAINMENT TIGHTNESS ON-LINE MONITORING

(LOW PRESSURE TEST)

CENTRALE NUCLEAIRE DE TIHANGE 3 EXAMPLE 1

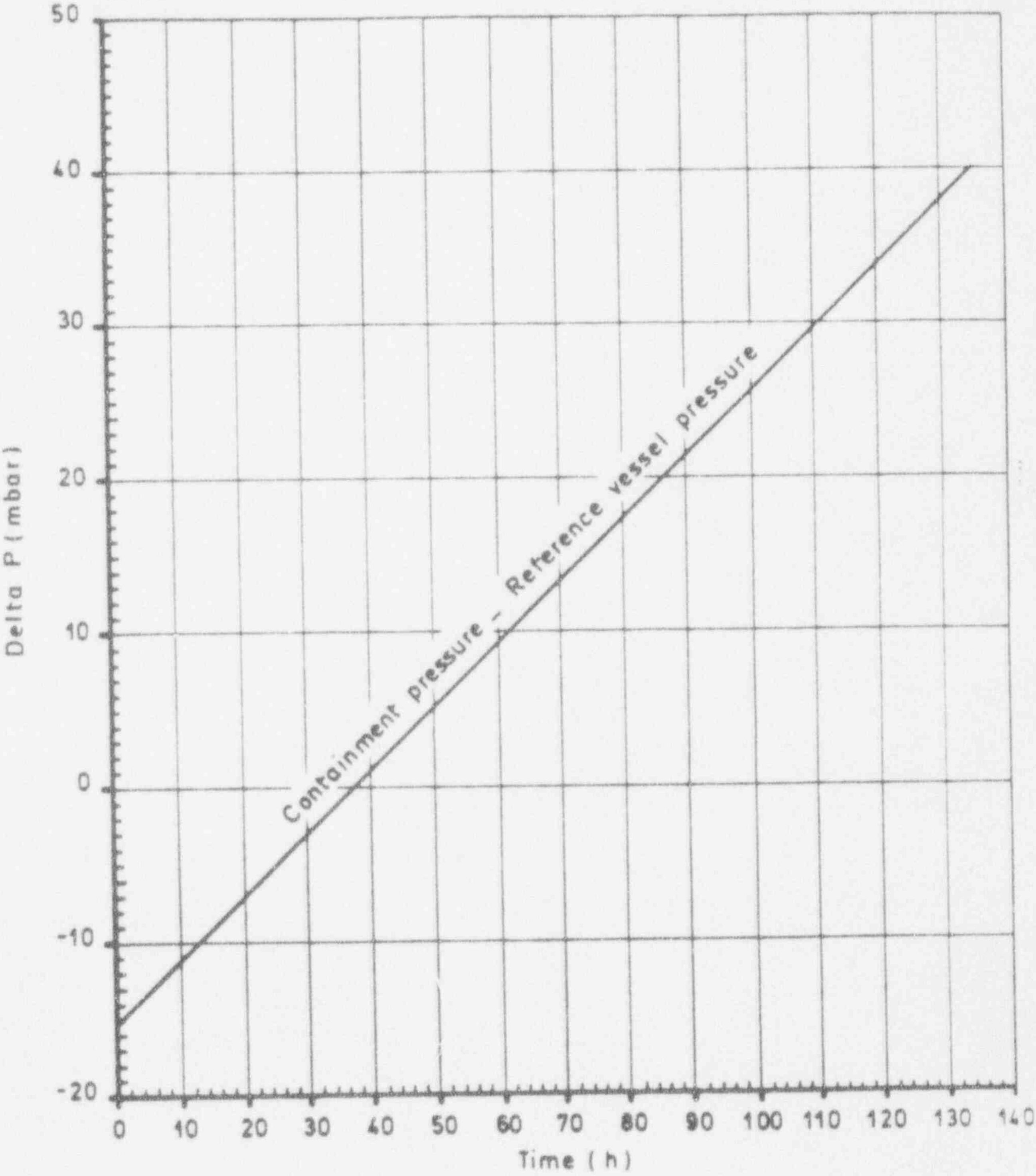
28 Jul. 87



CONTAINMENT TIGHTNESS ON-LINE MONITORING
(LOW PRESSURE TEST)

CENTRALE NUCLEAIRE DE TIHANGE 3   EXAMPLE 1

28 Jul. 87

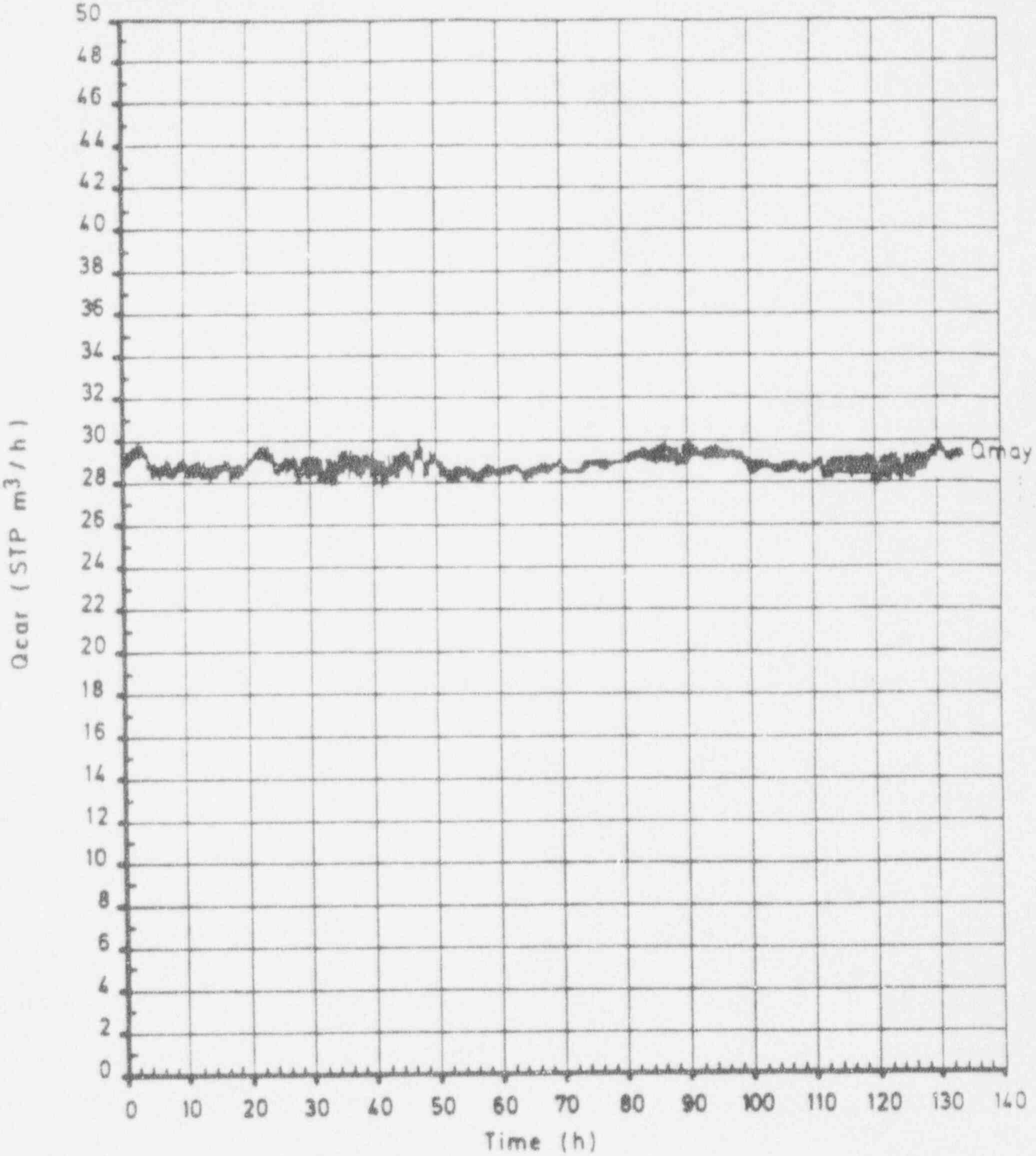


CONTAINMENT TIGHTNESS ON-LINE MONITORING

(LOW PRESSURE TEST)

CENTRALE NUCLEAIRE DE TIHANGE 3   EXAMPLE 1

28 Jul. 87



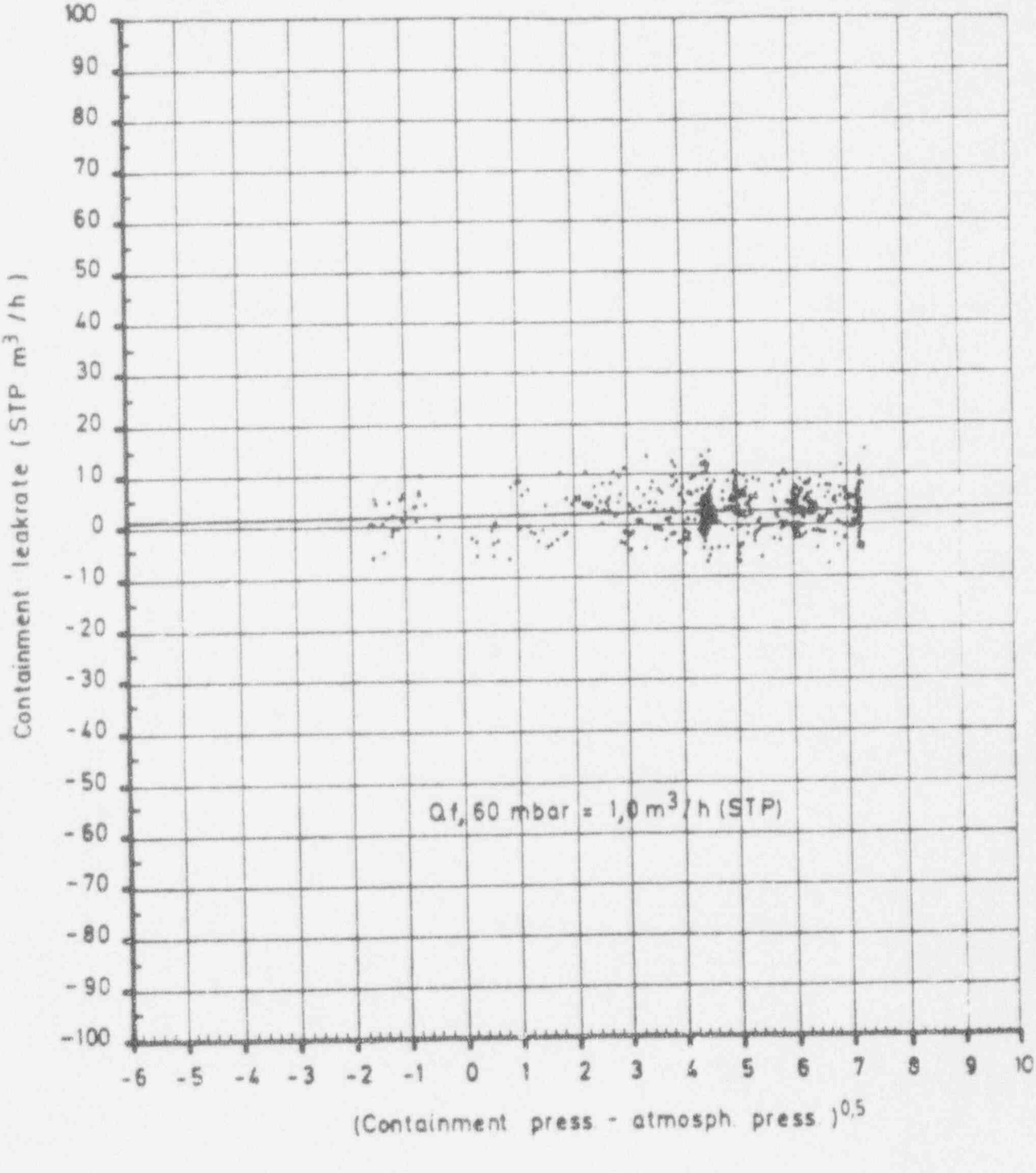
Containment regulation air makeup flow monitoring.

CONTAINMENT TIGHTNESS ON-LINE MONITORING

(LOW PRESSURE TEST)

CENTRALE NUCLEAIRE DE THIANGE 3 EXAMPLE 1

28 Jul 87

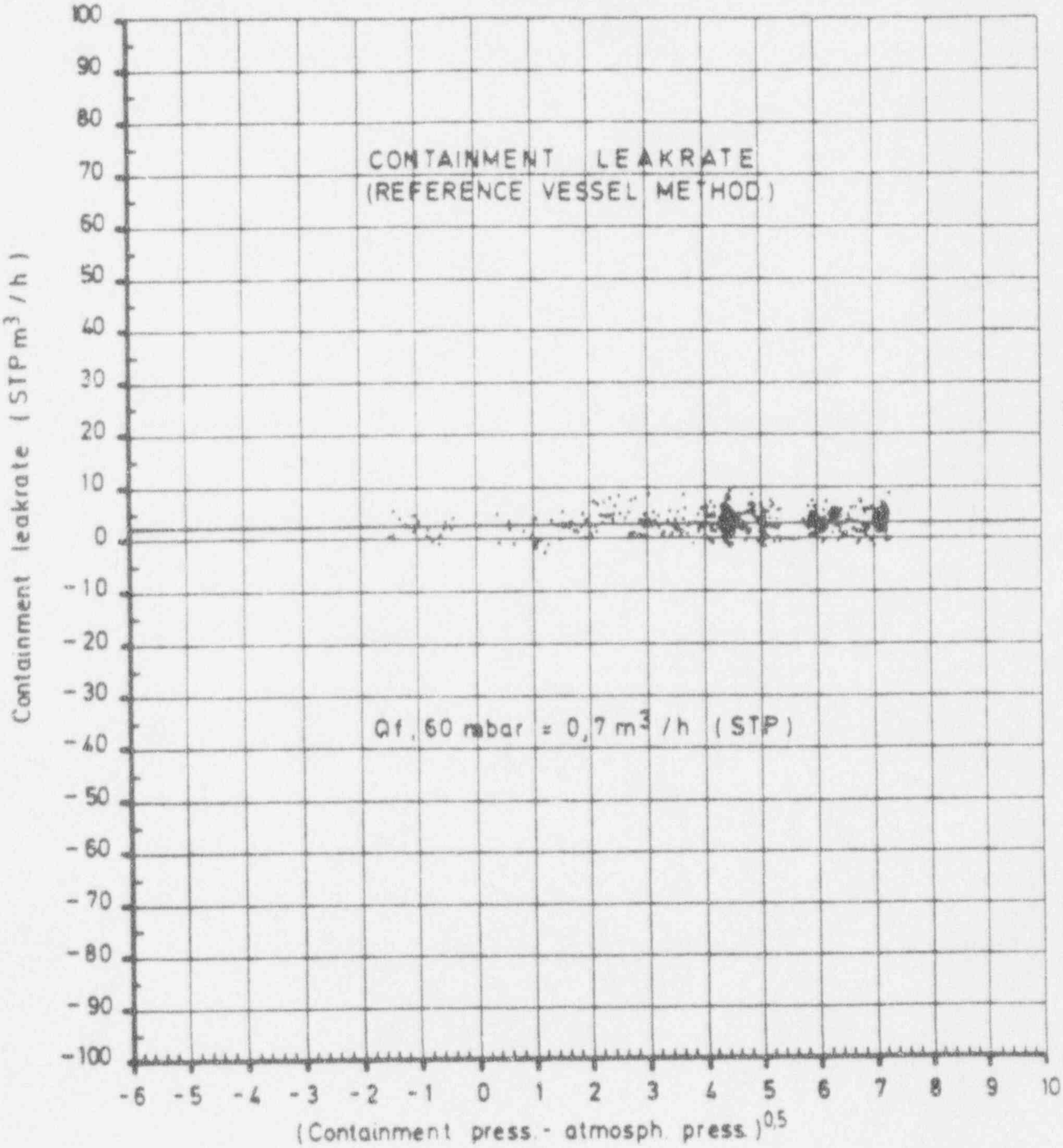


CONTAINMENT TIGHTNESS ON-LINE MONITORING

(LOW PRESSURE TEST)

CENTRALE NUCLEAIRE DE TIHANGE 3 EXAMPLE 1

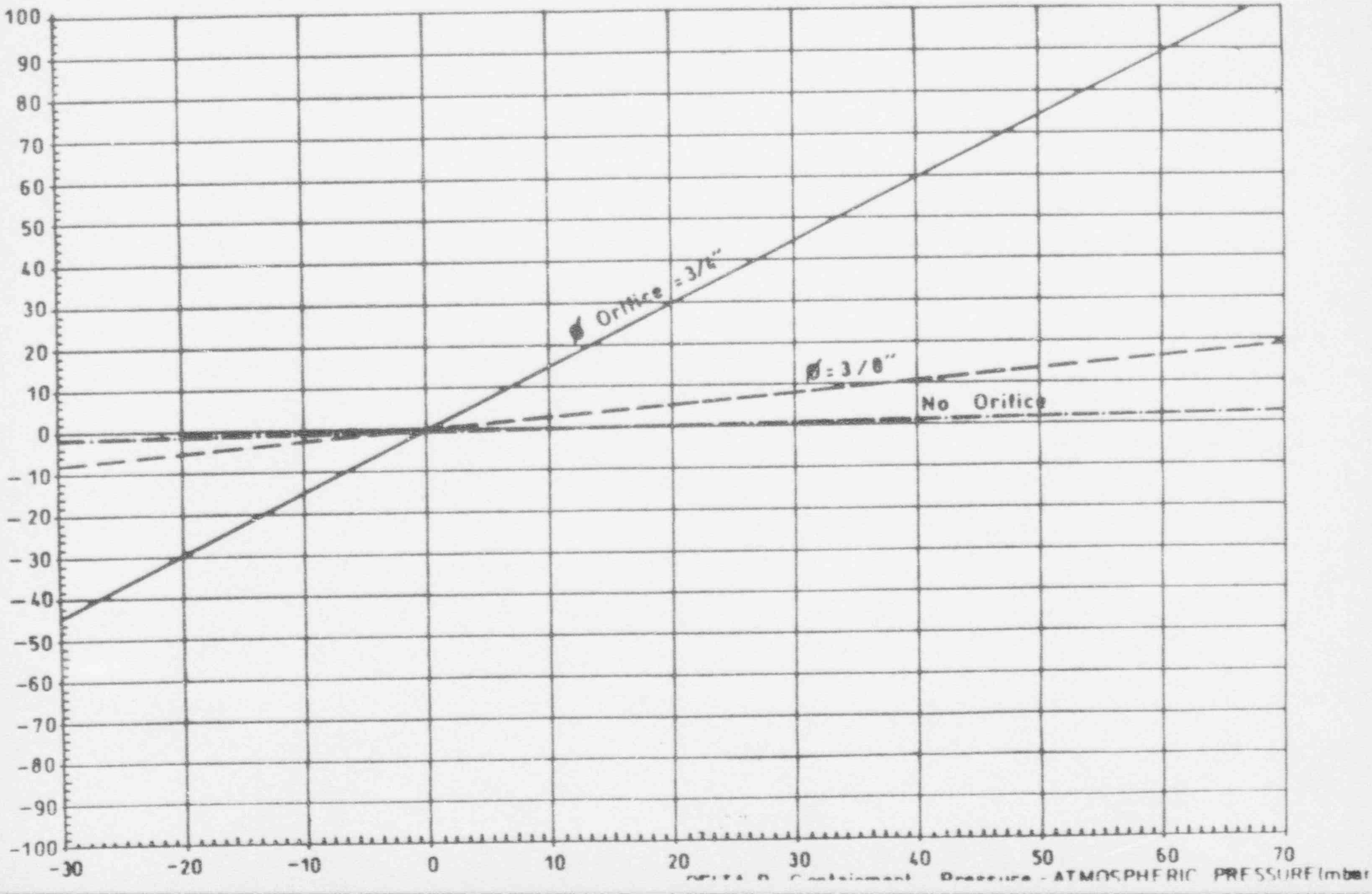
28 Jul 87



CONTA NMEN TIGHTNESS ON-LIN MON TORING

KERNCENTRALE DOEL 3

CONTAINMENT LEAKRATE VERSUS Δ P
FOR DIFFERENT CALIBRATED ORIFICES.



LABORELEC Tel 02/38.20.211
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pages

HEADING	CAT ON-LINE ON RINGHALS UNIT 3 PURCHASE ORDER R08080-CHAL "Cat on-line"
SUMMARY	The demonstration test of the Laborelec on-line containment integrity test on the Ringhals 3 nuclear power plant, performed in August 91, is described. The results of the test are summarized in the tables and graphics given in annex.
ANNEXES	

REVISION INDEX /DATE	1 / 16.10.1991		/		/	
EMISSION	NAME	Visa	NAME	Visa	NAME	Visa
Author	DAVID G DEBORSU T					
Verification	BAEYENS R					
Approval	HERNALSTEEN					

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	BUCCALO	Belgatom				
	CENTNER	"				
CIRCULATION (initials)						

STATUS	Quality Assurance ☐ yes ☒ no
	Documentary (key words)
	Confidentiality ☐ free ☐ limited to co-operators ☐ intern at L/E ☒ limited to beneficiary

REFERENCES LABORELEC	
Document	M03-91-081/R-GD/Mo
Task/Beneficiary	M03-10464 / BELGA

RINGHALS Unit3 : CAT on-line

1 . Scope : Demonstration of

- the feasibility of performing this new type of tightness acceptance test on a reactor building with a single containment.
- the performance of the instrumentation (data acquisition rack) and the user friendly aspect of the software developed in LABORELEC

2 . Principle of the measurement :

The leak of the containment is determined by making the difference between :

- the amount of air (gas) released into the containment.
- and the relative mass balance of dry air inside .

the mass of air being calculated according to the law of ideal gases

In the case of Ringhals where we only use the absolute method (1), this implies the knowledge of : the absolute pressure, the partial vapour pressure and of the mean temperature .

If we assume that the free volume is Vo , the total amount of dry air held in the reactor building is equal to :

$$V_{ac}\,(Nm3) = Vo * (Pc - Pwv) / 1013 * 273.15 / Tm \,.$$

where :

Pc = Absolute pressure in the containment (mbar) .
Pwv = Partial pressure of the water vapour (mbar) .
Tm = Mean temperature of the air (° K) .

Normally , for an isolated reactor building , the change in mass of air is only due to the instrumentation air consumption cumulated with the leaks of this loop inside the containment .
If we call this total air flow rate Qai (Nm3 / h) the leakage of the containment,is given by :

$$Q_f = dVac / dt - Qai \;(Nm3\,h)$$

The **test method is <u>based upon the evolution</u> (change) of this leak and its relationship with the differential pressure** governing this flow ; that's to say in case of Ringhals 3 , the difference between the absolute pressure inside the containment and the atmosphere .

---

(1) In Belgium , we commonly use , in conjunction with the absolute method , the so called "reference vessel " method which gives us a second value for the leak obtained from an other way to measure the change in pressure and differing essentially by the manner to approach the mean temperature of the air . This latter is given by a thin walled tubing developped along the height of the reactor building at 2 or 3 places and connected together to form a perfectly tight vessel in temperature equilibrium with the surrounding air of the containment .

As we do not try to measure the sum of an infinity of minute leaks (this is the purpose of the test type A at high pressure , results of which are more precise) but only to detect and quantify the flow of a leak throughout an orifice (a pipe) breaking the integrity of the confinement , we assume that the law of this relationship , is of the square root type :

We have : $Qf = Qfo + B \, SQRT(dP)$

The B term deals with the real leaks out of the containment and the Qfo term deals with measurement errors and air (gases) sources that are NOT related to the dP driving force .

In practice , the coefficients Qfo and B are determined by the linear regression in the experimental points .
The standard leakage ($Q_{f(60)}$) is DEFINED as the difference in ordinate of this straight line corresponding to a differential pressure of 60 mbar without the Qfo term offset .

Practically , we proceed as follows , to compute the standard leakage .
(for a comprehensive understanding , see also § 4)

-The sensors scanning and data sampling is repeated continuously .
-Each 30 seconds , the samples are read by the PC .
-Each 15 minutes , the mean value of the 30 samples of each channel are stored into a data base (in physical Units) located on a circular buffer with a capacity of 3 months .
-When the test is running , we wait until we get a elapsed time dt of 3 hours , and we compute the change in mass of air held in the containment from which we subtract the total amount of air introduced during the same elapsed time .
-The value obtained (divided by dt , expressed in Nm3/ h) is related to the mean differential pressure during the same period ; so we get a first set of data .The following ones are obtained by moving forward (quarter by quarter) this window of 3 hours .
-Finally when the test is completed we get the value of the coefficients of the best straight line by computing a linear regression in the pairs of data .

3 . Acceptance Criteria :

In Belgium , the upper limit for the maximum allowable standard leak $Q_{f(60)}$ is 17 Nm3 / h the standard deviation (sigma) included. As we are interested by the maximun of this value , the upper limit (for a confidence level of 95 %) is given by :

$Q_{f(60)}(max) = Q_{f(60)}(measured) + 1.7\,sigma <= 17\ Nm3/h$

assuming that we have , at least :

30 measured points
a **differential pressure** range of **minimum 50** mbars .

4 . TEST instrumentation :

4.1 Transducers

4.1a : Number and types :

Temperature sensors : RTD in platinum ; 100 ohms at 0 C (1/10 DIN 43760) . A total of 34 sensors , distributed as uniformly as possible , over the entire volume (Along the height and the diameter) and , from a electrical point of view , divided into 2 groups of 17 sensors each , connected in serial .

Humidity sensors : 4 lithium chloride , pt 500 from Wallac OY , type ERSEC LC-05/PT-500 , individually scanned and measured .

Air flow : 1 FCI flowmeter ; type AF-88 with a range 0-100 Nm3/h ; output 4 to 20 mA .

NB : all these sensors supplied by the owner .

Absolute pressure : 2 quartz manometer from MENSOR ; type DPG 1100 with a range of 0 to 1100 mBar abs.;
output 4 to 20 mA .
Accuracy : +- .04% of reading +- (.008 mA)
Calibration chart in appendix A & B .

Atmospheric pressure : 1 piezoresistive transducer from Kistler type 4109 with a range of 850 to 1100 mBar abs.
output signal : (nominal) 10 mV/mBar
Accuracy : linearity +- 1 mbar ;
hysteresys : .5 mbar .
Sensivity : .5 mbar .
Calibration chart in appendix C .

Differential pressure : 1 capacitive differential manometer from Rosemount , type 1151 DP-03 with a nominal range of 0 to 7.46 kPa.
output 4 to 20 mA .
Accuracy : .2 % of the calibrated range .
Calibration chart in appendix D .

4 1 b . Localization

Temperature and humidity sensors : in the containment , at places chosen as explained in $ 4.1a .

Flowmeter : close to the containment , on the main air pipe .

Manometers : in the measuring room , under Ringhals unit 4 .

4.2 Data acquisition rack , PC and peripherals .
(see diagrams on appendix E)

The test installation consists of two separate sets of devices , totally self supporting for their own function and communicating through a RS232C port or a modem for longer distances (up to several hundreds of meters) .

The first one (data acquisition) is equipped with all the current and voltage sources , necessary to feed the transducers and have the well suited inputs to connect the signals to be read. This acquisition rack is driven by a microcomputer , programmed to solve the specific industrial measurements problems . As the relative precision of the measurements have a great influence on the final results , the ADC is so designed that those precision requirements are met .

4.3 Data handling and presentation of the results .

The software developed in LABORELEC , is running under Concurrent DOS , which allows the possibility to perform several tasks simultaneously .
It consists of a PC AT 386 which manages the dialog with the operator , the acquisition system and the on-line computations of the leak . The program allows a direct follow-up of the graphics as well as the spread sheets and the regressions results . Also the extrapolated leak at 60 mBar can be displayed with its confidence intervals . A direct control of the measured parameters allows the operator to eliminate possible faulty transducers and to recalculate the leak with the remaining current transducers . Anyhow all the data are stored in a Dbase 3 file that allows off-line computations and reports afterwards .

5 Test duration and typical events .

The measurements have been started the 15/08/91 at 2h00 pm and have been stopped the 19/08/91 at 9h15 am after completion of the task.
After having solved several problems in connection either with the transducers either with the wiring or scaling factor , the test went without any other troubles until the end , exception made for the step in the absolute pressure measured by one of the Mensor and an erratic response of one humidity sensor .
Due to the redundance of the measurements devices , these have been eliminated without affecting the results .
After two days of measurements we increased the air flow to the containment , in order to avoid a too long test duration .

6 Results .

All the data collected during the test are given in the table 1 and plotted vs time on the graphics referenced R1T1*** .
[redacted]
A first search , by the shift , to detect the failure in the procedures or effective application of the procedures to isolate the containment did not succeed ; but it was obvious from the measurements that a leak was really present .

After a deeper investigation and a meeting of all the people involved in the test , the weak point was identified : the radiation monitoring loop , just like we had already in the first test in Belgium . A closer examination of the schemes of this circuit , followed by investigations on the loop itself have permitted to identify the leak : a valve let partially open on the loop in order to ease and assure a safer working for the circulating pump . Due to its localization on the loop this leak was negative (air suction) when the pressure in the containment was low and positive at higher pressure . This could explain , partly , the apparent instability of the leak during the test.
After this valve was closed , the leak measured has drastically been lowered , and this is clearly visible on the graphs ,after a couple of hours following the intervention . Although the low number of data , a computation of the leak for such a short period gave a value quite normal and acceptable of less than 5 Nm3/h .
The high value for the standard deviation associated is merely due to the small number of points and also to the fact that the change in pressure was too small and occured at a too high differential pressure . In fact , if we take the same Qfo value as in the previous test (which , by the way , should not vary significantly from one test to another) and draw a horizontal line (dotted line on curve R1T1LEAK.XLC(2)) it crosses the middle of the measured points cloud , indicating clearly a zero leak .
For a normal test , it would be necessary to blow the pressure down and to start a new complete test . As this was not the goal of the demonstration it has been decided to stop .

7 Conclusion .

The results gained from the test showed the feasability of the CAT on-line realized on a single containment , without necessity of any fundamental changes to the wiring or other components .
Moreover , it was shown that the LABORELEC system meets the objectives assigned to it . It can be emphasized the succesfull way on-line operator guidance is realized by the system on real problems that occured in the plant during the test .

[illegible]

T E S T C E R T I F I C A T E

CLIENT : [illegible]ERACENTRALE DOEL [illegible] 4   CERTIFICATE NR. : 91 [illegible]

DESCRIPTION : DIGITAL PRES. INDICATOR   RANGE: 0 - 1100mBAR ABS.

MAKE : MENSOR   ?CD.NR.: EP-PI-1572

Accuracy: 0.04% F.S.
= 0.44 mBAR

Tested against : BUDENBERG D.W.TESTER.
SER.NR.: 21022/T51A PISTON NR: 219C
Weight set nr: 487
Accuracy: 0.010%
Classe 'A' certificate nr. : 0171

Testresults afther calibration.

INPUT mBAR abs.	OUTPUT MAX to 0	DIFF.	Diff. in %	Acc.	OUTPUT 0 to MAX	DIFF.	Diff. in %	Acc
1020.6	1020.6	0.0000	0.00%	OK	1020.6	0.0000	0.00%	OK
920.5998	920.6	0.0002	0.00%	OK	920.6	0.0002	0.00%	OK
820.6015	820.6	-0.0015	0.00%	OK	820.6	-0.0015	0.00%	OK
720.6098	720.6	-0.0098	0.00%	OK	720.6	-0.0098	0.00%	OK
620.6184	620.6	-0.0184	0.00%	OK	620.6	-0.0184	0.00%	OK
520.6167	520.6	-0.0167	0.00%	OK	520.6	-0.0167	0.00%	OK
420.6198	420.5	-0.1198	-0.03%	OK	420.6	-0.0198	0.00%	OK
320.6313	320.5	-0.1313	-0.04%	OK	320.6	-0.0313	-0.01%	OK
220.6384	220.5	-0.1384	-0.06%	OK	220.6	-0.0384	-0.02%	OK
120.6221	120.5	-0.1221	-0.11%	OK	120.5	-0.1221	-0.11%	OK
60.6294	60.5	-0.1294	-0.21%	OK	60.5	-0.1294	-0.21%	OK

The accuracy of the test equipment used is traceable to national and international standards .

Conclusion: These testresults enable us to certify that the above instrument was found to operate correctly and meet with the manufacturer's specification.
Following the manufacturer's specification the calibration is only valid for 90 day's.

/3/224/1771-2/XD.300 (200)

mmer(s) appa-(a)t(en)	MEETINSTRUMENTEN							
	INGANG			UITGANG				
	meetbereik	waarde	%	minimum theoretische waarde	werkelijke aflezing ↓	werkelijke aflezing ↑	maximum theoretische waarde	Beoordeling
1	2	3	4	5	6	7	8	9
-FLU-346	1100 mbar	1019,1 mbar	93	18,8077 mA	18,8197	18,8193	18,8311 mA	
		825,0 mbar	75	15,9856	15,9928	19,9945	16,0144	
(mt 100%)	absolut	550,0 mbar	50	11,9872	11,9953	11,9938	12,0128	
-A01-78,W		275,0 mbar	25	7,9888	7,9943	7,9932	8,0112	OK
		3,2 mbar	0,3	4,0369	4,0399		4,0533	

TOEPASSING :
Q.A ☒
NIET Q.A ☐

uitvoerder

10	11
naam	Peter Michielsen
datum	25104191
paraaf	P.M.

kontroleur

10	12
naam	Rabben R.
datum	29/4/91
paraaf	[illegible]

13 opname volgens procedure NR

KCD / /

index

OPMERKINGEN

→ Span gecorrigeerd

KONTROLE OP DE NAUWKEURIGHEID : OK

PERIODE : 90 dagen

KCD

KERNCENTRALE DOEL
Entiteit: Doel 3-4
Onderwerp:
Dossier:

KCD / /

MEETINSTRUMENT
OPNAMEBLAD VOOR
HISTORIEK DOSSIER

Index:

Temperatuur lokaal: 23 °C

Relatieve vochtigheid: 48 %

Barometerdruk: 1019 mbar

15 **gegevens konstrukteur**

konstrukteur	MENSOR
model nr.	11900
serie nr.	043731
nauwkeurigheid	stroom: ±0,04% lezing ±0,008 mA
bereik	[illegible]

16 meetinstrument nummer

EP-PJ-1532

MINISTERE DES AFFAIRES ECONOMIQUES

ADMINISTRATION DU COMMERCE
Inspection générale de la Métrologie

24-26, rue J.A. De Mot 1040 BRUXELLES
Tél : 02/ 233 61 11

GB/JD

CERTIFICAT D'ETALONNAGE

D'UN BAROMETRE

Numéro de référence : 4.M/

Date(s) d'étalonnage : 5/3/19912

Date de délivrance :

Nombre de pages : 2

Instrument de mesure présenté par :

LABORELEC S.C.
Rue de Rhode 125
1630 LINKEBEEK

1. IDENTIFICATION.

1.1. Dénomination : Baromètre à lecture numérique.

1.2. Fabricant : MENSOR.

1.3. Description : Baromètre à tube de Bourdon en quartz et lecture numérique, d'une étendue de mesure de 0 à 1100 mbar, avec un échelon de 0,1 mbar. L'instrument est identifié par une étiquette située à l'arrière de l'instrument et portant les indications suivantes :

"MENSOR Digital Pressure Gauge
Part N° 0011900-404F
Range 0-1100 mbar Abs
Ser N° 043612
Date 88-02"

2. METHODE D'ETALONNAGE.

Le zéro de l'instrument a été réglé et étalonné à une pression de 0,04 mbar ± 0,02 mbar, mesurée au moyen d'une jauge à vide du type PIRANI.

L'instrument a été étalonné aux autres points par comparaisons avec un baromètre étalon de l'Inspection générale de la Métrologie. L'étalon a une étendue de mesure de 35 à 1150 mbar, avec une incertitude relative de ± 0,02 % à fond d'échelle.

La température durant les essais était de 21°C ± 2°C.

3. **RESULTATS D'ETALONNAGE.**

Les résultats suivants ont été obtenus, avec une incertitude de ± 0,2 mbar.

Lecture (mbar)	Lecture (pression ascendante) (mbar)	Lecture (pression descendante) (mbar)
0,0	-	0,04
150,0	150,02	149,92
300,0	300,02	299,92
450,0	449,94	449,88
600,0	599,98	599,91
750,0	749,92	749,83
900,0	899,85	899,79
950,0	949,85	949,79
960,0	959,84	959,78
970,0	969,82	969,77
980,0	979,81	979,77
990,0	989,81	989,77
1000,0	999,80	999,77
1010,0	1009,80	1009,77
1020,0	1019,78	1019,75
1030,0	1029,77	1029,74
1040,0	1039,75	1039,72
1050,0	1049,74	1049,71
1100,0	1099,78	--

L'INGENIEUR INDUSTRIEL,

G. BAIRY.

L'INSPECTEUR GENERAL, ff.,

Dr. H. VOORHOF.

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LABORELEC SECTION M

Dept M03

Etalonnage d'un capteur de pression -Ijking van een drukopnemer

		Capteur / Opnemer	Etalon / Ijktoestel	App. de lecture / Meettoestel
Marque	Merk	KISTLER	Beamex	Fluke 45
Type		4109	Pc 105	45
S.N.		192310	582	4930383
Gamme/Meetbereik		850-1050 mbar		
Precision/Nauwkeur.				

Date: / Datum:	31.7.91	Temp 24	Opérateur / Ijker: WV-GD

Pression ref. / Ref. druk	Unité / Eenh. mBar	Val. Croissantes / Stijgende Waarden: Lectures / Aflezingen	Pres. Corr. / Kor. Druk	Corrections / verbeteringen	Val. Décroissantes / Dalende Waarden: Lectures / Aflezingen	Pres. Corr. / Kor. Druk	Corrections / Verbeteringen	Corrections moyennes / Gemiddelde verbeteringen
(as found)		(Volts)			(as left)	mbar		
998.4		10.041			9.984	998.4		
1000.0		10.056			9.999	999.7		
1010.0		10.16			10.098	1009.5		
1020.0		10.25			10.196	1019.4		
1030.0		10.35			10.295	1029.3		
1040.0		10.45			10.393	1039.1		
1050.0		10.55			10.492	1049		
950.0		9.55			9.503	949.9		
960.0		9.65			9.603	959.9		
970.0		9.75			9.702	969.8		
980.0		9.85			9.802	979.8		
990.0		9.95			9.901	989.7		
					100.2629	-2.903338		
							1039.129	

Remarque / Opmerking

La Correction est la quantité à ajouter algébriquement à la lecture du capteur pour obtenir la valeur vraie.

De verbetering is de hoeveelheid dat algebraïsch moet toegevoegd worden aan de aflezing van de opnemer om de korrekte waarde te bekomen.

LABORELEC SECTION M

Dept M03

Etalonnage d'un capteur de pression -Ijking van een drukopnemer

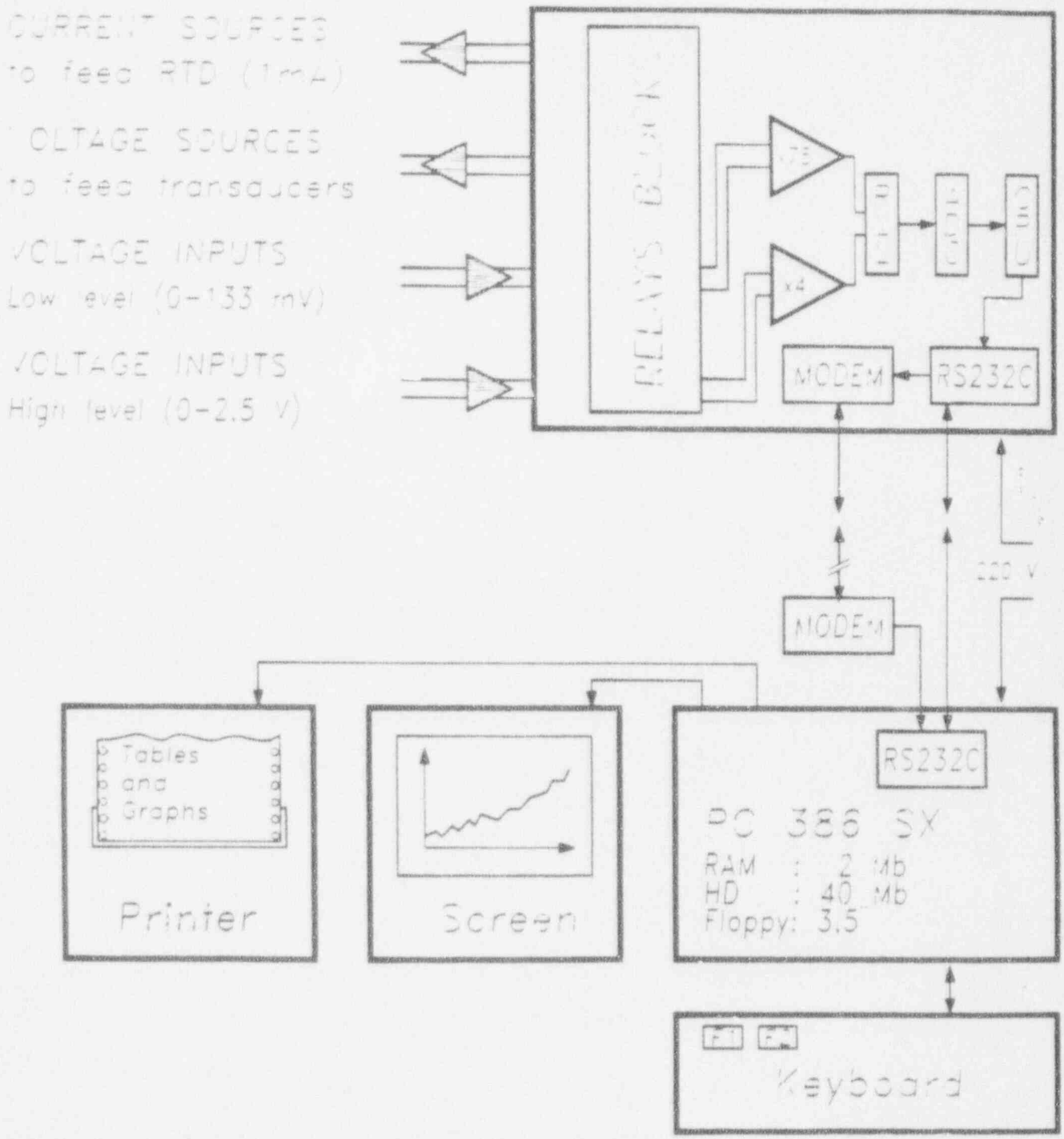
		Capteur Opnemer	Etalon Ijktoestel	App. de lecture Meettoestel
Marque	Merk	Rosemount	Beamex	Philips PS252F
Type		1100 DP	PC 105	
S.N.			582	
Gamme/Meetbereik				
Precision/Nauwkeur.				
Date: Datum:		9 / 91	Temp	Opérateur Ijker GD

Pression ref. Ref. druk	Unité Eenh. mBar	Val. Croissantes Stijgende Waarden: Lectures Aflezingen	Pres. Corr. Kor. Druk	Corrections Verbeteringen	Val. Décroissantes Dalende Waarden: Lectures Aflezingen	Pres. Corr. Kor. Druk	Corrections Verbeteringen	Corrections moyennes Gemiddelde Verbeteringen
0		9.996						
-10.0		8.30						
-20.0		6.61						
-30.0		4.91						
-35.4		4.00						
10.0		11.71						
20.0		13.42						
30.0		15.14						
40.0		16.86						
50.0		18.58						
58.2		20.00		Formula :				
60.0		20.32						
			dP =	5.85 * I (mA) -58.59 mBar.				

Remarque / Opmerking

La Correction est la quantité à ajouter algébriquement à la lecture du capteur pour obtenir la valeur vraie.

De verbetering is de hoeveelheid dat algebraïsch moet toegevoegd worden aan de aflezing van de opnemer om de korrekte waarde te bekomen.



RINGHALS – unit 3

C.A.T. on line

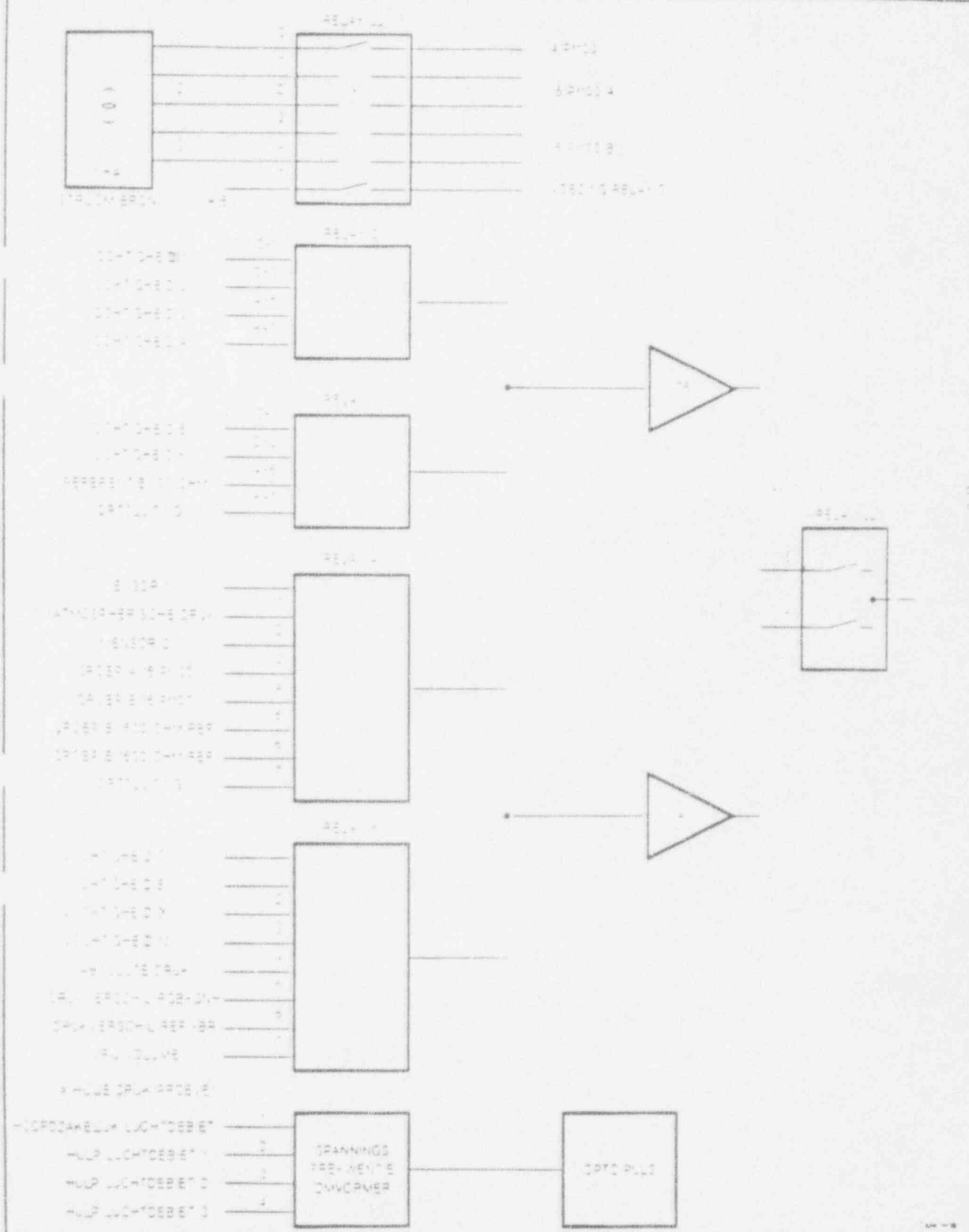
15/08/91

PROJEKT : CONFORMITEITSTESTEN REACTOR-GEBOUW ELECTRABEL

FUNCTIE:

HFST.

BLZ.

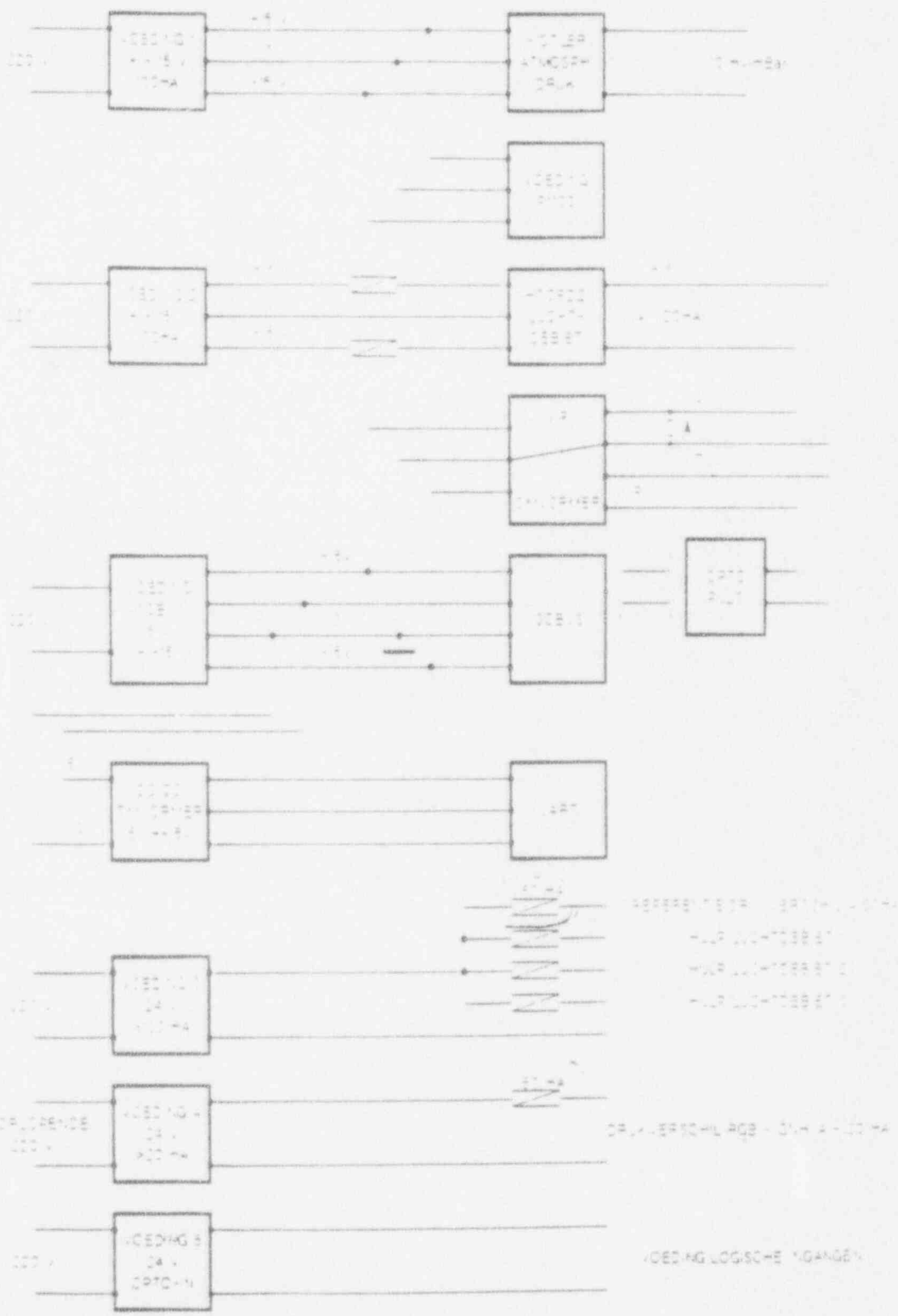


PROJEKT : CONFORMITEITSTESTEN REACTOR-GEBOUW ELECTRABEL

FUNCTIE:

HFST

BLZ.



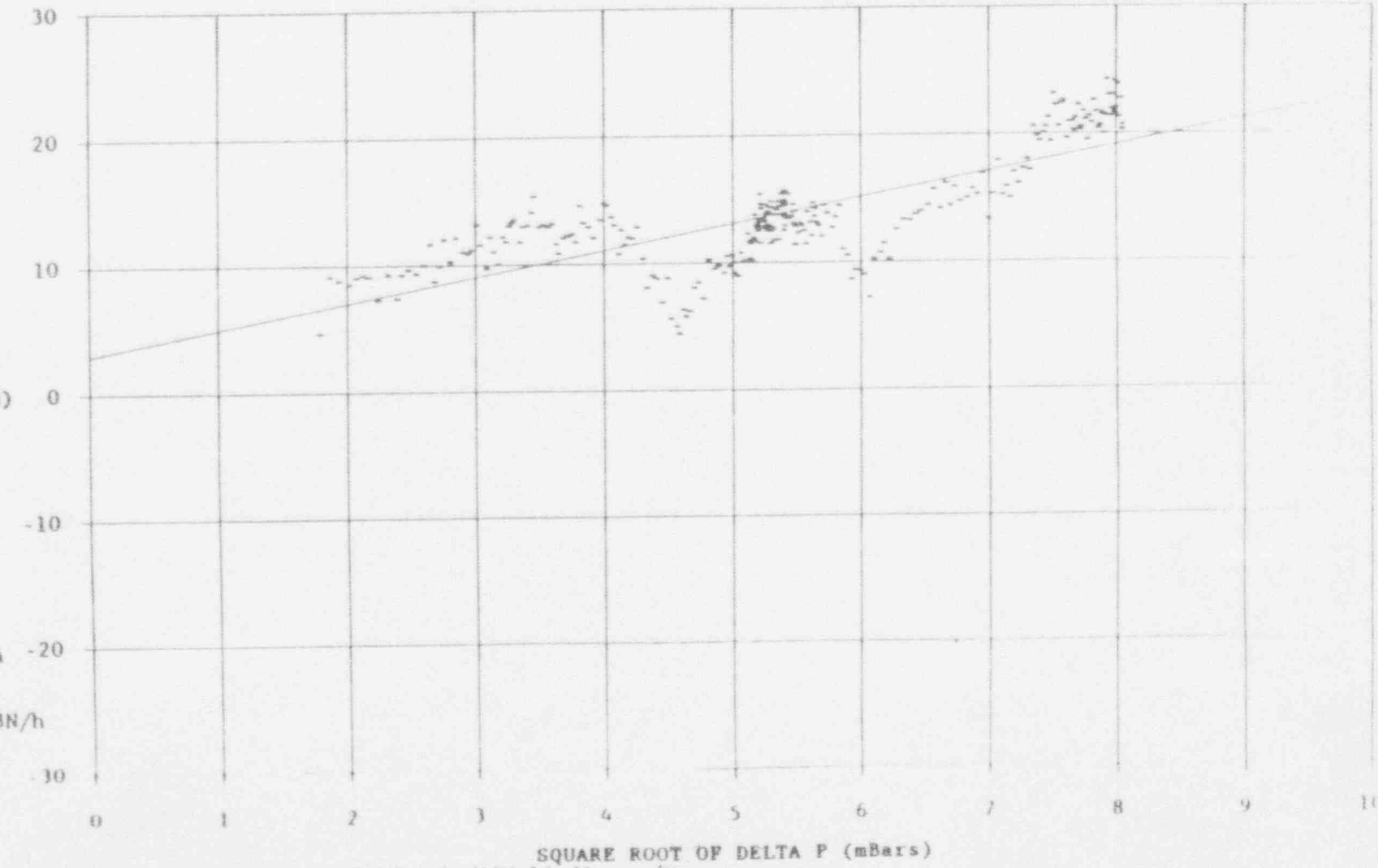
R1T1LEAK.XLC (1)

TIGHTNESS TEST RINGHALS UNIT 3 - 08/91

ERIODE :

5/8/91 16:45

8/8/91 10:15



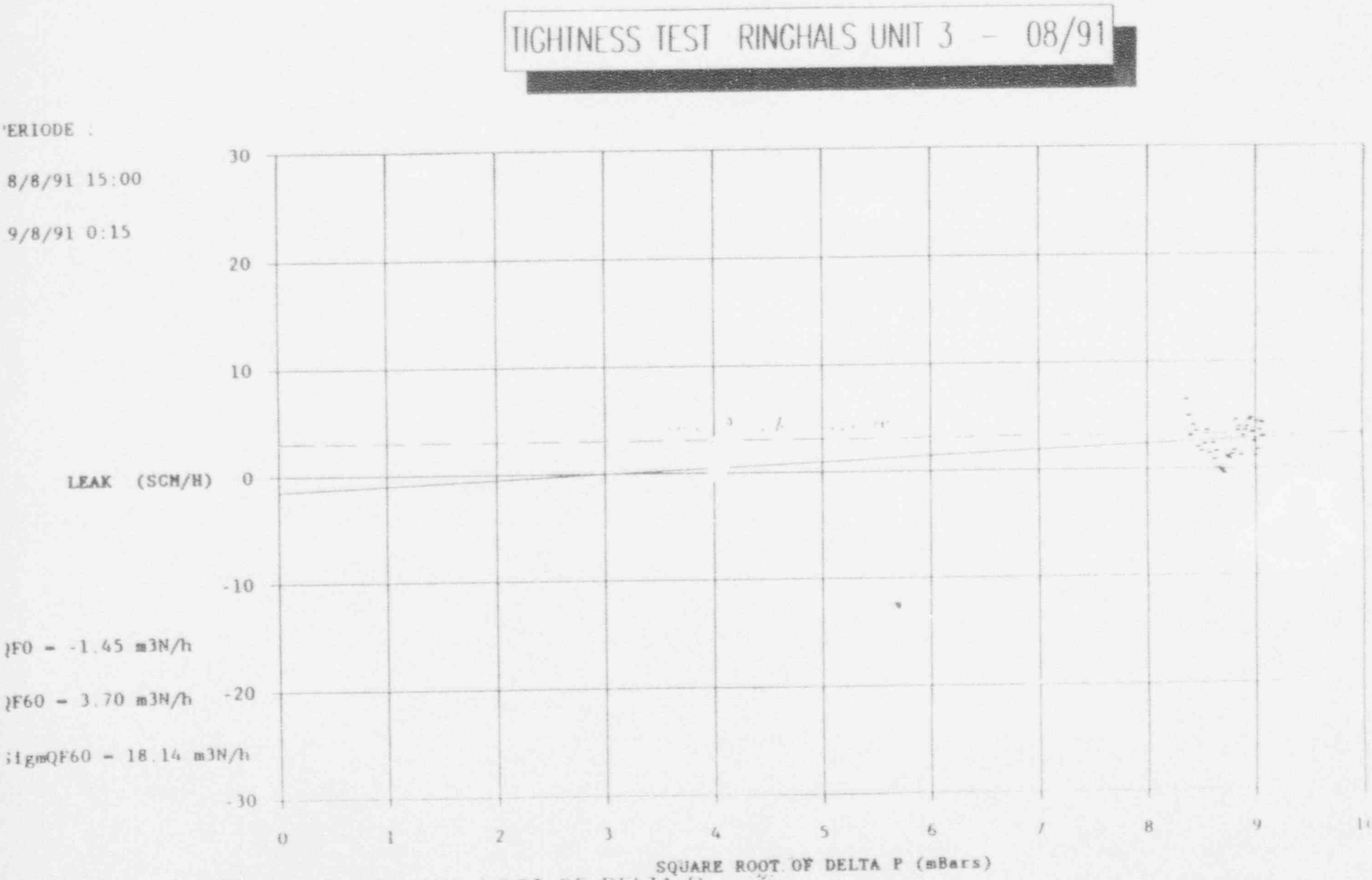
F0 = 2.94 m3N/h

F60 = 15.69 m3N/h

1gmQF60 = 1.58 m3N/h

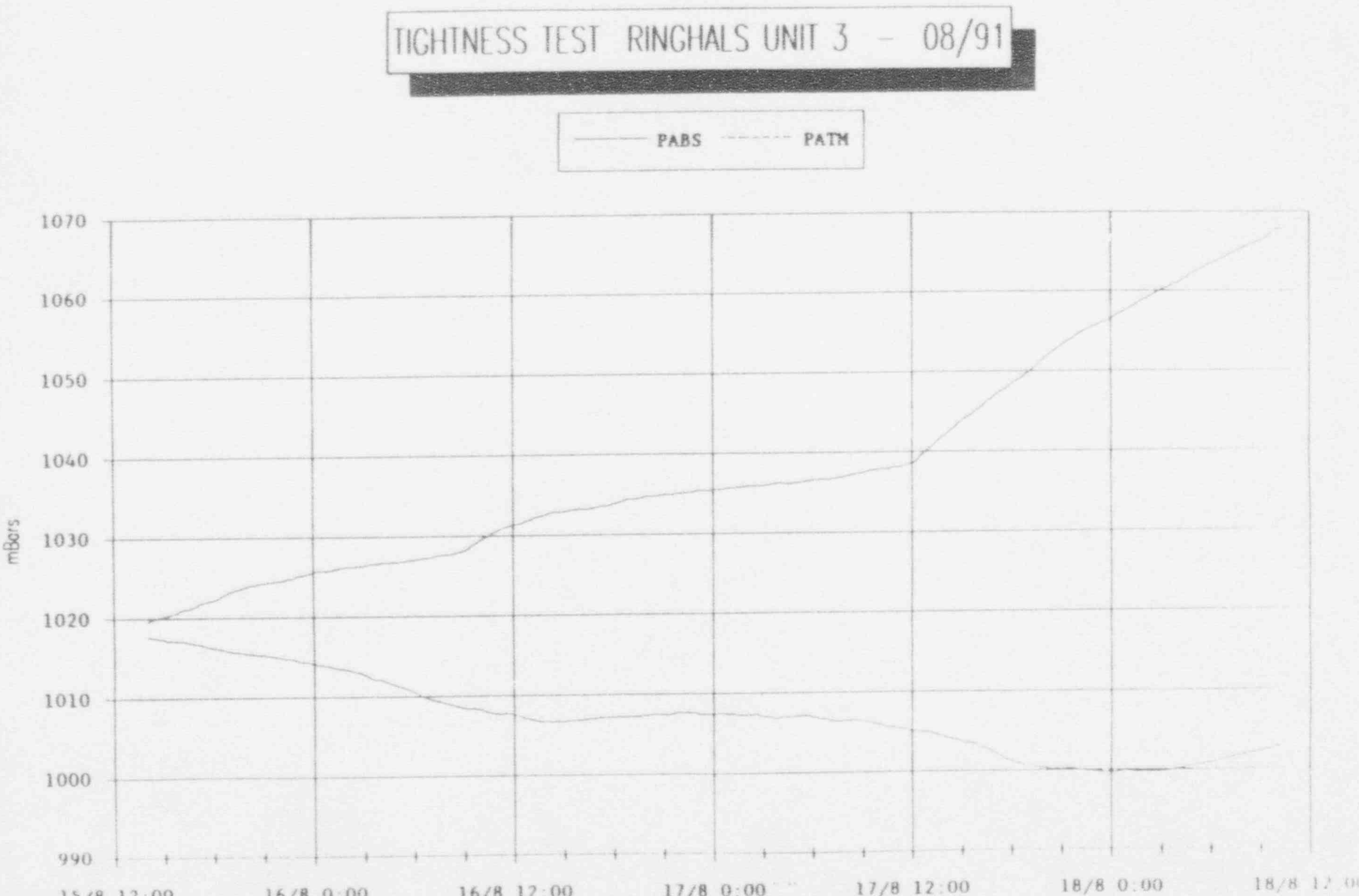
EVOLUTION OF THE LEAK vs SQUARE ROOT OF DELTA P

R1T1LEAK.XLC (2)



EVOLUTION OF THE LEAK vs SQUARE ROOT OF DELTA P

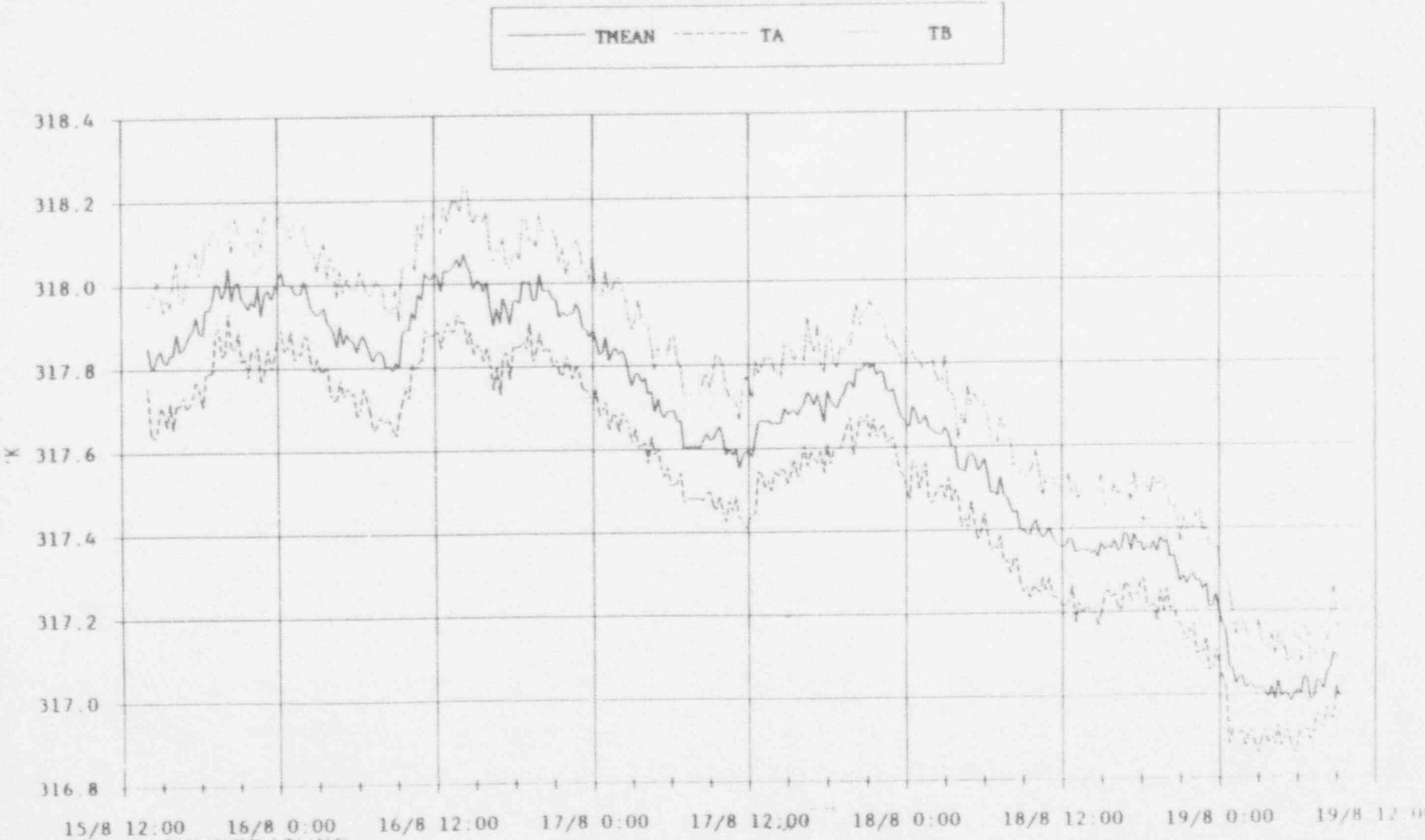
R1T101.XLC



VOLUTION OF THE PRESSURE IN CONTAINMENT AND ATMOSPHERIC PRESSURE

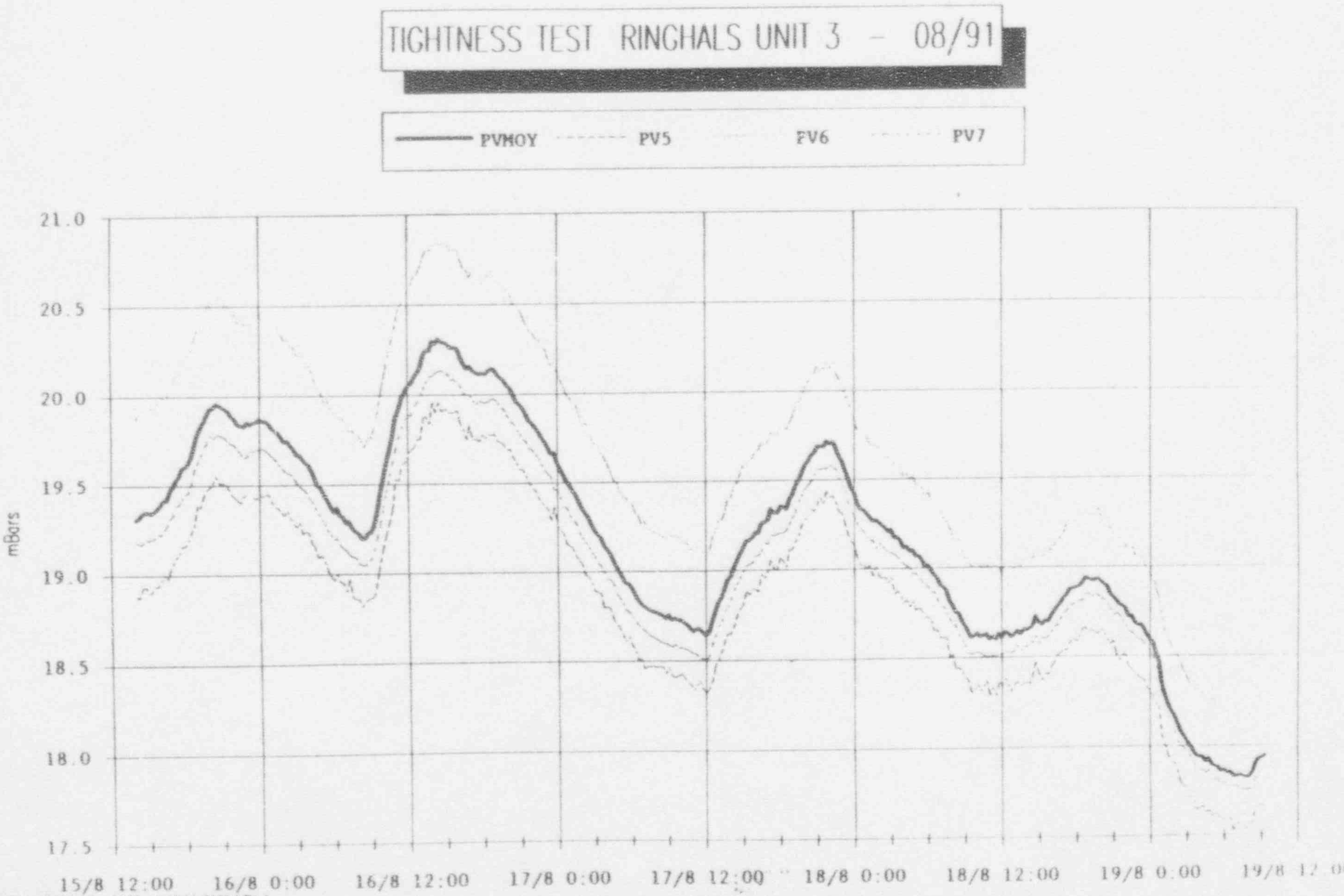
R1T102.XLC

TIGHTNESS TEST RINGHALS UNIT 3 - 08/91



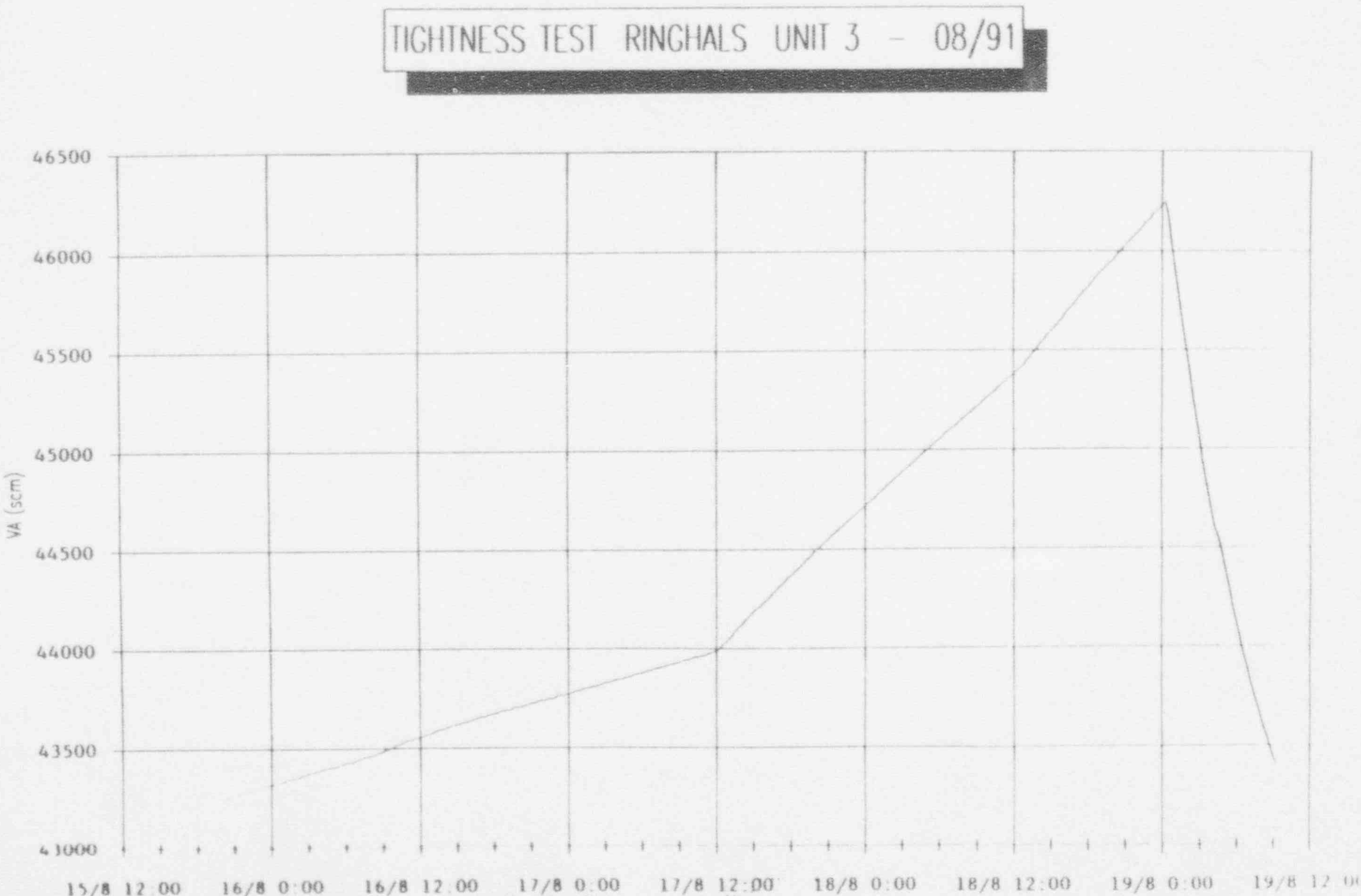
VOLUTION OF TEMPERATURE

RIT103.XLC



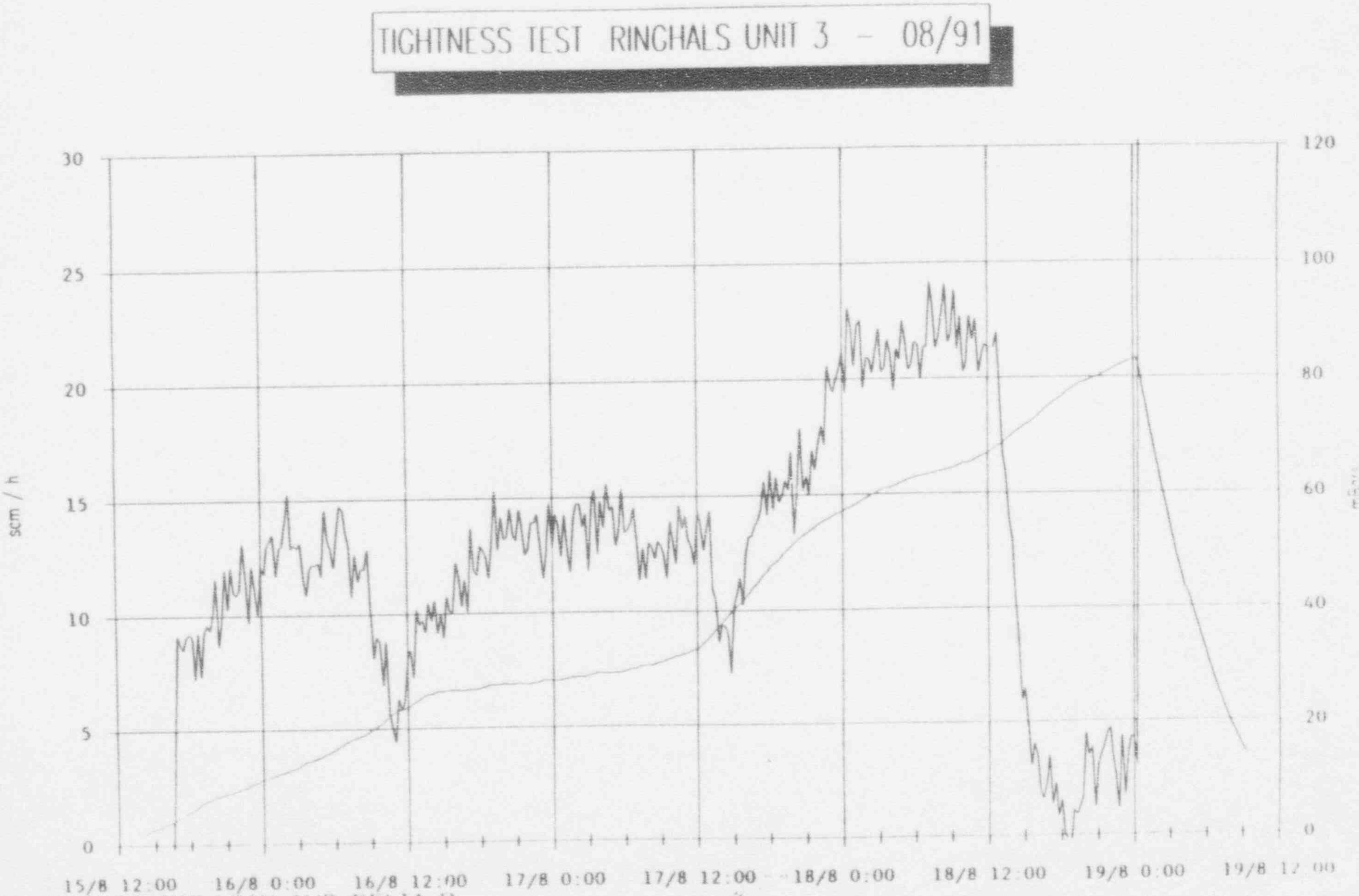
VOLUTION OF HUMIDITY

R1T104.XLC



EVOLUTION OF THE AIR VOLUME IN CONTAINMENT

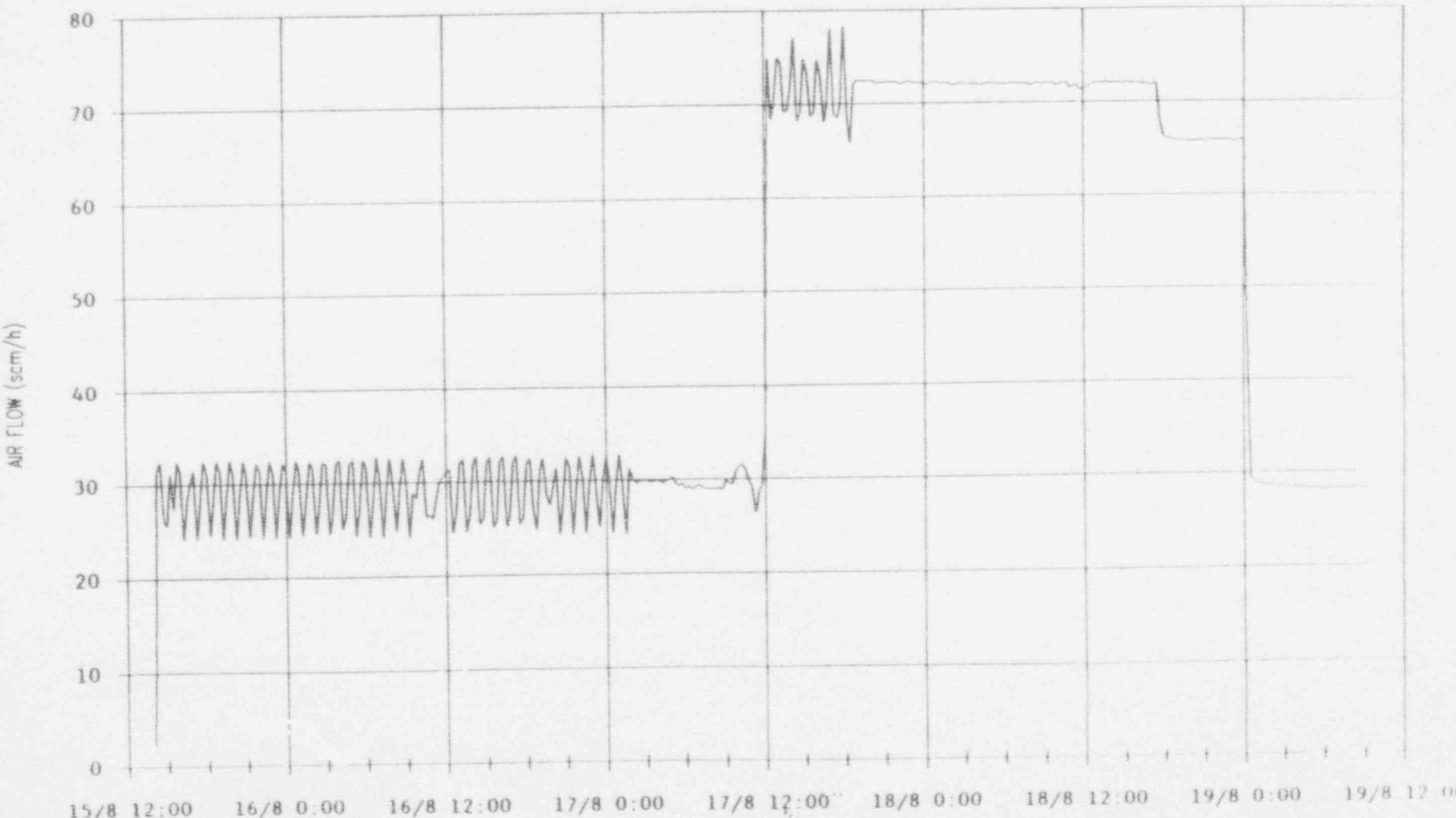
R1T105.XLC



VOLUTION OF THE LEAK AND DELTA P

R1T106.XLC

TIGHTNESS TEST RINGHALS UNIT 3 - 08/91



EVOLUTION OF THE AIR FLOW

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/15/91	14:00	1019.58	1017.7	317.85	19.31	1.88	2.2	-1.0	43107
08/15/91	14:15	1019.79	1017.7	317.81	19.32	2.11	31.4	-1.0	43122
08/15/91	14:30	1019.95	1017.5	317.80	19.34	2.33	32.5	-1.0	43128
08/15/91	14:45	1020.17	1017.5	317.83	19.35	2.62	26.3	-1.0	43133
08/15/91	15:00	1020.22	1017.4	317.84	19.35	2.76	25.7	-1.0	43134
08/15/91	15:15	1020.29	1017.2	317.82	19.35	3.02	31.2	-1.0	43141
08/15/91	15:30	1020.49	1017.3	317.81	19.36	3.17	27.4	-1.0	43149
08/15/91	15:45	1020.56	1017.2	317.83	19.38	3.33	32.4	-1.0	43148
08/15/91	16:00	1020.88	1017.2	317.83	19.40	3.65	31.4	-1.0	43161
08/15/91	16:15	1021.08	1017.1	317.89	19.42	3.92	24.2	-1.0	43162
08/15/91	16:30	1021.08	1017.0	317.84	19.42	3.97	28.3	-1.0	43168
08/15/91	16:45	1021.33	1016.9	317.85	19.47	4.36	30.0	4.6	43174
08/15/91	17:00	1021.55	1016.8	317.86	19.49	4.69	31.4	9.1	43182
08/15/91	17:15	1021.80	1016.8	317.88	19.53	4.97	24.2	8.8	43188
08/15/91	17:30	1021.96	1016.5	317.89	19.55	5.34	28.3	8.5	43193
08/15/91	17:45	1022.13	1016.4	317.93	19.60	5.64	32.4	9.0	43194
08/15/91	18:00	1022.18	1016.3	317.89	19.60	5.82	31.1	9.2	43201
08/15/91	18:15	1022.36	1016.2	317.88	19.63	6.07	24.6	9.1	43208
08/15/91	18:30	1022.71	1016.1	317.94	19.67	6.51	28.2	7.2	43213
08/15/91	18:45	1022.92	1016.0	317.94	19.72	6.89	32.4	9.2	43220
08/15/91	19:00	1023.20	1015.9	317.96	19.79	7.30	31.2	7.4	43227
08/15/91	19:15	1023.37	1015.8	318.01	19.83	7.58	24.2	9.3	43227
08/15/91	19:30	1023.50	1015.8	318.00	19.86	7.71	28.7	9.6	43232
08/15/91	19:45	1023.67	1015.7	317.97	19.89	7.97	32.5	9.3	43242
08/15/91	20:00	1023.86	1015.6	317.99	19.93	8.26	31.0	10.0	43246
08/15/91	20:15	1024.02	1015.5	318.04	19.93	8.46	24.2	11.6	43245
08/15/91	20:30	1024.03	1015.5	317.96	19.96	8.52	28.6	8.7	43255
08/15/91	20:45	1024.23	1015.4	318.00	19.95	8.77	32.5	9.9	43259
08/15/91	21:00	1024.25	1015.4	318.01	19.94	8.84	30.7	12.0	43260
08/15/91	21:15	1024.35	1015.3	317.97	19.93	9.02	24.3	10.3	43270
08/15/91	21:30	1024.35	1015.2	317.96	19.91	9.10	28.8	12.1	43271
08/15/91	21:45	1024.50	1015.1	317.94	19.89	9.33	32.2	11.0	43281
08/15/91	22:00	1024.56	1015.0	317.96	19.87	9.48	31.4	10.9	43281
08/15/91	22:15	1024.58	1014.9	317.95	19.84	9.64	24.2	11.2	43286
08/15/91	22:30	1024.81	1014.9	318.00	19.84	9.88	28.3	13.1	43290
08/15/91	22:45	1024.79	1014.8	317.93	19.83	9.94	32.4	11.6	43298
08/15/91	23:00	1025.10	1014.7	317.98	19.85	10.39	30.9	9.7	43303
08/15/91	23:15	1025.18	1014.5	317.99	19.84	10.63	24.3	12.2	43306
08/15/91	23:30	1025.27	1014.5	317.97	19.85	10.75	28.7	11.0	43313
08/15/91	23:45	1025.44	1014.3	317.99	19.85	11.05	32.2	10.0	43317
08/16/91	00:00	1025.62	1014.2	318.01	19.87	11.38	31.2	12.2	43320
08/16/91	00:15	1025.74	1014.1	318.03	19.86	11.59	24.2	11.8	43323
08/16/91	00:30	1025.78	1014.1	318.00	19.86	11.65	28.5	13.0	43329
08/16/91	00:45	1025.76	1013.9	318.00	19.85	11.76	32.4	13.3	43329
08/16/91	01:00	1025.81	1013.9	318.00	19.82	11.89	31.1	13.5	43332
08/16/91	01:15	1025.96	1013.6	317.98	19.80	12.25	24.5	11.7	43342
08/16/91	01:30	1026.04	1013.6	317.98	19.79	12.42	28.1	12.9	43346
08/16/91	01:45	1026.13	1013.5	317.98	19.76	12.52	32.3	13.0	43351
08/16/91	02:00	1026.20	1013.4	318.01	19.74	12.71	31.6	14.1	43351
08/16/91	02:15	1026.19	1013.3	317.98	19.75	12.87	24.6	15.3	43354

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/16/91	02:30	1026.31	1013.1	317.95	19.72	13.10	27.8	12.9	43365
08/16/91	02:45	1026.32	1013.0	317.94	19.70	13.24	32.2	13.1	43368
08/16/91	03:00	1026.35	1012.8	317.93	19.67	13.54	32.0	12.9	43372
08/16/91	03:15	1026.49	1012.5	317.93	19.67	13.92	24.7	13.2	43377
08/16/91	03:30	1026.61	1012.3	317.95	19.64	14.30	26.9	11.6	43381
08/16/91	03:45	1026.60	1012.1	317.91	19.62	14.41	31.9	10.8	43387
08/16/91	04:00	1026.71	1012.1	317.90	19.61	14.52	32.5	12.0	43393
08/16/91	04:15	1026.72	1011.9	317.89	19.57	14.77	25.2	12.2	43397
08/16/91	04:30	1026.67	1011.7	317.85	19.53	14.91	26.7	12.2	43402
08/16/91	04:45	1026.78	1011.5	317.90	19.49	15.21	32.1	12.3	43401
08/16/91	05:00	1026.73	1011.3	317.86	19.48	15.39	32.4	11.7	43406
08/16/91	05:15	1026.84	1011.2	317.88	19.44	15.64	24.4	14.6	43409
08/16/91	05:30	1026.93	1011.0	317.87	19.42	15.93	27.5	13.2	43416
08/16/91	05:45	1026.99	1010.7	317.86	19.38	16.24	32.4	12.9	43420
08/16/91	06:00	1027.05	1010.6	317.84	19.35	16.45	31.7	12.1	43428
08/16/91	06:15	1027.16	1010.3	317.86	19.37	16.86	24.2	13.4	43428
08/16/91	06:30	1027.21	1010.0	317.88	19.33	17.18	28.1	14.7	43430
08/16/91	06:45	1027.29	1009.8	317.86	19.32	17.52	32.8	14.6	43437
08/16/91	07:00	1027.33	1009.6	317.83	19.29	17.78	30.4	13.6	43443
08/16/91	07:15	1027.43	1009.4	317.81	19.29	18.03	24.2	13.0	43450
08/16/91	07:30	1027.60	1009.4	317.83	19.26	18.27	29.2	10.8	43456
08/16/91	07:45	1027.60	1009.2	317.84	19.24	18.45	32.6	12.6	43456
08/16/91	08:00	1027.68	1009.0	317.83	19.23	18.72	29.6	11.4	43461
08/16/91	08:15	1027.68	1008.9	317.80	19.20	18.83	24.9	12.0	43467
08/16/91	08:30	1027.82	1008.8	317.80	19.20	19.10	29.0	11.9	43472
08/16/91	08:45	1027.94	1008.6	317.79	19.23	19.37	32.6	12.8	43477
08/16/91	09:00	1028.15	1008.5	317.81	19.23	19.76	29.8	10.4	43484
08/16/91	09:15	1028.34	1008.4	317.80	19.27	20.03	24.1	8.1	43492
08/16/91	09:30	1028.77	1008.4	317.88	19.35	20.42	28.9	9.0	43497
08/16/91	09:45	1029.06	1008.4	317.89	19.45	20.76	28.3	8.8	43503
08/16/91	10:00	1029.41	1008.3	317.89	19.53	21.18	31.3	6.9	43515
08/16/91	10:15	1029.70	1008.1	317.94	19.62	21.71	32.6	8.8	43518
08/16/91	10:30	1029.92	1007.9	317.91	19.70	22.08	26.3	5.6	43527
08/16/91	10:45	1030.33	1007.8	317.98	19.77	22.60	26.6	5.0	43532
08/16/91	11:00	1030.53	1007.8	317.96	19.87	22.83	26.2	4.4	43539
08/16/91	11:15	1030.79	1007.7	318.03	19.92	23.20	28.3	6.3	43539
08/16/91	11:30	1030.99	1007.8	318.02	19.98	23.27	30.2	5.8	43546
08/16/91	11:45	1031.12	1007.8	318.01	20.01	23.44	30.6	6.2	43551
08/16/91	12:00	1031.30	1007.6	318.03	20.05	23.75	31.1	8.0	43554
08/16/91	12:15	1031.38	1007.5	318.02	20.06	24.03	31.4	8.4	43559
08/16/91	12:30	1031.52	1007.3	317.98	20.10	24.37	24.6	7.2	43568
08/16/91	12:45	1031.76	1007.1	318.03	20.12	24.76	27.0	10.2	43571
08/16/91	13:00	1031.89	1007.0	318.03	20.15	25.06	32.0	9.5	43576
08/16/91	13:15	1032.17	1006.9	318.04	20.22	25.38	32.5	9.8	43584
08/16/91	13:30	1032.38	1006.8	318.04	20.25	25.70	24.7	9.2	43591
08/16/91	13:45	1032.49	1006.7	318.06	20.24	25.87	26.6	10.5	43593
08/16/91	14:00	1032.58	1006.8	318.04	20.30	25.93	31.9	9.7	43597
08/16/91	14:15	1032.80	1006.7	318.07	20.28	26.23	32.7	10.6	43603
08/16/91	14:30	1032.93	1006.7	318.04	20.31	26.39	25.5	9.1	43611
08/16/91	14:45	1032.86	1006.7	318.03	20.29	26.33	26.3	10.0	43611

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/16/91	15:00	1032.92	1006.7	317.99	20.29	26.40	31.9	9.0	43619
08/16/91	15:15	1033.06	1006.7	318.01	20.28	26.51	32.7	10.8	43623
08/16/91	15:30	1033.14	1006.8	318.00	20.26	26.51	25.2	10.1	43628
08/16/91	15:45	1033.20	1006.8	317.98	20.26	26.54	26.1	10.1	43633
08/16/91	16:00	1033.31	1006.9	318.01	20.26	26.61	32.0	12.2	43635
08/16/91	16:15	1033.25	1006.9	317.94	20.21	26.55	32.7	11.7	43643
08/16/91	16:30	1033.23	1007.0	317.90	20.17	26.49	25.2	10.3	43650
08/16/91	16:45	1033.35	1007.1	317.94	20.15	26.52	26.4	11.5	43650
08/16/91	17:00	1033.47	1007.1	317.91	20.16	26.58	32.0	10.1	43660
08/16/91	17:15	1033.58	1007.2	317.97	20.13	26.64	32.7	13.7	43657
08/16/91	17:30	1033.60	1007.2	317.94	20.12	26.65	25.5	11.9	43663
08/16/91	17:45	1033.67	1007.2	317.90	20.11	26.68	26.2	11.7	43671
08/16/91	18:00	1033.86	1007.2	317.96	20.12	26.88	31.7	12.9	43671
08/16/91	18:15	1034.00	1007.3	317.96	20.11	26.97	32.5	12.7	43677
08/16/91	18:30	1034.14	1007.2	317.95	20.13	27.15	27.3	12.5	43683
08/16/91	18:45	1034.41	1007.3	318.01	20.14	27.38	24.8	11.5	43687
08/16/91	19:00	1034.46	1007.3	318.00	20.14	27.41	31.1	13.2	43691
08/16/91	19:15	1034.44	1007.3	318.01	20.10	27.43	32.5	15.3	43691
08/16/91	19:30	1034.49	1007.3	317.96	20.09	27.45	28.7	12.8	43700
08/16/91	19:45	1034.63	1007.3	317.96	20.08	27.52	27.4	14.2	43706
08/16/91	20:00	1034.78	1007.4	318.02	20.05	27.64	29.5	13.2	43705
08/16/91	20:15	1034.73	1007.5	317.98	20.03	27.45	31.4	13.3	43710
08/16/91	20:30	1034.81	1007.5	317.98	19.99	27.46	24.4	14.6	43715
08/16/91	20:45	1034.87	1007.5	317.98	19.95	27.57	28.2	13.4	43719
08/16/91	21:00	1034.94	1007.5	317.96	19.94	27.64	32.4	13.2	43725
08/16/91	21:15	1034.94	1007.5	317.96	19.92	27.63	31.5	14.5	43727
08/16/91	21:30	1034.92	1007.5	317.92	19.89	27.58	24.3	13.7	43733
08/16/91	21:45	1035.11	1007.6	317.93	19.85	27.64	28.5	12.5	43740
08/16/91	22:00	1035.06	1007.7	317.92	19.83	27.48	32.6	12.8	43740
08/16/91	22:15	1035.17	1007.6	317.93	19.81	27.66	30.1	13.9	43745
08/16/91	22:30	1035.26	1007.7	317.93	19.79	27.69	24.4	13.9	43750
08/16/91	22:45	1035.28	1007.7	317.95	19.75	27.76	29.7	14.3	43749
08/16/91	23:00	1035.41	1007.6	317.93	19.73	27.97	32.8	12.9	43759
08/16/91	23:15	1035.45	1007.4	317.89	19.70	28.17	28.7	11.5	43767
08/16/91	23:30	1035.43	1007.4	317.89	19.66	28.12	25.1	12.6	43768
08/16/91	23:45	1035.40	1007.4	317.87	19.67	28.12	30.0	14.8	43768
08/17/91	00:00	1035.56	1007.4	317.89	19.61	28.31	32.7	12.7	43776
08/17/91	00:15	1035.47	1007.5	317.87	19.58	28.02	29.5	14.3	43777
08/17/91	00:30	1035.53	1007.5	317.83	19.54	28.11	24.4	13.7	43786
08/17/91	00:45	1035.61	1007.5	317.83	19.50	28.22	30.0	12.4	43790
08/17/91	01:00	1035.70	1007.4	317.87	19.48	28.34	32.7	14.2	43790
08/17/91	01:15	1035.70	1007.4	317.81	19.45	28.41	29.1	12.6	43800
08/17/91	01:30	1035.79	1007.3	317.83	19.43	28.58	24.3	11.8	43801
08/17/91	01:45	1035.84	1007.3	317.84	19.39	28.68	31.3	14.1	43804
08/17/91	02:00	1035.89	1007.3	317.83	19.35	28.68	30.1	14.7	43810
08/17/91	02:15	1035.92	1007.3	317.84	19.33	28.75	29.7	14.7	43811
08/17/91	02:30	1035.94	1007.4	317.82	19.30	28.65	29.9	13.7	43815
08/17/91	02:45	1035.94	1007.3	317.79	19.26	28.77	29.9	14.3	43822
08/17/91	03:00	1035.97	1007.0	317.75	19.23	29.05	30.0	11.8	43829
08/17/91	03:15	1036.07	1007.1	317.78	19.21	29.06	29.8	14.8	43830

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/17/91	03:30	1036.14	1007.0	317.78	19.19	29.25	29.8	15.3	43833
08/17/91	03:45	1036.21	1006.8	317.76	19.15	29.50	30.0	12.5	43842
08/17/91	04:00	1036.27	1006.9	317.77	19.12	29.42	29.9	14.8	43843
08/17/91	04:15	1036.24	1007.0	317.73	19.10	29.29	29.7	13.7	43849
08/17/91	04:30	1036.18	1007.0	317.74	19.06	29.28	29.8	15.6	43847
08/17/91	04:45	1036.20	1007.0	317.69	19.03	29.27	30.0	14.4	43856
08/17/91	05:00	1036.30	1007.1	317.72	19.00	29.30	30.3	14.6	43857
08/17/91	05:15	1036.38	1007.0	317.69	18.96	29.41	29.7	12.9	43867
08/17/91	05:30	1036.41	1007.1	317.67	18.94	29.39	29.3	13.5	43871
08/17/91	05:45	1036.50	1007.1	317.69	18.93	29.45	29.6	15.4	43872
08/17/91	06:00	1036.60	1007.0	317.69	18.90	29.66	29.1	13.4	43879
08/17/91	06:15	1036.65	1006.9	317.69	18.87	29.82	29.3	13.6	43882
08/17/91	06:30	1036.70	1006.7	317.67	18.84	30.03	29.0	13.9	43889
08/17/91	06:45	1036.69	1006.7	317.67	18.82	30.03	29.2	14.5	43889
08/17/91	07:00	1036.68	1006.6	317.60	18.80	30.13	29.5	13.1	43898
08/17/91	07:15	1036.75	1006.4	317.61	18.79	30.42	29.2	11.4	43902
08/17/91	07:30	1036.85	1006.4	317.61	18.78	30.50	29.0	12.8	43906
08/17/91	07:45	1036.95	1006.4	317.61	18.77	30.58	29.0	11.4	43911
08/17/91	08:00	1037.05	1006.5	317.61	18.77	30.66	29.0	13.0	43915
08/17/91	08:15	1037.15	1006.5	317.61	18.76	30.50	29.0	12.8	43920
08/17/91	08:30	1037.26	1006.5	317.62	18.75	30.82	29.1	12.3	43923
08/17/91	08:45	1037.39	1006.5	317.64	18.74	30.97	28.9	13.1	43927
08/17/91	09:00	1037.44	1006.4	317.62	18.76	31.11	29.8	12.9	43931
08/17/91	09:15	1037.61	1006.3	317.62	18.73	31.32	29.7	12.5	43939
08/17/91	09:30	1037.75	1006.2	317.64	18.74	31.55	29.5	11.5	43942
08/17/91	09:45	1037.83	1006.1	317.65	18.73	31.78	30.8	13.9	43944
08/17/91	10:00	1037.88	1006.0	317.62	18.72	31.95	31.3	13.1	43951
08/17/91	10:15	1037.93	1005.8	317.59	18.71	32.16	31.6	12.1	43959
08/17/91	10:30	1037.92	1005.7	317.60	18.70	32.25	31.0	14.6	43956
08/17/91	10:45	1038.02	1005.6	317.58	18.68	32.43	29.7	13.6	43964
08/17/91	11:00	1038.13	1005.5	317.60	18.66	32.58	29.2	14.2	43967
08/17/91	11:15	1038.12	1005.4	317.55	18.68	32.69	26.5	13.1	43973
08/17/91	11:30	1038.32	1005.4	317.58	18.68	32.94	28.8	12.8	43978
08/17/91	11:45	1038.48	1005.2	317.59	18.65	33.23	29.2	12.0	43984
08/17/91	12:00	1038.53	1005.1	317.59	18.64	33.43	35.4	14.4	43986
08/17/91	12:15	1038.87	1005.1	317.58	18.65	33.79	75.1	13.8	44002
08/17/91	12:30	1039.46	1005.0	317.63	18.72	34.41	68.4	12.6	44018
08/17/91	12:45	1039.94	1005.0	317.66	18.77	34.88	70.2	13.5	44032
08/17/91	13:00	1040.39	1005.0	317.67	18.82	35.39	75.0	14.4	44048
08/17/91	13:15	1040.83	1004.8	317.66	18.85	35.99	74.4	11.0	44067
08/17/91	13:30	1041.28	1004.6	317.67	18.90	36.61	69.2	10.5	44086
08/17/91	13:45	1041.73	1004.5	317.66	18.95	37.24	69.4	8.6	44104
08/17/91	14:00	1042.09	1004.3	317.66	18.96	37.82	72.1	9.4	44118
08/17/91	14:15	1042.53	1004.1	317.66	19.02	38.41	77.1	9.3	44136
08/17/91	14:30	1042.97	1004.0	317.66	19.05	38.97	68.2	9.0	44153
08/17/91	14:45	1043.54	1003.9	317.70	19.09	39.65	69.2	7.2	44171
08/17/91	15:00	1043.92	1003.7	317.68	19.13	40.27	74.9	10.2	44188
08/17/91	15:15	1044.30	1003.5	317.69	19.17	40.81	73.4	10.7	44201
08/17/91	15:30	1044.58	1003.6	317.69	19.17	41.08	68.7	11.4	44213
08/17/91	15:45	1045.02	1003.5	317.68	19.18	41.65	69.1	10.2	44233

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/17/91	16:00	1045.37	1003.1	317.70	19.21	42.33	74.7	12.5	44244
08/17/91	16:15	1045.78	1002.9	317.71	19.21	43.00	73.1	13.2	44261
08/17/91	16:30	1046.35	1002.8	317.73	19.27	43.70	68.0	13.2	44279
08/17/91	16:45	1046.61	1002.5	317.72	19.27	44.22	69.9	13.7	44292
08/17/91	17:00	1046.98	1002.3	317.70	19.28	44.83	78.1	13.9	44310
08/17/91	17:15	1047.45	1002.0	317.73	19.34	45.63	68.9	14.4	44324
08/17/91	17:30	1047.65	1001.6	317.70	19.32	46.21	68.5	15.6	44338
08/17/91	17:45	1048.03	1001.4	317.66	19.32	46.81	69.7	14.1	44359
08/17/91	18:00	1048.52	1001.2	317.74	19.36	47.52	78.3	16.1	44368
08/17/91	18:15	1048.80	1001.0	317.71	19.35	48.03	68.5	14.3	44384
08/17/91	18:30	1049.09	1000.8	317.70	19.34	48.44	65.8	15.8	44399
08/17/91	18:45	1049.49	1000.8	317.69	19.40	48.94	72.2	14.7	44414
08/17/91	19:00	1049.94	1000.5	317.72	19.42	49.62	72.5	15.0	44429
08/17/91	19:15	1050.39	1000.5	317.73	19.47	50.13	72.4	15.7	44445
08/17/91	19:30	1050.86	1000.4	317.75	19.50	50.65	72.4	15.2	44461
08/17/91	19:45	1051.23	1000.3	317.76	19.54	51.09	72.4	16.9	44474
08/17/91	20:00	1051.77	1000.3	317.74	19.58	51.67	72.4	13.3	44498
08/17/91	20:15	1052.14	1000.2	317.79	19.61	52.19	72.4	15.2	44507
08/17/91	20:30	1052.50	1000.2	317.78	19.64	52.55	72.2	17.9	44521
08/17/91	20:45	1052.95	1000.2	317.79	19.65	52.96	72.3	15.2	44539
08/17/91	21:00	1053.30	1000.1	317.80	19.69	53.40	72.2	15.8	44551
08/17/91	21:15	1053.68	1000.2	317.79	19.69	53.73	72.3	15.0	44569
08/17/91	21:30	1053.98	1000.2	317.80	19.69	54.02	72.3	17.0	44580
08/17/91	21:45	1054.32	1000.2	317.77	19.72	54.42	72.3	16.1	44598
08/17/91	22:00	1054.63	1000.0	317.78	19.70	54.84	72.3	17.3	44610
08/17/91	22:15	1054.94	999.9	317.78	19.71	55.26	72.0	18.0	44623
08/17/91	22:30	1055.15	999.9	317.74	19.68	55.53	72.3	17.1	44640
08/17/91	22:45	1055.38	999.9	317.73	19.63	55.77	72.4	20.6	44653
08/17/91	23:00	1055.64	999.8	317.74	19.61	56.09	72.3	19.8	44664
08/17/91	23:15	1055.85	999.8	317.71	19.55	56.34	72.2	19.4	44680
08/17/91	23:30	1056.08	999.7	317.68	19.51	56.65	72.2	20.0	44695
08/17/91	23:45	1056.22	999.7	317.67	19.45	56.83	72.2	20.5	44706
08/18/91	00:00	1056.55	999.7	317.66	19.43	57.14	72.2	21.2	44722
08/18/91	00:15	1056.84	999.7	317.65	19.37	57.44	71.9	19.4	44739
08/18/91	00:30	1057.12	999.7	317.70	19.34	57.67	72.2	23.1	44745
08/18/91	00:45	1057.41	999.9	317.68	19.33	57.79	72.3	22.2	44760
08/18/91	01:00	1057.71	999.9	317.65	19.31	58.10	72.3	20.5	44778
08/18/91	01:15	1057.98	999.8	317.66	19.29	58.44	72.1	22.3	44789
08/18/91	01:30	1058.28	999.8	317.67	19.27	58.78	72.1	22.5	44802
08/18/91	01:45	1058.65	999.8	317.64	19.27	59.15	72.1	19.6	44822
08/18/91	02:00	1058.90	999.8	317.64	19.26	59.37	72.1	20.9	44833
08/18/91	02:15	1059.22	999.8	317.63	19.24	59.74	71.8	20.9	44849
08/18/91	02:30	1059.49	999.7	317.63	19.23	60.04	72.1	20.2	44862
08/18/91	02:45	1059.78	999.8	317.63	19.21	60.30	72.1	21.2	44875
08/18/91	03:00	1060.16	999.8	317.65	19.22	60.63	72.1	22.2	44889
08/18/91	03:15	1060.34	999.8	317.63	19.17	60.80	72.1	20.3	44901
08/18/91	03:30	1060.58	999.9	317.60	19.18	60.96	72.0	20.5	44915
08/18/91	03:45	1060.89	1000.0	317.60	19.15	61.14	72.1	21.7	44930
08/18/91	04:00	1060.97	1000.1	317.55	19.12	61.15	72.1	21.1	44942
08/18/91	04:15	1061.36	1000.2	317.54	19.[illegible]	61.46	71.9	19.5	44959

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/18/91	04:30	1061.66	1000.4	317.54	19.09	61.60	72.0	21.3	44974
08/18/91	04:45	1062.09	1000.5	317.58	19.10	61.91	72.0	20.8	44987
08/18/91	05:00	1062.33	1000.6	317.58	19.07	62.06	72.1	22.5	44998
08/18/91	05:15	1062.64	1000.6	317.57	19.07	62.32	72.1	21.6	45013
08/18/91	05:30	1062.92	1000.7	317.54	19.05	62.55	72.0	20.4	45030
08/18/91	05:45	1063.22	1000.8	317.55	19.01	62.70	72.0	20.6	45043
08/18/91	06:00	1063.50	1000.9	317.57	19.01	62.90	71.9	21.6	45052
08/18/91	06:15	1063.69	1001.0	317.53	18.98	63.00	72.0	21.5	45067
08/18/91	06:30	1063.94	1001.1	317.49	18.96	63.12	72.1	20.0	45086
08/18/91	06:45	1064.14	1001.3	317.49	18.94	63.16	72.0	21.4	45094
08/18/91	07:00	1064.46	1001.4	317.48	18.90	63.36	72.1	21.4	45111
08/18/91	07:15	1064.74	1001.5	317.53	18.89	63.52	72.0	24.2	45117
08/18/91	07:30	1064.98	1001.6	317.48	18.88	63.61	72.0	22.9	45134
08/18/91	07:45	1065.25	1001.8	317.48	18.82	63.77	72.1	21.3	45150
08/18/91	08:00	1065.46	1001.8	317.45	18.79	63.89	71.8	21.9	45163
08/18/91	08:15	1065.70	1002.0	317.44	18.75	64.01	72.0	23.0	45177
08/18/91	08:30	1065.94	1002.1	317.45	18.75	64.16	72.1	24.1	45187
08/18/91	08:45	1066.14	1002.2	317.40	18.70	64.20	72.0	21.5	45204
08/18/91	09:00	1066.40	1002.3	317.40	18.67	64.38	72.0	21.9	45217
08/18/91	09:15	1066.67	1002.4	317.39	18.64	64.55	72.1	23.8	45230
08/18/91	09:30	1066.99	1002.5	317.39	18.61	64.78	72.1	21.2	45247
08/18/91	09:45	1067.37	1002.6	317.41	18.62	65.03	72.0	22.7	45259
08/18/91	10:00	1067.74	1002.8	317.42	18.63	65.26	71.8	20.3	45273
08/18/91	10:15	1067.98	1003.0	317.39	18.61	65.30	72.0	20.6	45288
08/18/91	10:30	1068.16	1003.1	317.38	18.62	65.35	72.1	22.7	45298
08/18/91	10:45	1068.57	1003.2	317.38	18.63	65.68	72.1	21.6	45314
08/18/91	11:00	1068.86	1003.2	317.40	18.60	65.93	71.5	22.6	45325
08/18/91	11:15	1069.19	1003.3	317.38	18.62	66.22	71.8	20.2	45342
08/18/91	11:30	1069.47	1003.3	317.37	18.60	66.45	71.8	21.0	45356
08/18/91	11:45	1069.74	1003.3	317.36	18.63	66.69	71.3	21.5	45368
08/18/91	12:00	1070.03	1003.4	317.36	18.61	66.94	71.6	21.3	45382
08/18/91	12:15	1070.44	1003.4	317.36	18.64	67.35	71.6	21.3	45398
08/18/91	12:30	1070.79	1003.3	317.38	18.63	67.78	71.9	21.3	45411
08/18/91	12:45	1071.02	1003.3	317.37	18.61	68.01	71.9	22.0	45422
08/18/91	13:00	1071.46	1003.3	317.34	18.62	68.41	72.1	19.5	45445
08/18/91	13:15	1071.91	1003.3	317.35	18.65	68.83	72.1	16.6	45463
08/18/91	13:30	1072.34	1003.4	317.35	18.63	69.21	72.0	16.0	45482
08/18/91	13:45	1072.74	1003.4	317.35	18.65	69.61	72.1	13.9	45499
08/18/91	14:00	1073.21	1003.4	317.35	18.65	70.13	72.0	13.0	45518
08/18/91	14:15	1073.68	1003.4	317.34	18.66	70.54	72.0	10.6	45540
08/18/91	14:30	1074.15	1003.6	317.35	18.67	70.87	72.1	8.6	45558
08/18/91	14:45	1074.64	1003.7	317.33	18.72	71.28	72.0	5.9	45580
08/18/91	15:00	1075.07	1003.7	317.37	18.69	71.67	72.0	6.5	45595
08/18/91	15:15	1075.40	1003.8	317.35	18.68	71.95	72.1	4.9	45612
08/18/91	15:30	1075.85	1003.8	317.36	18.70	72.34	72.0	3.1	45629
08/18/91	15:45	1076.29	1003.9	317.35	18.70	72.74	72.0	4.1	45649
08/18/91	16:00	1076.85	1004.0	317.37	18.73	73.20	72.0	3.5	45669
08/18/91	16:15	1077.31	1004.0	317.35	18.75	73.64	72.0	2.0	45692
08/18/91	16:30	1077.79	1003.9	317.35	18.78	74.17	71.9	1.6	45710
08/18/91	16:45	1078.33	1003.9	317.39	18.80	74.69	71.9	2.3	45728

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/18/91	17:00	1078.76	1004.1	317.38	18.83	74.98	71.7	3.5	45745
08/18/91	17:15	1079.21	1004.0	317.34	18.84	75.47	71.9	1.4	45770
08/18/91	17:30	1079.82	1004.1	317.39	18.87	76.01	71.9	2.3	45789
08/18/91	17:45	1080.17	1004.3	317.36	18.88	76.20	68.0	0.9	45807
08/18/91	18:00	1080.51	1004.3	317.37	18.88	76.53	66.4	1.6	45821
08/18/91	18:15	1080.89	1004.3	317.34	18.89	76.95	66.1	0.1	45841
08/18/91	18:30	1081.41	1004.3	317.36	18.91	77.47	66.0	-0.2	45860
08/18/91	18:45	1081.84	1004.4	317.35	18.94	77.83	66.0	-0.5	45879
08/18/91	19:00	1082.30	1004.5	317.37	18.93	78.20	65.8	1.1	45896
08/18/91	19:15	1082.61	1004.5	317.34	18.92	78.53	65.8	0.9	45913
08/18/91	19:30	1083.07	1004.5	317.38	18.92	78.92	65.8	1.3	45928
08/18/91	19:45	1083.38	1004.7	317.36	18.93	79.07	65.8	1.7	45943
08/18/91	20:00	1083.73	1004.9	317.37	18.92	79.24	65.8	4.5	45958
08/18/91	20:15	1084.04	1005.0	317.33	18.90	79.43	65.7	3.5	45978
08/18/91	20:30	1084.41	1005.1	317.34	18.89	79.71	65.8	3.9	45993
08/18/91	20:45	1084.76	1005.2	317.30	18.85	79.93	65.8	1.2	46015
08/18/91	21:00	1084.95	1005.3	317.27	18.83	80.04	65.8	3.1	46029
08/18/91	21:15	1085.41	1005.4	317.29	18.81	80.42	65.8	3.6	46047
08/18/91	21:30	1085.71	1005.5	317.26	18.79	80.60	65.9	3.9	46065
08/18/91	21:45	1086.12	1005.6	317.28	18.78	80.88	65.8	4.5	46080
08/18/91	22:00	1086.52	1005.7	317.29	18.77	81.15	65.8	4.7	46097
08/18/91	22:15	1086.84	1005.8	317.27	18.72	81.43	65.9	3.4	46115
08/18/91	22:30	1087.27	1005.9	317.28	18.72	81.76	65.9	2.5	46133
08/18/91	22:45	1087.59	1006.0	317.25	18.69	81.96	65.9	1.1	46152
08/18/91	23:00	1087.86	1006.1	317.27	18.67	82.17	65.9	4.4	46162
08/18/91	23:15	1088.22	1006.2	317.21	18.67	82.41	65.7	1.7	46186
08/18/91	23:30	1088.57	1006.3	317.21	18.66	82.64	65.9	3.5	46202
08/18/91	23:45	1088.91	1006.4	317.24	18.62	82.91	65.9	4.4	46214
08/19/91	00:00	1089.16	1006.4	317.20	18.59	83.09	65.9	4.2	46232
08/19/91	00:15	1089.44	1006.6	317.17	18.57	83.26	47.5	3.0	46249
08/19/91	00:30	1087.56	1006.6	317.15	18.51	81.35	29.6	30.4	46173
08/19/91	00:45	1084.47	1006.6	317.07	18.47	78.29	29.2	72.6	46054
08/19/91	01:00	1081.45	1006.5	317.06	18.34	75.31	28.9	117.2	45929
08/19/91	01:15	1078.62	1006.5	317.03	18.28	72.45	28.8	158.1	45815
08/19/91	01:30	1075.99	1006.5	317.04	18.24	69.88	28.8	199.5	45700
08/19/91	01:45	1073.25	1006.5	317.04	18.19	67.08	28.7	238.8	45584
08/19/91	02:00	1070.69	1006.5	317.02	18.17	64.49	28.6	278.6	45478
08/19/91	02:15	1068.10	1006.5	317.03	18.13	61.90	28.6	318.1	45367
08/19/91	02:30	1065.69	1006.6	317.02	18.08	59.41	28.6	352.7	45265
08/19/91	02:45	1063.23	1006.6	317.01	18.06	56.91	28.5	390.3	45161
08/19/91	03:00	1060.98	1006.7	317.02	18.03	54.57	28.6	425.1	45064
08/19/91	03:15	1058.62	1006.8	317.01	18.01	52.10	28.5	431.4	44965
08/19/91	03:30	1056.34	1006.8	317.01	17.98	49.81	28.4	423.9	44868
08/19/91	03:45	1054.13	1006.9	316.99	17.94	47.51	28.5	412.9	44776
08/19/91	04:00	1052.19	1006.9	317.02	17.94	45.55	28.4	404.2	44688
08/19/91	04:15	1050.12	1006.9	316.99	17.94	43.46	28.4	394.1	44604
08/19/91	04:30	1049.28	1006.9	317.04	17.91	42.60	28.4	369.2	44562
08/19/91	04:45	1047.95	1007.0	316.99	17.93	41.17	28.3	351.4	44510
08/19/91	05:00	1046.09	1007.0	317.01	17.90	39.25	28.3	341.1	44429
08/19/91	05:15	1044.27	1007.0	317.00	17.89	37.44	28.2	332.9	44352

TIGHTNESS TEST RINGHALS UNIT 3 08/91

DATE	HOUR	P ABS (mBars)	PATM (mBars)	TMEAN (K)	HMEAN (mBars)	DELTA P (mBars)	I AIR (scm/h)	LEAK scm/h	VOL scm
08/19/91	05:30	1042.50	1007.0	316.98	17.88	35.65	28.2	323.1	44277
08/19/91	05:45	1040.87	1007.1	317.00	17.86	33.95	28.3	314.5	44206
08/19/91	06:00	1039.17	1007.2	317.01	17.87	32.13	28.1	306.5	44130
08/19/91	06:15	1037.46	1007.3	317.00	17.85	30.25	28.3	298.2	44058
08/19/91	06:30	1036.00	1007.5	317.04	17.85	28.64	28.2	290.6	43989
08/19/91	06:45	1034.49	1007.6	317.03	17.83	26.97	28.3	282.3	43926
08/19/91	07:00	1032.87	1007.7	316.98	17.83	25.29	28.2	275.2	43863
08/19/91	07:15	1031.53	1007.7	316.99	17.84	23.87	28.3	280.8	43804
08/19/91	07:30	1030.20	1007.8	317.03	17.83	22.44	28.3	284.5	43741
08/19/91	07:45	1028.94	1007.9	317.03	17.82	21.09	28.2	275.3	43688
08/19/91	08:00	1027.60	1007.9	317.01	17.83	19.72	28.4	268.1	43632
08/19/91	08:15	1026.55	1008.0	317.05	17.85	18.62	28.4	260.7	43580
08/19/91	08:30	1025.53	1008.1	317.07	17.90	17.49	28.4	252.9	43532
08/19/91	08:45	1024.57	1008.1	317.10	17.93	16.47	28.3	243.6	43484
08/19/91	09:00	1023.36	1008.2	317.09	17.94	15.21	28.4	236.7	43433
08/19/91	09:15	1022.43	1008.2	317.08	17.94	14.24	28.2	226.8	43394

Commission of the European Communities

Containment integrity and leak testing

Procedures applied and experiences gained in European countries

Report

EUR 11051 EN

Commission of the European Communities

nuclear science and technology

Containment integrity and leak testing

Procedures applied and experiences gained in European countries

Prepared by:
A subgroup of Working Group No 1
'Containment engineering safeguards'

Final report

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Science, Research and Development

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Foreword

A systematic effort to achieve progressive harmonization of safety practices and requirements for light water reactors was launched in 1973. Working Group No. 1 on "Safety methodologies, criteria, codes and standards" was set up for this purpose, in which the licensing (and regulatory) authorities and associated safety and control organizations are represented on one hand and the utilities and vendors on the other.

The main tasks of Working Group No. 1 can rougly be summarized as follows:

- Exchange of information and documentation on safety methodology, criteria, codes and standards and specific LWR safety problems applicable and/or under development in the various member countries.
- Identification of divergencies, similarities, common requirements, reasons for divergencies and establishment of synthesis reports in view of the elaboration of recommendations in areas and on items of common interest and considered mature for that purpose.

Because of the importance of containment integrity in reducing the consequences of nuclear accidents and because of the possibility that deteriorations of certain parts of the containment system may occur over long periods of time it was considered of high priority that the Working Group No. 1 of the European Community on "Methodology, Criteria, Codes and Standards" - WG 1 - and in particular the ad hoc subgroup "Containment Engineering Safeguards"* - investigated the problems associated with the containment leak rate determinations. When the activities of Working Group No. 1 started (in 1973) there were no generally applicable requirements for integrated leak rate

* The list of subgroup members is given in Appendix 2.

ments for PWR and BWR Containment Systems must adhere to the national codes and standards (in the country of plant siting) some of which are based on the principles developed by the American Society of Mechanical Engineers (ASME) as far as the steel structure is concerned and the American Concrete Institute (ACI) for concrete structures. The different national codes reflect differences from the ASME-ACI codes in particular as far as the considerations of loads of external origin are concerned such as historical seismicity, siting conditions, gas cloud explosions and aircraft crashes.

The accident internal service load is historically associated with the double ended primary coolant system pipe rupture which causes a maximum energy, pressure, temperature, and radioactive release into the containment. In some cases the release from the secondary system could be the worst case when considering containment loading.

Certain combinations of extreme internal/external loads are also used in containment design. A typical example is the combination of LOCA with some level of earthquake but there is no general agreement in European countries and the United States where the largest postulated LOCA has been combined with the largest Safe Shutdown Earthquake (SSE). In some European countries it is assumed in the design that a seismic event may cause a loss of coolant accident which then happens time delayed.

2.1. Containment layout for PWR and BWR power plants.

The containment layout mostly used in European countries is for both reactor types the double containment either with inner steel shell or with inner and outer concrete shell.

The inner containment, generally prestressed in the second concept, ensures resistance to internal pressure and leaktightness.

The outer reinforced containment, separated from the inner containment, protects it against external loads, and makes it

This gradation of pressure ensures that the direction of the airflow is always from areas of low activity to areas of high activity.

The internal ventilation system maintains a negative pressure of 1 mbar in the annulus. Here there is a controlled airflow from accessible compartments to plant compartments. However, there is no pronounced gradation of pressure between the individual groups of compartments in the annulus as there is in the containment. The pressure gradation of - 1 mbar in the annulus to - 2.5 mbar in the containment operating compartments ensures that the direction of the airflow will be inwards in the event of leaks in the isolating valves of the containment ventilation system.

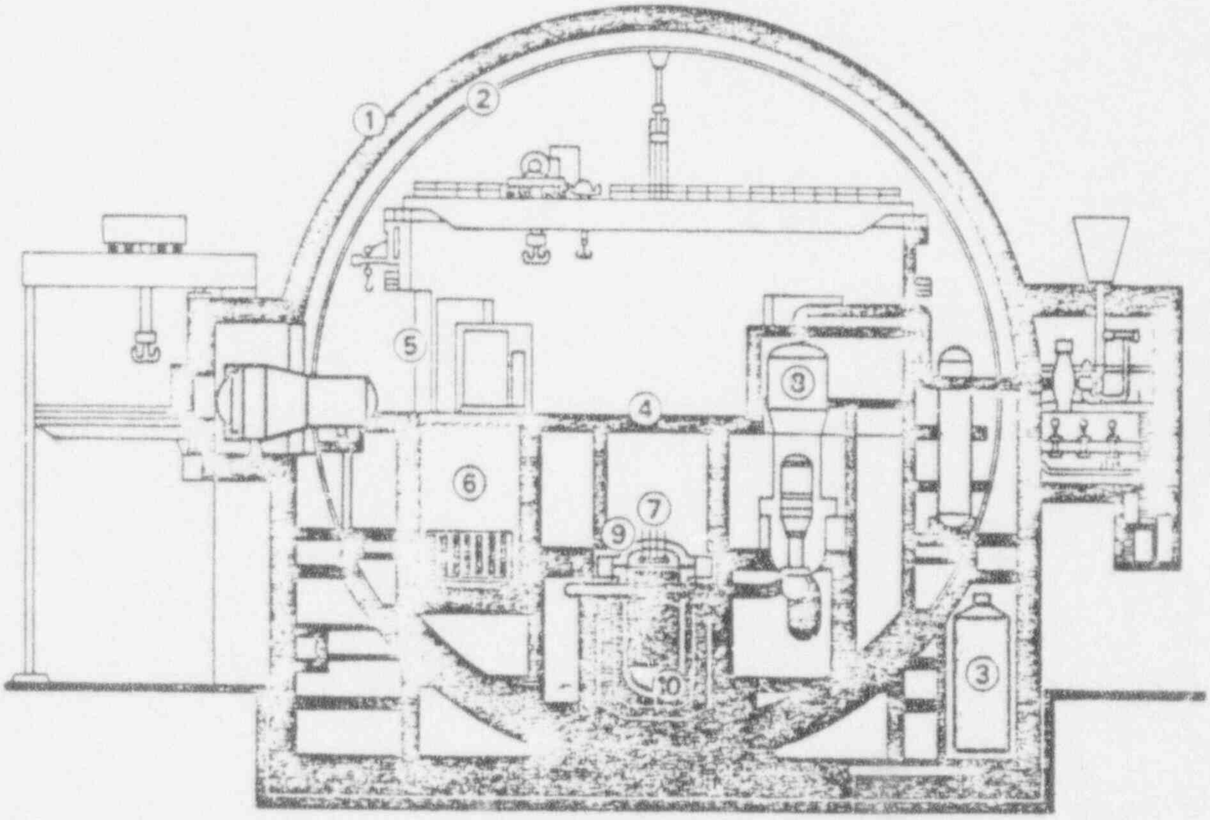
The exhaust air of the internal ventilation system is passed unfiltered directly into the stack.

In the event of an incident (activation of the emergency cooling system, but with the containment intact), the internal ventilation system in the reactor building is shut off. A special emergency ventilation system for the annulus is activated. The air inlet is closed via the building isolating valves and the air extracted to maintain negative pressure is fed to the stack via an emergency filter.

The annulus emergency extraction system also maintains the pressure at - 1 mbar, provided that there have been no pipe breaks or component failures resulting in a pressure increase in the annulus.

2.1.1.b The Borssele nuclear power plant is of a similar design to Philippsburg 2, see Fig. 1. The inner shell of the spherical steel vessel has an overall diameter of 46 m and a wall thickness of 22 - 30 mm. The outer shielding of the reactor building consists of reinforced concrete with a nominal thickness of 60 cm. The design pressure of the inner containment is 4,8 bar (absolut).

Fig. 1. - REACTOR BUILDING WITH DOUBLE CONTAINMENT
(KWU DESIGN)



1. SECONDARY SHIELDING
2. STEEL CONTAINMENT
3. WATER STORAGE
4. CONCRET COVER
5. MISSILE SHIELDING
6. FUEL ELEMENT STORAGE
7. CONTROL RODS
8. STEAM GENERATOR
9. REACTOR PRESSURE
10. COOLING WATER

Dimensions of containment structures in France

PALIER 900 - TYPE --->	CP1 - CP2
(with inner steel liner)	
Inside diameter (m)	37,0
Total internal height (m) - Level 0	56,63
Wall thickness cylinder (m)	0,90
Wall thickness dome (m)	0,75
Pressure (effective bar)	4,0

PALIER 1300 ET 1450 TYPE --->		P4	P'4	N4
(without inner steel liner)				
inside diameter (m)	inner shell	45,0	43,8	43,8
	outer shell	50,8	49,8	49,8
Total internal high (m) (/Level Zero)	inner shell	66,30	59,38	60,78
	outer shell	1,75	61,78	63,18
Wall thickness cylinder (m)	inner shell	0,90	1,20	1,20
	outer shell	0,55	0,55	0,55
Wall thickness dome (m)	inner shell	0,95	0,95	0,95
	outer shell	0,40	0,40	0,40
Pressure (effective bar)		3,8	4,2	4,3

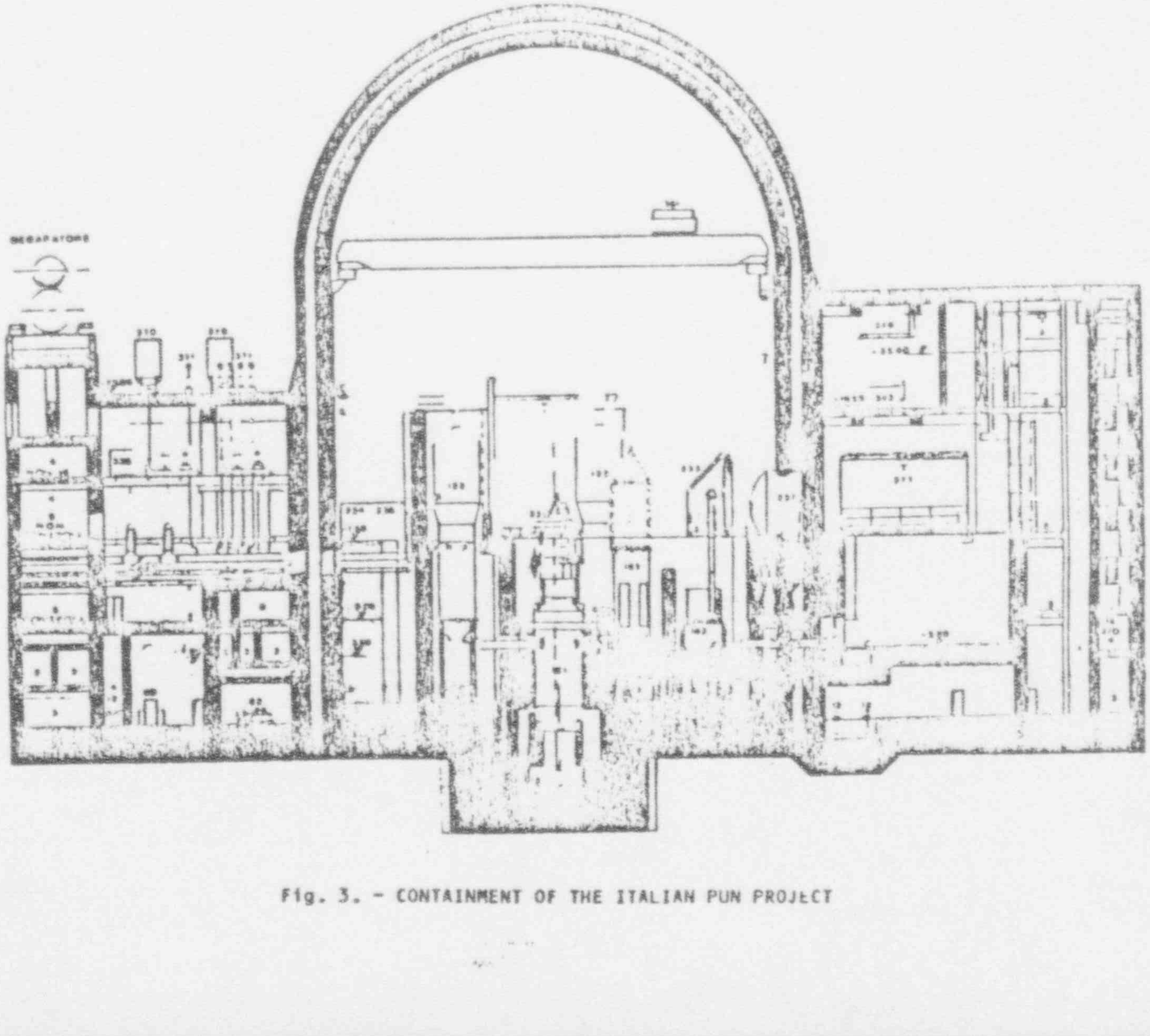


Fig. 3. - CONTAINMENT OF THE ITALIAN PUN PROJECT

pressure relief valve also dumps energy into the wetwell pool during primary coolant system pressure control. The containment system is protected against negative consequences of drywell sub-atmospheric pressures by vacuum breaker swing check valves which allow pressure equalization between the two regions. The drywell design pressure is typically 4 bar compared with maximum expected LOCA pressures of less than 3 bar. The wetwell design pressure depends on the size of the wetwell and ranges from 2 - 4 bars. The wall of the reactor building serves as a secondary containment and the space between it and the containment, if not lined concrete, is slightly below atmospheric pressure to control the leakage to the environment.

In Italy Mark II and Mark III containments are in use with a negative control leak concept for critical parts (main steam lines) mainly actuated in accidental conditions.

The Mark II containment, adopted for COARSO plant now in operation, is a pressure suppression system. It consists of a drywell, a pressure suppression chamber (wetwell) and 99 downcomers vent pipes connecting the drywell to the suppression pool. The drywell is a frustum of cone containing the reactor pressure vessel and accessories. The wetwell, in cyclindrical form, is located below the drywell. The downcomers vent pipes are designed to discharge and condensate steam below the water surface in case of a loss of coolant accident.

The Mark III containment will be utilized in MONTALTO plant, now in construction. It is based on the suppression pressure concept as well, but with larger volumes and different layout. The drywell surrounds the reactor and is connected to the suppression pool through horizontal vents in the lower part. The wetwell is located around the drywell. Both are of cylindrical form. A further rectangular pool is provided on the top of the drywell for refuelling operations and to supply a further water volume in case of a loss of coolant accident.

3.2. Italy

The construction of the Italian water cooled reactors essentially reflect the procedures applied in the USA and on top of that require that the reactor and related primary cooling system be housed in a double containment system.

3.3. The Netherlands

The basic provisions governing nuclear installations in The Netherlands are set out in the Nuclear Energy Act (Kernenergiewet) which became effective in 1969. Neither of the two nuclear power plants in The Netherlands (Borssele and Dodewaard) were entirely treated in accordance with this Act because of its late appearance. In fact the "Dutch rules for Pressure Vessels" have been applied and as these rules are not specifically made for nuclear power plants, they are supplemented by rules used in the USA e.g. the appendices of 10CFR50, parts III and XI of the ASME Boiler and Pressure Vessel Code and the Regulatory Guides of USNRC.
For new power plants the IAEA codes of practice and related safety guides will be adopted amended for The Netherlands situation. For leak testing a draft guideline has been finished in Summer 85 and is subject to review by the Reactor Safety Committee.

3.4. France

The list of documents given in the appendix for France applies only to the acceptance tests and periodic tests for the prestressed concrete containment structures with leak-tight metal liner for PWR's. France has developed its own documents for these tests. The philosophy differs from the American practice mainly by replacing P/2 tests to be executed every three years by full P tests during the initial refueling shutdown and then every ten years. This is described in addition G to the RCC ("Règles des conceptions et du construction des centrales nucléaires à haute pression").

It becomes evident from Appendix 1 where the codes and standards used in the design, construction and testing of containment, containment isolation, containment ventilation and post accident cooling are given for the different countries. Also it is conspicuous in this appendix that the larger industrialized countries like Germany and France have already worked on a development of national codes, while the nations with smaller national efforts in the nuclear area use the codes of the manufacturer. This is particularly clear for countries like Belgium and The Netherlands who have used American, French and German codes dependent on the manufacturer of the plant.

For the containment testing the applicable code in the USA is Appendix J of 10CFR50. All countries involved have used this as a basis, but as a result of their experience interesting deviations have developed. Since the comparison is done on the older plants of the European countries, the origin of these deviations can still be traced.

In this report

- the pre-operational testing,
- the periodic testing, applied methods, test pressures and intervals, instrumentation and extrapolation to the calculated accident condition,

are discussed.

4.1. Choice of testing method

The two main testing methods are the absolute method and the reference method. It is remarkable that with the growing experience in the different countries the reference method is loosing ground in favour of the absolute method. Only in Belgium the reference method is still recommended as a cross-check of the results of the absolute measurement.

As a draw-back of the reference method the German study mentions the irreproducibility, while the French study points out the principal difficulties as follows: the reference method is used

The main methods to perform the leak tests are based e.g. on:

- measurement of absolute pressure, temperature and humidity (A tests)
- measurement of pressure differential relative to a reference chamber (A tests)
- measurement of absolute pressure of cable penetrations (B tests)
- measurement of variation in the differential pressure (B and C tests)
- measurement of the make up flow rate (B and C tests)
- tracing substances (B and C tests)
- soap bubbles (B tests)

4.2. <u>Pre-operational and periodic testing (type A tests)</u>

Overall containment tests (so-called type A-tests) are performed as acceptance tests before the installations are taken into service, and as periodic tests to proof that leaks do not exist and that equipment and seals have not degraded excessively. It is also used for the first measurement of the containment leak rate. In a number of countries these pre-operational leak rate tests are performed at the calculated accident pressure, Pa, the design pressure, Pd, and at a reduced pressure.
The idea of a measurement at reduced pressure is to have a reference measurement so that the periodic testing later in reactor life can be done at this reduced pressure only.

4.2.a There is very little uniformity in the use of this reduced pressure between the different countries. In the French reactors this measurement at reduced pressure is abolished entirely. The reason given for this is that the risk of derioration of the static parts of the containment structure can only have two causes:

- design or construction defects in the penetrations, which are revealed after several months of operation and
- structural fatigue, which is a factor to be considered in the long term.

In view of the possibility of the instruments drifting during a test, or to a malfunction of them by other causes, it is considered in some countries that a period of time be spent at the start of a test with the containment sealed but not under pressure. The result of the leak rate calculation should indicate a zero leak rate. Free water surfaces should be monitored during the test. It would appear desirable to also establish that no water or gas is flowing into the containment before the test starts.

4.3. Extrapolation methods.

Different methods are used to extrapolate the leak rates measured at test pressure to leak rates at accident pressure (limiting value usually 3/4 of 0,25%/day). Sometimes leak paths are considered totally turbulent, and a pure pressure dependent extrapolation relation is used. In other cases the extrapolation is based on the pre-operational leak rates measured at the accident pressure (or slightly above) and at about the same test pressure as used in the periodic tests. The French avoid the extrapolation uncertainties by executing their tests always at the accident pressure.

The permissible leak rate for BWR containments in Germany is 1%/day owing to the smaller containment volume and the associated detection problems.

Extrapolation of measurements can only be very approximate (the nature of the flaws within the concrete is highly complex and obeys Darcy's law, the size of the cracks and the gaseous-phase phenomena depend on the pressure etc.).

Note:
Observations that are made at 1 bar and at P/2 indicate the need for considerable caution before tests are performed at accident pressure P (Tests at lower pressure are not performed for extrapolation reasons).

6. Local leak-tightness tests

For components under subatmospheric conditions during normal operation (as e.g. airlocks, ventilation valves etc.) the leak tests are carried out in some plants with a leakage monitoring system and can take place during power operation.

The components involved in the type B tests are electrical penetrations, door seats of the personnel air locks, penetrations in the personnel air locks, the plug seats of the equipment entrance ways, the seal of the transfer tube and any resilient joints in the penetrations.
The type C tests concern the isolation valves.
They are tested by functional tests, comprising tests of smooth running (by operating the drive and checking of the actuators).
Isolation of the containment is not possible in power operation since the disconnection of auxiliary systems would cause rapid shutdown of the reactor. In-service testing is therefore carried out only during refuelling or during startup and shutdown.
The testing frequencies for these components vary widely from country to country.

Generally components under subatmospheric condition and electrical penetrations can be tested during normal operation, but in several countries most of the tests are performed during the refuelling shutdown. Sometimes these variations are due to the component design (e.g. some newer penetrations designs have a possibility for continuous monitoring). But in other components no apparent reason can be found why in one country the testing is done every month and in another every year. (In France tests coincide with refuelling operation).
Especially in this area international exchange of experience might prove to be useful; particularly on differencies between test results "before" and "after" maintenance (so-called "as found" and "as left" tests).

8. Actual problems of periodic containment leak rate tests

The discussion within the ad hoc subgroup "Containment Engineering Safeguards" concentrated on some of the most important factors influencing the results of containment leak rate tests as are:

a) diffusion of gas into the concrete and certain insulation materials;
b) unequal distribution of the relative humidity in the containment;
c) temperature changes of the ambient air which surrounds the containment, and
d) insufficient stabilizing time before commencing the official measurements;
e) extrapolation from reduced to accident pressure;
f) confidence level on the leak-tightness between two subsequent tests;
g) correlation between local and overall tests.

8.1. Gasdiffusion

According to the discussion within the ad hoc subgroup a period of about 2 days is necessary to saturate the concrete before starting leak tests. Temporary overpressure can considerably reduce the saturation time. Detailed information is expected from a Netherlands test programme to study the influence of the variations of the physical state of the concrete.

If the saturation time is not or cannot be respected the leak rate may be overestimated. Since it is only necessary for the utility to demonstrate that a certain leak rate has not been exceeded, the overestimate should be acceptable to licensing authorities.

8.2. Relative humidity

Although an unequal distribution of the relative humidity may influence considerably leak rate tests there is no correction foreseen in the US regulations Appendix J to 10CFR50 which is presently considered as basis in most European Member countries.

According to the German KTA rule the gradient dp/dt is limited to 0.05 bar/h. If the pressure is increased more quickly a stabilization time of 6 h is required.
In the initial test, measurement is carried out after a rising gradient. Any gas diffusions which might then still be taking place in the concrete are conservatively determined as a proportion of the leak rate
According to French practice the pressure gradients are limited to 0.15 bar/h with rising pressure and 0.10 bar/h with decreasing pressure.

There is currently considerable debate in particular in the USA as to whether the current measurement period of 24 hours can be reduced significantly.

It appears necessary to demonstrate for each containment that it will remain leak tight for a period matching the duration of an accident pressurization of the containment. An additional time margin should be added to give confidence and the measuring period should take into account the precision and reliability of the measuring instruments. This latter point is discussed in the above-mentioned ANSI Standard 56.8 from 1981 which describes the use of the Instrument Selection Guide. Consideration should be given to establishing a time duration of the test which is justifiable.

8.5. Extrapolation to the accident pressure

The correlation between the leak-tightness from the reduced pressure to the accident pressure is normally based on the results of the preoperational tests.
Often, during operation, important modifications are made on the containment penetrations.
In such a case the extrapolation coefficient could vary, and a new coefficient might be defined.

10. Containment ageing problems

It was confirmed that containment ageing is for a great deal depending on testing and maintenance of the penetrations. To obtain the basis for calculating an ageing coefficient of a containment it will be necessary to test the leak rates of the penetrations quantitatively which seems to be a design problem. It was reported about a safety sealing device already available which can be installed around defective penetrations.

10. Evolution of the Concrete Containment in the French PWR Program.
By J.L. COSTAZ, EDF, Paris la Défense,
BARRE, Coyne et Bellier, Paris,
Presented at the 7th SMIRT Conference, August 1983, Chicago.

11. Significant aspects concerning the leakage tests of the safey containments: operational experience evaluation.
By G. CRIMALDI, (ENEA-DISP),
Presented at the CSNI Specialist Meeting on Water Reactor Containment Safety, Toronto, Canada, 17th-21st October 1983.

12. Unpublished documents submitted by expert members of the ad hoc subgroup.

Regulations, Guidelines and Specifications of the containment system (construction and testing) ITALY	Functional design	Containment structures	Internal structures, foundations	Containment isolation	Heat removal systems	Emergency ventilation system	Containment inspec. +test	Testing of em.vent. system, isolation syst. heat rem.syst.
USNRC 10CFR50 Appendix A, paragraph: Appendix J	2/4/16/50 52/53/54			54/55 56/57	38/39/40/41 42/43/50		Appen- dix J	
USNRC Regulatory Guide no. 1.----	19/26 29/46	10/15/19/136 55/18/35/57	10/15 55/57	11/26 29/73/141	1/26/29 40/73/82	RG 8.8		
Italian Regulations (e.g. ENEL/ANCC publications)		v						
ACI 318-71 Building Code Requirements			v					
ASME Boiler and Pressure Vessel Code, section no.:		III	III					
AISC Specification of Structurel Steel			v					
ANSI N271 "Containment Isolation Provisions"				v				
UNICEN standard (UNI-3768) "Leak Tests"							v	
APED 4470 "Extrapolation of Containment Vessel Leak Tests"							v	
Operating License issued by Ministero Industria							v	v
ACI 349 Code requirements for Nuclear Safety rslated structures		v	v					
ANS/ANSI 56.8 Containment system leakage testing requirements							v	

Regulations, Guidelines and Specifications applicable to the containment (acceptance tests and periodic tests) adopted by EDF for FRANCE	Fessenheim and Bugey	W900 CP 1/2 reactor
USNRC 10CFR50 Appendix J	v	v
Note REAM "Palier W900 - Auscultation des bâtiments"		v
Note SEPTEN "Sûreté des enceintes de confinement en béton précontraint"		v
ORNL, NSIC 26 by P.C. ZAPP "Testing of containment systems"		v
ANSI N45.4 1972 "Leakage rate testing of containments"		v
Bureau Veritas "Mesure des taux de fuite des enceintes"		v
Power Engineering, 1976 "Containment leak rate testing"		v

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"Containment Engineering Safeguards"

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