Basics of Web Tension Control
Summary

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This presentation is intended to take the mystery out of web tension control. It is intended for operators, designers and engineers who would like a better understanding of their existing process and how they might improve both efficiency and consistency.

The presentation covers the different aspects of machines including unwinds, rewinds and point-to-point applications. It also looks at the different methods of control be it either speed or torque.

Lastly we will explore the different types of tension systems including: manual, open loop and closed loop. We will discuss different components and methods used in each, as well as the advantages and disadvantages. This section is intended to help the audience best select the system best suited to their individual applications.

The audience should be able to take away some basic "do's and don'ts" as well as some practical advice on how to improve their tension.

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Basics of Web Tension Control

Presented by:

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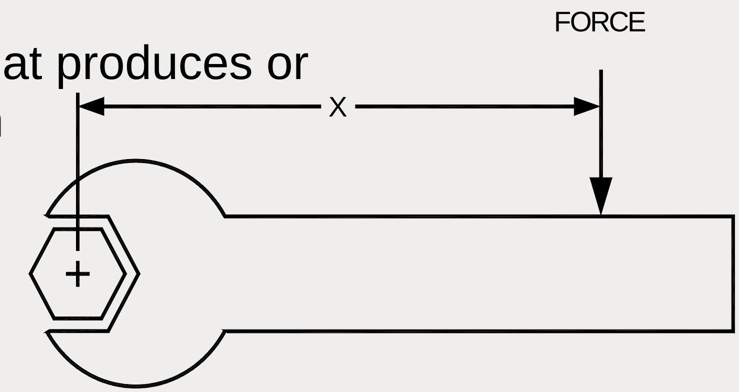
MAGPOWR

Terms and Relationships Defined

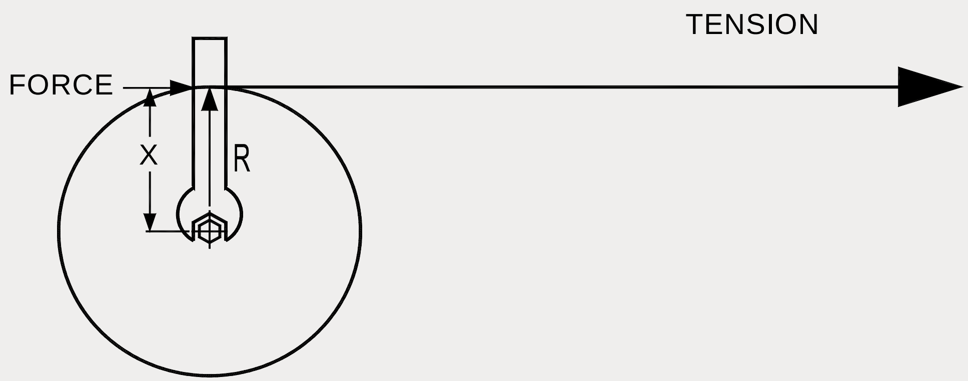
Force = A push or pull

Torque = A force at a distance (X) that produces or
tends to produce rotation



TORQUE (TQ)= FORCE (F) x PERPENDICULAR DISTANCE (D)

(from axis of rotation)
Sometimes called "Lever Arm"



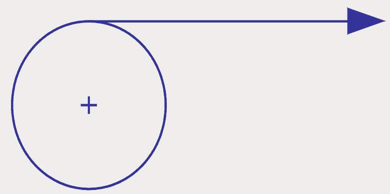
TORQUE (TQ)= TENSION (T) x RADIUS (R)

$TQ = T \times R$

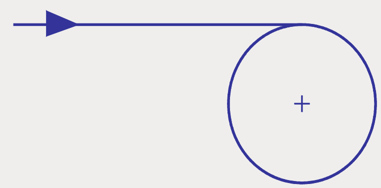
Typical Tension Control Applications

Normal Running Conditions

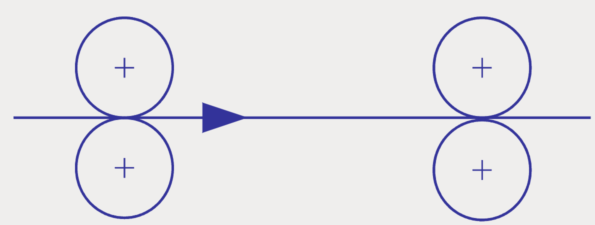
- Unwind



- Rewind



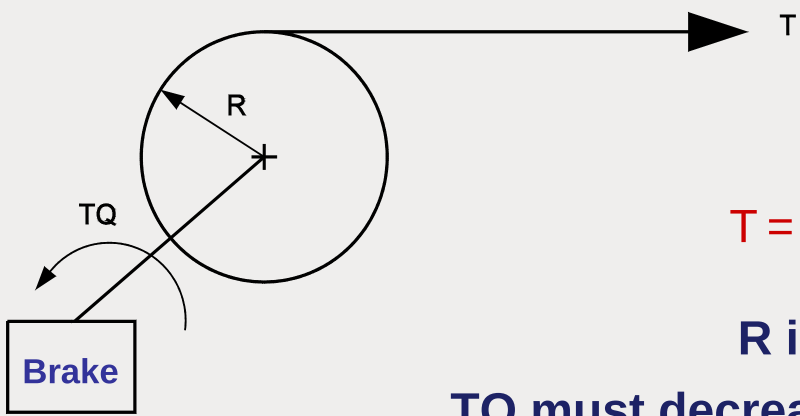
- Point - to - Point



Typical Applications - Unwind

Center Unwind

$$TQ = T \times R$$



"Hold back" to create tension

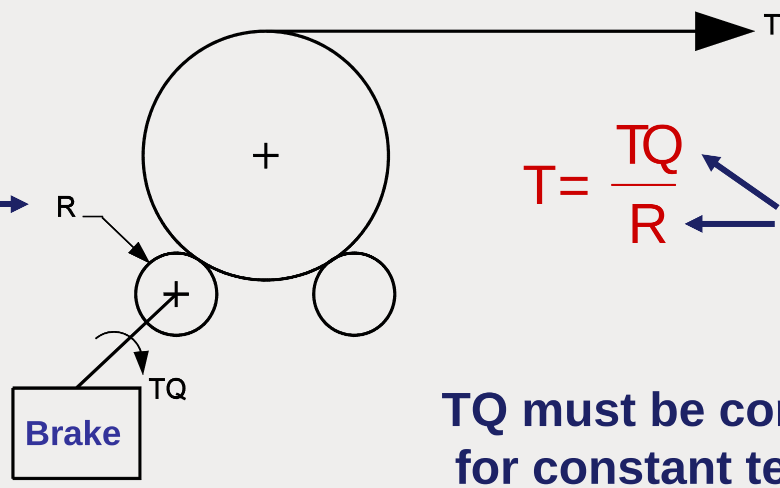
$$T = \frac{TQ \downarrow}{R \downarrow}$$

R is decreasing

TQ must decrease for constant tension

Surface Unwind

Constant →



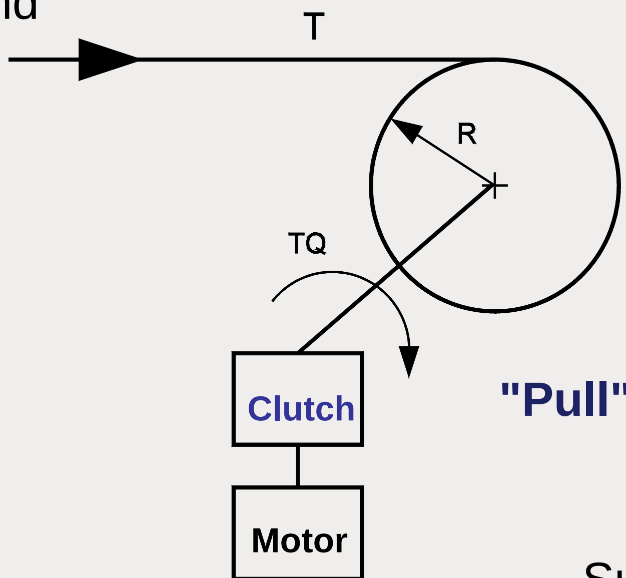
$$T = \frac{TQ}{R}$$

Constant

TQ must be constant for constant tension

Typical Applications - Rewind

Center Rewind



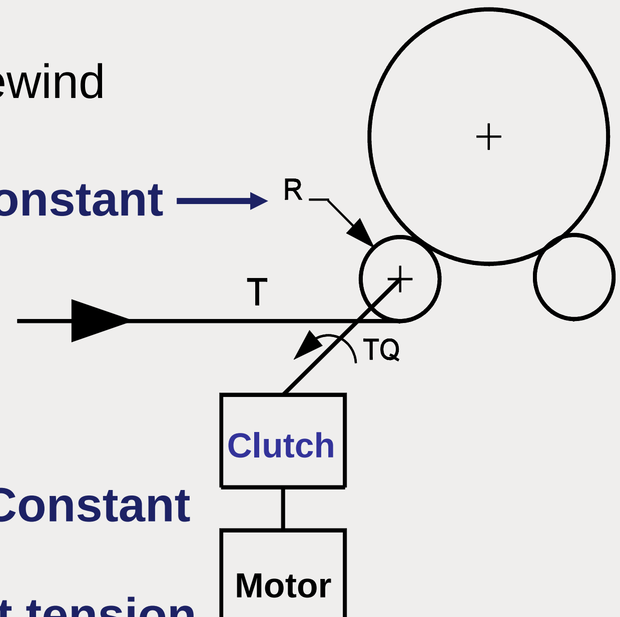
$$T = \frac{TQ}{R\uparrow}$$

"Pull" web to create tension

R is increasing
TQ must increase for constant tension

Surface Rewind

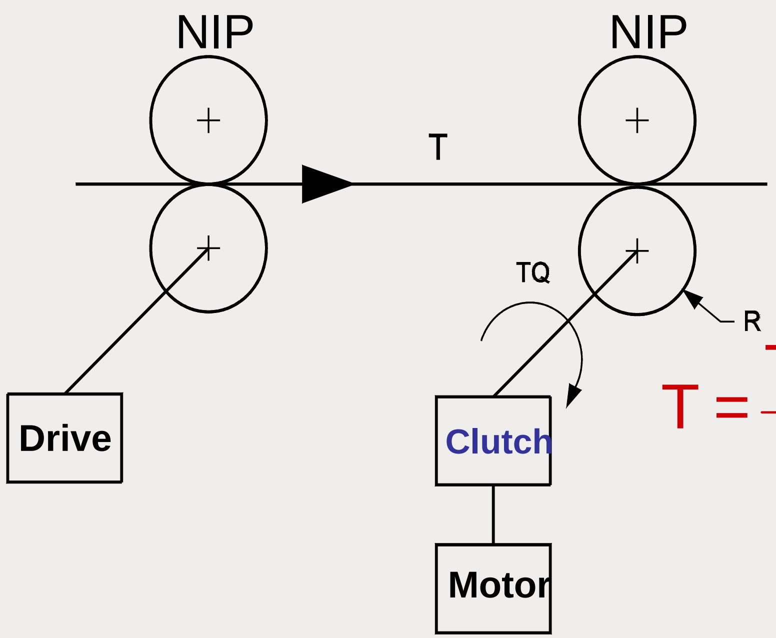
Constant →



$$T = \frac{TQ}{R} \leftarrow \textbf{Constant}$$

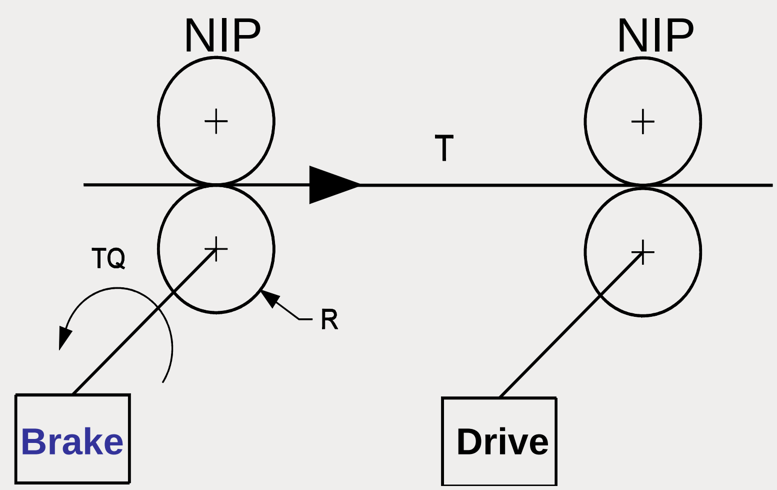
TQ must be constant for constant tension

Typical Applications
Point-to-Point



$$T = \frac{TQ}{R}$$

Constant



$$T = \frac{TQ}{R}$$

Constant

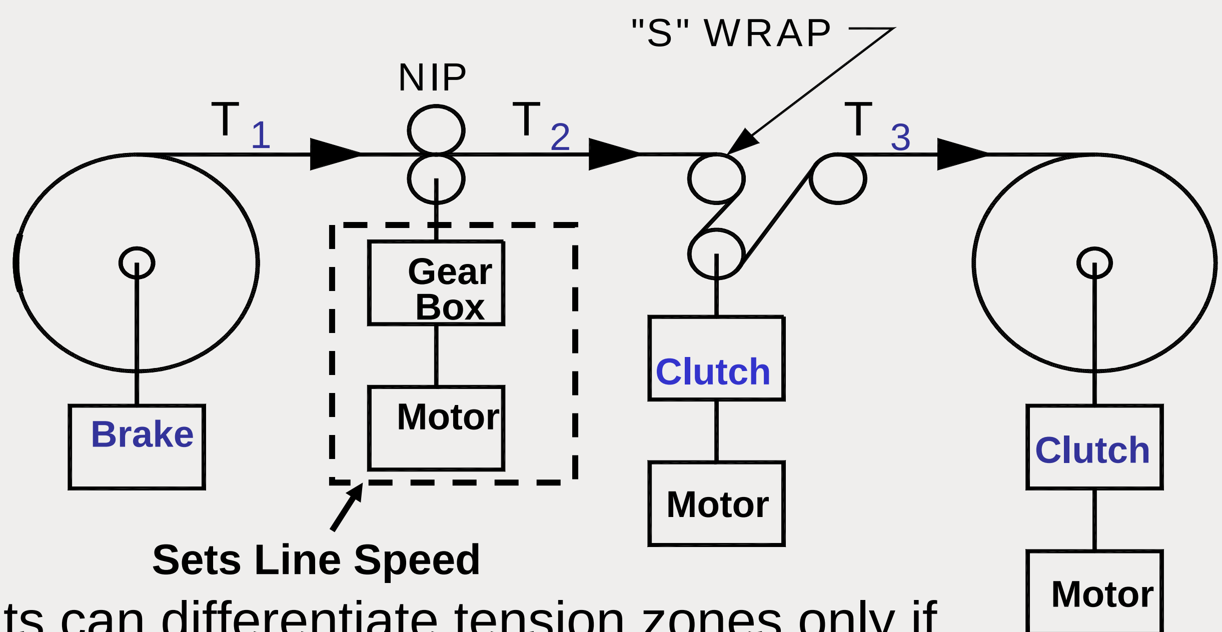
Constant torque produces constant tension

Creating Tension Zones

What is a tension zone?

What are some typical sources used to create tension zones?

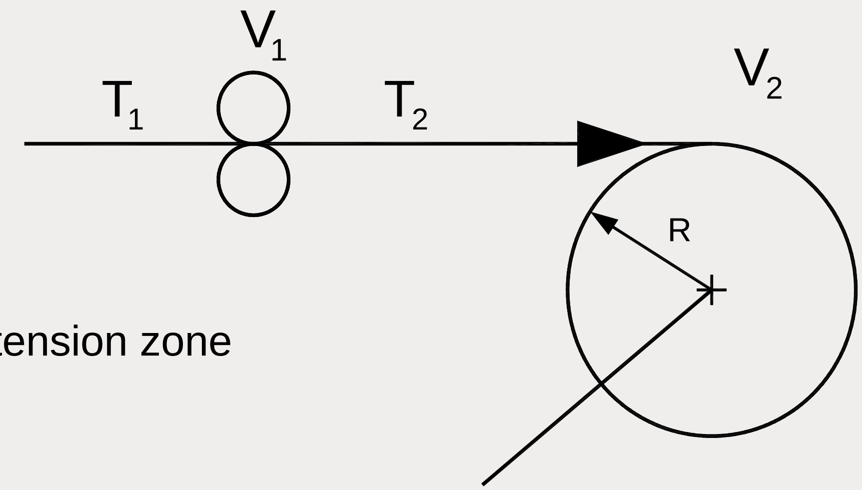
A section of web where a different tension can be created in the web



- Nip points can differentiate tension zones <u>only</u> if the web cannot slip through them

We show high ratio gear boxes or regenerative drives on the motors

Methods of Control
(Speed Control)



Where:

- T_1 = Tension in the previous tension zone
- T_2 = Rewind tension
- V_1 = Nip roll velocity
- V_2 = Rewind velocity
- E = Elasticity of the material
- A = Cross sectional area of the material

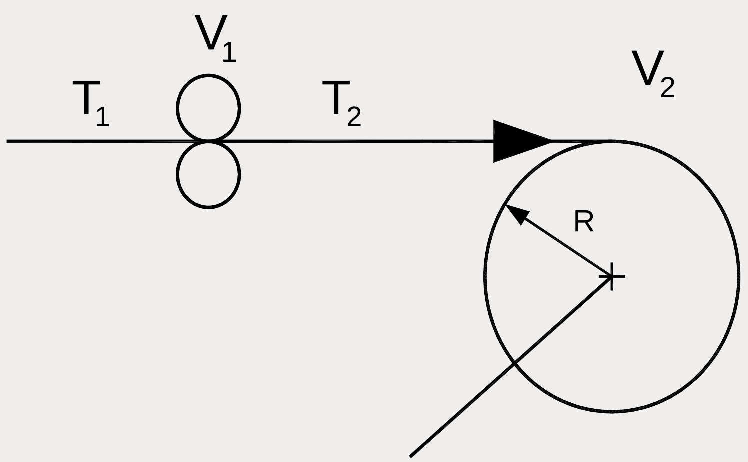
$$T_2 = T_1\left(\frac{V_2}{V_1}\right) + \frac{EA(V_2 - V_1)}{V_1}$$

The larger the elasticity (E), the less likely the material is to stretch. For most values of EA, use **TORQUE CONTROL**

For stretchy material, where E is small, speed control can <u>approach</u> being as good as torque control

Speed Control Case

$$T_2 = T_1\left(\frac{V_2}{V_1}\right) + \frac{EA(V_2 - V_1)}{V_1}$$



Example: $T_1 = 0$
$V_1 = 100$ fpm
$V_2 = 102$ fpm
EA = 500 lb

Controlling Function

$$T_2 = 0\,\text{lb}\left(\frac{102\text{fpm}}{100\text{fpm}}\right) + \frac{500\text{lb}(102\text{fpm} - 100\text{fpm}))}{100\text{fpm}} = 10\text{ lb}$$

$$V_2 = 1.0025\ (102\text{ fpm}) = 102.255\text{ fpm}$$

If we allow a 0.25% error in V_2:

Then:

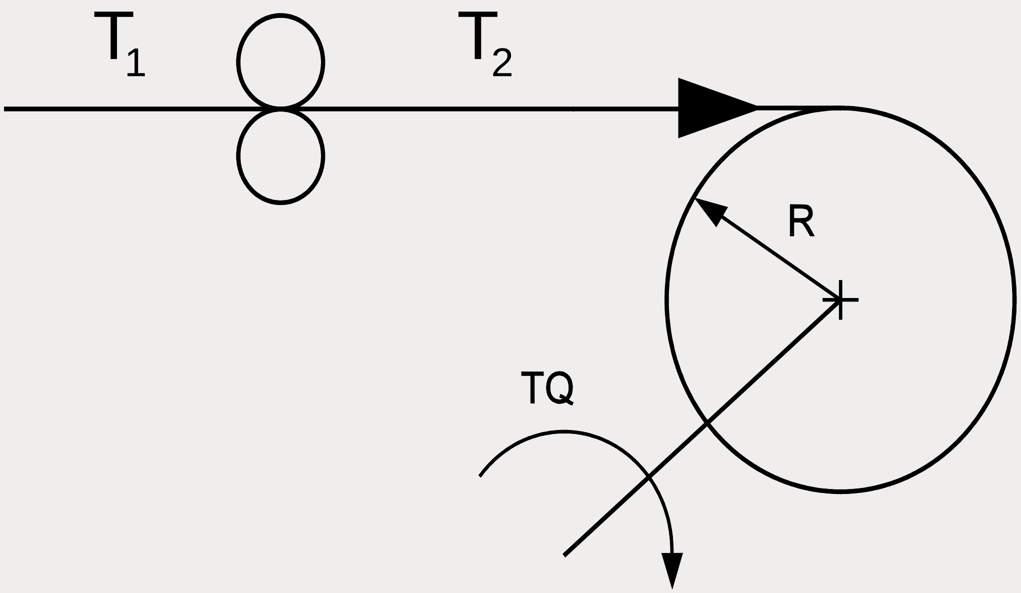
$$T_2 = 0\,\text{lb}\left(\frac{102.255\text{fpm}}{100\text{fpm}}\right) + \frac{500\text{lb}(102.255\text{fpm} - 100\text{fpm})}{100\text{fpm}}$$

$$= 11.275\text{lb}$$

Therefore: 0.25% error in speed results in a 12.75% error in tension.

$$\text{Error} = \frac{11.275 - 10}{10} = 12.75\%$$

Methods of Control (Torque Control)



$$T_2 = \frac{TQ}{R}$$

Where:

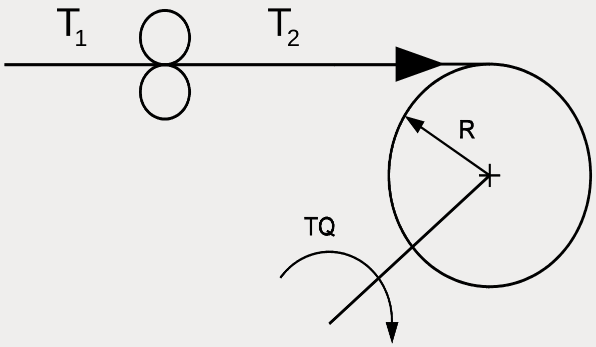
T_2 = Rewind tension

R = Radius

TQ = Torque

Torque Case

Magnetic Particle Clutch or Brake



Example: R = 1 ft
TQ = 10 lb-ft

$$T_2 = \frac{TQ}{R}$$

Controlling Function

$$T_2 = \frac{10\,lb\text{-}ft}{1\,ft} = 10\ lb$$

Allow a 0.25% error in torque (TQ):

TQ = 10 lb-ft (1.0025) = 10.025 lb-ft

Then:

$$T_2 = \frac{10.025\,lb\text{-}ft}{1\,ft} = 10.025\ lb$$

Error = $\frac{10.025 - 10}{10} = .25\%$

Therefore: **0.25% error in torque results in a 0.25% error in tension**

Torque and tension are directly related !

Summary

Torque vs. Speed

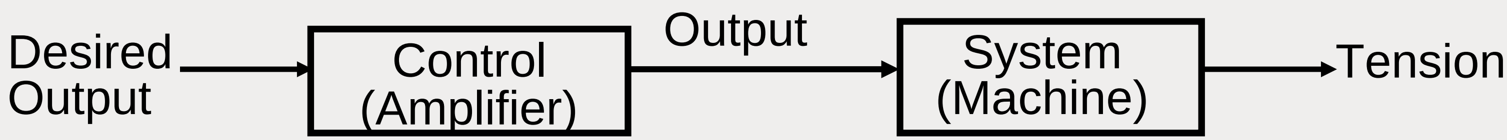
- For a 0.25% error in the controlled output, the resultant error in tension was:

- 0.25% = Magnetic particle clutch or other torque device

- 12.75% = Speed case

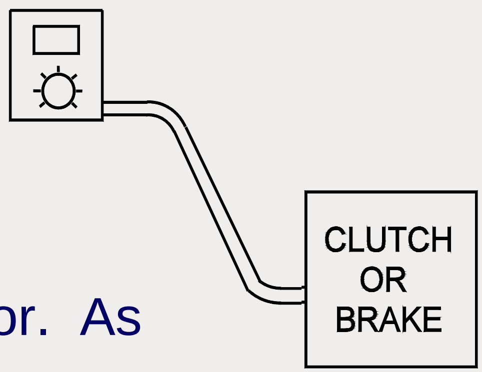
Manual Systems

Manual Control



Output / tension is influenced only
by operator adjustment.

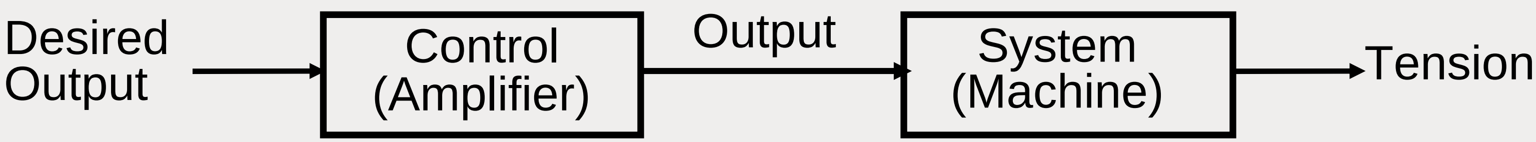
If the operator walks away, the control output does not change
Therefore, on unwind/rewind, tension will change as the roll diameter changes



Example: Driving a car with a fixed accelerator. As you go up a hill, the car will slow down.

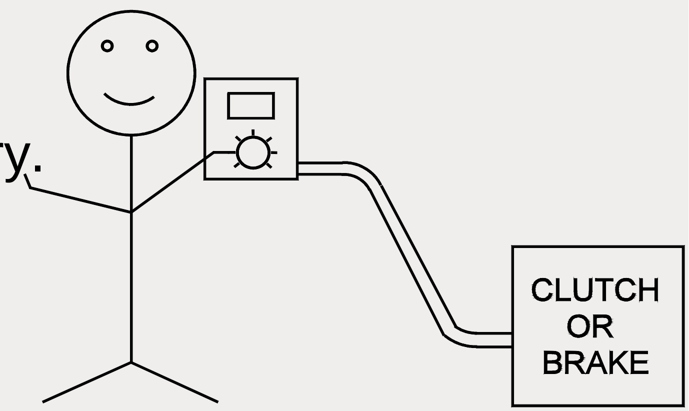
Manual Systems

Manual Control



Output / tension is influenced only
by operator adjustment.

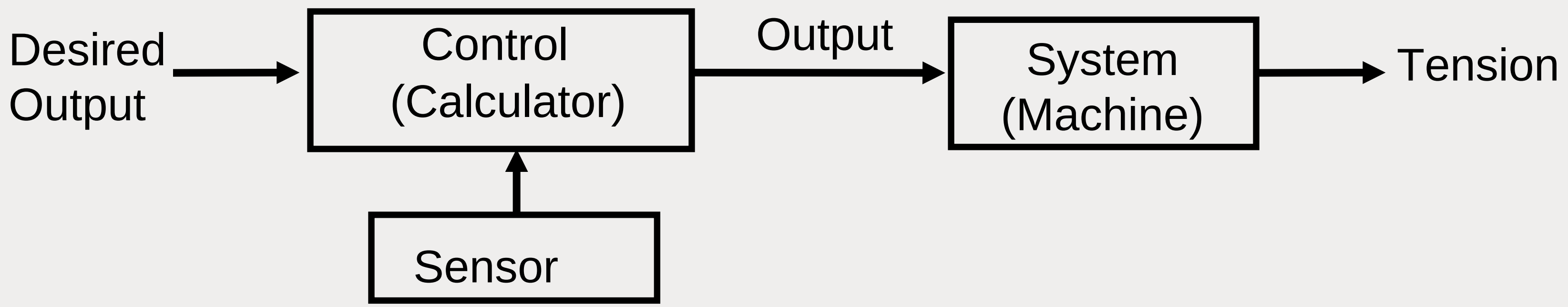
To try to keep tension constant as the roll diameter changes, the operator must adjust the control output as he thinks it is necessary.



Example: Driving a car and as you go up a hill, you try to adjust the accelerator by visually estimating the incline. (No speedometer)

Open Loop Systems

Open Loop Control

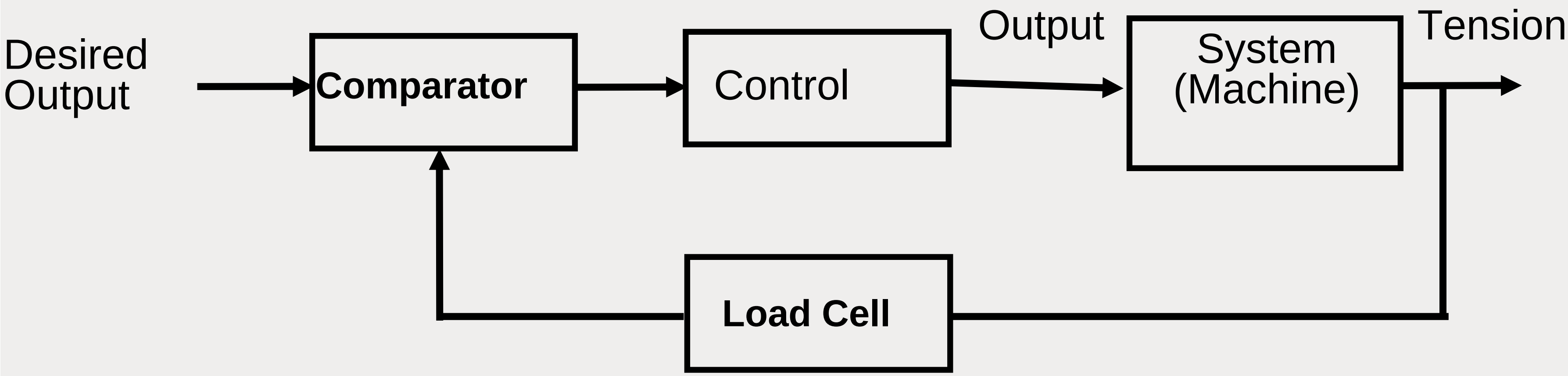


Output / tension is influenced by operator adjustment and calculations made from a sensor input.

Example: Driving a car equipped with a sensor that detects changes in incline and makes the accelerator adjustment to try to keep speed constant. (Sensor is not measuring speed.)

Closed Loop Systems

- Provide some form of feedback
  - Tension Sensors
  - Dancer Arm
  - Free Loop



Example: Driving a car and controlling the speed by adjusting the accelerator based upon the speedometer reading.

(Actual speed feedback "Cruise Control")

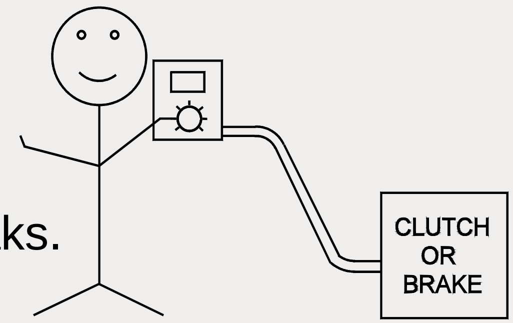
Manual Tension Controls

- Unwind Applications
  - Not good
    Hot brakes & web breaks.

- Rewind Applications
  - Good
    If taper tension is required.

You get what you get, based on roll build

- Point - to - Point
  - Good
    Constant torque on a constant radius equals constant tension.



$\uparrow T = \dfrac{TQ}{R\downarrow}$ ← **Constant**

$\uparrow SW = \dfrac{TQ \times rpm\uparrow}{7}$

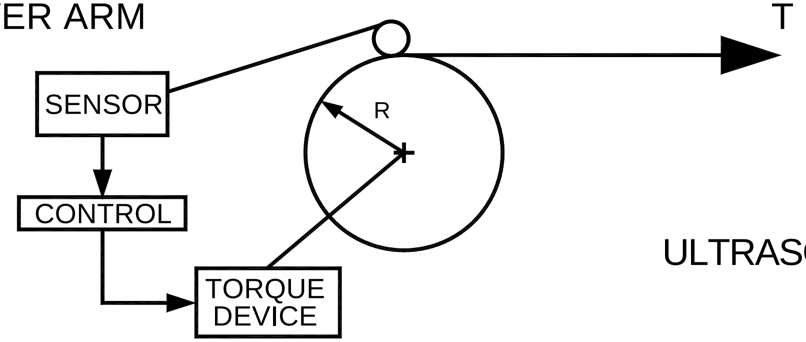
$\downarrow T = \dfrac{TQ}{R\uparrow}$ ← **Constant**

$T = \dfrac{TQ}{R}$ — TQ ← **Constant**; R ← **Constant**; T ↑ **Constant**

HP is constant

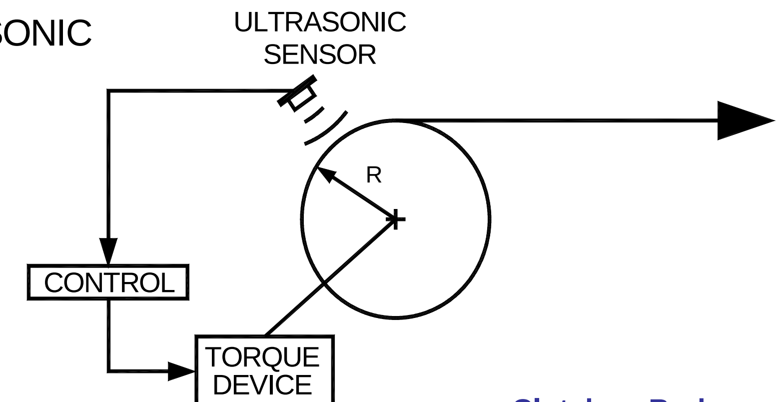
Automatic Open Loop Tension Controls (Roll Diameter Compensation)

FOLLOWER ARM



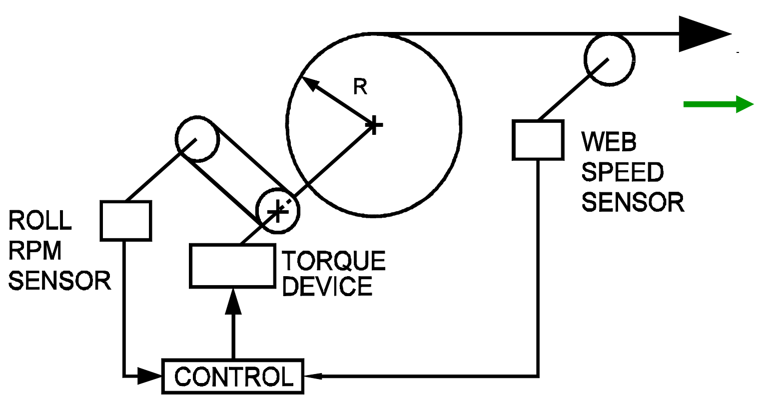
Clutch or Brake

ULTRASONIC



Clutch or Brake

ROLL RPM VS WEB SPEED



Problem: Control needs some rotation to calculate diameter. On start-up, the control does not know what output is correct.

Open Loop Systems Summary

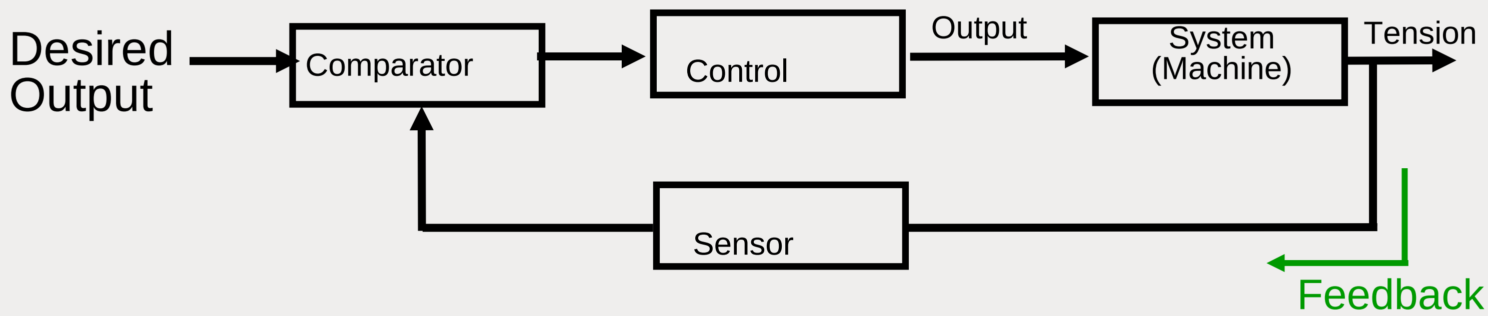
- Compensates for changes in roll diameter only

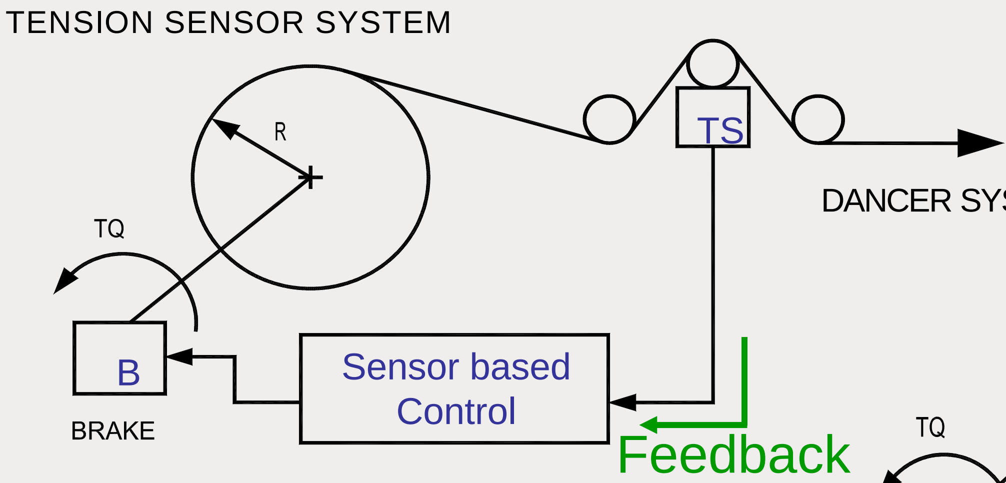
- Does not compensate for or reduce tension transients that occur due to other parts of the system
  Open loop does not have tension measurement

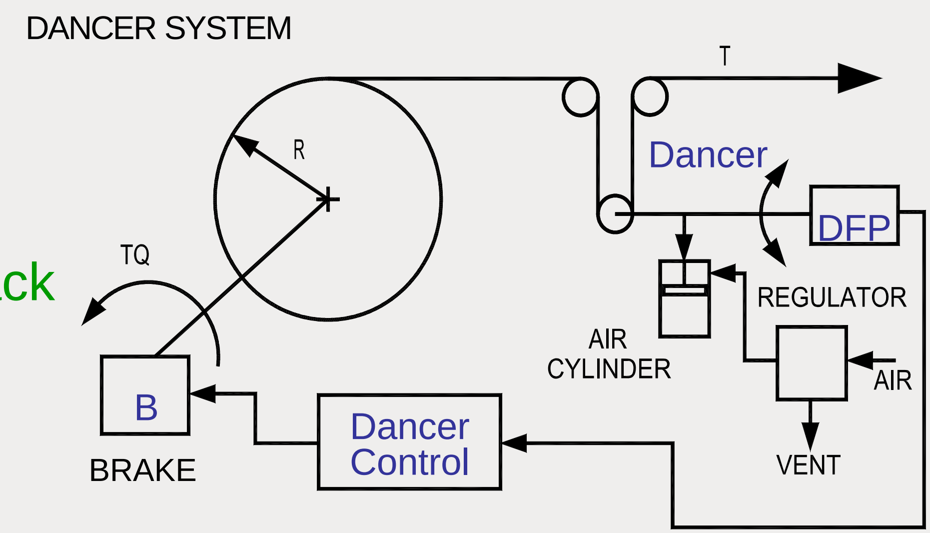
- Does not compensate for tension errors due to non-linearity of device being controlled (i.e. brake, clutch, motor etc.
  No feedback

- Ultrasonic control is the easiest to install and set up
  It's easy and it works!

Closed Loop Systems







Summary (do’s and don’ts)

- Identify what is setting line speed
- Don’t control tension on the device setting line speed
- Use a torque device to control tension
- Make sure web does not slip through nips
- Don’t use manual controls on center unwinds
- Beware of diameter calculator controls
- For indexing or out-of-round roll applications use a dancer system

Thank You

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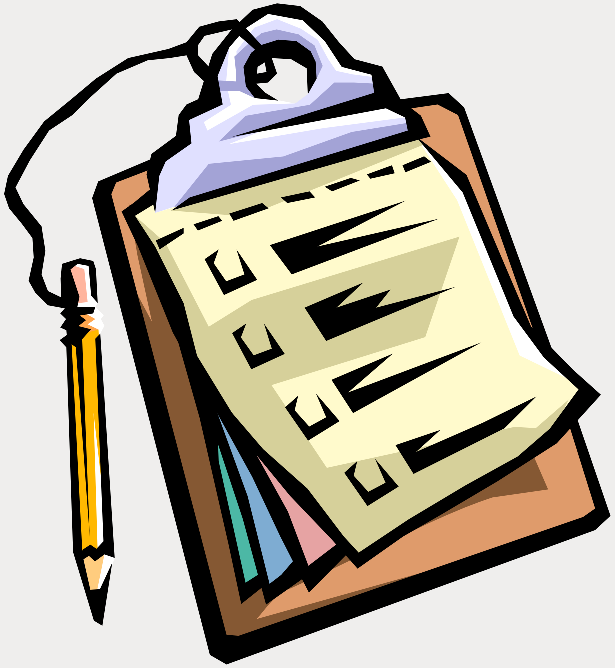

Please remember to turn in your evaluation sheet...