Results of Tests on Seal Loading. Ref: RP/2014 Engineering. March -01a

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A Study on the methods and ways to understand the sort of loads that a swelling seal generates internally and how these work and be applied in practise.

A High level Look at ways to quantify the effects of Swelling on Seal Loading performance in water swelling seals. Author R.W.Hibberd - Ruma Products BV Holland 2014

Contents.

1.0 Pre-Amble Ruma 2008

An area of study in the early phases of water swelling elastomer in an effort to understand the swelling curves of water swelling elastomers. In many applications the swell curve has a steep front swell which quickly tails of. From a chemical point of view we understand what is happening as well as why this occurs and we use it daily to enables us to predict the swelling in wells. However this is effectively where our knowledge stopped at that time.

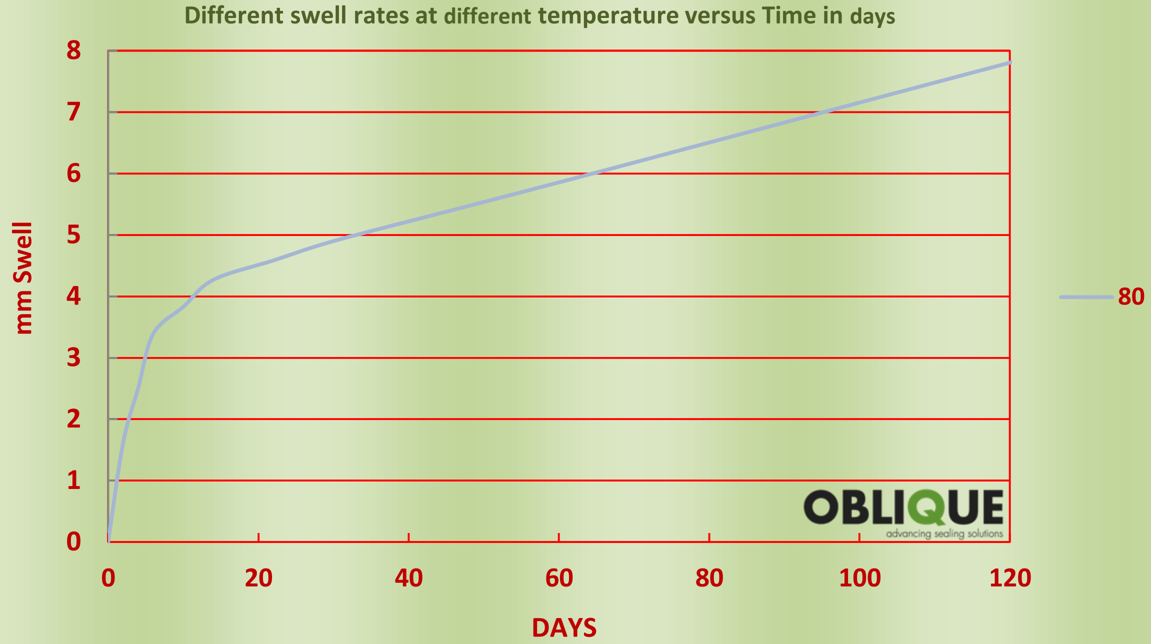

Fig 1 Standard water swelling elastomer Swell Curve

What Fig 1 graph clearly illustrates is shape of the curve and how the quickly the initial swell crest builds up and then flattens out. What is seen is that after the steep crest the actual swell curve shape follows the same form irrespective of the temperature and tails off to a gradual Curve.

1.1 Proposed Tests

It was proposed in to conduct a series of tests that looked into mechanical ways that swelling could be understood and quantified, while at the same time trying to understand the magnitude of the forces involved and how these could be harnessed and used to create sealing.

The tests would consist of a number of separate but interlocking testing programmes.

1. The first series of tests would try to design and build a testing set up that would measure the level of contact force being created by swelling versus Time.
2. The second tests would look at swelling form and Contact foot print (to be reported later)
3. The third was to look at the holding force created by the contact foot print. (later report)

The goal was then to take each of the above and integrate them into one new form of prediction. The logic behind the whole series of test was as follows. By measuring the contact force versus time we would be able to quantify the change measured. If we now have a seal in a pipe and measure the contact area increase versus time we have the two parts of a seal measurement. If Force is pressure and contact area then we can calculate total force being generated (theoretically). If we now measure the amount of force required to dislodge the seal from its position we can then equate this back to the theoretical force being calculated.

Additionally we can then model these to generate sealing force and be able to equate that back to well pressure.

This was the goal we set ourselves.

1.1.1 Internal Forces

As with a balloon when it is being blown up a mechanical force is being created to compress air into the space inside the balloon. This compressed air affects the mechanical balance in the balloon. When you take it out of the bag it is small and flat, everything is in a form of mechanical balance. If compressed air is allowed to enter the balloon it will gain in size and has a maximum inflation for each pressure that is internal in the balloon. The compressed air is altering the mechanical balance. The air internally is being contained by the forces of the mechanical stretch of the rubber from the inflating balloon this stretch is effectively following HOOKS LAW.

Something comparable has to be happening in the swelling elastomer, water is entering the elastomer , the elastomer is holding this water and the whole is swelling. However where as a balloon is inflated and when released the air escapes this does not seem to happen to water swelling elastomers. So not only is water being drawn in but it being held there by more than just the elastomer. To do this a force or forces have to be in place there and these have to have a magnitude.

The aim is to measure this and try to quantify this.

The initial test was firstly to see if there was a force being generated and try to quantify this. This was done by creating a seal in a Perspex tube. The tube had a series of pressure gauges along its length at the area a swelling seal would encompass. The idea was that as the seal were to swell there would be an increase in pressure and this could be measured. The results were initially disappointing, there was no pressure and certainly nothing was measured. However what this did show was that swelling of the elastomer is a 1 to 1 swell. A 1 cc swell is accompanied by a 1 cc loss of water. In other words there is not net volume change, which explains why a swell was visible on the sealing but not measureable on the gauges.

It was therefore important to look to a swelling method that would allow swell contact to occur but to contain the swell to allow for it to build up a pressure and be measured. The system devised was to have a piezoelectric cell to quantify the load force, with the elastomer creating this force.

At the time of the tests we were working with the University of Groningen and their Labs helped build the Cells and the Computer Interface program that was used to convert the force into an output signal and then register this.

2.0 Test Setup

Fig 1

Fig 2

1. Pressure sensor.
2. Test sample
3. Fluid contact and Filter
4. Assembly Entablature

2.1 Test Repeatability

To be able to conduct the test we needed to do we first had to INVENT the test and test method and having created that something that worked. Repeatability improvement took a lot of work but were primarily those the problems listed below. Often the solution was simpler than finding the cause of the problem. Our second biggest problem was load cells that could go higher than 80-90 bar and over 100C. We never could find these to go higher than here.

Problems	Cause	Solutions
Irregular pressure Curve line	Rubber Deformation Through room in the Sample Holder	Tight Production tolerances. Sample pressed into a Steel Ring. Free space removed or reduced.
Measurements at High temp give irregular initial curve build up.	Expansion of Sample and House	Rubber, sensor, sensor house and sample fluids pre-warmed.
Negative pressure build-up at the test beginning.	Sensor cables warming up and giving false readings	Cable pre heated and Zero Compensation added
Pressure build up falls away as Oven door is opened.	Cables cooling of quickly giving false readings.	Oven Door kept closed during tests.
Sensors Getting Broken	Sensors sticking to swollen rubber during dis-assembled.	New Design, of housing. Porous Nut system abandoned.

3.0 Tests Results Found

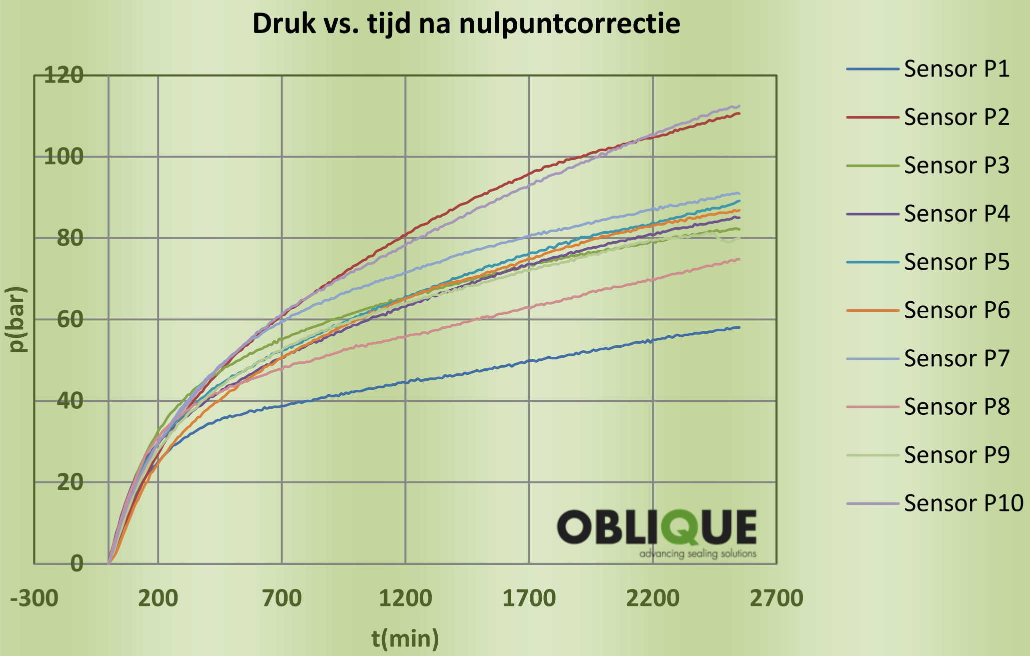

Fig 3. A 10 sensor sample spread

This graph illustrates the variation in the results obtained effectively if the two highest and two lowest were eliminated the results could be more or less distilled into the following.

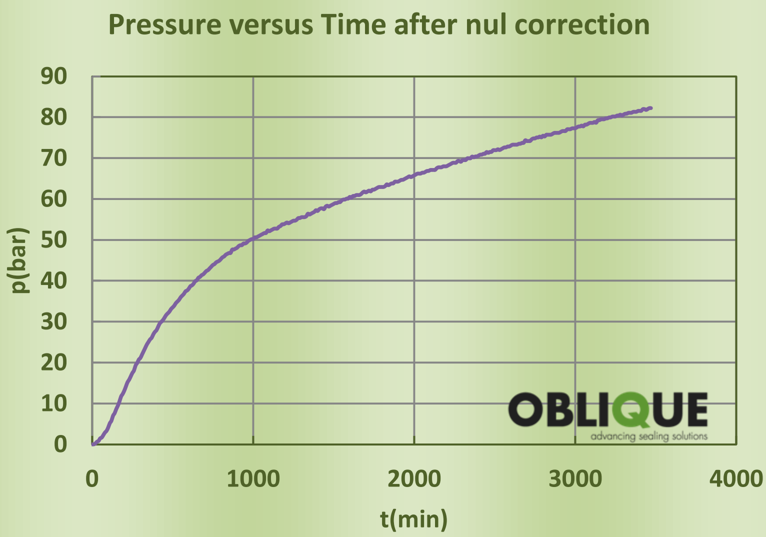

Fig 4

Once topped and tailed and then averaged the 1844 shows the following Pressure build up due to swelling. As previously seen it follows the same form as the swell curve forms, which is logical but important to have had confirmed.

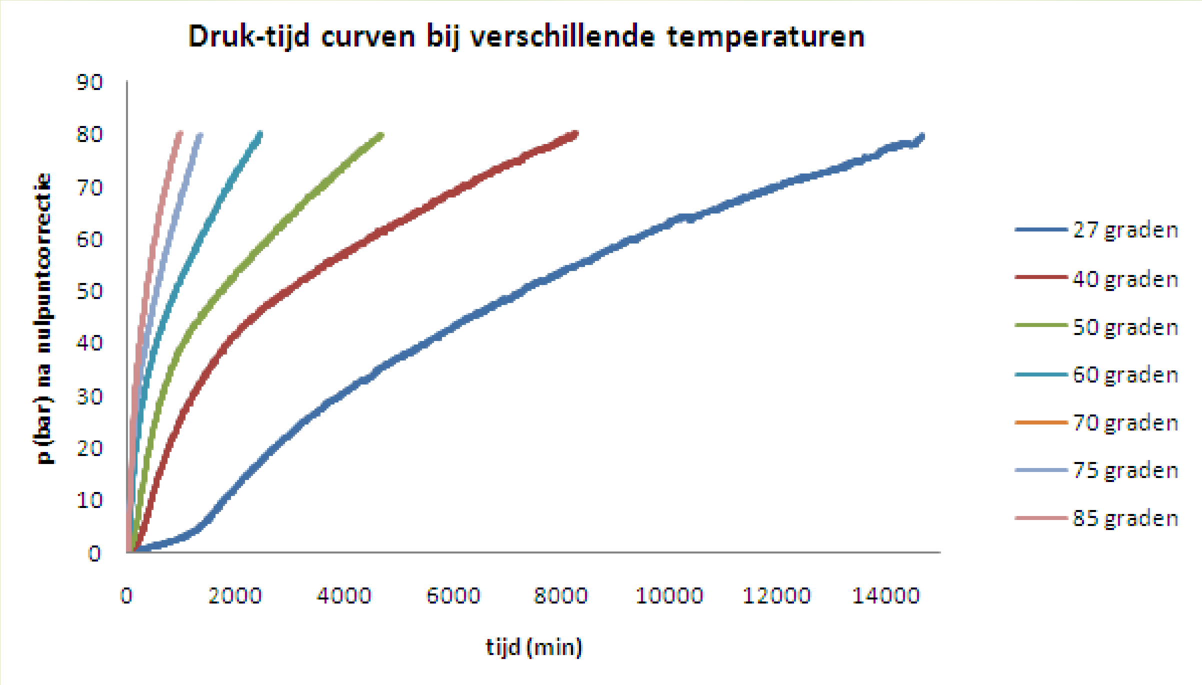

Fig 5

Fig 5 shows clearly the pressure building up in the seals in a similar manner to how the swell builds up and the effect s temperature has on the basic curves over a long period of time. The pressure sensors used are limited by their temperature and pressure ranges.

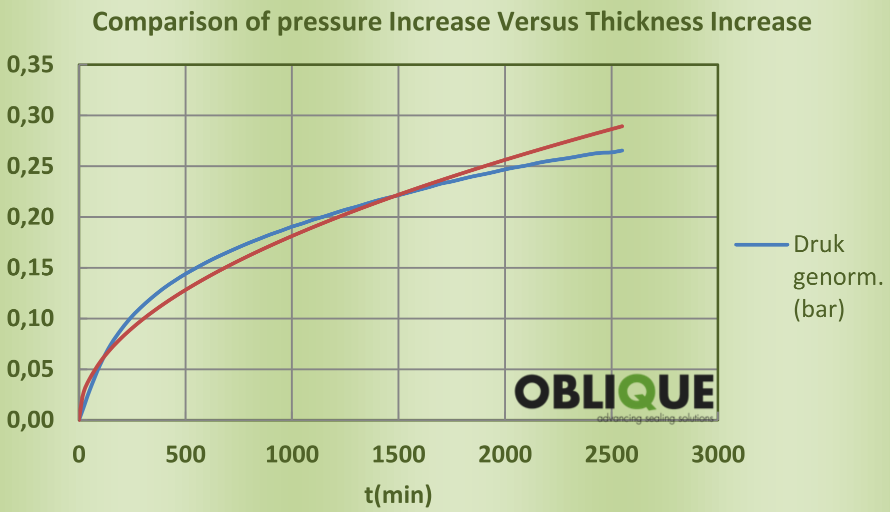

Fig 6

Fig 6 shows the swell Curve superimposed upon the Pressure curves and the similarity in curve form.

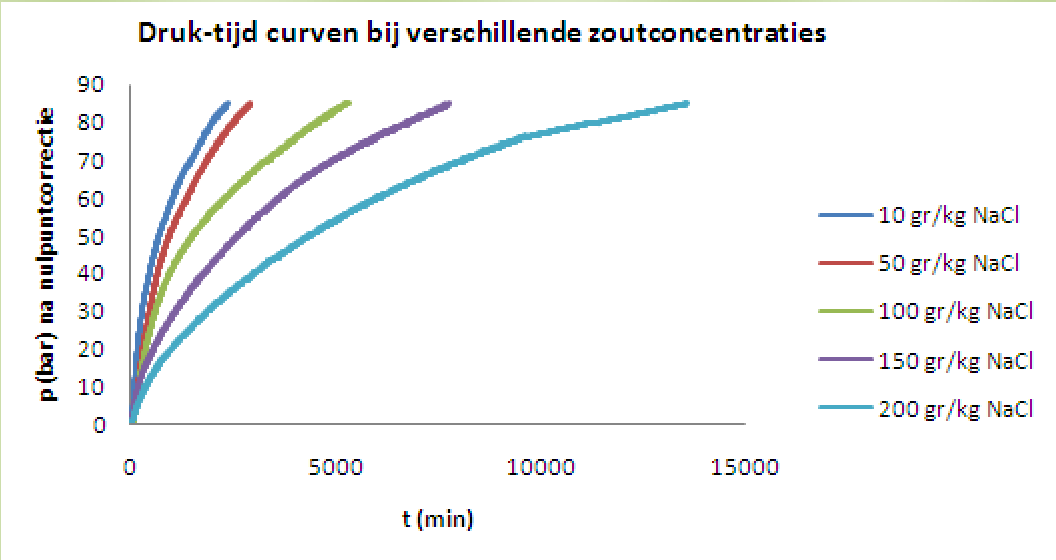

Fig. 7

As we have seen with Temperature and here with different salt concentration the pressure curve follows the swell curve in all the various forms.

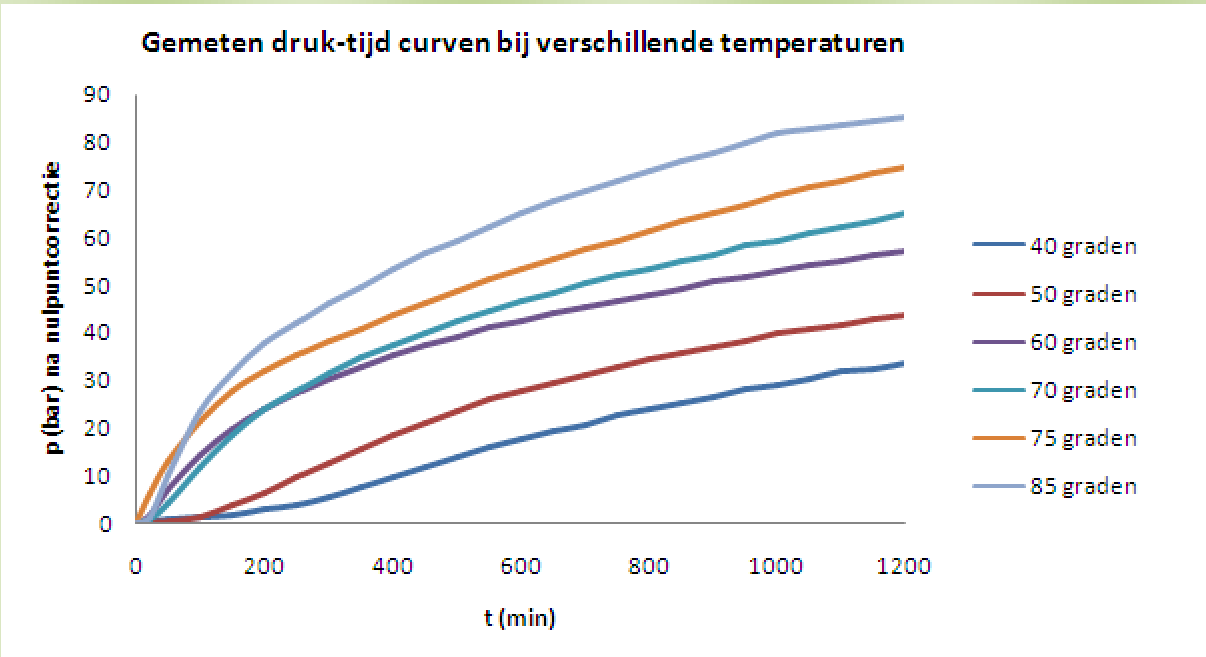

Fig 8

The curve as seen above in Fig 5 but showing the original build up for a short period of time.

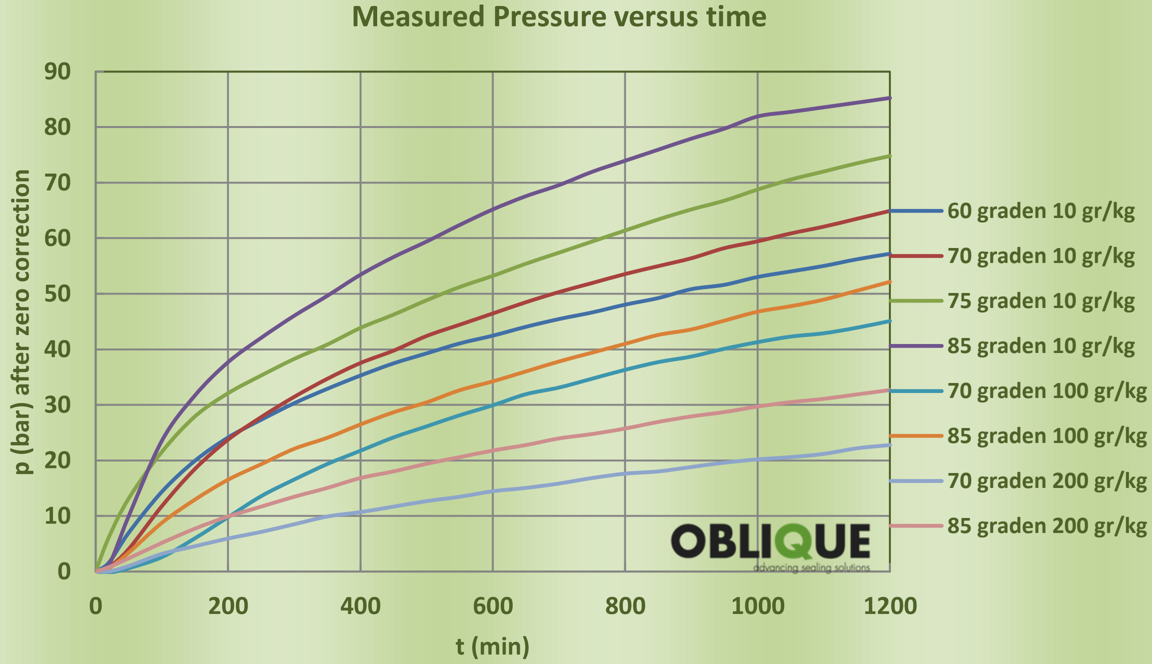

Fig 9

The effects of changes in salinity and Temperature on the pressure build up curves.

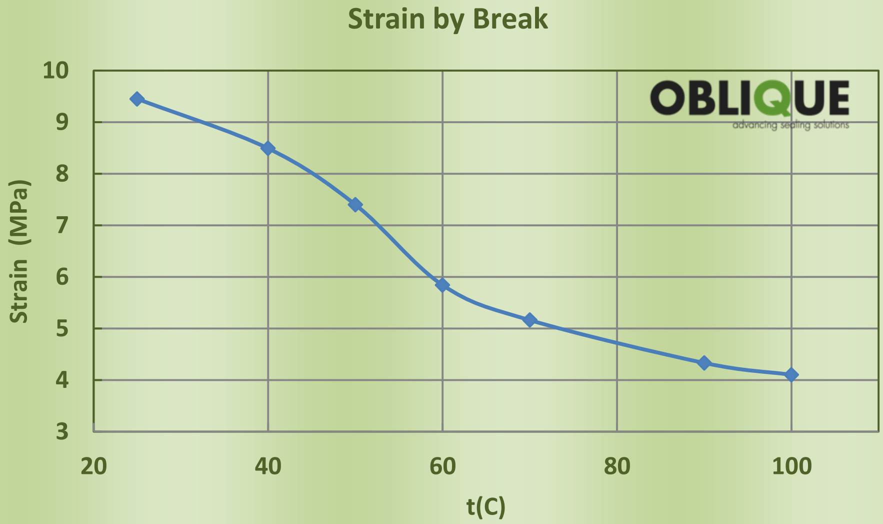

Fig 10

Fig 10 shows the effects of Temperature on Strain values. This change in value is one of the more important links in being able to

4.0 Conclusions and Recommendations

4.1 Conclusions

Both the test method as well as the test results show clearly the magnitude of the forces that swelling elastomer can generate when swelling. They also show that while absolute swell is low so is absolute pressure which indicates that for low temperature high pressure sealing applications sealing could be problematic or lengthy time delays need to be built into the system.

4.2 Recommendations

The original tests were limited by the availability of relatively cheap high temperature and low pressure Piezoelectric cells. The market needs to be re-visited to see if there are now new cells available with a higher performance. It is also recommended to look at this project again for use on very low temperature applications where swelling might be an issue and potentially focus of pressure performance rather than swelling performance.

5.0 Authorisation

The author wishes to acknowledge that this document is a condensed version of the work done by Student Richard Wessel as part of a College student sponsoring Program. Whilst the Author was responsible for technical and mechanical aspects of this study, Richard was responsible for the testing, and subsequent documenting of this work.

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