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Measurement Solutions

Pressure & Level • Temperature • Force • Needle & Manifold Valves • Diaphragm Seals

Diaphragm Seals Thermal Error Calculations Types 10, 25, 25H, 30

Three major factors contribute to thermal error:

1) Type of fill fluid used
2) Fill fluid volume
3) Diaphragm flexibility

The choice of fill fluid in Table I contributes directly to thermal errors in proportion to the coefficient of thermal expansion of the fluid. The resulting internal pressures produce adverse forces on the diaphragm which in turn are reflected in the pressure instrument.

The fill volumes in Table II & Table III contribute significantly to thermal errors. The greater the fill volume the greater volumetric expansion. Whenever possible, fill volumes should be minimized. If fill volumes cannot be adjusted, choose a fluid with the lowest coefficient of thermal expansion. The flexibility of the diaphragm is expressed as a spring rate (Table II). The smaller the diaphragm, the greater the spring rate. Any force used to move the diaphragm is considered an error because it subtracts from a direct reading of the pressure. Not only does it take more force to push a smaller diaphragm (spring bias), but high spring rates also reflect greater thermal errors when internal pressures push on it. It is desirable to have the lowest spring rate possible.

The thermal error (Err) can be expressed by the equations below. The first error formula (1) assumes a uniform gradual heating of the entire filled system. The second error formula (2) is used when the diaphragm, capillary and pressure instrument are at different temperatures and a thermal gradient exists.

Table I. Fill Fluid Expansion Factors

		Recommended Temperature Range		
Fill Fluid	**Viscocity (cSt)**	**Vacuum/ Compound**	**Pressure**	**E_t(1/°F)**
Glycerin (99.7%)	1,110	N/A	60 °F to 462 °F	0.000294
Silicone 200	5	-130 °F to 176 °F	-130 °F to 356 °F	0.000588
Silicone 200	50	-4 °F to 250 °F	-4 °F to 392 °F	0.000582
Silicone 200, Food Grade	350	N/A	0 °F to 572 °F	0.000533
Silicone 510	50	-60 °F to 250 °F	-60 °F to 400 °F	0.000533
Silicone 550	125	-40 °F to 325 °F	-40 °F to 450 °F	0.000520
Silicone 710	500	0 °F to 348 °F	0 °F to 500 °F	0.000430
Halocarbon 4.2 Oil	4	-40 °F to 176 °F	-40 °F to 347 °F	0.000565
Syltherm 800	9	4 °F to 392 °F	-40 °F to 750 °F	0.000962
Mineral Oil	57	-4 °F to 338 °F	-4 °F to 482 °F	0.000356
Neobee M-20	10	-10 °F to 200 °F	-10 °F to 400 °F	0.000511

Table II. Diaphragm Spring Rates and Volumes

Diaphragm Diameter Inches	Applicable Type	R_s	V_s
1.28	25	10,000	0.19
	25H		0.12
2.10	29	2,600	0.85
2.40	30	800	0.18
3.00	10	240	0.48

Table III. Accessory Internal Volume

Component	Volume
Capillary (1)	0.053"/ft³
2" Nipple	0.024"/ft³
2" Nipple	0.048"/ft³

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

Equation 1

Err = $(T)(E_t)(R_s)(V_T)$ expressed in inches H_20

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_20 pressure change/inch³ of fill liquid volume change).
- V_T = The total volume of the fill fluid in the diaphragm seal system (inches³).

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:

$$\text{Error \%} = \frac{\text{Err}}{\text{Measured Span (in inches } H_20)} \times 100$$

Equation 2

Err = $[\,(T_s \times V_s) + (T_p \times V_p \times L) + (T_p \times V_p)\,]\;[\,E_t\,]\;[\,R_s\,]$ expressed in inches H_20

Where:

- V_T = $V_s + V_p L + V_D$
- V_T = Total volume of filled system (inches³)
- V_s = Volume of seal (inches³)
- V_p = Volume of capillary (inches³/foot of length)
- V_D = Volume of inst. device (inches³)
- 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)

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