# *Pressure and Leak rate test of the cooling components of RE4 .*

- *Theory*
- *The apparatus*
- *The procedure*
- *The results*
- *References*
- *Thanks*

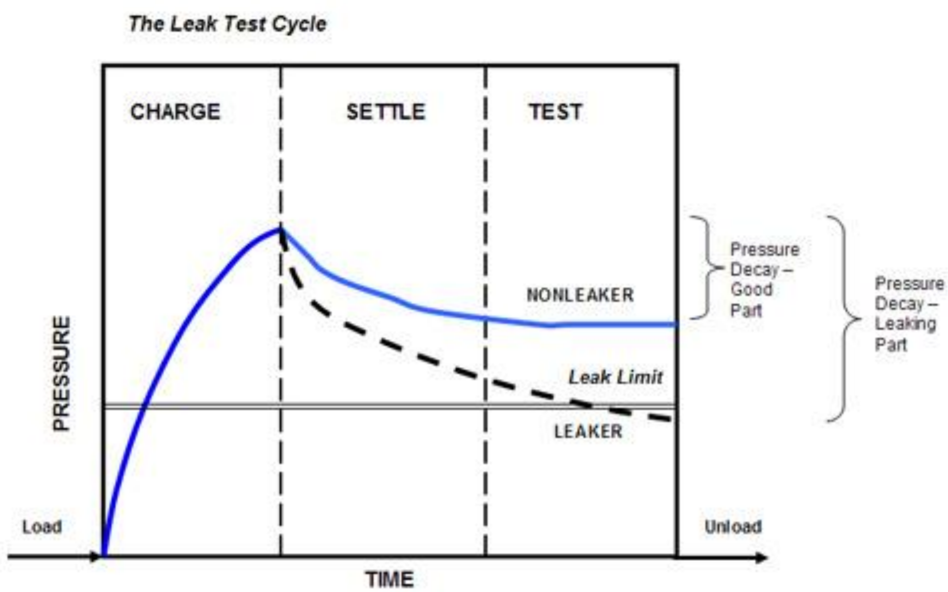
## Theory

The burst pressure test will not be performed in India at the recommended pressure of 30bar (x3 service approx 9bar) pressure for reasons of infrastructure. However the leak rate measurement will be done at 20bar, see below. The components in the chamber circuit are specified as follows;

| | |
|---|---|
| 8-6mm Cu pipe( half HARD) | ~200Bar |
| Sagana 8mm Unions | >200Bar |

The pressure decay method is suggested given its limited infrastructure, it is however on the outer limit for such leak rates. Namely 1 x 10^-4 [mbar.l/s] @ the operating conditions of 9bar. This gives a leak rate of 5 x 10^-4[mbar.l/s] @ 20bar, to be done with Argon. At this initial stage in the QC, up to QC 4, we will use gas (Argon) to avoid possible damage to the chamber from water leaks. From the “Super Module” stage on, water will be used. See notes on the sensitivity using gas or water

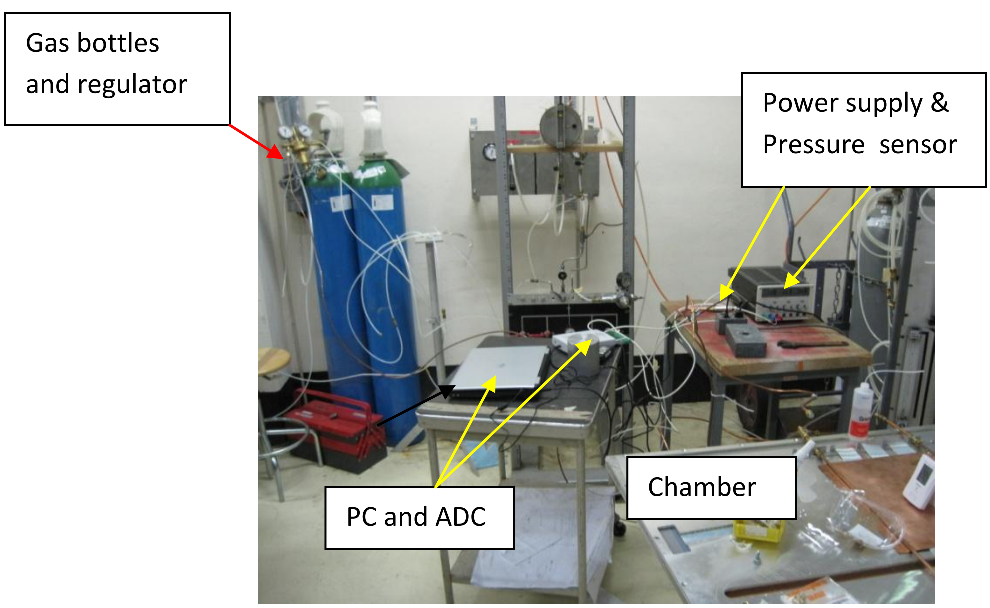
The nominal case for performing leak tests with the decay method, as given in the literature, is shown below in this idealised plot .



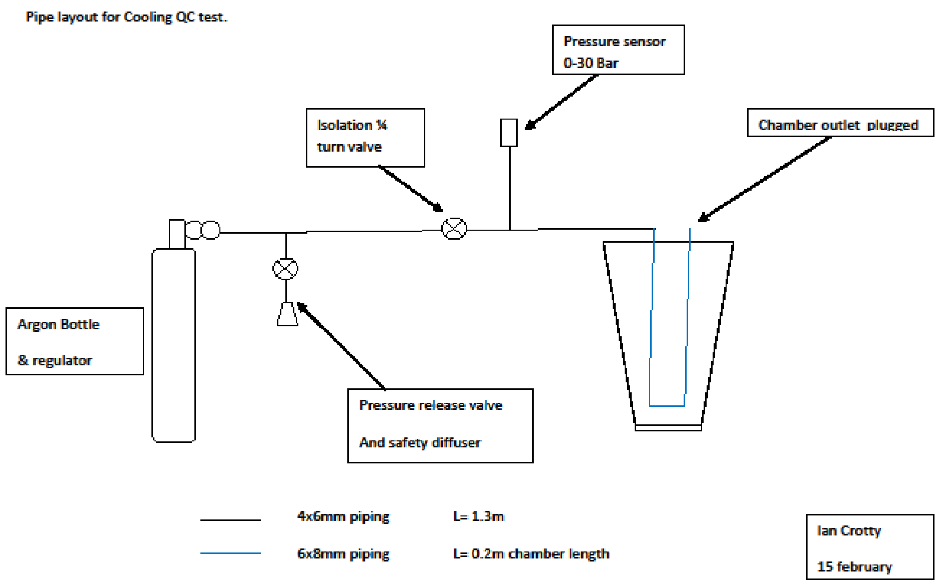

However in the real world the test is not that evident.

The settle phase is in fact the establishment of thermal equilibrium after the adiabatic heating during the "charge" phase, the application of the 20 bar Argon in this case. The negative slope in test phase defines the rate of pressure drop required to determine the leak rate. Working back from the acceptable leak rate a worst case ΔP/Δt can be established and any value greater than this rejects the piece.

# The apparatus



Schematic for the QA of the RE4 chamber cooling system.




# The procedure

## *Calibration with no chamber circuit connected.*

Connect and start recording with the ADC connected to a PC.

5 separate compression phases to 20bar should be implemented in order to "put in place" all components and take an average of the $\Delta P/\Delta t$ of the last 4, if there is no trend one way or another.

Firstly raise the pressure, using the regulator on the argon bottle, in steps of approx 5 bar with a plateau of some 5/10 secs up to the test pressure of 20bar±0.1bar.

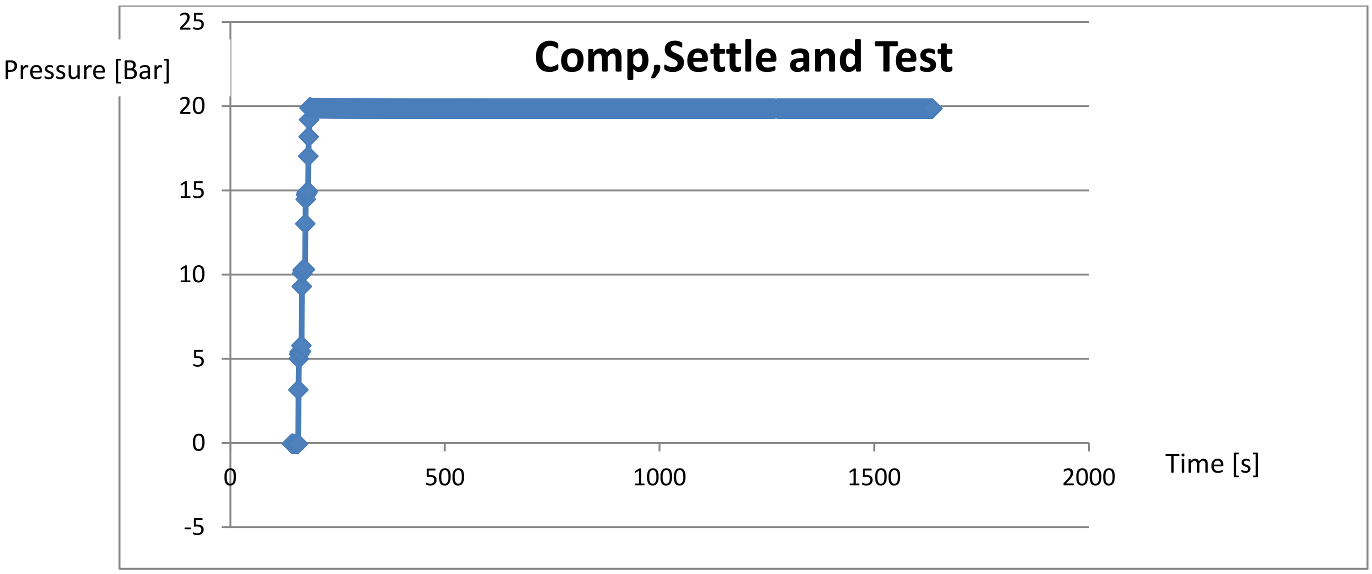
Isolate the circuit with the ¼ turn valve separating the supply from the test piece.

Turn off the bottle. Turn down the regulator to be ready for the next test session.

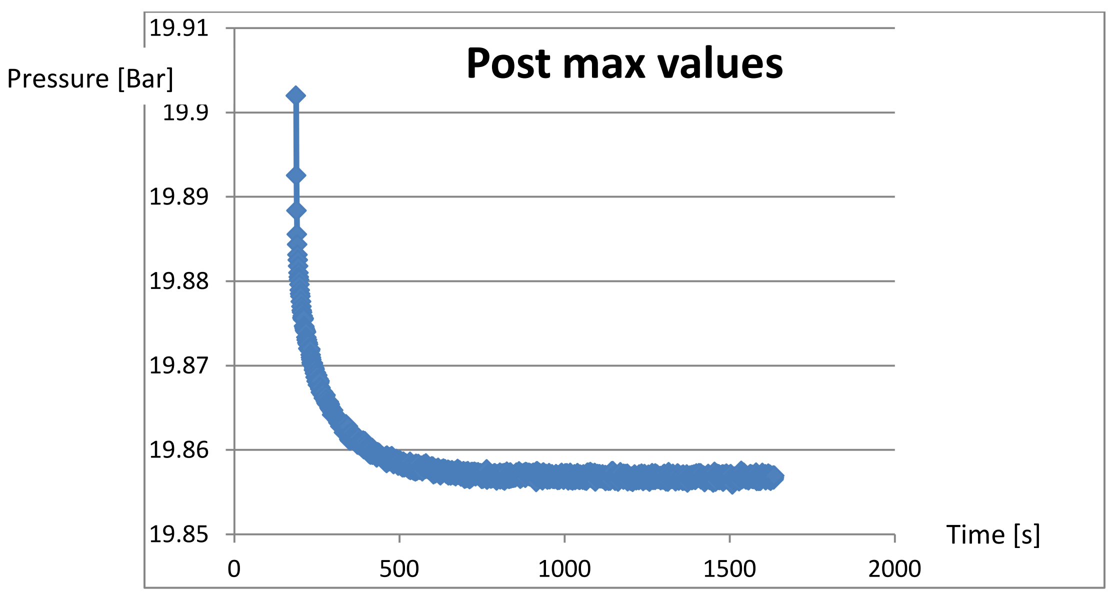
The plot from the ADC should be observed in real time to be sure the system is responding and to have an initial idea of the integrity of the circuit.

From this data the leak rate of the test rig can be calculated in units of [mbar.litres/sec].

The volume of the circuit is calculated in litres. That is everything after the isolation valve, not including the chamber in the case of the calibration phase. The ΔP/Δt comes from the slope of the curve in the "Test" phase as illustrated in the "Nominal case" above. Using excel, or another spread sheet, the data can be plotted as shown below.

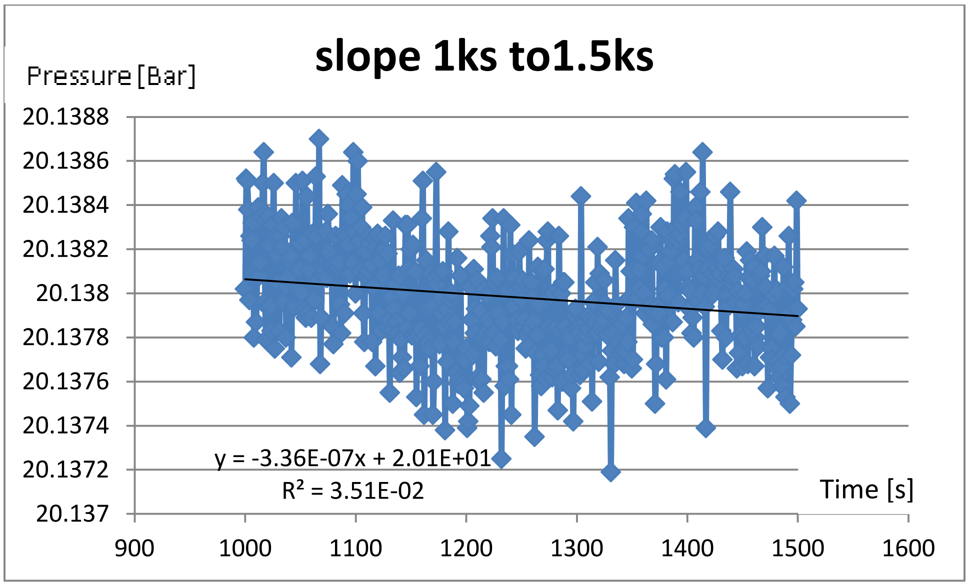



On this scale the 5bar steps in compression are not clearly visible and the settle and test phases are also not visible. These 3 phases must be isolated. The values taken after the maximum attained can be plotted, an example is given below;




Note the ordinate scale of 10milleBar.

The next step is to distinguish between the settle phase and the test phase (ΔP/Δt). From the >50 trials carried out, on chamber circuits, so far this empirical evidence shows that the ΔP/Δt slope can be taken after 500-1000s both with and without the chamber circuit in question. The total period since the highest value should be in the 1ks to 1.5ks range




Notice the ordinate scale of 200microBar

The duration of the slope must be kept short as temperature fluctuations will start to appear. 500s or less than 10 minutes gives acceptable results as experienced in the non air conditioned ISR tunnel.

Using the 'trendline' fit as done in "excel" the equation for the slope in bar/s can be calculated. See below for details.

Leak rate = ΔP/Δt x Vol [mbar.l/s]

For this calibration phase rather low values should be obtained as a the vol is very small.

## The test of the chamber circuit

Here again 3 measurements will be made using the two closest to make an average.

The chamber is connected to the test rig and the identical procedure is carried out including the separation of the phases in order to obtain the ΔP/Δt . Values slightly worse can be expected due to the increase in volume, perhaps a factor 3 or 4.

## *Results*

If the slope is clearly steep (one division change)on a scale of 10mbar/division over a period of 500 secs then the test can be stopped as the system is leaking.

On a scale of 1mbar per division the slope should be negligible when seen on a time base of 10/15mins .

From the fit given in the case above an equation is supplied ;

$$Y = -3.36E-07x + 2.01E+01$$

$$P = -3.36E-07t + 2.01E+01$$

This can be converted into:

$$\Delta P/\Delta t = -3.36E-07 \text{ [bar/s]}$$

To obtain the leak rate;

$$\Delta P/\Delta t \times Vol \quad \text{[mbar.l/s]}$$

Giving in the case used in the ISR;

$$Vol = 0.14 \text{ [litres]}$$

$$\Delta P/\Delta t = -3.36E-07 \times 1E+3 \text{ [mbar/s]}$$

$$\text{Leak Rate} = 4.7E-05 \text{ [mbar.l/s]}$$

These results are then entered into the RE4 DB to act as validation of the chamber cooling piping fabrication in India.

## *The Notes*

Quote from, ref #2;

Air is a compressible media with a relatively low viscosity compared to

common liquids. This means that air travels through a leak path approximately 200 times faster than liquids. Air has essentially no surface tension. This allows it to escape much more easily than liquid through a small hole.
It is very important, however, to remember that air can go through holes that do not leak liquid. This is one reason for requiring a specified maximum allowable **air** leakage rate.
The primary advantage of using air as a test fluid is speed in leak testing.

Another quote on gas/water testing rates advantages.

| | | |
|---|---|---|
| Viscosity | Water | 890[ µPa.s] |
| | Air/Nitrogen/Helium | 18-19 [ µPa.s] |
| | Argon | 22.9[ µPa.s] |
| | Engine oil | 0.319[ µPa.s] |

So using air or Argon instead of water gives a factor 50 in sensitivity

References;


1 http://www.hkatechnologies.com/HKA%20Leak%20Testing%20in%20Manufacturing.pdf

2 http://technicaltoolproducts.com/media/docs/QFSI%20Leak%20Test%20PRIMER.pdf

3 http://www.tmelectronics.com/CalibrationVsDecayMeasurements032805.pdf



## *Achnowledgement;*

Many thanks to the CMS cooling team for their advice and assistance in establishing this first level test.

Also to colleagues from LHC on their practices.



Ian Crotty


13 April 2012