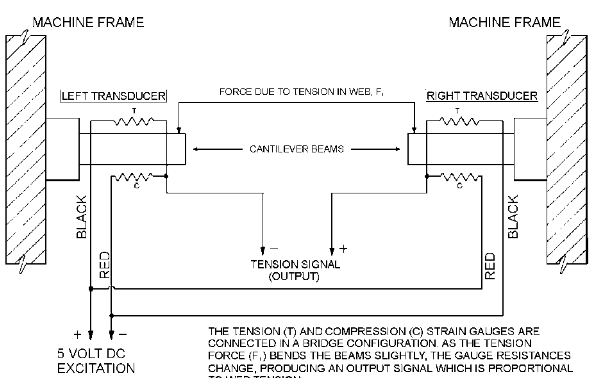
TENSION TRANSDUCER STRAIN GAGES: WHICH TECHNOLOGY IS BETTER?

The Foil vs. Semiconductor (Silicon) Strain Gage Debate

DFE has been producing high-quality strain-gage tension transducers since 1974. Web process manufacturers and OEMs buy DFE transducers because they are accurate, long-lasting, reliable, and virtually maintenance-free.

DFE uses a silicon-type strain gage as the transducer tension-sensing element because of the gage's proven durability, longevity and low-noise output. The alternative, a foil-type strain gage, is used by some of our competitors. Although a much older technology, foil strain gages enjoy continuing popularity because of their widespread availability and relatively low cost.



Typical shaft-end transducer arrangement showing strain gage wiring configuration

One North American manufacturer of foil-gage tension transducers claims that **foil strain gages** drift 56% less than **semiconductor gages**. The implication is that foil gages are the superior choice for tension sensor technology.

In this firm's ad campaign, the term 'drift' was not defined, nor was it clear where readers could learn more about the study details or methodology used to measure the 'drift' from the differing technologies. We also noted that this manufacturer was careful to apply the claim only to the strain gages themselves <u>not</u> to transducers utilizing the gages.

Regarding methodology, presumably this foil-advocating competitor compared voltage output data directly from the company's best transducer (load cell) against the Brand X semiconductor-gage transducer over some extreme temperature range. The text does not qualify this.

Dover Flexo rarely receives negative customer feedback about transducers, and never has it been about temperature-related drift. Our initial reaction was to dismiss the attack against silicon strain gages. After all, even though *the output from all strain-gage tension devices drifts slightly due to temperature changes and other effects*, the fractional amount is insignificant in the industrial applications we serve. And *56% less than slight* is *meaningless* in real terms.

Without more detail about the test conditions under which the drift data was derived it was difficult to invalidate this manufacturer's deceptive claim. However, we do not accept misleading assertions at face value. The following is a comprehensive and transparent analysis of tension transducer performance, strain gages and drift issues.

Strain Gages and "DRIFT".

Transducers are typically not used as tension sensors in isolation but are components of a measurement system with the transducer output signal being amplified and often observed on a readout display of an indication device or controller. What is commonly referred to as "drift" is also known as "null displacement" or "zero shift". It is a change in the tension transducer's no-load output signal over time. The 'drift' we sometimes see when looking at zero tension on an unloaded transducer is manifested as a slight offset from the zero point on the output device's meter.

'Zero-shift' error is a common condition that is easily corrected for and does not suggest flawed performance from a transducer. The observed meter scale offset from zero can be corrected simply by resetting the amplifier's ZERO adjustment.

Some transducer manufacturers contend that the zero shift condition can and should be corrected by completely recalibrating the amplifier to the transducer. However, complete recalibration is rarely necessary.

When an amplifier/ indicator device is originally calibrated to operate with a transducer, the effective measurement range does not change even if a zero shift occurs over time. For instance, if the tension meter were calibrated for a 50 lb range, the range is still 50 lbs even if the output with no load on the transducer has moved from zero. The entire 50 lb range has simply shifted upscale or downscale by a small amount.

Zero-Shift Causes

Zero-shift effects can be caused by one or more of these factors:

1) **Preloading**. Incorrect installation of the transducers can result in a preload on the sensing beams. This is very common and is not a shortcoming of the transducer. Drift from preloading can be very serious. Fortunately, eliminating the preload condition requires only an installation adjustment; this will also usually eliminate the zero shift. According to Dover Flexo's Technical Support Team, transducer preloading is the most common cause of reported zero shift. DFE transducers are designed with a coupling that minimizes the likelihood of an incorrect installation.

2) **Stress relief**. The sensing-beam metal is stress relieving over time. This usually finishes within 1-2 weeks after first use. The gage detects the changes of strain in the metal and thinks it is an applied load. This effect is relatively small unless the beam is made from a material unsuitable for strain gage use.

3) **Final curing**. The final stage of gage adhesive curing is occurring. This typically ends 2-3 weeks after the strain gage is applied. This is also a small effect but greater than the stress relief effect.

4) **Incidental contact**. Something is touching the transducer roll other than the web. Perhaps a gear is installed on the shaft, or a pulley and belt, or the roll is filled with water, etc. For any transducer to output an accurate tension signal, nothing but the web must contact the roll and nothing can contact the shaft.

5) **Electronic problems or wiring errors**. Power supply or amplifier circuitry drifting may appear to be zero shift. Faulty ground connections can allow the electronics to drift. This can also appear to be zero shift, but, of course, it's not.

6) **Ambient temperature variation**. This is an issue for all transducers regardless of the

type of strain gage. It also affects the magnetoelastic- and LVDT-type transducers. DFE has taken special care to minimize the effects of temperature variation with proprietary design and manufacturing techniques.

In addition, regarding the criticisms of semiconductor gages made by some competitors, these facts should be considered:

a) Silicon strain gage materials are available in a wide variety of physical and electrical characteristics. True statements made about one material may be completely inaccurate for another. This makes it possible for a competitor to infer that a silicon strain gage that has a very high temperature coefficient means that the DFE gages do too. Not true. All silicon strain gages are NOT the same.

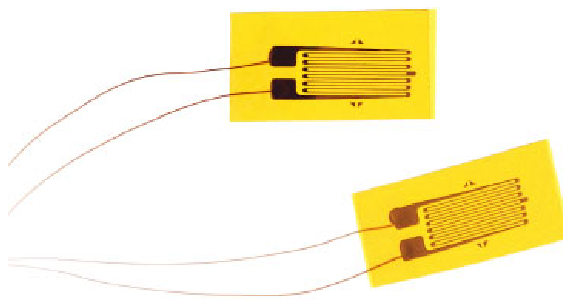
b) Zero shift from temperature variation is not a problem for most applications. Only processes incurring wide temperature swings exhibit it to any meaningful extent. And these situations can be mitigated with simple shielding techniques or directed ventilation. Temperature-induced zero shift rarely affects the quality of the product being processed.

c) Competitor advertising which touts less drift is actually a tempest in a teacup. The elimination of all drift would have a negligible effect on process quality.

The Real Differences between Foil and Silicon Strain gages

While functionally similar in that they each demonstrate a resistance change under an applied strain, there are two major differences between silicon and foil strain gages:

1) Semiconductor gages have electrical outputs relative to strain applied that are 25 to 50 times that of foil gages.
2) The available geometries of silicon gages are typically small, simple straight strips. Metal foil gages are configured in various complex 2-dimensional patterns. This increases the area exposed to applied strain in order to boost the signal output.



Typical metal-foil strain gages

How do these differences affect transducer design and performance?

- **Overload Protection.** The greater sensitivity (larger output) of silicon gages means that less stress is needed to produce a useable amount of signal, and therefore a transducer's bending beam can be built more robustly and better protected from overload than beams with foil gages. Transducers designed with silicon gages are typically highly reliable, long-lasting and trouble-free.

  With their lower sensitivity, foil-gage transducers must operate close to the gage yield point (point of permanent deformation) at load in order to deliver a useable amount of signal. Therefore their beams are designed to bend more and, as a consequence, are less forgiving of overloads.

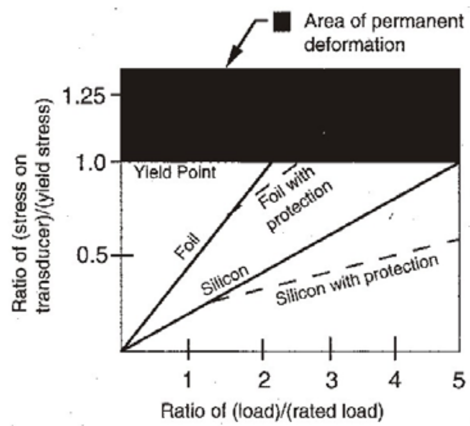


Figure 1. Typical force transducer stress vs. load using foil gages or silicon gages with and without overload protection.
Courtesy of Mr. Robert Little, ATI Industrial Automation, www.atindustrialautomation.com

- **Fatigue Life.** Silicon gages have an extremely long fatigue life as compared to foil gages. This is an important issue for tension transducers, which are sometimes operated continuously for up to 3 shifts per day. As a result of operating near their yield points, foil gages suffer from shortened life spans and fatigue life when compared to silicon gages. (Have you ever seen an industrial foil-gage transducer with a 5-Year Warranty?)

- **Low tension output and extended range.** The larger signal output from silicon gages allows measurement of very low tensions. Transducers with foil gages have difficulty with low tensions because the nominal output is so low it can be lost in the ambient electronic noise present in the electrical system. Not so with silicon gages. Even at relatively low tensions the output is strong and usable. The higher output magnitude also makes it possible for transducer signals to be brought directly into PLC inputs, lowering system costs. Transducers built with silicon gages typically have a broader operating range.

- **Electronic noise and interference.** The low output of foil-gage transducers requires associated amplifier electronics to have a much higher gain for the amplified signal to be useful. The high gain makes the system much more susceptible to EMI and RF noise. Sudden changes in tension resulting from electronic transients can create wasted product if the tension signal is part of a closed-loop control system.

- **Gage Creep.** When foil gage beams are manufactured, the thin foil gages are typically adhered to a thin organic substrate, which is then adhered to the transducer beam. So there are two layers of adhesive and one layer of substrate between the gage and the beam. Silicon gage transducers use only one thin layer of adhesive between the gage and the beam. This makes silicon gages much less susceptible to gage creep (drifting output over time) and non-repeatability. Transducers using silicon gages tend to maintain better accuracy over the long-term.

- **Hysteresis.** Silicon-gage transducers exhibit less hysteresis than foil-gage transducers and are therefore more repeatable. The hysteresis effect can be described as an offset in measured output (voltage) for two different occurrences of the same input value (i.e. tension). Hysteresis can be measured by measuring device output as we approach a given input value from opposite directions (i.e. increasing and decreasing tension).

  For example, let's consider a transducer loaded to 40 lbs and producing 115mV output. If we apply 50 more lbs and then remove the 50 lbs a transducer with no hysteresis will return exactly to 115mV output. Take away 20 lbs and then add it back. Output should be 115mV if there is no hysteresis. If the transducer shows hysteresis, the output might go to 120mV in the first case and 100mV in the second case.

Obviously, significant hysteresis is undesirable because it affects measurement accuracy.

Other Misleading Advertising Claims

Another web tension equipment manufacturer and foil-gage advocate claims that silicon strain gages "can be severely affected by temperature, steam, corrosive gases, chemicals and many other common contaminants." But any type of strain gage is affected by these factors. This is well known, so everyone puts a protective coating like RTV over the gages. No manufacturer of transducers that we know of uses unprotected gages of any type. This is just another misleading, unfounded claim.

Some years ago, this particular manufacturer made silicon gages. DFE tried to use some but the gages were poorly made. The manufacturer in question finally discontinued making them. Now that they are a foil-gage competitor to DFE, this company suggests that no one is able to make a viable, reliable silicon gage for tension measurement. Wrong again.

Some manufacturers of foil gage transducers highlight their use of a "full wheatstone bridge" electronic configuration as a major competitive strength. They don't mention that they must use this configuration in order to generate a sufficient output signal. This technology doesn't offer any improvement over DFE's transducers because we also employ a full wheatstone bridge circuit.

It seems that in the crowded and mature tension control industry, the foil gage players are clutching at straws to enhance their product appearance.

Advantage: Silicon Gages

In conclusion, there is no real performance advantage to *using* foil-gage tension transducers. The benefits of this technology to the foil-gage transducer *manufacturer* include low cost and high availability. In comparison, transducers made with semiconductor (silicon) gages are stronger, more accurate and longer lasting. They are less susceptible to electrical noise, and cover a wider tension range. If DFE chose not to use silicon strain gages, we would not be able to offer a 5-Year product warranty.

We suggest to customers considering the purchase of foil-gage tension transducers from our drift-focused competitors to request and examine the data and exact research details under which the competing transducer types were compared. Ask them whose transducers and which models were used in the study. What temperature range was used, and what time frame, and how were the conditions controlled? Was the study a fair apples-to-apples comparison?

The most important question when deciding on one's transducers: which performance characteristics are really most critical to the success of the given web process?

If you'd like to read more about this subject from an unbiased source please download the report ***Silicon or Foil: Which Strain Gage should be used in Force/ Torque Transducers?*** *(538KB pdf) at http://www.dfe.com/pdf/Silicon-vs-Foil.pdf.*

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