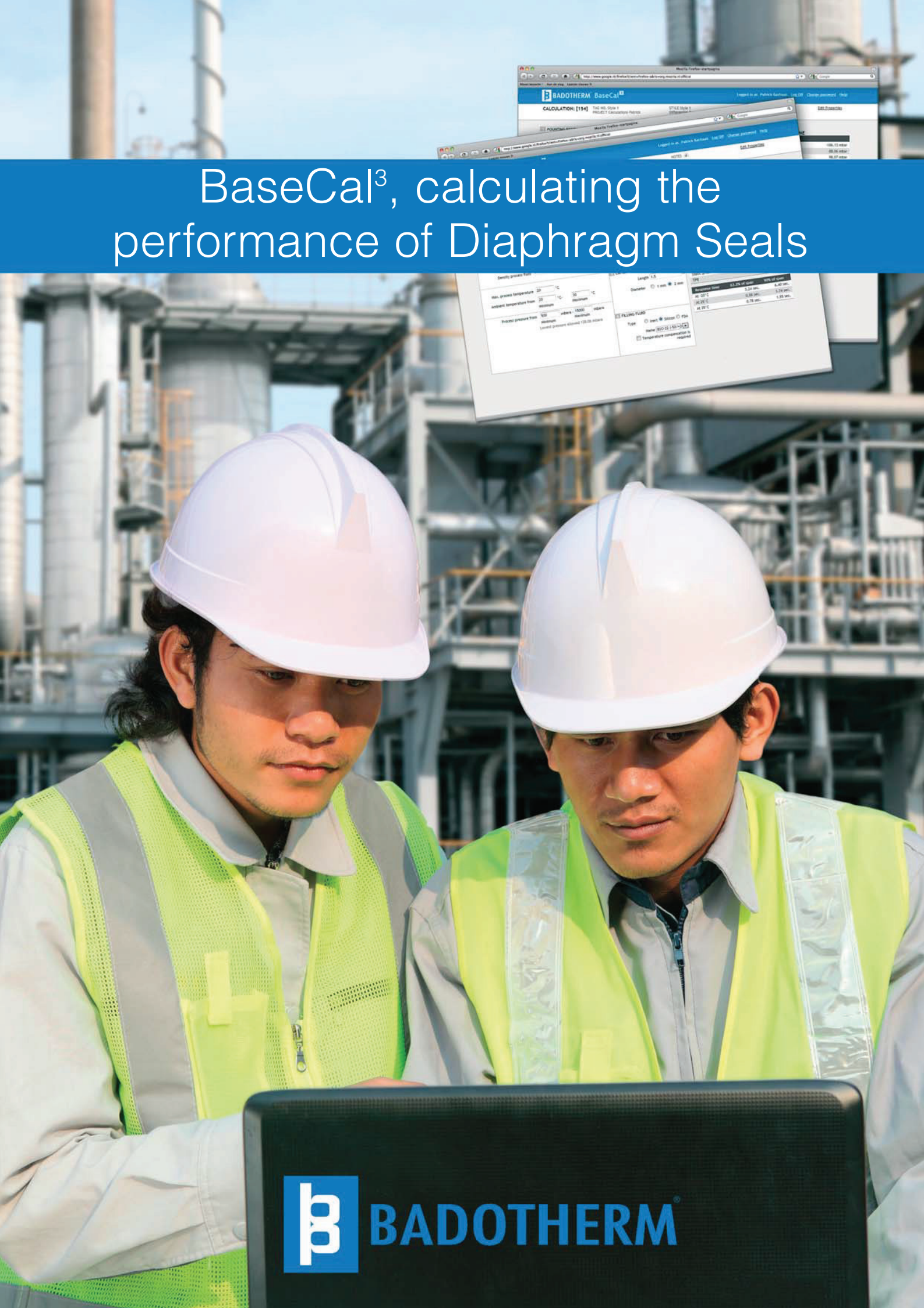


BaseCal³, calculating the performance of Diaphragm Seals

BASECAL: THE DIAPHRAGM SEAL PERFORMANCE CALCULATION TOOL

BaseCal is the web-based performance calculation tool for diaphragm seal applications, powered by Badotherm. The tool is intended for instrumentation engineers or anyone wishing to understand the effect of all variables and conditions on a diaphragm seal application. The tool calculates the total installed performance of the diaphragm seal application, including the transmitter. BaseCal allows you to easily change different variables and conditions, so you can simulate and analyse the effects of these different variables.

Mounting a diaphragm seal to a pressure transmitter changes the performance of the transmitter. The diaphragm seal application will have additional temperature and pressure effects and changes the response time depending on the transmitter diaphragm seal configuration. The performance of the entire system needs to be evaluated when specifying a diaphragm seal system for a new application to ensure satisfactory performance once installed.

BaseCal will help you select the best diaphragm seal application. The tool can also be used to evaluate and analyse existing measurement problems in your process. Our objective is to help you acquire more understanding and knowledge regarding diaphragm seals mounted on pressure instruments and overall, engineer better applications.

BaseCal is designed to support the user in selecting the correct diaphragm seal configuration to measure level, pressure, or differential pressure. It is not only the selection of the type of diaphragm seal that is important, but mostly the combination of all critical values that determine the performance of the application. BaseCal uses exclusionary logic to align Badotherm diaphragm seals with a variety of well-known industrial transmitters.

- BaseCal ensures configured combinations that would result in reliable measurements, especially during the design for dP level applications.
- BaseCal will not generate a result when the configuration made is in conflict with diaphragm seal technology.
- BaseCal is based on the laws of physics and provides possibilities and limitations for diaphragm seal technology.

BaseCal provides a total probable error (TPE) and response time based on the process conditions. It is important to know that BaseCal is independent and will not favour any particular solution or transmitter manufacturer. The outcome of a correct selected configuration and the diaphragm seal performance are warranted by Badotherm. This warranty is only valid when the diaphragm seal application is assembled and tested by Badotherm.

Diaphragm seal applications

A diaphragm seal application consists of a measuring instrument, typically a pressure transmitter, with one or two diaphragm seals and either a direct mount construction or with capillary lines, filled with a fill fluid. A correctly prepared and filled diaphragm seal application will accurately transfer process pressure on the diaphragm to the sensing element of the measuring instrument. This is based on Pascal's principle which states that a pressure exerted on a fluid is transmitted undiminished through that fluid in every direction. The process pressure exerts a force on the outside face of the seal, the flexible diaphragm. As the diaphragm flexes under this force it pushes inwards and attempts to compress the transmission or fill fluid behind the diaphragm. The transmission fluid is designed to withstand compression so the force is channeled proportionally and directly in to the measuring instrument to produce a resultant reading on the connected instrument.

The importance of proper engineered diaphragm seal applications

Diaphragm seals are often used in the most hazardous and extreme environments. The process media can be very aggressive, corrosive, toxic, and/or highly viscous. The process conditions can be with very high or low temperatures, or it can crystalize or polymerize. A proper diaphragm seal selection is important, because diaphragm seals are used in those conditions where processes are difficult to measure and accurate measurements are required. Accurate measurements and reliable pressure measurements enables better and more efficient plant management. A well-tuned diaphragm seal application engineered to your process conditions increases the durability and lifetime of the applications. This increases the general uptime of the instrument and reduces the total cost of the application. Using diaphragm seals gives the opportunity for easier and better maintenance, hence keeping costs under control.

PERFORMANCE EFFECTS ON DIAPHRAGM SEAL APPLICATIONS

The diaphragm seal application will be exposed to various factors and conditions influencing the performance, such as varying process and ambient temperatures, location of the transmitter, fluctuating static and process pressures, choice of instrument, etc. All these factors have an effect on the performance of the diaphragm seal application. These are also the factors which have a performance specification written around them on product datasheets (e.g. accuracy). This specification describes the worst case tolerance for the independent factor. BaseCal takes into account the worst case tolerance or error for each of the following factors:

- Process temperature effect: showing the error of a combined effect of the fill fluid characteristics and its related expansion or contraction error of the seal volume. This is based on the volumetric displacement of the diaphragm, which is dependent on thickness, diameter and material of construction. All based on the maximum process temperature.
- Ambient temperature effect: showing the error of a combined effect of the fill fluid characteristics and its related expansion or contraction error of the system volume (capillary + transmitter) showing the effect based on the maximum ambient temperature deviation.
- Mounting effect: this shows the error based on the (vertical) mounting of the transmitter and the diaphragm seals, taking also into account the change in density of the fill fluid based on the maximum ambient temperature deviation, and thus the pressure of the liquid column of the fill fluid.
- Accuracy effect: this shows the combined error based on the accuracy of the selected transmitter and the error of the selected diaphragm, taking into account the span effects related to the temperature effects.
- Static pressure effect: this shows the error based on the static pressure effect of the selected transmitter and selected diaphragm seal application (only applicable for dP measurements).

Total probable error (TPE)

It is difficult to make a general statement on the performance of any diaphragm seal application based on only one single effect or factor. It is the combination of the set of factors that determines the total performance. Statistical mathematics shows that the most realistic way to combine the effects of independent factors is by using the root-sum-square (RSS) method instead of just summing or averaging them. The result of the RSS method is what we refer to as the Total Probable Error of the diaphragm seal application. BaseCal's TPE is based on the following effects:

- Process temperature effect
- Ambient temperature effect
- Mounting effect
- Accuracy at process temperature
- Static pressure effect

The total probable error is the most likely error that will appear on the measurement outcome of the diaphragm seal application. It is based on the statistical mathematic combination of the worst case tolerances of the independent factors that influence the diaphragm seal application.

With BaseCal it is possible to show the difference between a well-engineered diaphragm seal application and a poor designed application. See below calculation example, based on a level measurement (see drawing).

EXAMPLE CALCULATION

Mounting position
Style 2
H1: 50cm
H2: 850cm

Process data
Distance between 0-100% level: 600cm
Density process fluid: 1.02 g/cm2
Maximum process temperature: 125 °C
Ambient temperature from 10°C to 55°C
Process pressure from 1050 to 15000 mbara

Diaphragm seal
size: 2"
type: BC
diaphragm material: AISI 316L

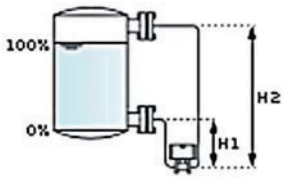
Capillary
length: 17mtr
diameter: 1mm

Filling Fluid
type: silicon
name: BSO-21

DIAPHRAGM SEAL PERFORMANCE

Total Probable Error (TPE)		
Process temperature	1.84 mbar	0.31%
Ambient temperature	5.19 mbar	0.86%
Mounting effect	22.58 mbar	3.76%
Accuracy at process temp.	1.17 mbar	0.19%
Static pressure effect	2.11 mbar	0.35%
TPE	23.37 mbar	3.89%

Response time	63.2% of span	90% of span
At -20°C	4740.12 sec.	9370.38 sec.
At 25°C	229.49 sec.	453.65 sec.
At 35°C	182.26 sec.	360.31 sec.



Based on these characteristics the following errors are calculated in BaseCal. The TPE is 23.37 mbar which equals 3.89% of the span. The Response time at 90% of the span at 25°C is 453 sec (almost 8 minutes).

IMPROVING THE DIAPHRAGM SEAL PERFORMANCE

In practically all situations it is not possible to change the process conditions as these are required to produce a certain product. However, changes in the selection of the diaphragm seal application variables are possible. In this example the following changes are made to improve the performance of the measurement:

- Reduce capillary length to minimum required length of 9.0 meter
  Resulting in a smaller ambient temperature effect due to smaller volume in the application. Accessiblilty of instrument should not be guiding, but performance of the measurement.
- Increase diaphragm size by selecting USL type seal
  Resulting in a smaller process temperature effect due to a larger diaphragm. Large diaphragms are more sensitive resulting in more accurate measurements. They are less sensitive to ambient and process temperature changes. Larger diaphragms are capable of larger volumetric displacements. This also allows them to accommodate the volume changes of the fill liquid in the instrument and long capillaries due to ambient temperature changes.
- Increase capillary diameter to 2mm
  Increasing your response time due to larger flow. This change slightly increases the ambient temperature effect.
- Change filling fluid to BSO-22, a silicone based fill fluid
  BSO-22 has a lower viscosity than BSO-21 and lesser expansion coefficient. Hence the response time improves, and the temperature effect reduces.
- Apply tracing on capillary and transmitter limiting the ambient temperature variation between 18°C to 22°C
  Eliminating the ambient temperature effect by keeping the temperature conditions constant. Tracing of +/- 2°C can be simulated by entering 18°C as minimum and 22°C as maximum ambient temperatures.

Support

Should you require any technical support in using BaseCal, or do you have any other questions relating to diaphragm seal technology, Badotherm is always there to help.

EXAMPLE CALCULATION - IMPROVEMENT

Mounting position
Style 2
H1: 50cm
H2: 850cm
Process data
Distance between 0-100% level: 600cm
Density process fluid: 1.02 g/cm2
Maximum process temperature: 125 °C
Ambient temperature from 18°C to 22°C
Process pressure from 1050 to 15000 mbara

Diaphragm seal
size: 2”
type: USL
diaphragm material: AISI 316L
Capillary
length: 9mtr
diameter: 2mm
Filling Fluid
type: silicon
name: BSO-22

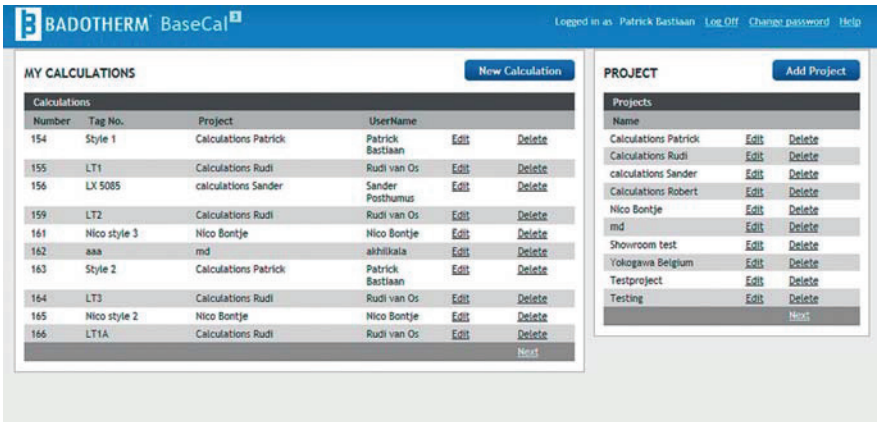
DIAPHRAGM SEAL PERFORMANCE

Total Probable Error (TPE)		
Process temperature	0.83 mbar	0.14%
Ambient temperature	0.13 mbar	0.02%
Mounting effect	1.59 mbar	0.27%
Accuracy at process temp.	0.54 mbar	0.09%
Static pressure effect	1.69 mbar	0.28%
TPE	2.53 mbar	0.42%

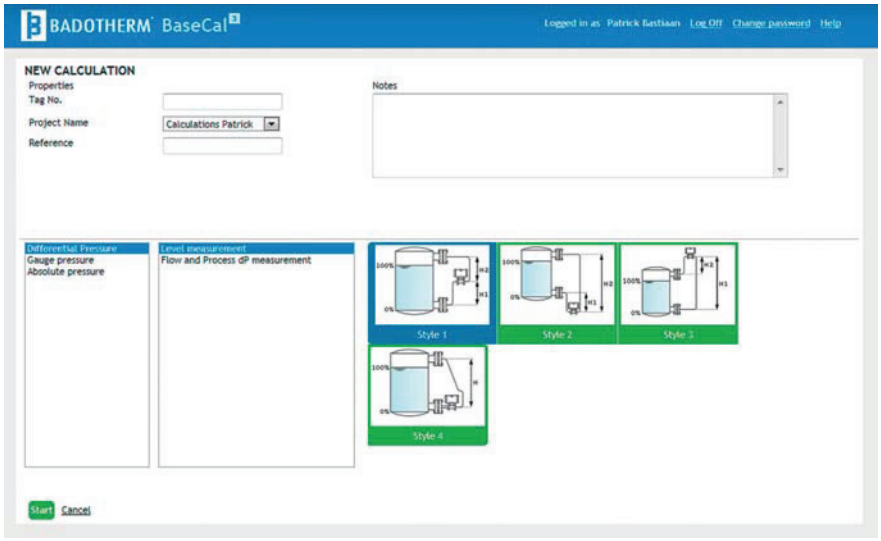
Response time	63.2% of span	90% of span
At -20°C	3.97 sec.	7.85 sec.
At 25°C	1.08 sec.	2.13 sec.
At 35°C	0.96 sec.	1.90 sec.

The diaphragm seal performance improves enormously. The TPE reduces to 2.53 mbar which is equal to 0.42% error on the span. The Response time at 90% of the span and 25°C reduces to only 2.13 seconds. Of course, you don’t have to apply all changes. You can check the effect of each of the steps. There can be a great advantage in using BaseCal to find the best solution for your application.

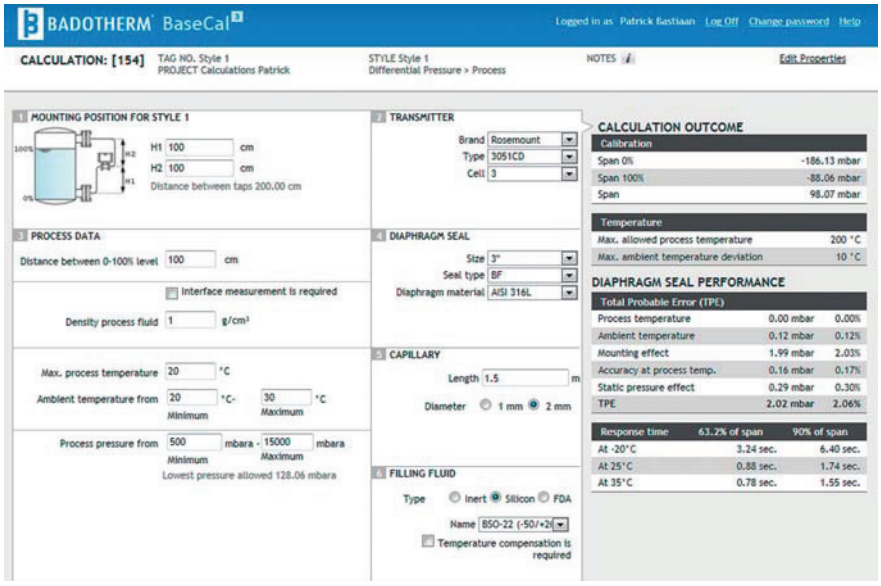
BASECAL3 - HOW TO GET STARTED



BaseCal is a web-based software tool available at www.BaseCal.com. In order to make use of BaseCal, you first need to register and create an account. After registering, an activation notification with a password will be sent to your email account. After you log on, you enter the main screen. The main screen has a section to manage your projects and a section to manage your calculations.



When starting a new calculation you have to enter some (mandatory) properties, such as tag number, and link these to a pre-defined project name. Furthermore you can add a reference and add notes in the text box. Next, you select the measurement: differential (level or flow), gauge, or absolute pressure measurement. The last step is the selection of the mounting style of the transmitter in relation to the diaphragm seal which is visualised in different drawings. Click start and you enter the calculation screen to start making the configuration.



The calculation screen is divided in two sections. On the left side you can enter all the different variables for the calculation in 6 different sections: 1) mounting position, 2) transmitter, 3) process data, 4) diaphragm seal, 5) capillary, and 6) filling fluid. On the right side the calculation outcome and the diaphragm seal performance is shown. The diaphragm seal performance consists out of the Total Probable Error and the Response Time of the diaphragm seal application.

About Badotherm

We are a European manufacturer of mechanical process instruments with a worldwide distribution network. We have regional Diaphragm Seal assembly facilities in Europe, the Middle East, India, the Far East and the Americas. We design, engineer and manufacture Diaphragm Seals, Pressure Gauges, Temperature Gauges and Thermowells, Instrument Valves and Manifolds. Next to our product offering, we develop tailor-made solutions for challenging conditions in the field of Diaphragm Seal measurements. Headquartered in the Netherlands, we employ over 225 people in seven different countries.

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