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Hydraulics as a Scale on the Farm

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Scales are often used on the farm to weigh things such as feed, lambs, calves, and square bales of hay. Larger objects such as round bales, silage, or livestock may be weighed less often, if at all. In many cases, scales for this type of measurement may cost more than $1,000.

Hydraulic cylinders and front-end loaders can be used as accurate scales for a fraction of the cost.

Basic Principle

"Hydraulics" is a term the industry commonly uses to describe the science of transmitting force and/or motion through confined liquids. "Power hydraulics" and "hydrostatics" are more specific terms used in industry for the field.

In hydraulics, pressure is required for pushing or exerting a force or torque. In a hydraulic system, pressure controls force.

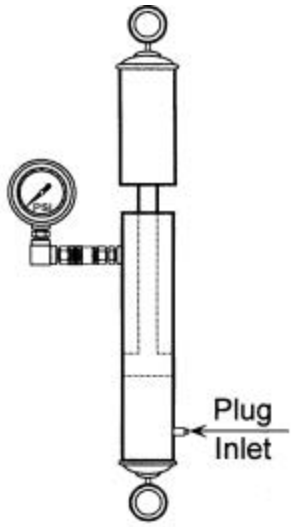
Pressure is defined as a force per unit of area or

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

For example, if a hydraulic system operates at 20 pounds per square inch (psi) of pressure, the hydraulic fluid is under pressure of 20 psi.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{\text{20 pounds}}{\text{1 square inch}}$$

Figure 1



Application -- Static Hydraulic Cylinders

The terms "force" and "weight" can be interchangable. The previous formulas can be used to determine the weight of an object based on the pressure exerted on a hydraulic system. A single hydraulic cylinder or several cylinders connected in a series with an object hanging below would exert pressure on the system.

Figure 1 illustrates how a single cylinder could be configured to measure the pressure exerted by the weight. A quick coupling system allows the same gauge to be used with several applications. Make sure that the cylinder is filled with hydraulic fluid before attaching the gauge.

Table 1 provides guidelines for using different sizes of cylinders for different weighing capacities.

Cylinder Diameter (Inches)	Shaft Diameter (Inches)	Area of Cylinder* (Sq. Inches)	Area of Rod* (Sq. Inches)	Weight per 1 Pound of Pressure**	Maximum Operational Weight for 3000 psi-Rated Cylinder***
1.5	0.750	1.77	0.44	1.33	3,100
2.0	1.000	3.14	0.79	2.36	5,600
2.5	1.250	4.91	1.23	3.68	8,800
3.0	1.375	7.07	1.49	5.58	13,400
3.5	1.500	9.62	1.77	7.85	18,800
4.0	1.750	12.57	2.41	10.16	24,300

* The area of a cylinder or rod is determined by multiplying the radius of the circle by itself and multiplying that value by 3.146(pi). (Area of a circle = Pr^2).

** Area of the cylinder minus the area of the rod.

*** The suggested operational maximum weight is approximately 80% of the calculated maximum weight. It is subject to the proper calibration of the cylinder.

Calibration

The figures in Table 2 are based on calculations that assume theoretical values. They provide guidance in the design of a weighing device. Only a couple of factors may justify calibration. Not knowing the gauge is accurate and not knowing the correct diameter of the cylinder or rod can drastically affect the accuracy of the scale. In general, the theoretical values are valid. To prove this, a 2-inch cylinder with a 1-inch shaft was tested using 1000 pounds of tractor weights which were weighed on a certified scale. The cylinder has a theoretical value of 2.36 pounds of weight per pound of pressure on the gauge. The test comprised ten replications, starting with the weight of the platform and adding 10 100-pound weights at a time.

The calibration showed an average difference of only 0.01 pounds of pressure per pound of weight from the theoretical value of 2.36. This cylinder, used to 1,000 pounds, without calibration, would give a reading 5 pounds lighter than the actual weight. Another way of evaluating the accuracy would be to say the measurement is 99.6% of the actual weight.

More than one cylinder in a series or parallel circuit can be used to weigh larger amounts. A parallel connection will divide the load between the cylinders. This would require a gauge on each cylinder, but would allow for a capacity without increasing the cylinder size. A series connection would need only one gauge, but all cylinders would have the same load, reducing the capacity of the scale in comparison to the same number of cylinders connected in a parallel circuit. **All gauges, fittings and hydraulic hoses must be rated for hydraulic use at no less than the rating of the cylinders used or the maximum pressure that would be reached by the scale.**

Table 2

Weight of Tractor Weights (pounds)	Average Pressure on Gauge (PSI)	Ratio of Weight to Gauge Pressure
190	77.73	2.444
290	120.00	2.417
390	1.6727	2.332
490	210.00	2.333
590	250.00	2.360
690	296.36	2.328
790	340.00	2.324
890	380.00	2.342
990	430.00	2.302
1090	470.00	2.319
	average	2.350

Application - Front-end Loader

A hydraulic gauge also can be used to turn a hydraulic front-end loader into a scale. There are differences in calibrating this system versus a static hydraulic cylinder. A front-end loader uses many feet of hydraulic hose. It has a hydraulic pump and reservoir. Front-end loaders are also different in design from manufacturer to manufacturer and use different attachments for lifting. The relationship of weight to pressure will change for the same equipment if different attachments are used. The pressure will be different for a bucket versus a fork, versus a hay spike, versus a bucket with a hay spike attached. The farther away the load extends beyond the cylinders or the hinge point, the greater the pressure must be to lift the same weight.

Calibrating the front-end loader will take only a few hours. Objects of known weight are lifted by the front-end loader and the pressure is noted.

Procedure for Large Round Bales

On a certified scale, weigh at least three bales of various size, condition, or species makeup.

Lift each bale so that the loader is at the same height and record the pressure on the gauge.

Divide the weight of the bale by the pressure read on the gauge.

Calculate an average ratio.

The average ratio of weight to pressure is then used to calculate the weight of other bales.

For example:

Three bales of different sizes and makeup were weighed on a local certified truck scale.

Bale #1	Bale #2	Bale # 3
Actual Weight - 880 lbs	Actual Weight - 1,340 lbs.	Actual Weight - 1,720 lbs
Cubic Feet per Bale - 52.0	Cubic Feet per Bale - 140.8	Cubic Feet per Bale - 106.5
Grass/Legume	Grass/Legume	Alfalfa
Gauge Reading – 550 psi	Gauge Reading - 800 psi	Gauge Reading - 1,000 psi
Ratio of weight to pressure - 1.60	Ratio of weight to pressure - 1.67	Ratio of weight to pressure - 1.72

An average ratio is determined by adding the three readings together and dividing:

$$\frac{1.60+1.67+1.72}{3} = 1.663$$

The average ratio is 1.663. A table can then be generated to use when weighing bales by **multiplying pressure times the ratio** (ex. 300 * 1.663) and then rounding to a whole number.

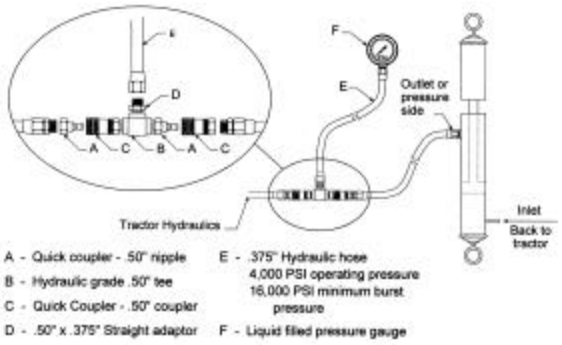
Table 3 is an example based on the average ratio in the example above.

Pressure Reading	Weight	Pressure Reading	Weight
300	499	**800**	1,330
350	582	**850**	1,414
400	665	**900**	1,497
450	748	**950**	1,580
500	831	**1,000**	1,663

Tractor weights, sacks of feed, or other objects of known weight could be used to calibrate. The important thing to remember is to place the known weight in the same location on the front-end loader as the commodity being calibrated.

A "quick coupling" system can be built with parts from many different suppliers for less than $100.

Figure 2 shows how such a system could be constructed to be a part of the existing hydraulics of the front-end loader.



Suppliers

There are many suppliers of cylinders, gauges, and hydraulic fittings and hoses.

These include auto part stores, farm supply and implement dealers, and specialty suppliers such as industrial hydraulic and pneumatic system installers.

When considering what to purchase, keep in mind the range of weight that is being measured and the accuracy desired. The larger the cylinder the more weight capacity, but the larger increment of weight per pound of pressure. For example a 2-inch cylinder, with a pressure capacity of 3000 psi, has the capacity to weigh up to approximately 5,700 lbs. Each pound of pressure will equal approximately 2.36 pounds of weight. A 3-inch cylinder may have a capacity of over 10,000 pounds and each pound of pressure would equal approximately 6.0 pounds. The same is true for pressure gauges. An oil filled gauge is recommended.

A gauge with a 500 psi capacity may have 10 psi increments, and a gauge with a capacity of 1,000 psi may have 20 psi increments.

A kit is available from ***Weigh-All Field Scale*** of Fort Gibson, Okla., for less than $250 if you would rather purchase than build and calibrate your own system.

Summary

Hydraulics can be a powerful tool to record the agronomical performance of the farm and provide information related to feeding animals. The construction, configuration, and calibration of the scale are well within the capabilities of most producers.

Calibration is a must for different temperatures, apparatus, and age and wear of the cylinder or hydraulic system being used as a scale.

Parts are available through many companies. The pressure gauge capacity and the hydraulic hose and fittings should all meet standards greater than the maximum pressure of the hydraulic cylinder, the operating pressure of the tractor, or the maximum pressure generated by the weight to be measured.

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