

FORCE ANALYSIS OF PRIMARY TILLAGE TOOLS

FORCES ON TILLAGE TOOL

- **FORCES OF GRAVITY**
- **SOIL REACTION FORCES**
- **FORCES ACTING BETWEEN THE IMPLEMENT AND PRIME MOVER/POWER SOURCE**

- **SOIL REACTION FORCES**
 - **USEFUL FORCES**
 - **FORCE FOR CUTTING THE SOIL**
 - **FORCE FOR BREAKING THE SOIL**
 - **FORCE FOR MOVING THE SOIL**
 - **PARASITIC FORCES**
 - **FRICTIONAL FORCE**
 - **ROLLING RESISTANCE**

The parasitic forces act upon the stabilizing surfaces like:

Landside

Supporting wheels

Parasitic forces acting on stabilizing surfaces like the landside, rear furrow wheel can be controlled but not the soil resistance forces.

SOIL REACTION FORCES DEPEND ON

- **Resistance of the soil**
 - Shear
 - Adhesion
 - Frictional resistance
 - **Soil acceleration**

ALL THE PROPERTIES ABOVE ARE DYNAMIC PROPERTIES OF SOIL AND ARE ACTIVE WHEN THE IMPLEMENT IS IN MOTION

Forces on a tillage tools (MB)

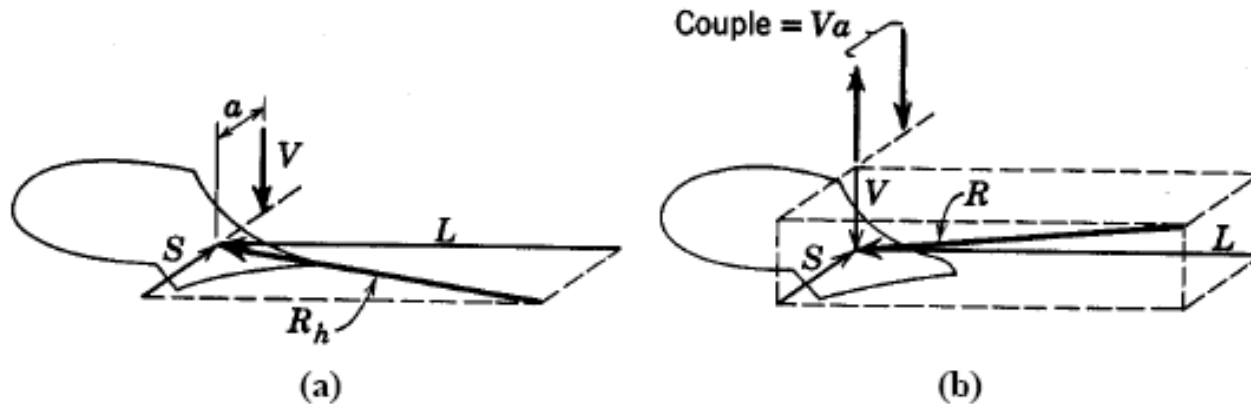
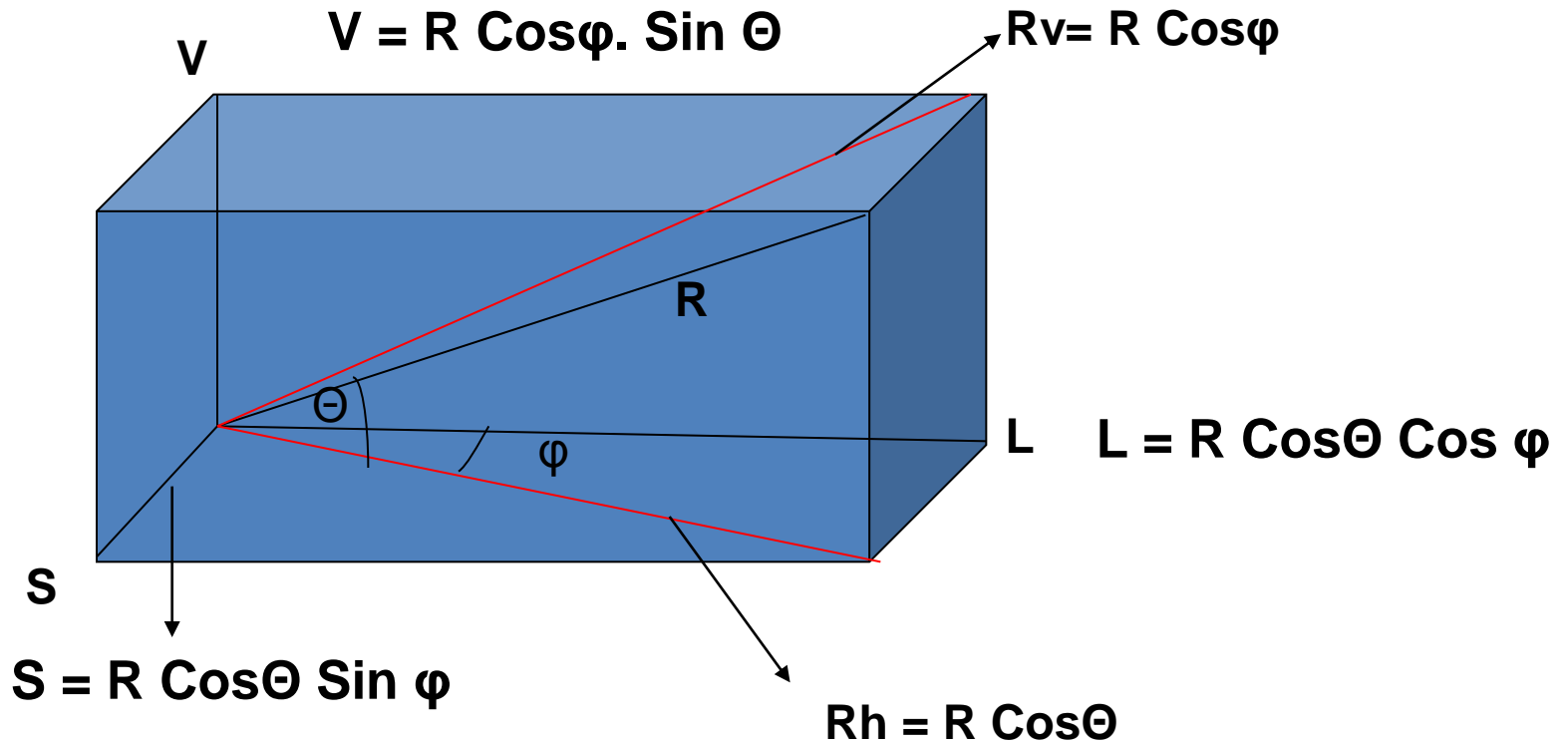


Figure 8.55 – Two ways of expressing the total soil reaction on a tillage tool when a rotational effect exists: (a) two non-intersecting forces, R_h and V , (b) one force R and a couple Va in a plane perpendicular to the line of motion

- R = resultant of all soil reaction forces on the tool (both soil useful and parasitic forces)
- L = longitudinal component
- S = lateral component
- V = Vertical component
- R_h = Resultant of L and S
- R_v = Resultant of L and V

- a = lateral distance between V and R_h for tools or implements having rotational effect
- Va = Couple tending to rotate the implements in longitudinal axis
- Q = resultant of all parasitic forces
- Q_h = **Component of Q in horizontal plane**. It includes stabilizing support forces and the longitudinal friction forces
- Q_v = **component of Q in vertical plane** which includes vertical support forces and the longitudinal friction forces or rolling resistances
- P = resultant pull
- P_h = component of P in horizontal plane
- P_v = Component of P in vertical and longitudinal plane
- W = Force of gravity on the implement

Force analysis of MB plough



$$R_h = (L^2 + S^2)^{1/2} = R \cos \Theta$$

$$R_v = (L^2 + V^2)^{1/2} = R \cos \phi$$

VERTICAL FORCE RELATION

- **MB plough has a vertical component of soil reaction force because of suction. (downward)**
- **Magnitude of V varies on**
 - **Soil type**
 - **Soil condition**
 - **Depth of cut**
 - **Share edge shape (top beveled share has less V than a bottomed beveled share)**
 - **Sharpness**
 - **Speed of plough**
- **Penetrating ability of the plough depends on the magnitude of the downward force of V. In case of mounted and semi-mounted implement 'V' influences the vertical load on the tractor rear wheel**

DRAFT AND ITS MEASUREMENT

What is draft?

- ❏ Draft is the force that is required to overcome the horizontal resistance offered by the implement when it is moved forward
- ❏ Horizontal component of the pull is called draft
- ❏ If Pull = P
- ❏ Draft = $P * \cos\theta$, θ is the angle the pull makes with the horizontal

What is unit draft?

- It is the draft per unit area of the cross section of soil tilled by the implement
 - Sandy soil: 1.4 – 2 N/cm²
 - Silty loam soil : 2 – 5 N/cm²
 - Heavy soil: 4 -8 N/cm²
- Expressed as Kgf/cm² or N/cm²
- Some cases, expressed as N/ m width of implement

Factors that affect draft

- ❖ **Speed**
- ❖ **Width and depth of operation**
- ❖ **Moisture content of the soil**
- ❖ **Friction characteristics of soil**
- ❖ **Soil type**
- ❖ **Degree of compaction**
- ❖ **Shape and sharpness of the implements**
- ❖ **Adjustment of implements**
- ❖ **Attachment of the implements**
- ❖ **Previous crops**

MEASUREMENT OF DRAFT

- **INSTRUMENTS**
 - **SPRING DYNAMOMETER**
 - **HYDRAULIC DYNAMOMETER**
 - **LOAD CELL**
 - **RING TRANSDUCER**
 - **EXTENDED OCTAGONAL RING TRANSDUCER (EORT)**

Spring dynamometer

While

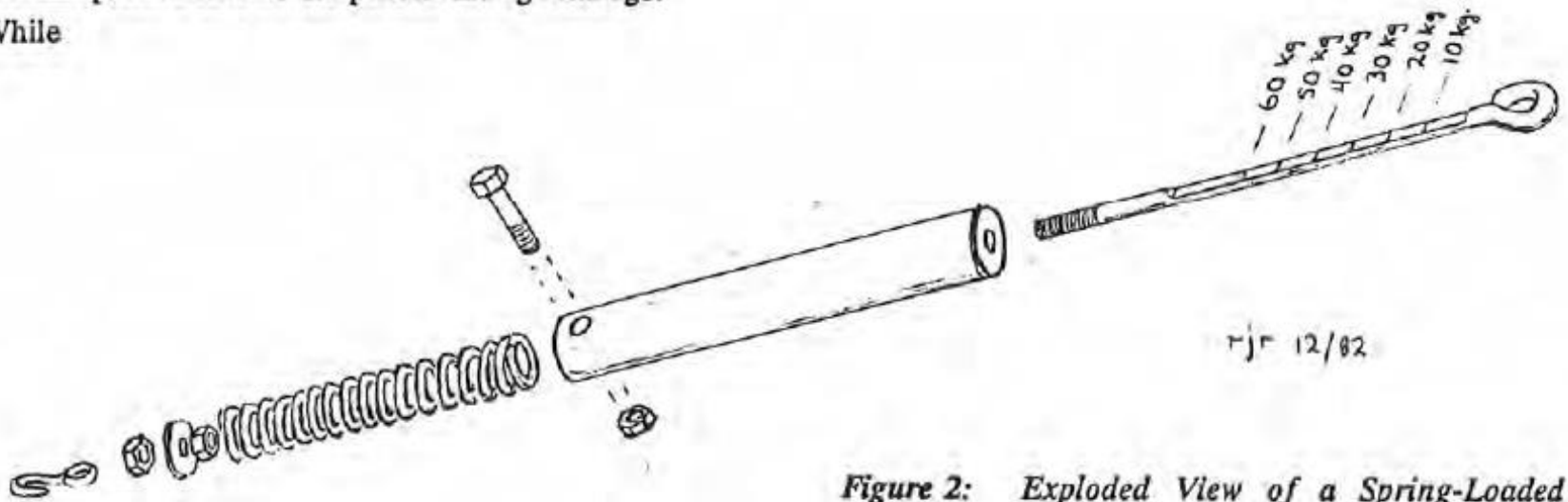
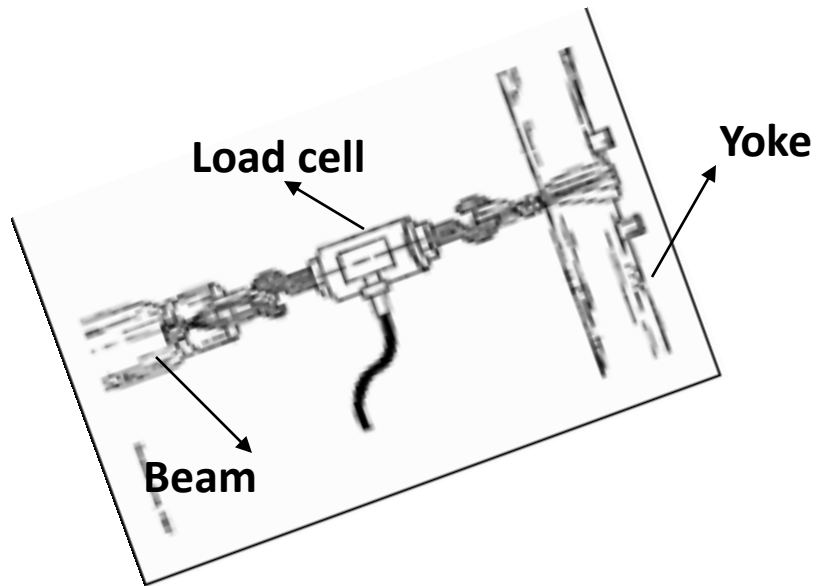


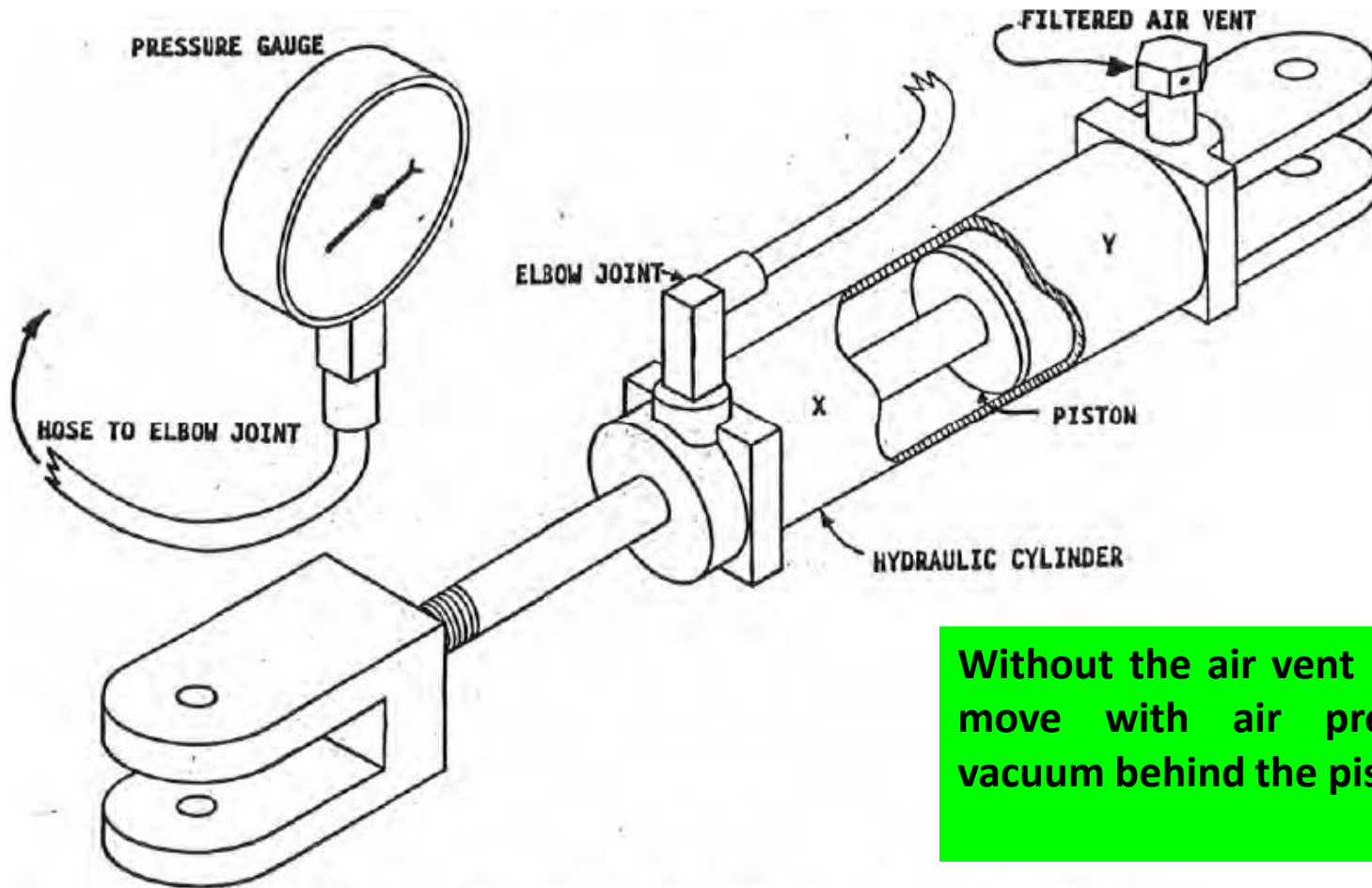
Figure 2: Exploded View of a Spring-Loaded Dynamometer.

Draft measurement in case of B.D Implements



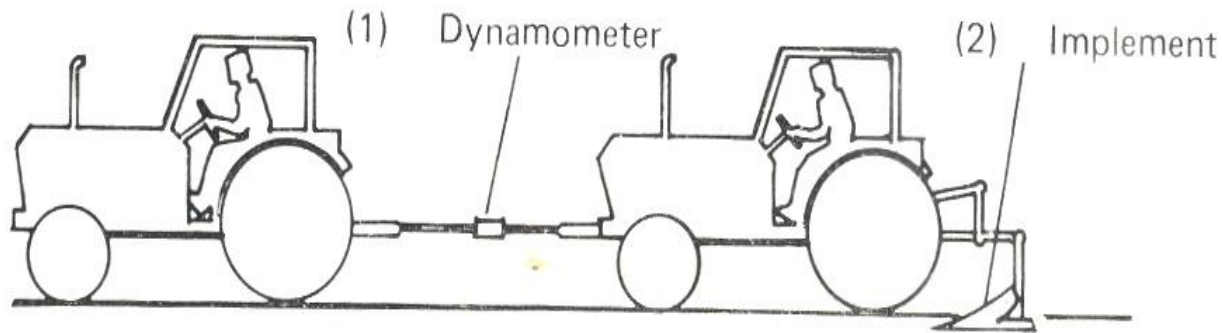
Draft measurement by load cell / load transducer

Hydraulic dynamometer



Without the air vent piston will move with air pressure or vacuum behind the piston

Measurement of draft in tractor drawn implement



5 MEASURING OF DRAFT FOR A TRACTOR-MOUNTED IMPLEMENT

Measure the draft without implement (A)

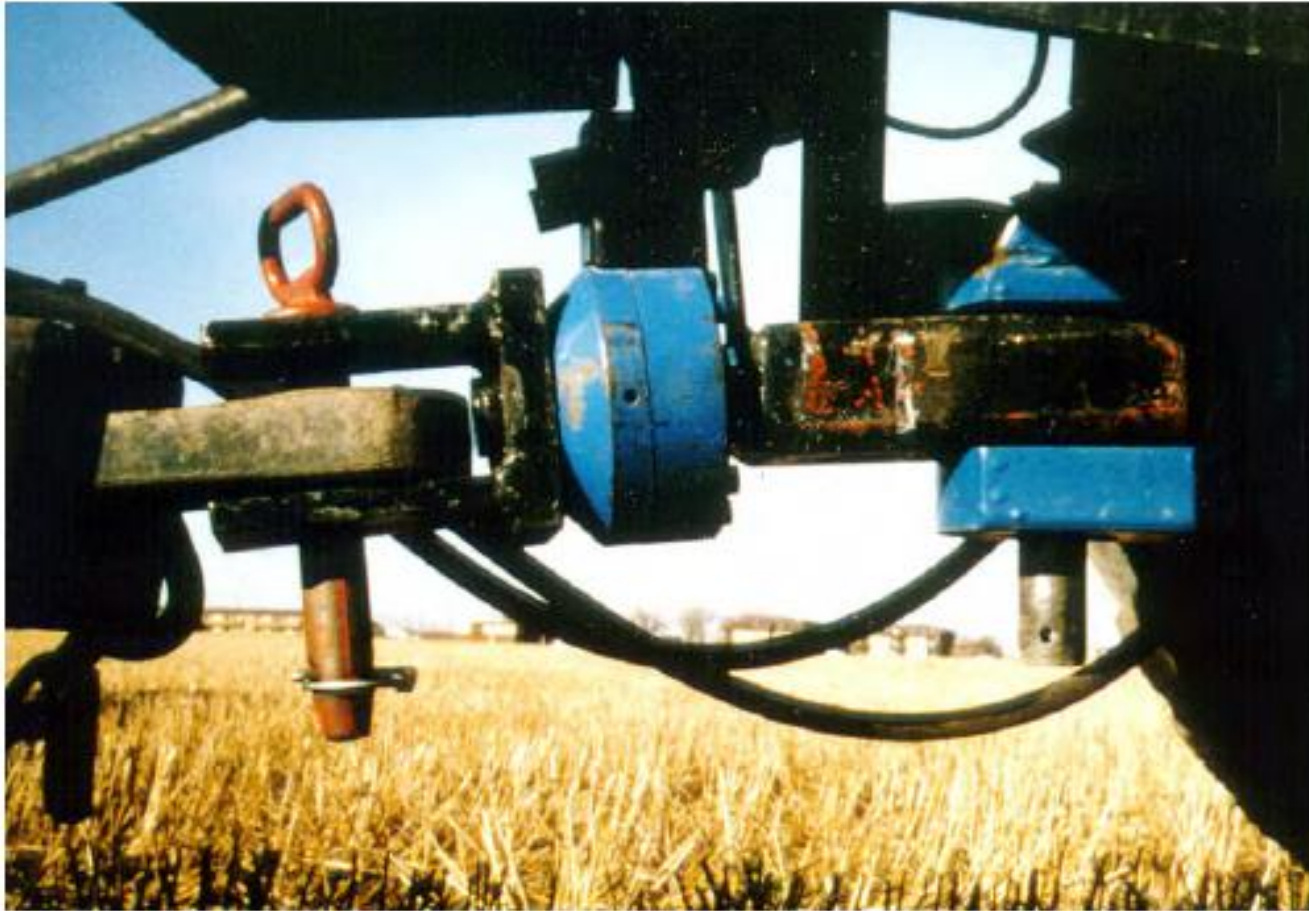
Measure the draft with implement (B)

Draft = B - A

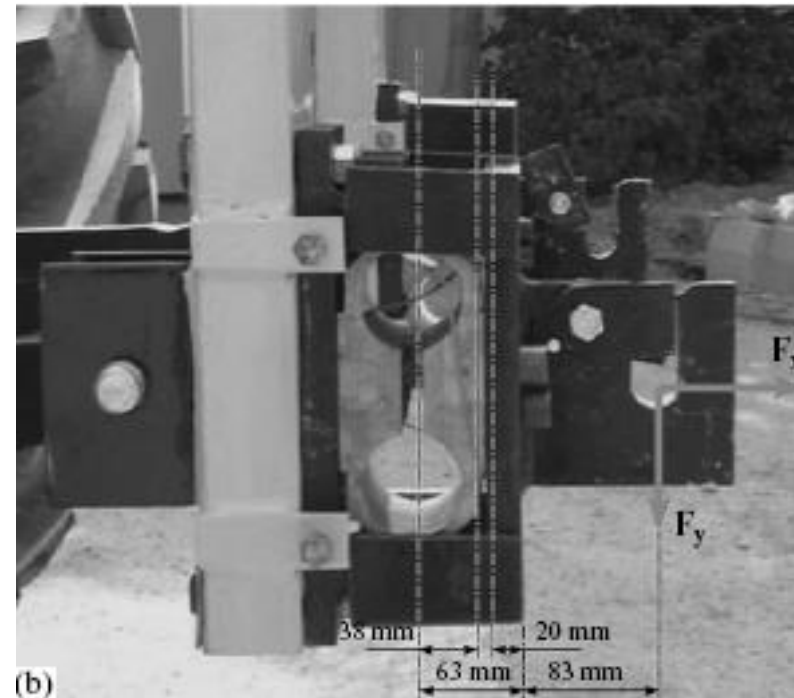
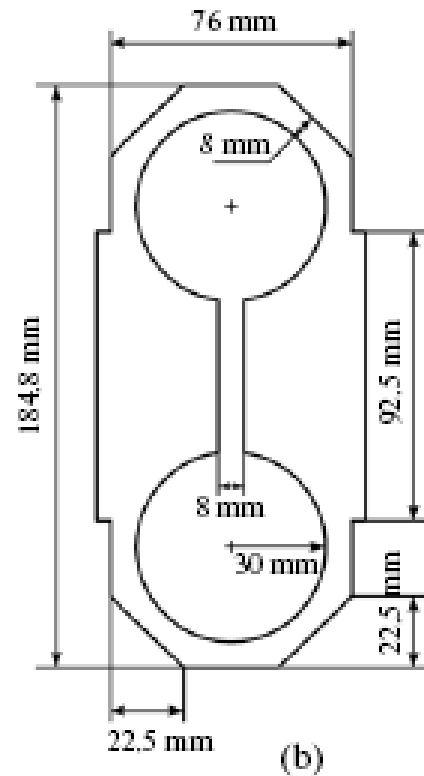
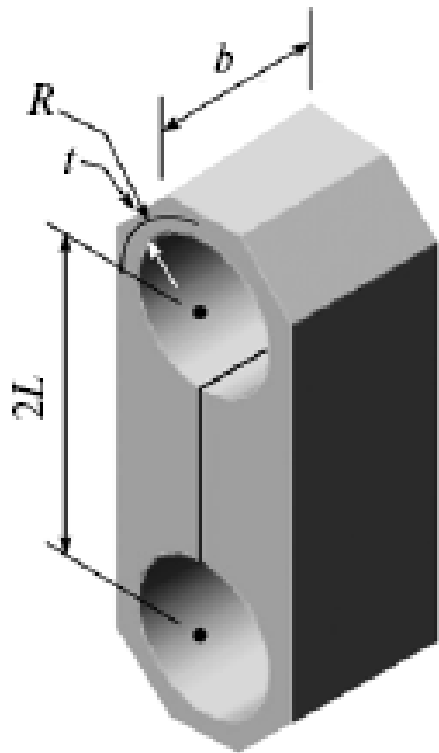
LOAD CELL

- A load cell is a transducer that is used to convert a **force into electrical signal**. This conversion is indirect and happens in two stages.
- Through a mechanical arrangement, the force being sensed deforms a **strain gauge**.
- The strain gauge measures the deformation (strain) as an electrical signal, because the **strain changes the effective electrical resistance of the wire**.
- A load cell usually consists of four strain gauges in a **wheatstone bridge** configuration.
- Load cells of one strain gauge (quarter bridge) or two strain gauges (half bridge) are also available.
- The electrical signal output is in the order of a few millivolts and requires amplification by an amplifier before it can be used.
- The output of the transducer is plugged into an algorithm to calculate the force applied to the transducer.
- A data logger is used to store the data

Draft Measurement System (Load cell) Mounted on a Tractor



Extended octagonal ring transducer



Calibration of the EORT

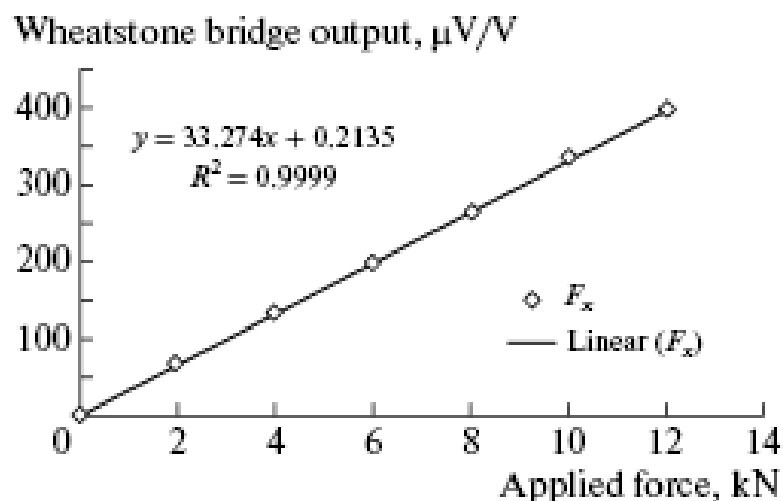


Fig. 6. Calibration curve for horizontal force of the EOR transducer no. 3.

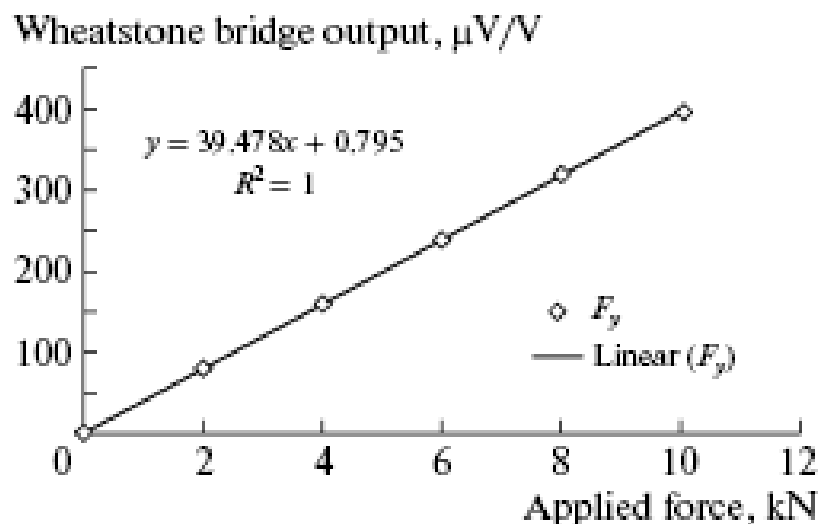


Fig. 7. Calibration curve for vertical force of the EOR transducer no. 3.