The field of force measurement has the same types of constraints as any other discipline ... weight, size, cost, accuracy, useful life, rated capacity, extraneous forces, test profile, error specs, temperature, altitude, pressure, corrosive chemicals, etc. Flexures are configured in many shapes and sizes, to match the diversity of applications out in the world.

Bending Beam Cell: The cell is bolted to a support through the two mounting holes. When we remove the covers, we can see the large hole bored through the beam. This forms thin sections at the top and bottom surface, which concentrate the forces into the area where the gages are mounted on the top and bottom faces of the beam. The gages may be mounted on the outside surface, as shown, or inside the large hole.

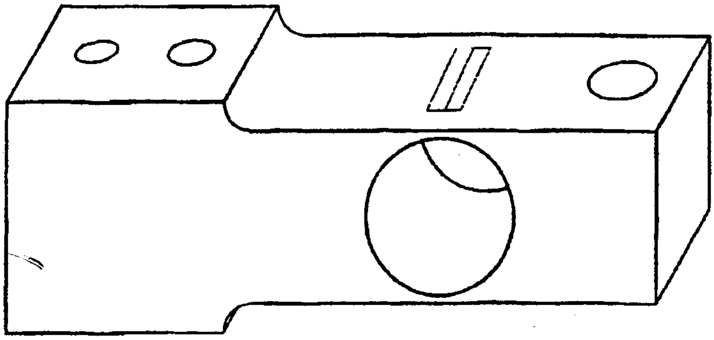


Figure 8. Bending Beam Flexure

The compression load is applied at the end opposite from the two mounting holes, usually onto a load button which the user inserts in the loading hole. MB series cells are available in capacities from 5 to 250 lbf. SSB series cells have a splash-proof sealing cover and come in sizes from 50 to 1000 lbf.

Double-ended Bending Beam Cell: A very useful variation on the bending beam design is achieved by forming two bending beams into one cell. This allows the loading fixtures to be attached at the threaded holes on the center line, between the beams, which makes the sensitive axis pass through the cell on a single line of action. In general, this configuration is much more user friendly because of its short vertical dimension and compact design.

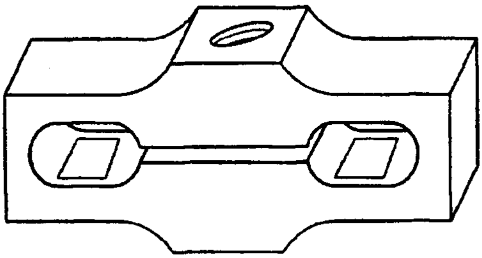


Figure 9. SML Double-ended Beam

The SML cell is available in capacities from 5 to 1000 lbf; the 5 and 10 lbf cells can also be ordered with tension/compression overload protection, which makes them very useful for applications where they could be damaged by an overload.

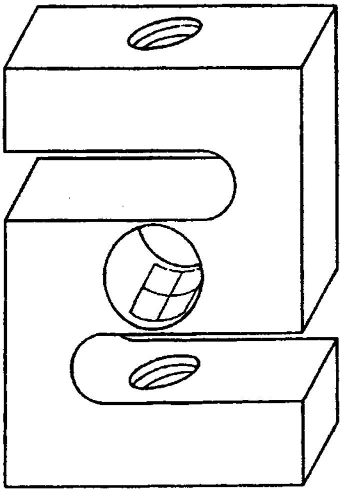


Figure 10. Typical S-Beam

S-Beam Cells: The SM (Super-Mini) cell is a low-cost, yet accurate, cell with a straight-through loading design. (See Figure 10). At slightly higher cost, the SSM (Sealed Super-Mini) is a rugged S-cell with splash-proof covers. Either series gives exceptional results in applications which can be designed so as to operate the cells in tension.

Although the forces on the gaged area appear the same as in a bending beam cell, the theory of operation is slightly different because the two ends of the "S" bend back over center, and the forces are applied down through the center of the gaged area. However, considering it as a modified bending beam cell may assist the reader in visualizing how the cell works.

Some caution should be exercised when using these cells in compression, to ensure that the loading does not introduce side loads into the cell. As we shall see later, the Low Profile™ series is better suited to applications which may apply side loads or moment loads into the cell.

SMT Overload Protected S-Cell: The incorporation of overload protection is a major innovation in S-Cell design. By removing the large gaps at the top and bottom, and replacing them with small clearance gaps and locking fingers, the whole cell can be made to "go solid" in either *mode* (tension or compression), before the deflection of the gaged area exceeds the allowed overload specification. Those gaps and fingers can be seen in Figure 11, which shows the flexure with the covers removed. The double-stepped shape of the gaps is necessary to ensure that overload protection operates in both modes.

The SMT series is ideally suited for applications that may generate forces as high as eight times the rating of the load cell. The two loading holes are in line vertically, which makes the cell easy to design into machines which apply reciprocating or linear motion, either from a rotating crank or from a pneumatic or hydraulic cylinder.

The covers provide physical protection for the flexure, but the cell is not sealed. Users should therefore be cautioned not to use it in dusty applications which might build up collections of dust in the overload gaps. Should a buildup occur, the overload protection would come into effect before the load reaches the rated capacity, thus causing a non-linear output.

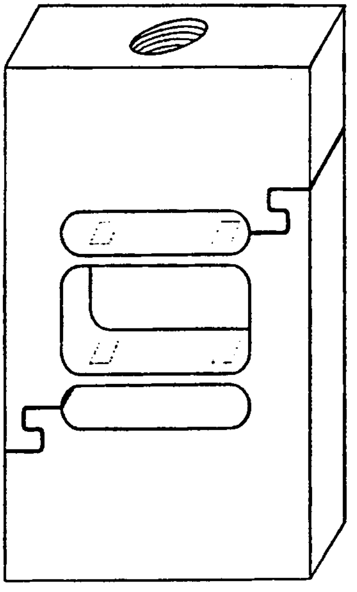


Figure 11. SMT Overload Protected Flexure

The SMT series is especially suited for use in laboratories or medical facilities where large loads could be applied accidentally by untrained or non-technical personnel.

LBM and LBT *Load Button* Cells: Many applications require the measurement of forces in a very confined space. Where high precision is required, the Interface *Low Profile*™ cell is the obvious choice. However, where space is at a premium, the smaller LBM or LBT can fulfill the need for force measurements at a very respectable precision, sufficient for most applications.

These miniature compression cells range in capacities from 10 lbf to 50,000 lbf. Diameters range from 1 inch to 3 inch, with heights from 0.39 inch to 1.5 inch.

The shaped load button has a spherical radius to help confine misaligned loads to the primary axis of the cell.

SPI *Single Point Impact*™ Cell: Although the SPI resembles competitive weigh pan cells, it was specifically designed to have greater than normal deflection at full scale, to provide for the addition of stops to protect the cell against compression overloads. This was necessary because the usual deflection of 0.001 inch to 0.006 inch of most load cells is much too small to allow for the accurate adjustment of an external stop to protect the load cell.

SPI cells with capacities of 3 lbf, 7.5 lbf and 15 lbf contain their own internal compression overload stop which is adjusted at the factory to protect the cell up to four times the rated capacity. These cells have an additional bar under the lower surface, to provide a mount for the internal compression stop screw. Capacities of 25 lbf, 50 lbf, 75 lbf and 150 lbf can be protected by placing hard stops under the corners of a weigh pan to catch the pan before excessive deflection damages the SPI cell.

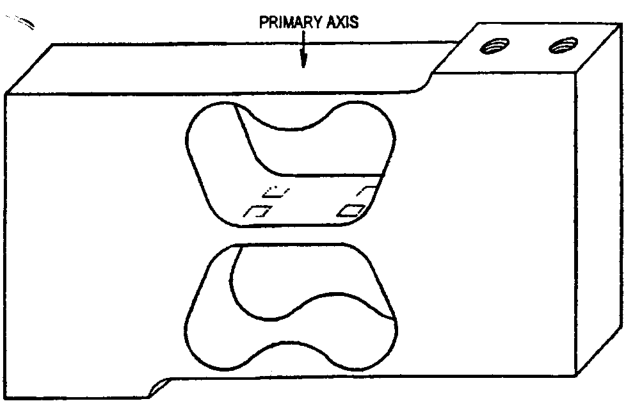


Figure 14. Typical SPI Flexure Layout

Figure 14 shows the internal layout typical of the larger capacities of the SPI. The cell mounts to the scale frame on the step at the lower left corner, while the scale pan is mounted on the upper right corner with its load centroid over the *primary axis* at the center of the cell.

The center bar, containing the gages, is a bending beam. It is supported by the outer frame containing four thin flexure points, two on the top and two on the bottom, to provide mechanical strength for side loads and moment loads. This construction provides the superior moment canceling capability of the SPI, which ensures a consistent weight indication anywhere within the weigh pan size limits.

The SPI is also very popular with universities and test labs, for its precision and ruggedness. It is also very convenient for lab use. Fixtures and load pans can be mounted easily on the two tapped holes on the top corner.

1500 Low Profile™ Rotated Bending Beam: The Model 1500 combines the moment canceling advantages of the Low Profile™ design, with the lower capacity desired by many customers who have precision testing applications.

Although the external appearance of the 1500 is quite similar to the 1000 Series cells, the internal construction is quite different. Figure 16 shows the cross section of one of the two crossed beams, and the similarity to the SML double-ended beam is obvious. Moever, the additional crossed beam, at 90 degrees to the beam shown in section, ensures moment stability in all directions around the primary axis.

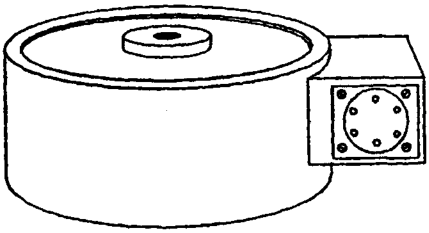


Figure 15. Model 1500 Outline

The Model 1500 is available in capacities from 25 to 300 lbf, to complement the Model 1200, whose lowest capacity is 300 lbf. In addition, the diameter of the Model 1500 is only 2.75 inches, and the connector orientation allows better clearance for the mating connector to clear nearby objects.

Note that the base is integral with the cell, which aligns the whole cell for straight-through applications. The balanced design around the primary axis ensures maximum cancellation of moment forces. The cell is sealed to protect it from the environment in typical production situations.

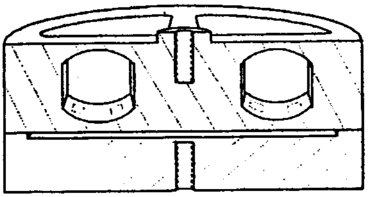


Figure 16. Model 1500 Flexure (Cross Section View)

Flexure Configurations: Shear Beams

SSB Shear Beam Cell: From the outside, a shear beam cell might look identical to a bending beam cell, but the theory of operation is entirely different. When the covers are removed we can see that the large hole, instead of passing all the way through the cell, is actually bored part way through from either side, leaving a thin, vertical web in the center of the cell. You can see the gage mounted on that web in Figure 17.

Notice that the gage is pictured as oriented at 45 degrees to the vertical; this is to remind the reader that the application of a force on the end of the beam causes the web to be stressed in shear, which has a maximum effect at 45 degrees.

The shear beam design is typically used to make larger capacity beam cells because they can be made to be more compact than a bending beam cell of the same capacity. Mounting of either cell is similar; because there is considerable moment loading on the mounting end of the beam, the larger capacities require Grade 8 mounting bolts to provide enough tensile strength to withstand the forces under full load.

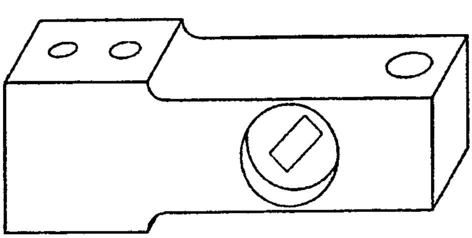


Figure 17. Shear Beam Flexure

Low Profile™ Shear Beam Cell: This structure was a dramatic advance in the design of precision load cells, first introduced to the precision measurements community by Interface in 1969. It offered higher output, better fatigue life, better resistance to extraneous loads, a shorter load path, greater stiffness, and the possibility of compression overload protection integral to the cell.

The top view in Figure 18, with the sealing diaphragms removed, shows how the eight holes are bored down through the flexure to leave eight shear webs, formed by the material left between the holes after the boring operation.

Referring to the section through the flexure in Figure 18, the reader can visualize how the radial shear webs, along with the center hub and the outside rims on both sides, resemble two shear beam cells end-to-end. The Low Profile™ cell thus exhibits the stability of a double-ended shear beam, augmented by the fact that the circular design is the equivalent of four double-ended cells, thus providing stability in eight directions about the center point.

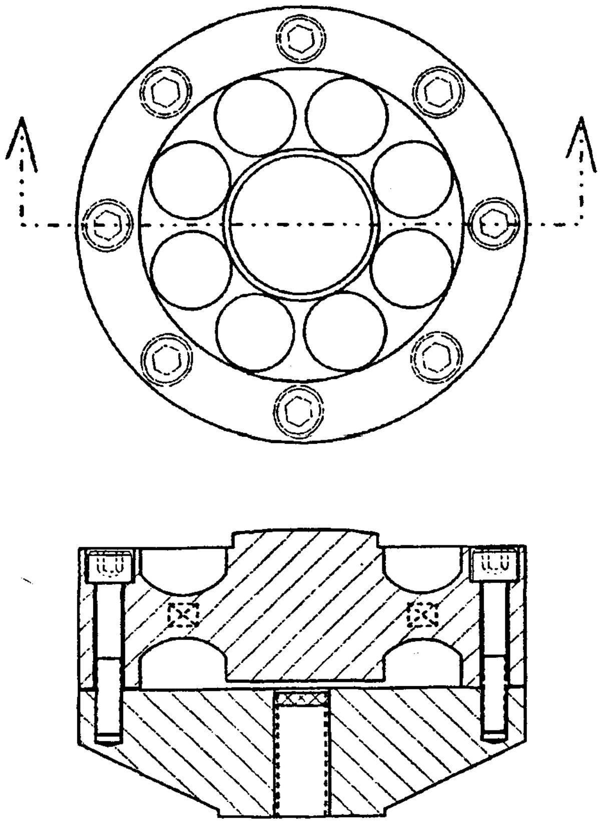


Figure 18. Model 1111 Cutaway Views

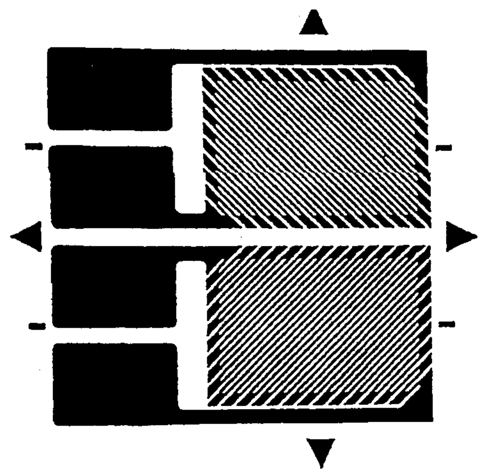


Figure 19. Shear Gage

The two gages shown in Figure 18 are aligned straight across, rather than at 45 degrees because the gages themselves have their grid lines set at 45 degrees. (See Figure 19)

Figure 18 also shows the base, bolted to the flexure around its outside rim. The base is a flat surface, guaranteed to provide optimum support for the flexure. Use of the base, or a support surface with its equivalent flatness and stability, is required to ensure the exceptional performance of the Low Profile™ Series. Note that the threaded hole in the base is on center, and a plug is permanently installed to seal dirt and moisture out of the space between the bottom hub of the flexure and the flat surface of the base.

The Low Profile™ Series comes in both compression models and universal models.

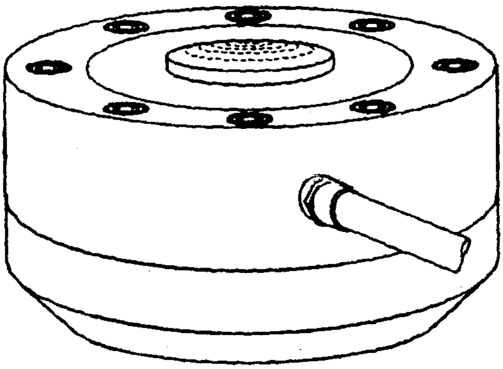


Figure 20. Model 1211-10K

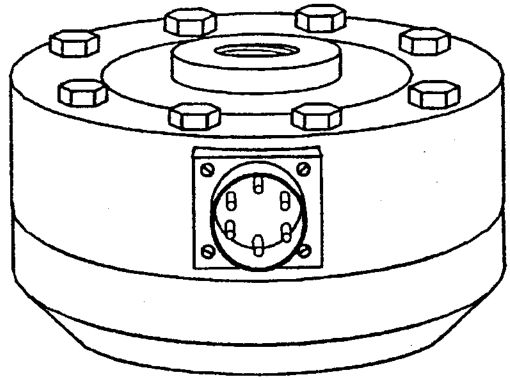


Figure 21. Model 1210-10K

The standard configuration for compression cells is shown in Figure 20. The bolts for mounting the cell to the base are socket head cap screws, flush with the top surface, so that the load button protrudes above the top surface of the cell for clearance. The integral load button has a spherical surface, to minimize the effects of misaligned loading on the output. The seven-wire cable version is stocked, because users prefer the extra protection against moisture intrusion into the electrical system. Connector versions are available as a factory option, where the cells will be protected against the environment.

The standard configuration for universal cells is shown in Figure 21. Hex head machine bolts are used to mount the cell to the base, although socket head cap screws can be provided as a factory option. The electrical connections are brought out to a PC04E-10-6P connector on stock cells, and several connector styles are also available on special order.

Compression overload protection is available as an option on both compression cells and universal cells. It provides protection up to 500% of rated capacity on cells up to 25,000 lbf rating, and up to 300% of rated capacity on larger cells. (See Catalog for restrictions on Fatigue Rated cells.) This protection is obtained by limiting the travel of the center hub as it is deflected under load toward the flat surface of the base. (See Figure 18.) By carefully grinding and lapping the mounting surface of the cell, the gap between the hub and the base is adjusted so that the hub hits the base at about 110% of rated capacity. Any further loading drives the flat hub surface against the base, with very little further deflection. Since this total deflection is of the order of 0.001" to 0.004", this critical adjustment can be done only at the factory, where the cell is mated to the base and tested as a completed assembly.

NOTE

This overload protection operates only in compression and is available on both compression and universal cells, except for fatigue rated cells (see below).

The Low Profile™ Series comes in both compression models and universal models.

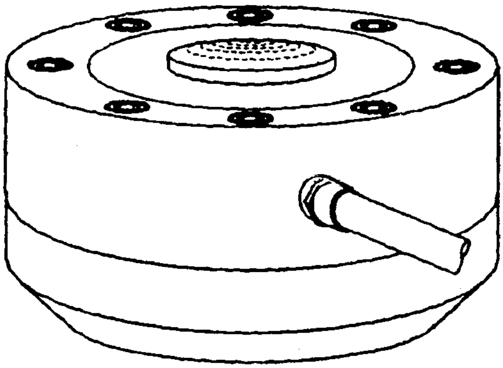
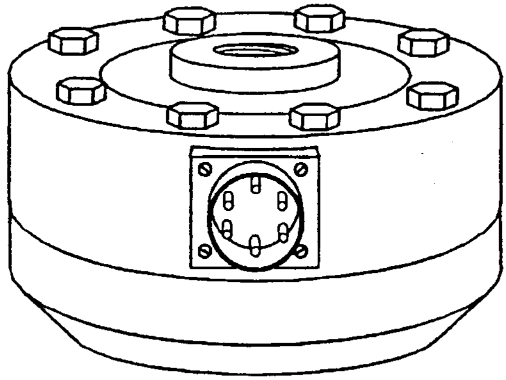


Figure 20. Model 1211-10K



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NOTE

This overload protection operates only in compression and is available on both compression and universal cells, except for fatigue rated cells (see below).

The Low Profile™ Family is available in three major application series ... Precision, Ultra Precision, and Fatigue Rated. The smaller cells, from 250 lbf to 10,000 lbf capacity, are in a package 4.12" in diameter and 1.38" thick. Intermediate capacities are contained in packages of 4.75", 6.06", 7.50", 8.00", and 8.25" diameter, from 1.75" to 2.50" thick. The largest universal cell, at 200,000 lbf capacity, is 11" in diameter and 3.5" thick. The basic construction of all the cells in the family is quite similar. The major differences within each series are in the number of shear beams and the number of gages in the legs of the bridge. The product differentiation between the types relates to the specific application which they are designed to support.

Extraneous Load Sensitivity: One process step which is standard in all Low Profile™ Series cells is adjustment of extraneous load sensitivity. Although the design itself cancels out the bulk of this sensitivity, Interface goes one step further and adjusts each cell to minimize it even more.

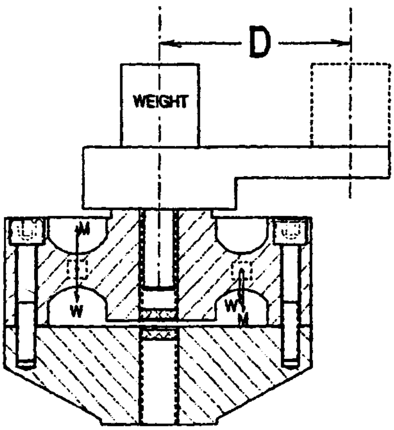

Figure 22. Moment Adjustment

Figure 22 shows a simplified view of a moment testing setup. Assuming a weightless arm mounted on a load cell's hub, the load cell's flexure will be stressed by the application of weight "W" on the centerline of the cell. The stress vectors are shown as "W" in the detail in Figure 23.

Notice that there is an equal "W" vector on both the right side and the left side of the flexure, because the force of the weight is on the centerline of the cell. The gages are wired into the bridge circuit so as to sum up all the force vectors acting in the same direction in the cells' shear webs, so the weight vectors in this example are additive.

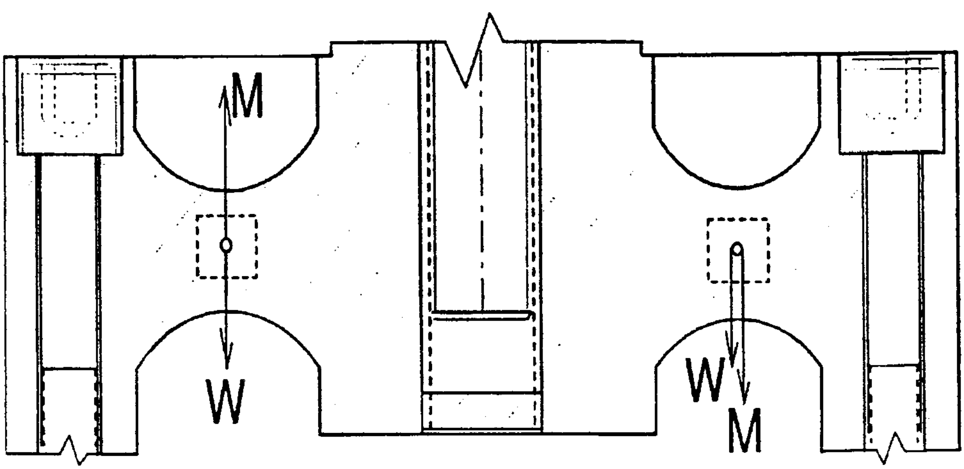

Figure 23. Weight and Moment Vectors

If we now move the weight to the end of the arm, "D" distance off the centerline, the cell sees the weight vectors and also a new set of vectors due to the moment "M", the twisting action caused by the weight's position at the end of the arm, tending to push down on the web on the right side and pull up on the web on the left side.

Remembering that the gages are connected so as to add the "W" vectors, we can see that the "M" vectors will cancel, thus not causing any output signal due to the moment. This statement will be true, of course, only if both webs are exactly the same dimension and if the two gages have exactly the same gage factor. In practice, everything has a tolerance, so the cancellation of moments probably won't be within specified limits when the cell is first assembled. In actual practice, the test station is designed so that the arm can be rotated to any position, and each pair of webs is tested and adjusted for optimum cancellation of moments.

The Low Profile™ Precision Series: This series, with capacities from 300 lbf to 200,000 lbf, forms the backbone of the force testing capability at companies all over the world. It features very competitive prices combined with specifications which satisfy the majority of force testing applications. It offers 4 mV/V output in 5,000 lbf and greater capacities, resistance to extraneous loads, a short load path, very low compliance (high stiffness), and a very respectable static error band specification (±0.04% to 0.07 % FS).

The Low Profile™ Ultra Precision Series: This series, with capacities from 300 lbf to 200,000 lbf, was developed to satisfy the most demanding requirements of sophisticated testing labs. It features a very moderate price adder over the Precision Series, combined with specifications which are better than the Precision Series cells in the critical parameters, such as static error band (±0.02% to 0.06% FS), non-linearity, hysteresis, non-repeatability, and extraneous load sensitivity.

The Low Profile™ Fatigue Rated Series: This series, with capacities from 250 lbf to 100,000 lbf, is the standard of the industry in the world of aerospace fatigue testing. It features a guaranteed fatigue life of 100 million fully reversed load cycles. Although constructed in the same packages as the Precision Series, the Fatigue Rated Series has tighter specifications on resistance to extraneous loads and it offers stiffer compliance, for example, 33,000,000 lb/inch in the 100,000 lbf capacity. Since fatigue testing generally involves applying bimodal forces to test samples through the load cell, compression-only cells are not available in this series. Also, because of the cells' very low deflections, overload protection is not available.

Most people generally have an idea about the meaning of the word "fatigue", as it relates to the failure of a truck spring, for example. They envision the part, after thousands of hours of operation under vibration and shock loads, finally just "giving up" and failing. However, the phrase "fatigue rated", as it applies to an Interface load cell, has a much more explicit and well defined meaning.

Fatigue Rated Load Cell

A Fatigue Rated Interface load cell will still meet its performance specifications after being subjected to 100 million fully reversed load cycles. Also, its static overload rating is 300% in both *modes*, tension and compression.

The fatigue rated design was developed to support the critical testing requirements in the aircraft and space programs. Not only was it necessary to have a load cell which would survive while driving the life test of critical aircraft and missile parts, but it was also crucial that the load cell still meet the specifications during the whole test, to avoid having to repeat expensive tests due to failure of a load cell.

Another advantage of the Low Profile™ design was the ability to install two, sometimes three, or in some cases four electrically isolated bridges in one load cell package. Many customers used this feature to provide a backup recording of the whole test, from the "B" bridge, to verify the test in the event of a failure in the primary data chain from "A" bridge of the load cell. The "B" bridge thus is able to back up the test system for either a failure of Bridge "A" in the load cell itself or for the failure of any element in the data/recording channel for Bridge "A".

A more technically complete explanation of fatigue as it applies to load cell flexure design is contained in the Appendix section of the Interface Catalog.

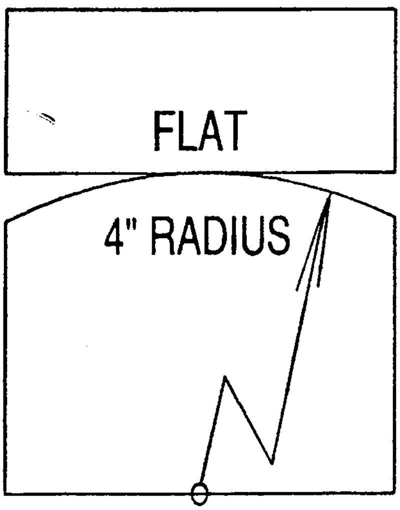

Figure 24. Load Button And Plate

Compression Loading: The application of compression loads on a load cell requires an understanding of the distribution of forces between surfaces of various shapes and finishes.

The first, and most important rule is this: Always avoid applying a compression load flat-to-flat from a plate to the top surface of a load cell hub. The reason for this is simple ... it is impossible to maintain two surfaces parallel enough to guarantee that the force will end up being centered on the primary axis of the load cell. Any slight misalignment, even a few micro inches, could move the contact point off to one edge of the hub, thus inducing a large moment into the measurement.

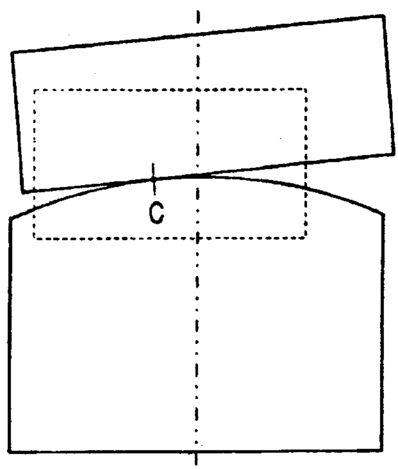

Figure 25. Five Degree Misalignment

One common way to load in compression mode is to use a load button. Most compression cells have an integral load button, and a load button can be installed in any universal cell to allow compression loading. Minor misalignments merely shift the contact point slightly off the centerline. Figure 25 shows a major misalignment, and even the five degrees shown would shift the contact point only 3/8" off center on a load button having a 4 inch spherical radius, which is the type normally used on load cells up to 10,000 lbf capacity. For 50,000 lbf loading a 6 inch radius is used, and for 200,000 lbf loading a 12 inch radius is used.

In addition to compensating for misalignment, the use of a load button of the correct spherical radius is absolutely necessary to confine the stresses at the contact point within the limits of the materials. Generally, load buttons and bearing plates are made from hardened tool steel, and the contacting surfaces are ground to a finish of 32 μinch RMS.

Use of too small a radius will cause failure of the material at the contact point, and a rough finish will result in galling and wear of the loading surfaces. The half-sections in Figure 26 show (in exaggerated form) the indentation radius (R_1) on a flat plate caused by a load button having a 4 inch spherical radius, and the corresponding indentation (D_1). The strains transmitted into the flat plate by a 10,000 lbf load are well within the specs for hardened steel.

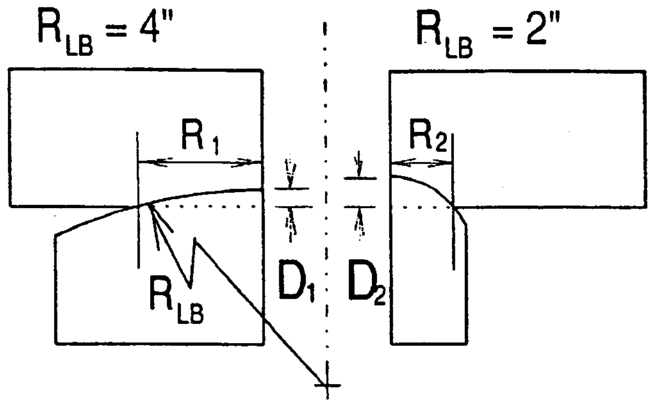

Figure 26. Indentation of Correct Load Button Spherical Radius versus Smaller Radius

Compare that with the indentation radius (R_2) and the corresponding indentation (D_2). In this case, the strains could actually cause the steel to fracture.

Any one of the cells seen so far can be used in compression by mounting a load button in the cell and providing a smooth, hardened steel plate to apply the load to the cell. The disadvantage of this application is that, although the load will be supported properly for weighing, it will not be constrained from moving horizontally. The usual solution for this problem is to provide *check rods* which are strategically placed to tie the load to the support framework. Of course, it is essential the these rods be exactly horizontal; otherwise, they will induce forces into the weighing system which don't reflect the true loading.

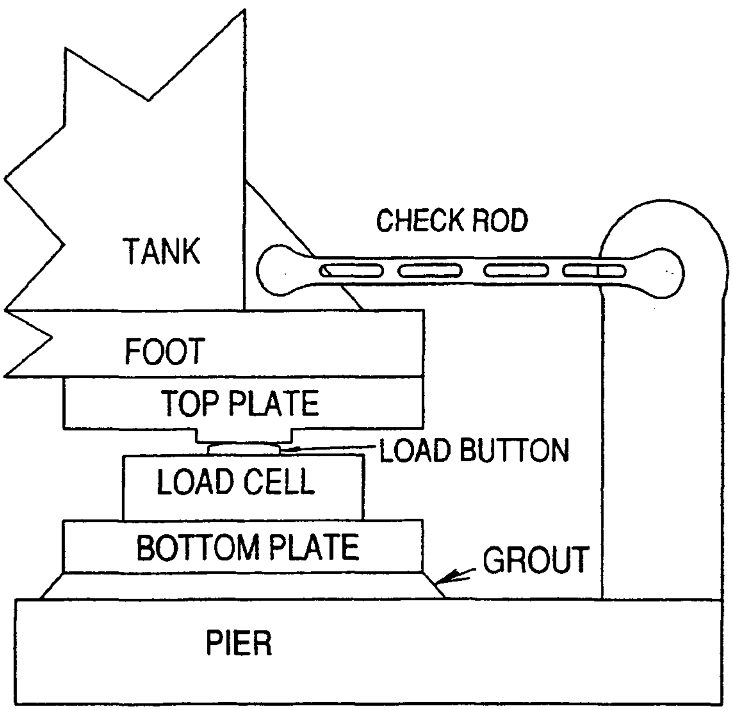

Figure 27. Typical Compression Foot and Check Rod Installation

WeighCheck™ Weighing System: The complex mountings and check rods in a compression weigh system can be replaced in most cases with the simple, innovative self-restoring and self-checking system developed in Figure 28 and pictured in Figure 29.

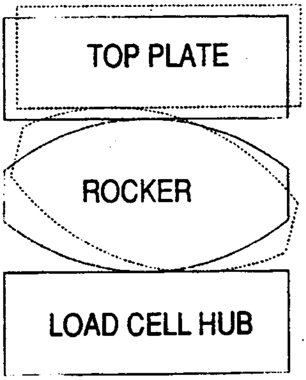

Figure 28. "Football" Self-Centering System

Note that, as the rocker rotates, the top plate rises. Thus, the weight of the load will tend to return the rocker to its original position. The spherical radius of the "football" can be very large, but it can be made much shorter than the equivalent round ball. The reader could imagine making a rocker by slicing a thick horizontal section out of a round ball and then glueing the remaining two pieces together.

In Figure 29, the rocker is modified even more drastically to remove all the unnecessary material. The only sperical surfaces that remain are at the top and bottom, to make contact with the top plate and the loading surface inside the load cell. The sealing boot is made of molded rubber, to keep dirt and water away from

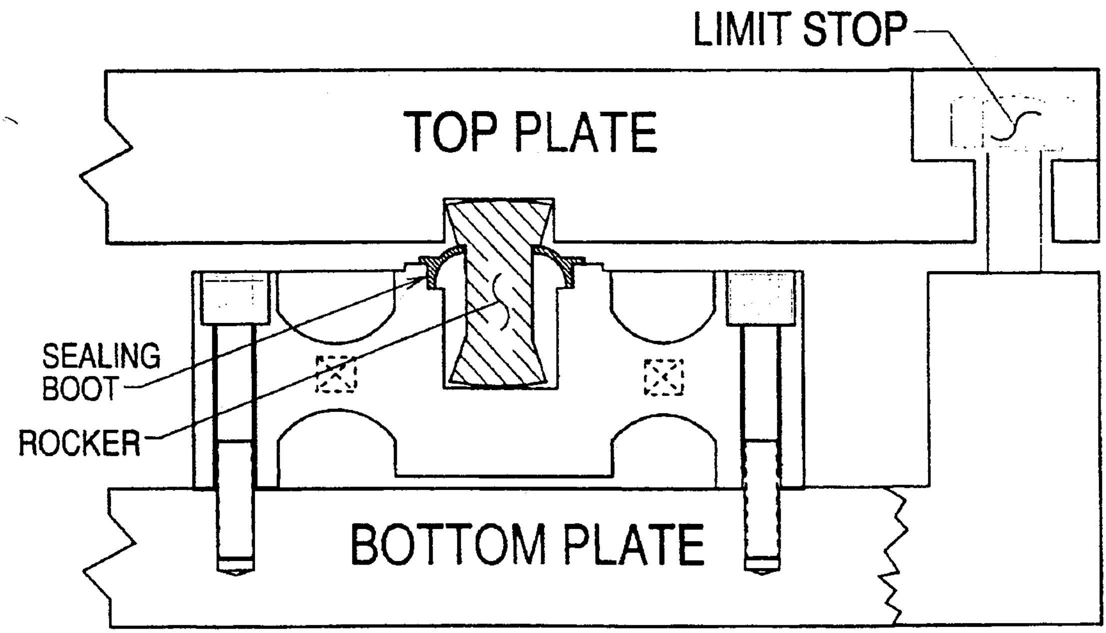

Figure 29. WeighCheck™ Weigh Mount

the lower surface of the rocker. The boot is held down against the hub of the load cell by a lip on the rocker.

There are two limit stops, one at each end of the top plate, formed by oversize clearance holes in the top plate and shoulder bolts which are screwed firmly into each end of the bottom plate. These limits operate both horizontally and vertically to contain the system in all directions.

The unique rocker provides a weigh mount with an extremely low profile, only 4" tall in the low capacities (5,000 and 10,000 lbf) and 5" tall in the high capacities (25,000 and 50,000 lbf). It is available in a tool steel version or a stainless steel version.

LoadTrol™ Oil Well Pump-Off Control Cell: All of the cells in the Interface product lines are either beam cells, S-cells, or shear beam cells, except for this single exception, the LoadTrol™ , a pipe column cell.

Interface would not normally make a column cell as a standard product, for reasons which will be shown in the next section which describes the disadvantages of the simple column cell. However, the pipe design was particularly suited to this application, which required the cell to measure the tension in the polish rod, the rod which goes all the way down to the bottom of an oil well, to drive the pump which raises the oil to the surface.

The polish rod must carry the weight of its whole length, plus the pumping forces, plus the weight of the column of oil in its way to the surface. The two spool flexure designs which Interface provides are rated at 30,000 lbf and 50,000 lbf. They both have an overload rating of twice the rated capacity, necessary because certain pumping conditions can cause serious thumping loads on the system, thus imposing high impact loads on the flexure.

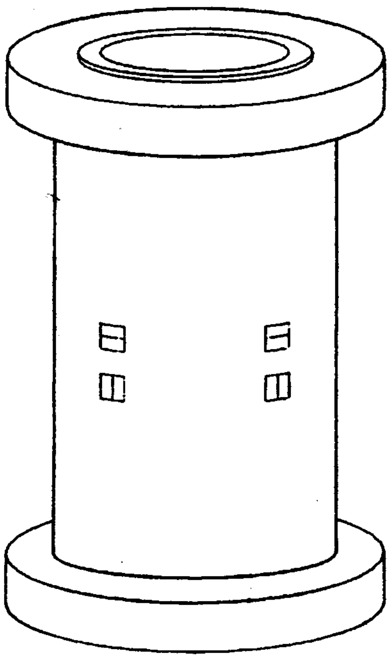

Figure 30. LoadTrol™ Flexure Spool

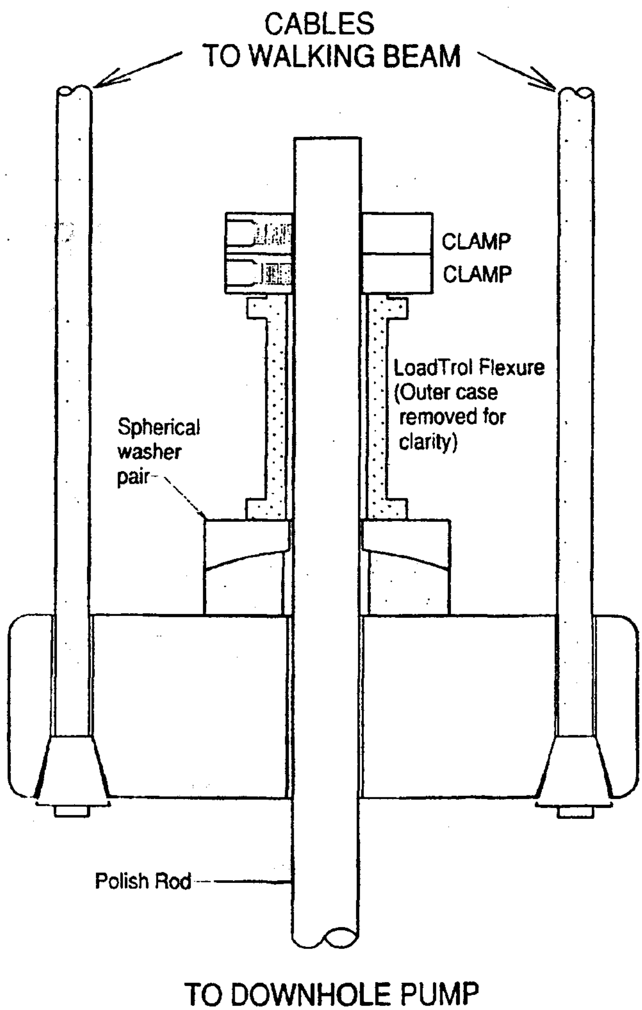

Figure 31. Oil Well Pumping Application

Although it has been used in other applications, the spool flexure was designed specifically for controlling oil well pumps, as shown in Figure 31. We are all familiar with the "rocking horse" pumps which dot the countryside all over the United States. The two cables pull up on the crossbar, which drives up through the spherical washers, through the load cell which

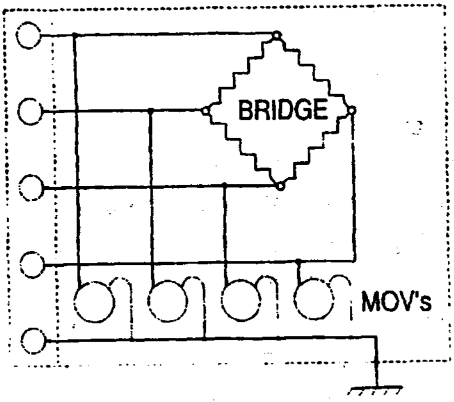

Figure 32. LoadTrol™ MOV's

drives the polish rod through the clamps at the top of the rod. The spherical washers take out any misalignments which might otherwise introduce moments into the load cell.

The system is relatively simple and foolproof. However, since it used outside, it is subject not only to the weather, but also to the nemesis of all electronics systems ... lightening. Therefore MOV's (Metal Oxide Varistors) are included inside the casing of the LoadTrol to short any excessive voltage directly to the case ground, to protect the gages. (See Figure 32)

Competitive Load Cell Product Configurations

The Simple Column Cell: All Interface, Inc. products are designed around either the bending beam, the shear beam, or the pipe column. In order to understand the reasons behind this decision, we need to understand the design of the plain column cell, the other major type of load cell.

The cross-section view in Figure 10 shows the components of the simple column cell. The "flexure" is the heavy column (A) running up the center of the cell, with massive blocks at the top and bottom and a thin, usually square, column in the center. This column, plus the heavy outer shell and the diaphragms (B) are the basic support elements for the measurement flexure, the column (A) which runs from S_1 to S_2.

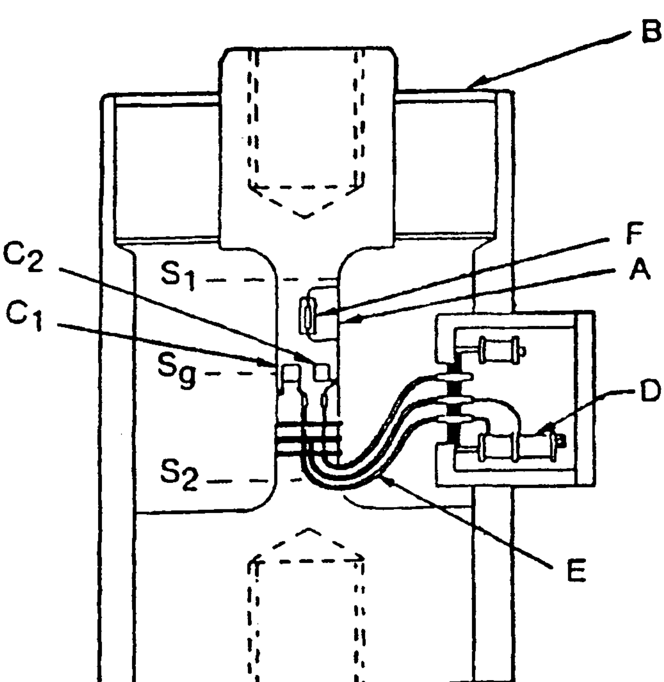

Figure 33. Simple Column Cell

The column stress between S_1 and S_2 is about the same anywhere along its length, so the main gages (C_1 and C_2) are placed in the center, at Sg. Compensation for the non-linearity of the column design is accomplished by the semi-conductor gage (F).

Loads are applied by the customer's fixtures which can be screwed into the threaded holes at the top and bottom ends of the column.

The "doghouse" on the side of the casing contains the bridge compensating resistors (D) which are wired (E) to the gages.

At first glance, this might

seem to be an uncomplicated design. The physical parts themselves are relatively simple to produce. However, several characteristics seriously restrict its usability.

- The thermal path from the column (A) to the outer case is very long and has a thin cross section, thus causing the temperature gradients to take a long time to stabilize. If heat is applied to one side of the case, the case itself will expand on the hot side, and a moment will be applied to the column, causing a zero shift.
- If heat is applied to the doghouse side of the cell, the compensating resistors will change resistance before the column sees the temperature change. Thus, the resistors will be attempting to compensate for a change which has not even occurred yet, causing a zero shift and an output shift.
- The diaphragms are an important part of the support, to keep moment loads away from the column. However, since they are outside of the gaged areas of the column, they are a non-gaged parallel path which introduces their errors (non-linearity, hysteresis, and thermal response) directly into the measurement path. The diaphragms can not be strong enough to protect the column from pure moment loads, without introducing significant errors.
- Changes in pressure due to barometric change or altitude testing act on the diaphragm, causing a zero shift. For example, a six inch diameter diaphragm would induce a force change of 375 pounds into a column cell in a test from sea level to space orbit altitude.
- The cell is quite tall, making it more difficult to integrate into compact testing equipment.
- Since the cross sectional area of the column changes with loading and is different between tension and compression modes, the output is non-linear and unsymmetrical. Non-linear semiconductor gages can be used to compensate the non-linearity, but only in one mode.

Advantages of the Low Profile™ cell: By contrast, the Low Profile™ cell compares dramatically better in all respects to the simple column cell.

- The thermal path is massive and surrounds the whole cell. The thermal path between the outside surface and all the gages is very short. Temperature gradients are almost non-existent, and they settle out very quickly.
- Compensating resistors are mounted on the flexure, in close proximity to the gages.
- The diaphragms are used only as a sealing mechanism, not as a support, so they do not introduce appreciable errors into the cell.
- There are two opposing diaphragms, one on the top and one on the bottom of the cell. Their opposing forces due to pressure are equal and opposite, thus canceling out pressure effects.
- The cell is short and squat, thus making it much easier to integrate into system designs. Column cells range in height from 6" to 24", compared to a Low Profile™ cell's height with base, of 2.5" to 6.5".
- The design is intrinsically moment canceling and is rotationally symmetrical. In addition, moment cancellation is enhanced by special testing and adjustment in the

factory.

- Since the cross sectional area of the flexure does not change appreciably with loading, the output is intrinsically more linear and is also symmetrical between tension and compression modes.
- The output of the shear beam cell is up to 2.5 times the output of a column cell at the same stress level in the flexure.
- The overall Low Profile™ design is more compact, with all the components bonded to the flexure structure, thus making it better able to withstand the 100 million cycle fatigue life.