Overview and Application of Internally Gaged Force Sensing Fasteners

HOW STRAINSERT BOLTS AND STUDS CAN BE APPLIED

- Fasteners can be accurately tightened and the preload measured to a tolerance of better than 1% of the maximum load. This method can replace the most common method of measuring load with a torque wrench which has load measurement accuracy many times worse than +/-20%.
- Bolted equipment can be inspected after assembly. There is no practical method – except with internally gaged bolts – to measure preload on a tightened bolt.
- Internally gaged fasteners strategically placed in equipment can act as built-in sensors for overload detection.
- Assemblies can be monitored and inspected under simulated or actual service conditions to see if any external forces exceed the preload. Overloads due to vibration, shock, etc. can be easily measured at any time during the life of the assembly.
- Bolts may be permanently installed providing very accurate analysis of bolt loading over a continuous time period. In applications of this type, internally gaged bolts become a new basic research tool.
- Gaged bolts and studs can be used as tension load cells or modified for compression applications.

STRAINSERT FASTENERS OFFER:

- **Bolts with Full Load Carrying Capacity** – Bolts with Strainsert internal gage installations have the full load carrying capacity of the original ungaged bolt. Cross-sectional area of the threaded portion of a full shank bolt is always smaller than the cross sectional area of the shank. The difference in areas permits a hole to be drilled in the shank for the gage installation without weakening the bolt. (#10 and 1/4" diameter bolts may have reduced load carrying capacities).
- **Guaranteed Accuracy** – Giving precise calibration and accuracy guarantees for Strainsert Bolts and Studs is not a simple matter. Most gage installations are in fasteners supplied by the customers or purchased from the fastener manufacturers. Consequently, there is no control over the fastener material, design or quality.

For this reason, Strainsert Bolts and Studs typically have a combined error due to repetition, nonlinearity and hysteresis of less than 1% of maximum load.

- **Loading of Gage Installations –** Prior to shipment, all gage installations are calibrated as part of the quality control procedure. Unless otherwise specified, bolts and studs are loaded to approximately 70% of yield, up to 500,000 lbs.

CALIBRATION SERVICE AVAILABLE

For applications which require the utmost in accuracy, detailed calibration data can be supplied on order for any Strainsert Bolt and Stud. Loading is done in five equal steps up to maximum load; unloading is done in similar steps in reverse. The entire calibration process is repeated three times. For each step-load, the signal is recorded.

Calibration readings are analyzed and compared to either a best fitting or customer specified straight line calibrations. Linearity, repetition, and hysteresis are determined from the data. For calibrations up to 500,000 pounds, in-plant loading facilities are used. Bolts or studs which require higher loads are calibrated on other suitable devices. See Calibration Section for further discussion of calibration options.

INTERNAL GAGE INSTALLATIONS

Gages installed in Strainsert Bolts and Studs are foil type, electric resistance strain gages. They are bonded and sealed in a small hole along the longitudinal neutral axis of the bolt. After installation the gages are practically immune to physical, chemical and environmental damage.

Internal gage installations by Strainsert are as good as the very best external gage installations. The patented installation technique (U.S. Patent #2,873,341) has been proven over 40 years of successful applications.

Actually, there are reasons to expect the performance of an internal gage installation to be superior to conventional external installations. A further benefit, gages in a full-bridge internal installation are located very close to each other and are bound to be in a uniform temperature environment.

GAGE CONFIGURATION COMPENSATES FOR BENDING AND TORQUE

Quarter-bridge installations consist of two gages in series mounted 180 degrees apart on the circumference of the hole with the grid in an axial direction. This arrangement provides the best indication of bolt load and also helps minimize bending and torque influences. To eliminate lead-wire temperature effects, a three-wire lead system is used. Trim resistors or other compensations are not furnished with quarter-bridge gage installations.

Full-bridge internal gage installations are made in the same size hole as for quarter-bridge. They are wired as shown on page 37 with axial active gages and circumferential complementary gages. Trims and compensations are offered only if there is room for the necessary components.

FORCE SENSING BOLTS AND STUDS IN BOLTED STRUCTURES

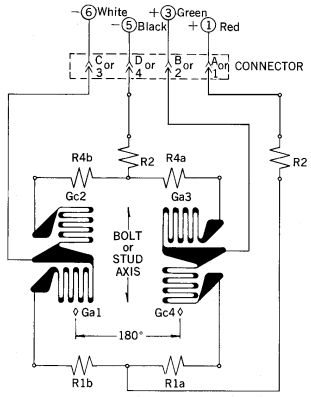
When structures are joined together by tightening or "torquing" a bolt or a stud, a tension force is induced in the shank of the fastener. This tension force causes a compressive or clamping force on the joined members. In the absence of other external forces, this clamping force is exactly equal to the tension in the bolt or stud. Thus, a force sensing fastener will provide very accurate measure of such clamping force.

In service, bolt preload may be relieved due to one or more causes. This could result in malfunction or failure. Ability to measure bolt force by means of force sensing bolts can avoid such difficulties. It is important, however, to make measurements on the bolted assembly when no external or service force are present in order to have direct before and after comparison.

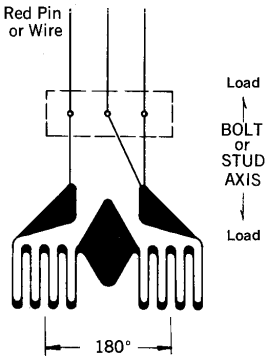
Force sensing bolts and studs can be very useful in determining effects of operational service forces, although it should be clear that the bolts do not directly measure service forces. One exception to this occurs when the service force is larger than the clamping preload, resulting in joint separation. Under this condition, the service force is equal to the bolt force, which is measured accurately by the force sensing bolt.

When the operational service force only partly relieves the compressive force at the joint, but is too small to cause separation, or when service force is in the direction increasing joint compression, then the bolt force is no longer equal to either the compressive clamping force or the service force. It is equal to their difference. There may be a small change in the bolt force as the service force is applied, but this will be far smaller than the service force, which will mainly increase or decrease the compressive clamping force on the joined members. The bolt force change due to service force will depend mainly upon the relative stiffness between the bolt and the bolted member, as well as other variables. Determination of service or external forces in a bolted joint by means of preloaded force sensing bolts is not recommended.

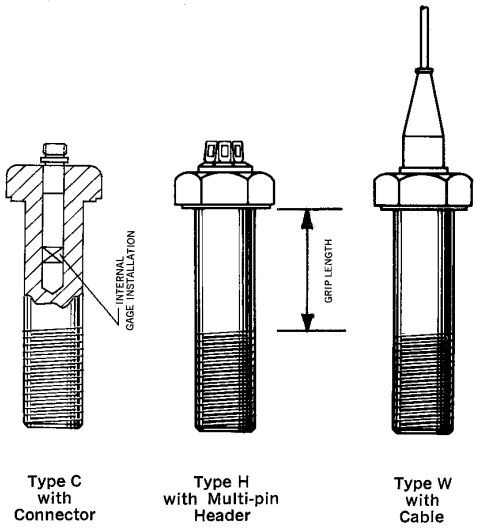
INTERNAL GAGE WIRING DIAGRAMS



Full-Bridge (FB)



Quarter-Bridge (QB)



Type C with Connector | Type H with Multi-pin Header | Type W with Cable

LEGEND

Ga:	Active Gage
Gc:	Complimentary Gage
Excitation:	+1 and –5
Signal:	+3 and –6

BRIDGE TRIM RESISTORS

Initial Zero Load Balance:	R1a or R1b
Signal Trims:	R2 (Optional)
Zero Load Temp. Compensation:	R4a or R4b (Optional)

U.S. Patent No. 2,873,341

LEAD WIRE TERMINATIONS

Three basic lead wire terminations are available for bolts and studs:

- Type C – screw type miniature connector, requires mating cable assembly.
- Type H – a multi-pin header for soldered lead wire connections
- Type W – permanent factory installed cable

Quarter- and full-bridge internal gage installations can be made in bolt sizes down to 1/4 inch diameter.

1/4 inch diameter screws are available as Type H or Type W only. (type C available with raised adapter)

Lead wire configurations for studs depends on size. See price and stock list for a guide to the ST Series Studs.

BOLT GRIP LENGTH REQUIREMENTS

For proper performance the gage installation in a bolt should be below the head in the unthreaded section of the shank. This is the point where strain is most representative of bolt force. Minimum grip lengths recommended for various bolt sizes are shown below.*

BOLT DIA. (inches)	1/4	5/16	3/8	7/16	1/2	9/16	5/8
MIN GRIP LENGTH (inches)	7/8	1	1	1	1-1/16	1-1/8	1-1/4

BOLT DIA. (inches)	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2
MIN GRIP LENGTH (inches)	1-3/8	1-1/2	1-5/8	1-3/4	2	2-1/4	2-1/2

Bolts with shorter grip lengths are gaged on special order.