Thermal Bias Calculations

The following information can be useful in prediction of "worst case" errors when diaphragm seals are applied to both gage pressure and differential pressure instruments.

These calculations assume uniform gradual heating of the entire filled system. In most cases the temperature at the diaphragm seal will be different from the temperature of the pressure instrument. If temperature gradients exist, temperature weighting may be applied.

Reductions in fill fluid volume reduce errors. It is best to minimize volume whenever possible. In differential applications it is recommended to keep the volume of the high and low pressure legs identical.

Elastomer diaphragms have very low errors, but have unpredictable spring rates. Consideration should also be given to elastomer temperature limitations.

There are a number of factors that determine the amount of error created by temperature changes; the error (Err) can be expressed by the following equation:

$Err = (\ T)(E_t)(R_s)(V_T)$ expressed in inches H_2O

Where:

T = The number of degrees of the temperature change (°F).
E_t = The coefficient of thermal expansion of the fill liquid (the volumetric change constant of the fill liquid per °F).
R_s = The spring rate of the process diaphragm (inches H_2O pressure change/inch^3 of fill liquid volume change).
V_T = The total volume of the fill fluid in the diaphragm seal system (inches^3).

The above equation is simplified by assuming that the entire fill liquid volume is exposed to the same temperature shift (T). In reality, each element of the seal system (seal diaphragm cavity, capillary and instrument device) will be influenced a different amount due to temperature changes. Therefore, a more rigorous examination of the error would require that the liquid expansion in each element of the system be examined; for purposes of this approach the error equation can be expanded as follows:

$$Err = [(\ T_S \times V_S) + (\ T_P \times V_P \times L) + (\ T_D \times V_D)]\ [E_t]\ [R_s]$$

(expressed in inches of H_2O)

Where:

$V_T = V_S + V_P L + V_D$
V_T = Total volume of filled system (inches^3)
V_S = Volume of seal (inches^3)
V_P = Volume of capillary (inches^3/foot of length)
V_D = Volume of inst. device (inches^3)
L = Length of capillary (feet)
T_S = Change in temperature of liquid in seal (°F)
T_P = Change in temperature of liquid in capillary (°F)
T_D = Change in temperature of liquid in inst. device (°F)

In order to analyze the significance of these temperature induced errors, it is helpful to express the error as a % of measured span. This can easily be done by the following equation:

$$\text{Error \%} = \frac{Err}{\text{Measured Span (in inches } H_2O)} \times 100$$

Table I. Fill Fluid Expansion Factors

Fill Fluid	E_f (1/°F)	Temperature Range (°F)
Glycerine	0.000294	30 - 300
Silicone 200-10	0.000600	-35 - 450
Silicone 704	0.000444	30 - 520
Silicone 710	0.000430	30 - 650
Silicone 550	0.000520	-40 - 600
Silicone 510	0.000533	-60 - 400
Fluorolube FS-5	0.000486	-40 - 500
Silicone 200-350	0.000533	0 - 300
Halocarbon Oil 6.3	0.000565	-40 - 400
Ethylene Glycol	0.000294	-30 - 300
Propylene Glycol	0.000406	-50 - 200
Syltherm 800	0.000962	-40 - 450
Mineral Oil	0.000356	Note 1
Neobee M-20	0.000511	-4 - 320

Note 1. To be advised.

Table III. Accessory Internal Volume

Component	Volume
Capillary (1)	0.053"^{3}/ft
2" Nipple	0.024"^{3}
4" Nipple	0.048"^{3}

(1). Volume is based on capillary 1/8" (3.17 mm) O.D. x 0.025" (0.635 mm) wall.

Table II. Diaphragm Spring Rates and Volumes

Diaphragm Diameter Inches	Applicable Series	R_S	V_S
0.83	200	140,000	0.015
1.38	140K	10,000	0.19
	140KT		0.12
	300BX, 700		(a)
1.90	190K, 300BX, 700	2,600	(a)
2.40	300A/J3	800	0.18
	300B		0.21
	300J4		0.19
	300BX,700		(a)
	300A/B-Aminco		0.07
2.50	100A-5M/10M	800	0.35
	300BX, 700		(a)
3.00	100A, 330A	240	0.48
	100B, 330B		
	300BX,700		(a)
4.00	300BX,700	40	(a)
	600A/B		0.41
	600A/B-Aminco	40	0.13
4.80	300BP/BT	40	0.41

(a) Varies depending on seal configuration.
(b) This data is based on 316L diaphragms, and an average of the most common seal configurations.