# TECHNICAL SUPPORT



  

# UNDERSTANDING PIVOTS AND BEARINGS

## 1.0 INTRODUCTION

Levers are used to support the platform and transmit force throughout the scale. However, without pivots and bearings to support the levers, they are useless. Precision machining of pivots and bearings is necessary to ensure as little friction as possible is present in the lever system. This lesson will help you:

- ❑ Identify types of pivots and bearings
- ❑ Identify proper pivot and bearing hardening techniques
- ❑ Identify proper grinding and honing techniques
- ❑ Identify sources of avoidable and unavoidable friction
- ❑ Define range and sensitivity

# 2.0 PIVOTS AND BEARINGS

In studying levers we will talk about fulcrum, load and power points. Levers are supported at these points by pivots and bearings. Pivots are knife edges which rest in bearings to provide not only support, but as little friction and freedom to turn as possible. Of course it is not possible to totally eliminate friction, but its effects can be minimized. Pivots and bearings are designed so they can be removed and replaced. Pivots and bearings take the hardest wear and abuse of all scale parts.

## 2.1 Pivot Types

All pivots are designed to provide lever support with minimum friction. Since there are various scale manufacturers and designs available, the types of pivots that are used will vary.

### Teardrop Pivot

The teardrop pivot derives its name from its shape. See Figure 1.

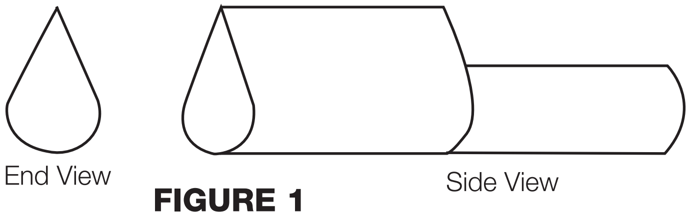


**FIGURE 1**

Teardrop pivots are used in scales up to 1000 lb capacity, feed mill scales, and beam scales. Other names for the teardrop pivot are the pear-shaped and pippin-shaped pivots. They are usually made from an amalgam of hardenable steel with a low carbon steel backing.

### Square Pivot

Square pivots have four edges. Some square pivots have all four edges ground so they can be turned when one edge becomes worn. Some have three edges knocked off so they can be used only one way. They are used on Thurman and Cardinal hopper levers, and to support weigh beams. They are simple to change as they do not need to be gauged. Some square pivots are welded in place. Square pivots are sometimes called diamond pivots.

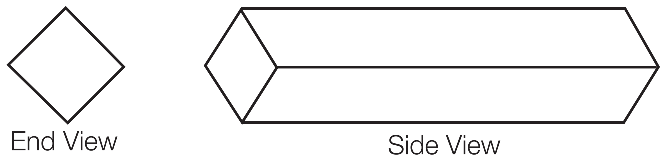


**FIGURE 2**

### Block Pivot

Block pivots are also called pentagonal pivots because they have five sides. The tapered block pivot is flat on one side and machined to a knife edge on the opposite side. The pivot shown has one end tapered to provide minimum contact with the friction plate.

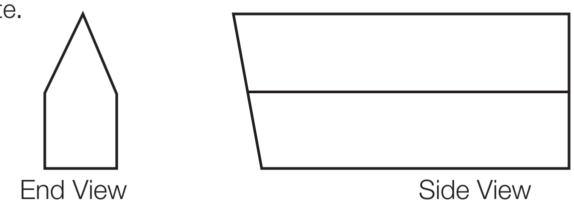


**FIGURE 3**

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## Triangular Knife Edge

The triangular pivoted or knife edge is used in precision balances of capacities up to five kilograms. They are made of agate, stellate or high-carbon alloy steel.

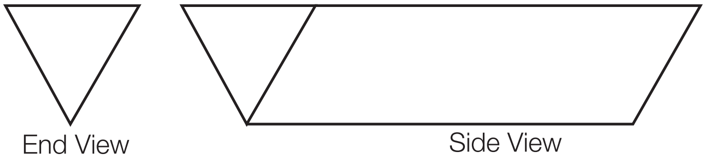



**FIGURE 4**

# 2.2 Pivot Requirements

A pivot point must retain the following characteristics over a reasonable time frame.

## Sensitivity

A good knife edge in theory makes contact at one single point. However magnification of the edge will show some rounding. The rounding can be nonpermanent (elastic) or permanent. Wear will also cause increases in radius development. The bearing associated with this pivot will also yield to pivot pressure and will develop a rounded groove. The less contact the pivot makes with the bearing the more sensitive the pivot.

## Accuracy

Accuracy can be affected if the pivots do not return to their correct seating position. This can be caused by friction. The tendency to not return to their proper position is more pronounced with radiused and "V" bearings than with the flat bearings.

## Mechanical Stability

A pivot is caused to be mechanically unstable when subjected to shock loading and/or lateral forces when loading or unloading. Means must be provided to ensure that knife edges are not easily disturbed from their normal working positions and if disturbed come back to their original positions.

## Range of Movement

The angle of the knife edge must be sufficiently acute and the angle of the bearing must be sufficiently obtuse to provide sufficient range of movement and to withstand dirt buildup.

## Strength

There can be considerable pressure on the knife edge because of the weight of the platform and live load. The knife edge must be able to withstand pressures on the order of 22 tons/cm$^2$.

## Durability

Application of a load on a truck scale will cause immediate flattening of the knife edge. Subsequent loading will not cause further flattening. However deterioration of the edge continues even where a pivot has been subjected to maximum loading early in its life. The radiusing of the knife edge increases by abrasion, proportional to the angular movement. Wear is also caused by shock loading, erosion and movement of the pivots in their bearings. A knife edge with an obtuse angle is more durable than one with an acute angle. Wear is increased rapidly if the angle of movement is greater than five degrees. Some stainless steel has been used but the hardness requirement is difficult to meet.

## 2.3 Hardening

Pivots and steel bearings are made from a steel alloy which gives the following properties:

- Hardness for wear resistance
- Toughness or strength
- Quality of not deforming during heat treatment
- Resistance to staining and corrosion

All pivots and bearings must be heat treated for hardness and tempered at the pivot knife edge and the bearing contact point. The pivot should be as hard as the bearing and vice-versa. Under large loads pivots may mushroom, but if manufactured correctly, they will return to their original shape. A pivot should be hardened as shown in Figure 7.

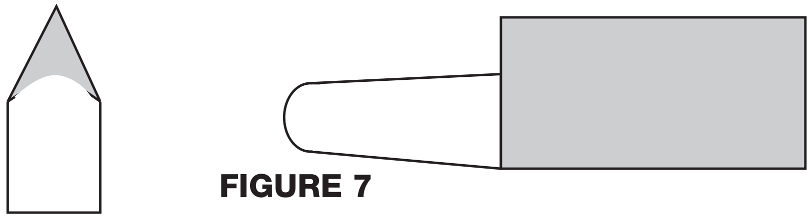


**FIGURE 7**

If the entire pivot or bearing is completely hardened and tempered, it will become brittle and crack under extreme loads. Conversely, if it is soft, it will wear out quickly and cause friction. Pivots and bearings, because of their hardness, very seldom wear out. Their biggest enemy is corrosion. To prevent corrosion while they are being stored, pivots and bearings are plated with nickel. However, under normal use the nickel will wear off. That is why it is necessary to grease bearings to keep them from corroding.

### Lapping

Lapping is the cutting or polishing of a surface with a lap. A lap is a tool made from soft metal (brass or aluminum) used to sharpen a pivot or bearing. Lapping sharpens the edge of the pivot or frees the pivot or bearing from scratches or gouges. Lapping must be done equally on both sides of the pivot or the angle will change, which will cause a change in lever ratio. Lapping takes off just a small portion of the surface.

### Grinding

In some cases it may be necessary to grind a pivot to smooth rough surfaces. Grinding can change the location of the pivot edge, thus changing the lever multiple. It is also possible to disturb the parallel of the knife edge which will cause friction. Care must be taken when grinding as case-hardened materials may have their hardness ground away. This leaves a soft metal which will not be able to stand up to the normal rigors of scale operation. In this case the part must be replaced. It is more advantageous to replace pivots than to grind them. Sometimes you have no choice but to grind if the pivots/bearings are not readily available. The heat produced during grinding can jeopardize the pivot hardness.

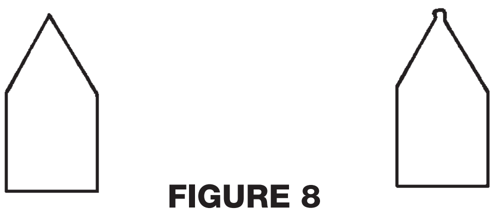


**FIGURE 8**

### Honing

Honing a pivot is accomplished to change a lever's ratio. Honing changes the position of the knife edge in relationship to the distance to the knife edge on another pivot. Honing is used to lengthen or shorten the distance between the load and fulcrum pivots.

To hone a load pivot that is fast, you must hone the side of the load pivot farthest away from the fulcrum pivot which shortens the distance between the two knife edges, increasing the ratio. To hone a load pivot that is slow, you must hone the side of the load pivot nearest the fulcrum pivot, which lengthens the distance between the two knife edges, decreasing the ratio.

A small, coarse handstone is normally used for honing. Do not use a file! Do not make a major change in the angle of the pivot side or the pivot will not seat properly in the bearing. The pivot also will bind, causing friction and repeatability problems.

## 2.4 Friction

Since scales are mechanical devices they contain moving parts. When parts move against one another friction develops. It is impossible to eliminate all friction but its effects can be decreased. We will look at causes of unavoidable and avoidable friction with regard to scales.

### 2.4.1 Unavoidable Friction

Surface resistance of a pivot edge as it revolves on the bearing surface is a source of unavoidable friction. Even a fine razor edge has a surface. No matter how fine the edge of the pivot is, it will develop a small radius because it cannot withstand the strain of load. After some usage the pivot edge will wear down to a point where it will be able to withstand the load strain for years without affecting the scale accuracy. Figure 9 shows a teardrop pivot before use. Figure 10 shows the same pivot after it has worn to the point where it will give years of service.

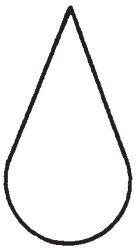


**FIGURE 9**

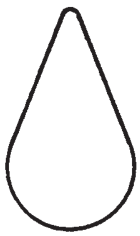


**FIGURE 10**

Another source of unavoidable friction is the anti-friction plate. The anti-friction plate keeps the pivot and/or bearing from sliding out of place. The anti-friction plate is often called a "friction plate" or just a "friction." The use of a friction plate in Figure 11 is the ideal method. The contact between the end of the pivot and the friction plate is reduced to a minimum.

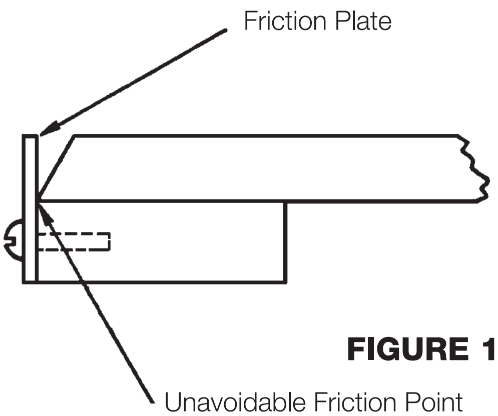
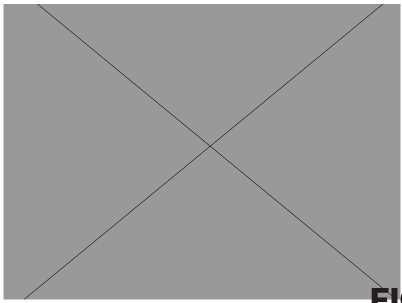



**FIGURE 11**

This method should be used where economy will allow and when it is technically possible. This method is being used more frequently because of its dependability. Rough handling can cause the pivot tip and/or the plate to break.



Unavoidable Friction Point

**FIGURE 12**

The method shown in Figure 12 is commonly used on the understructures of commercial and industrial scales. It is cheaper to build and the friction plate is reinforced by the lever body and is less likely to break. Rough handling is less likely to break this antifriction system.

## 2.4.2 Avoidable Friction

Improperly made and/or aligned bearings can be a source of avoidable friction. Normally if the bearing is bad, the pivot is also bad. A sharp pivot and smooth bearing equal minimal friction. Using the wrong pivot can cause friction. The scale understructure generally receives a severe punishment when being loaded and unloaded. Therefore, it is not advisable to use a sharp bottom “V” bearing in the understructure. As the fine edge of the pivot wears it will jam into the sharply lapped bearing bottom. Round bottom “V” bearings are much more suited for understructure applications.

A soft, blunt, or broken pivot tip and/or coarsely finished anti-friction plate (steel) can be sources of friction. A crooked pivot will also cause tension and friction, as will soft pivots and bearings. A soft pivot dulls quickly and soft metal has a tendency to cling. A hard and sharp pivot edge will cut its way through bearings that are too soft, restricting the pivot’s ability to rotate.

Incorrect pivot installation will cause friction. If the pivot is tapered on one end, it is to be installed in one direction only. The tapered end must fit against the friction plate. This makes sure the pivot touches the friction steel at only one point. If a non-tapered edge touches the friction plate there will be an increase of friction and binding. Friction plates keep the levers from sliding out of position, thus reducing friction. Frictions are hard and brittle and can break. Hardness of the pivot must match the hardness of the friction plate. If the pivot is harder than the plate, a groove will be worn into the friction plate and the pivot can be come caught and bind in the groove. It may be possible to take the nick out out the friction plate by grinding. If the plate is case hardened (hardened to only a certain depth) you may grind to soft metal. This will cause quick wearing of the friction plate and replacement with a friction plate of the correct hardness will be required.

There are other sources of friction, such as the steelyard rod rubbing against something or the platform rubbing against the frame. Keep all moving parts at a safe distance from stationary parts.

## 2.5 Parallel

The pivots must be straight, sharp and hard to eliminate friction and function with precision. They must also run parallel to each other on two planes.

### Gauge Parallel

Figure 13 shows pivots in proper gauge parallel. (Distance A = Distance B)

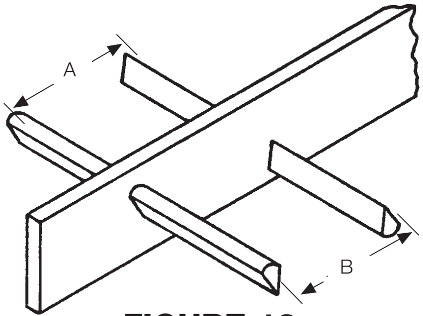



**FIGURE 13**

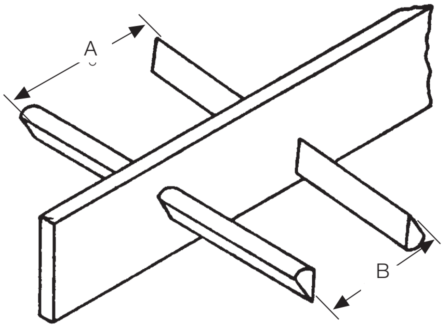



**FIGURE 14**

The pivots in Figure 14 are NOT in proper gauge parallel (Distance A is greater than Distance B). The ratio of the lever is smaller at A than at B. The pivots of a lever must have a certain amount of end play in their bearing to ensure freedom of movement. Because of this end play the levers can change their positions. When this occurs there will be a change in ratio with resultant inconsistent indication.

### Plane Parallel

Pivots must also be parallel to each other in a 90° plane; use a pivot gauge to measure. See Figure 15 for pivots in correct plane parallel.

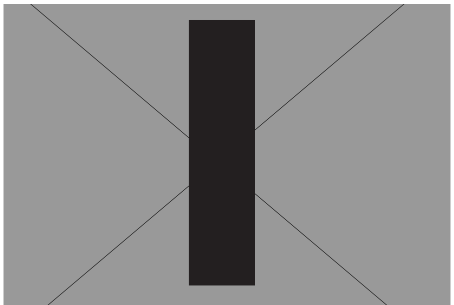


**FIGURE 15**

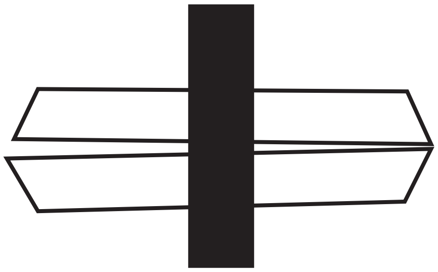


**FIGURE 16**

Figure 16 illustrates pivots not in proper plane parallel. Pivots set in this manner will cause inconsistency. The bearings will have a tendency to slide down on the sloping pivot and jam against the friction points, causing friction. The lever will be less sensitive besides having poor repeatability.

## 2.6 Service Tips

- ❑ Use an old file to check pivot hardness. If the pivot is hard, it will cut the teeth of the file.
- ❑ When installing pivots, use round stock, or preferably a brass hammer. A hardened hammer can break the pivot.
- ❑ Use a pivot gauge when measuring.
- ❑ If the scale is not returning to zero, check for cut or worn bearings to be replaced or lapped. In a small capacity scale, cut bearings will have a large affect, while in large capacity scales, cut bearings may work well.
- ❑ When pounding out pivots, place a block behind the lever to support the lever casting. Without support, the lever may break when pounded.

# 3.0 SENSITIVITY



Sensitivity is the amount of structural displacement caused by the addition of any weight to any portion of a balanced structure.

The degree or amount of sensitivity depends on the distribution of mass above and below the fulcrum point of a lever.

When we talk about sensitivity in conjunction with scales, we are referring to the amount of beam travel from balance position to a new point of equilibrium.

*NOTE:* A beam is a graduated lever used to balance a scale. Weight can be read from the beam graduations.

## 3.1 Neutral Lever

If the pivot edges of a lever are on a straight line, see Figure 17, and the mass of the lever is equally distributed above, below, right and left of the edge of the fulcrum pivot, the lever will be neutral.

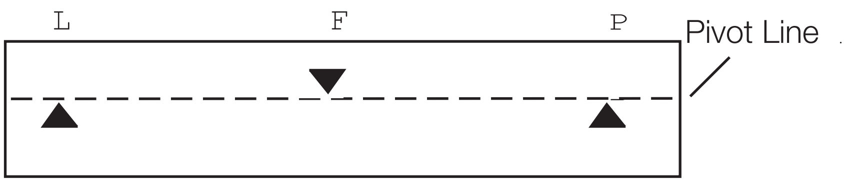



**FIGURE 17**

If the body of the lever is slightly heavier below the fulcrum pivot a pendulum effect will be created. The heavier the mass below the fulcrum pivot, the less sensitive the lever will be.

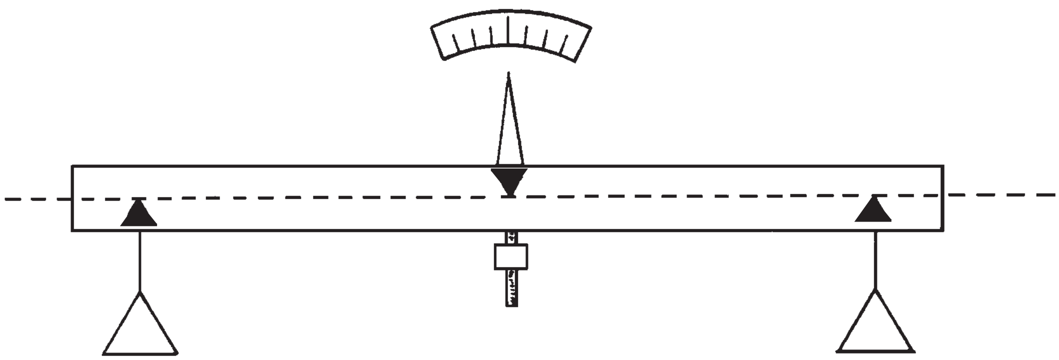


**FIGURE 18**

Figure 18 shows a neutral lever with an indicator and gravity ball attached. If a pan is hung on the load and power pivots the lever becomes an equal arm scale. The gravity ball will stabilize the otherwise neutral lever. The sensitivity can be increased by raising the gravity ball or decreased by lowering the gravity ball.

### Gravity

All objects, including levers, have a center of gravity. If an object is suspended by its center of gravity it will remain motionless until an external force is applied. We can say the lever is balanced. If the lever is moved in any direction it will stop in the position it is moved to. It will remain in this position until an external force is again exerted on it.

If we suspend the lever at a point below its center of gravity the lever will become top heavy and unstable. It will turn on its axis or fulcrum. The change in position will not be abrupt, but be preceded by oscillations caused by its momentum. The number of oscillations will depend on friction and the amount of fulcrum displacement from the center of gravity.

If we suspend the lever at a point above its center of gravity the lever will become very stable. However, it will also become very insensitive.

Let's refer back to our equal arm scale in Figure 18.

With the indicator pointing to the chart centerline we will place a 1/4 ounce weight on the right hand pan, moving the indicator to the right, two graduations. We will then remove the 1/4 ounce weight and the indicator points again to the center. Now we will place a 10 pound weight on each pan. Again we have a centerline indication. If the lever is solid and does not deflect under the load, a 1/4 ounce weight placed in the right hand pan will again move the indicator to the second graduation. This indicates that the sensitivity of the lever is constant. The reason the sensitivity is constant is because all pivots are in a straight line. In other words adding weight to the load and power pivots adds weight even with the fulcrum pivot, not above it nor below it.

## 3.2 Open Range

If the edges of the load and power pivots are below the straight line passing under the edge of the fulcrum pivot (see Figure 19) the lever would have what is referred to as open range.

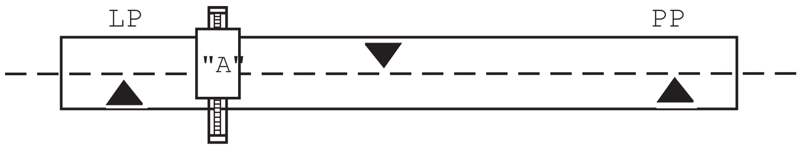



**FIGURE 19**

If we raise the gravity ball the sensitivity may be increased to the point of neutrality or even to instability if we raise it far enough.

However, when weight is placed on the load and power pivots, the sensitivity will decrease. The bigger the load the less sensitive the lever will be. Remember the load and power pivots are below the fulcrum pivot line, so when weight is added to the load and power pivots, the weight is being added below the fulcrum pivot. The results are decreased sensitivity and increased stability.

## 3.3 Closed Range

Let's look at a lever that is said to have closed range. (Figure 20).

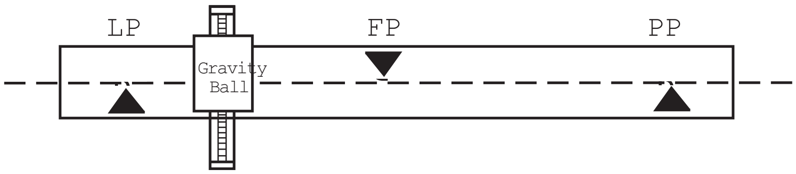



**FIGURE 20**

A lever is said to have closed range when the edges of the load and power pivots are higher than the edge of the fulcrum pivot.

When pans are hung on the power and load pivots the lever will be unstable (top heavy). The lever can be stabilized by lowering its gravity ball which increases the mass below the fulcrum pivot.

As the pans are loaded, the increasing load will gradually overcome the stabilizing effect of the gravity ball. This is true because the weight is felt at the loaded power pivots which are located above the fulcrum pivot line. As the weight increases it will first cause neutrality and finally a top heavy, unstable condition.



### 3.4 Lever Deflection

To construct a lever or weighbeam with no deflection, it may be necessary to over-dimension the body, making it very clumsy and heavy. Because of its great inertia, the lever would require more time to pick up momentum when changing directions during oscillation.

To ensure a reasonably uniform sensitivity, a slightly closed range can be used.

Levers are usually made as light as possible to decrease the weight of the lever system, minimize inertia, and to save material.

If the deflection is not too great and is temporary, it can be compensated by a closed range in the pivot line. A permanent deflection will render a scale useless. Deflection in any lever will decrease its sensitivity. If the lever is incorrectly proportioned it will change its ratio. A correctly proportioned lever with, let's say, a 10:1 ration must have a similar deflection factor. If the load arm deflects 0.001" then the power arm should deflect 0.001" to maintain the lever ratio.

Closed range, to compensate for deflection, can be utilized only in scales with predetermined, one-spot indication (beam scales) or in a scale equipped with balance indicators that only have a zero indication. Scales with graduated charts (each graduation representing a certain weight value) must not utilize closed or open range.

Using a neutral pivot line on a flexible lever would result in gradual loss of sensitivity due to the increase in mass below the fulcrum pivot as the load and power pivots deflect downward.

Levers and beams are usually constructed so the larger mass of the lever body is below the pivot line. This produces sufficient pendulum action to stabilize the scale. Closed range has an opposite effect, causing the scale to become unstable.

The stabilizing effect of the lever body has to be greater than the unstabilizing effect of the closed range when the scale is unloaded. As the scale is being loaded, a gradual deflection will take place which will eventually eliminate the range. This stabilizing effect of the lever body must remain active until the load and power pivots sink to the level of the fulcrum pivot. Should the stabilizing effect of the lever mass be insufficient and become nullified before the pivot line becomes neutral, the scale will become unstable at this point. A further increase in load will result in a gradually increasing loss of sensitivity.

## 4.0 Sensitivity Requirement (SR)

The sensitivity of a scale is the distance the beam or indicator travels when a certain unit of weight is placed on the scale platform. The term "sensitivity" is not the same as the sensitivity requirement or SR.

SR is the amount of weight necessary to make the scale travel a certain specified distance. The SR requirements for commercial scales vary depending on the type of scale. SR tolerances are prescribed in Handbook 44.