The Mechanics of Tension Control

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Introduction

- What is tension?
- Why is tension important to me?
- Where is tension control important in the process?
- How do tension controls work?
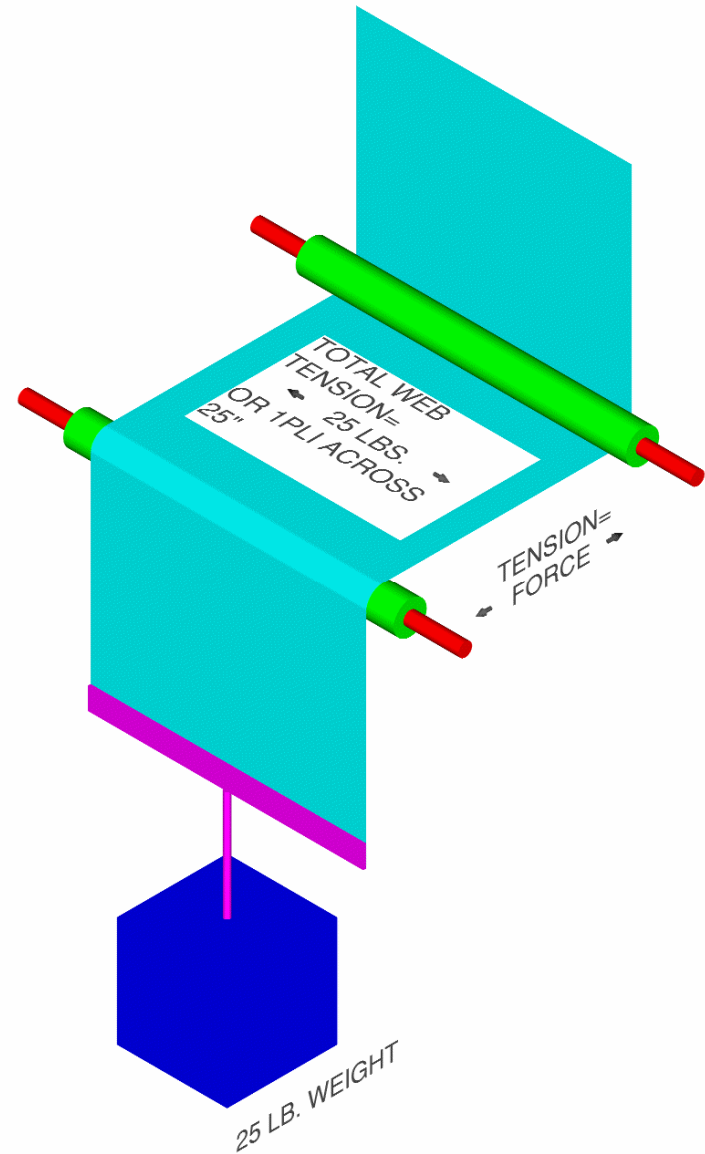- What is the difference between closed loop and open loop tension controls?

What is tension?

Tension is the force applied to a continuous web of material in the machine direction
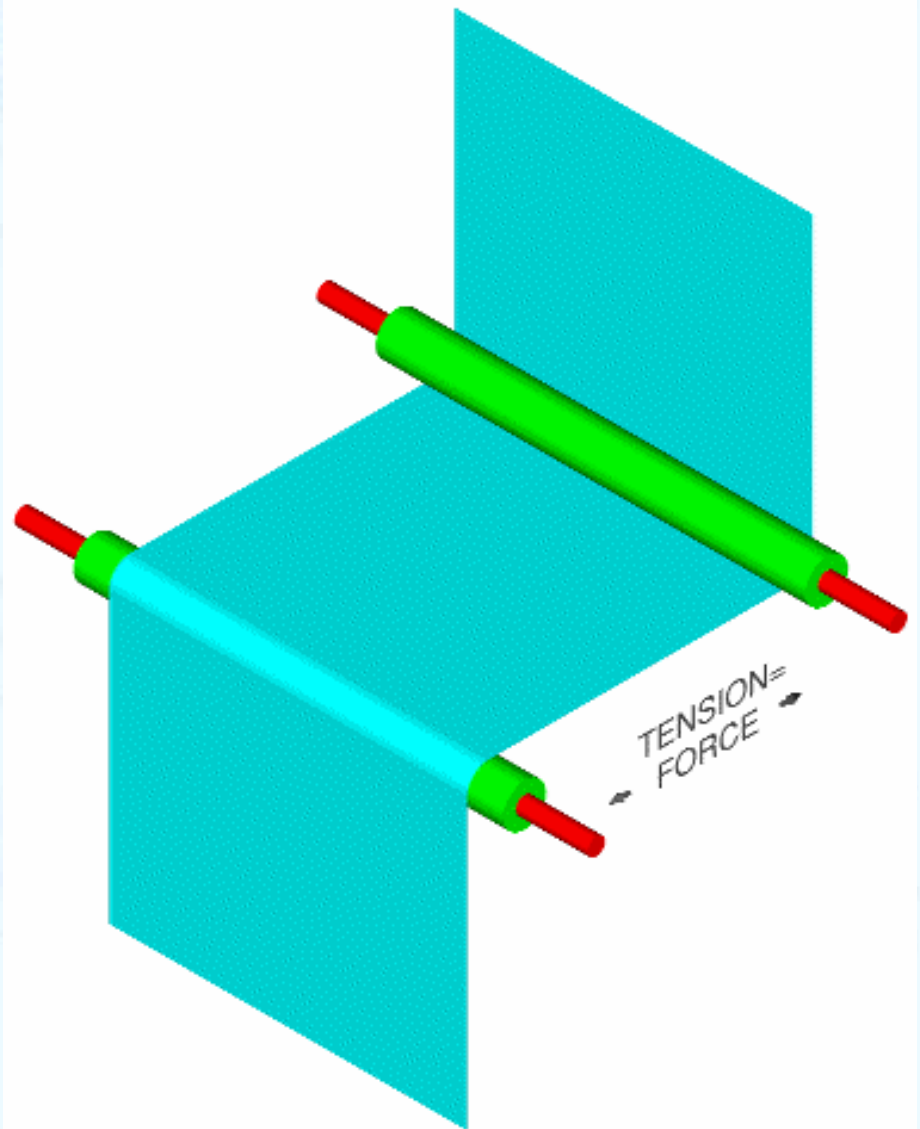
What is tension?

Tautness on the web as if you hang a weight off the webs edge

How is tension measured?

- Typically tension is measured in PLI (Pounds per Linear Inch) in the USA
- PLI = total pounds of tension divided by web width in inches
- Total web tension = PLI times web width in inches

Why is tension important?

- Needed to control your web
  - Unwind
  - Process
  - Rewind
- Web handling principal requires web traction with all idler and driven rolls

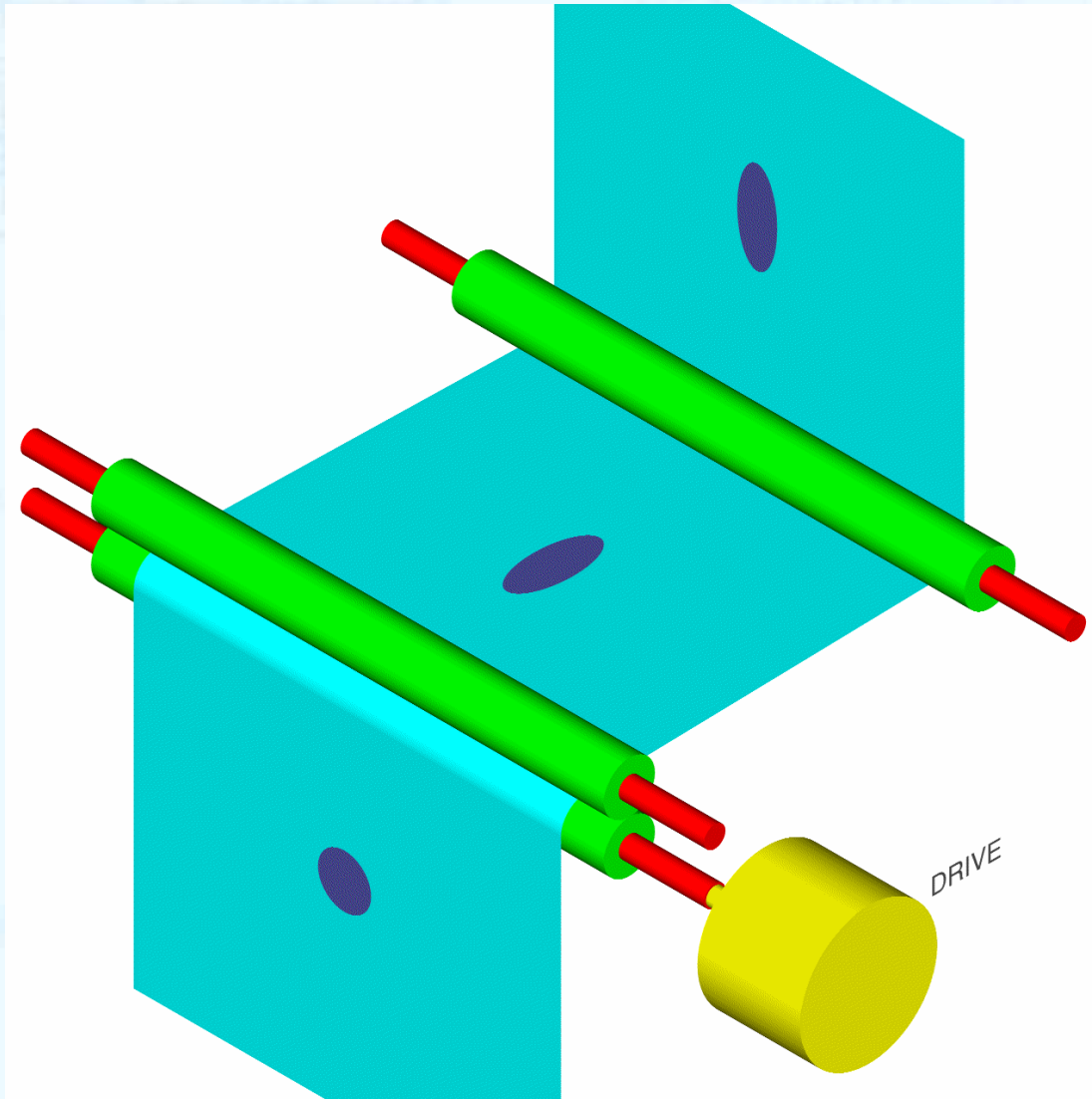# Why is tension important?

Web handling principal
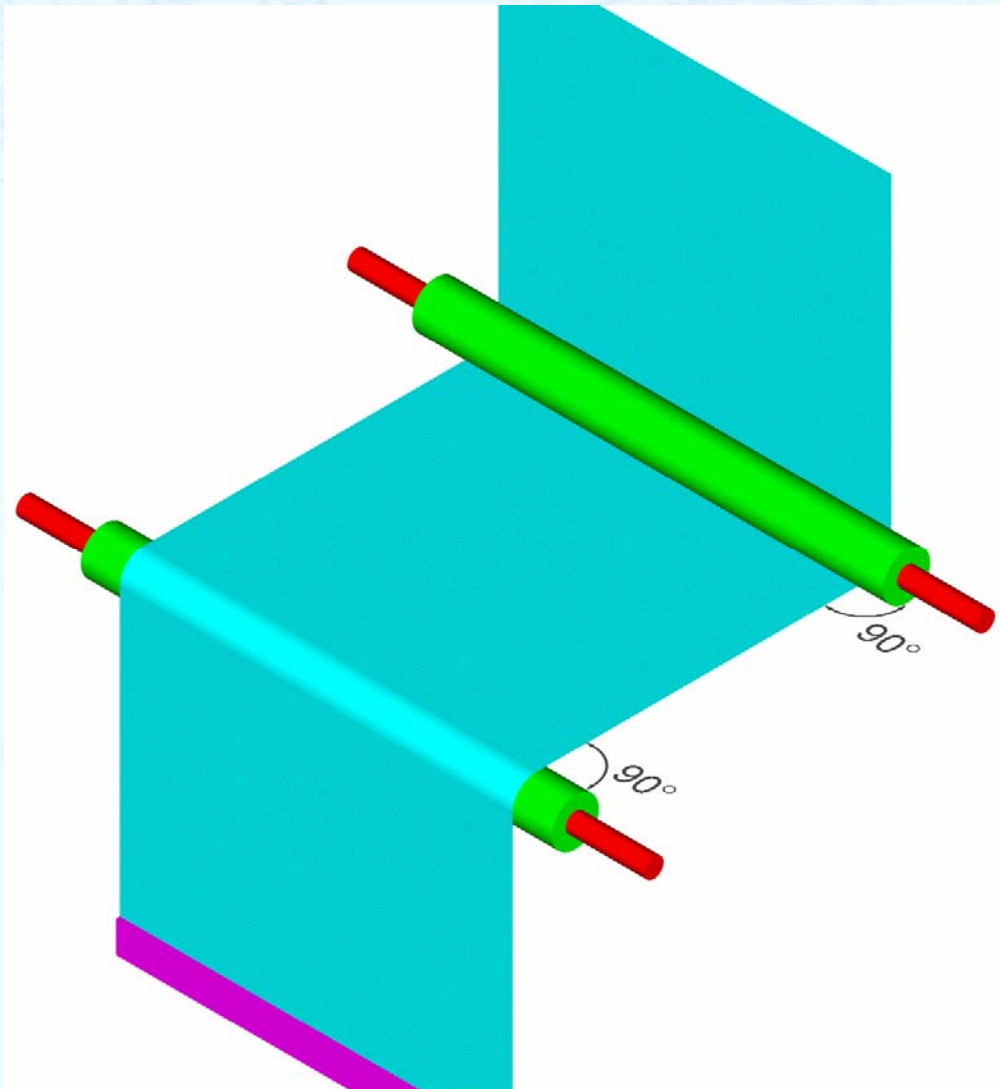
Why is tension important?

- Web guide systems will not work without web tension and traction
- Many wrinkle removal systems like bowed rolls rely on tension and traction to work
- All webs stretch in the machine direction

Why is tension important?
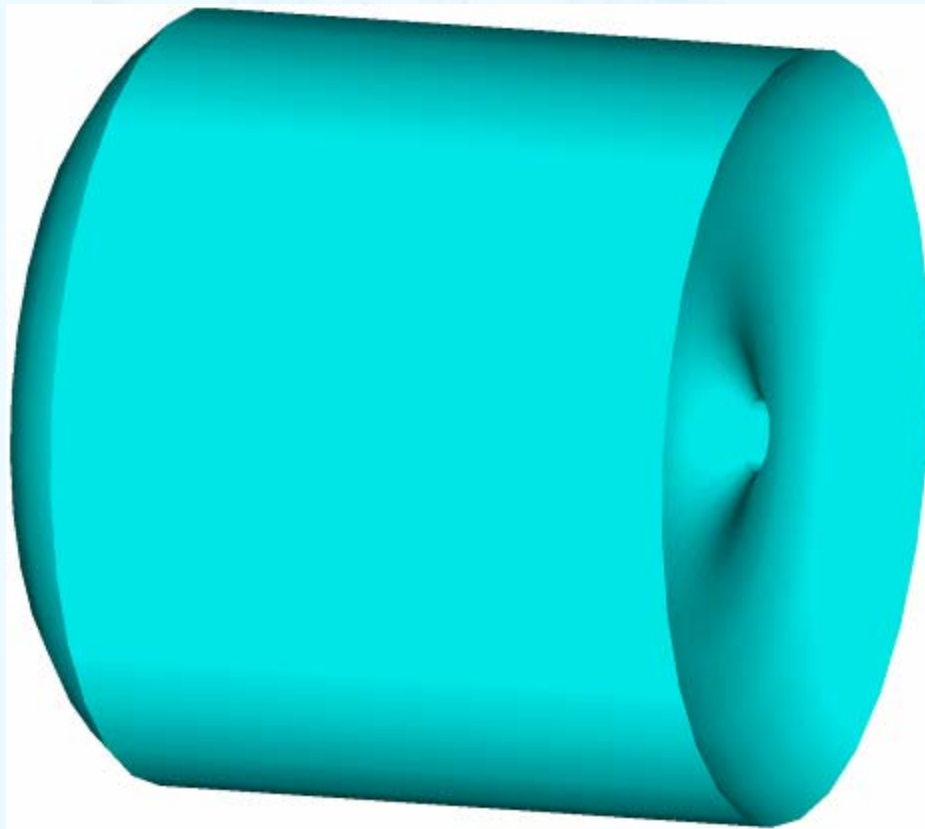
Effects of web
stretching
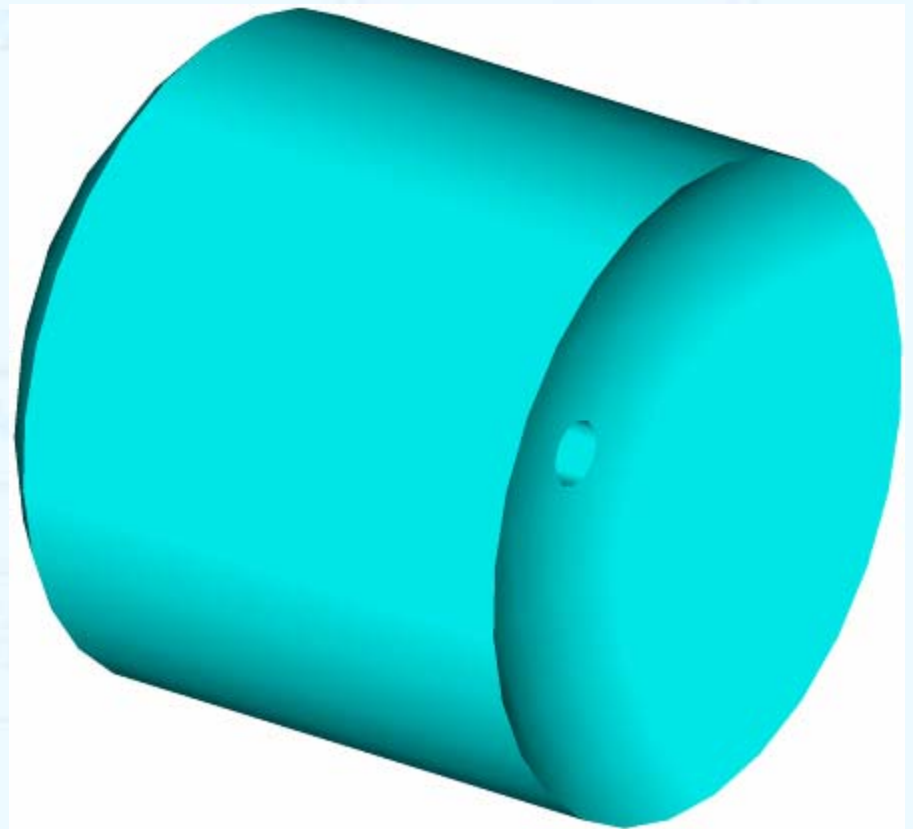
Why is tension important?

- Problems at unwind and rewind stations
  - Telescoping
  - Dished
  - Wrinkles
  - Web breaks

Why is tension important?

Example of dished roll

Example of telescoped roll

Why is tension important?

- Registration
  - Print to print
  - Pint to die
- Avoid web curl when laminating

Why is tension important?

Example of laminating process
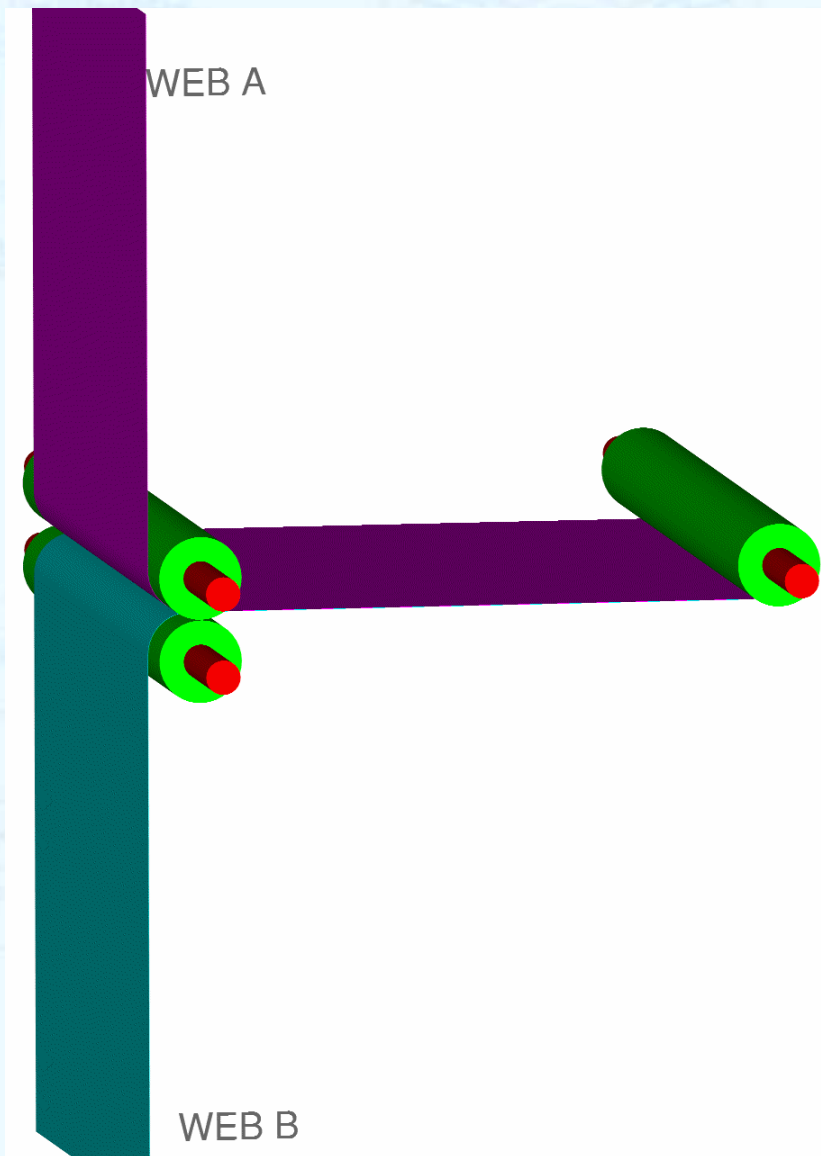
WEB A

WEB B

Why is tension important?

Web curl where tension in "web A" is greater than "web B"
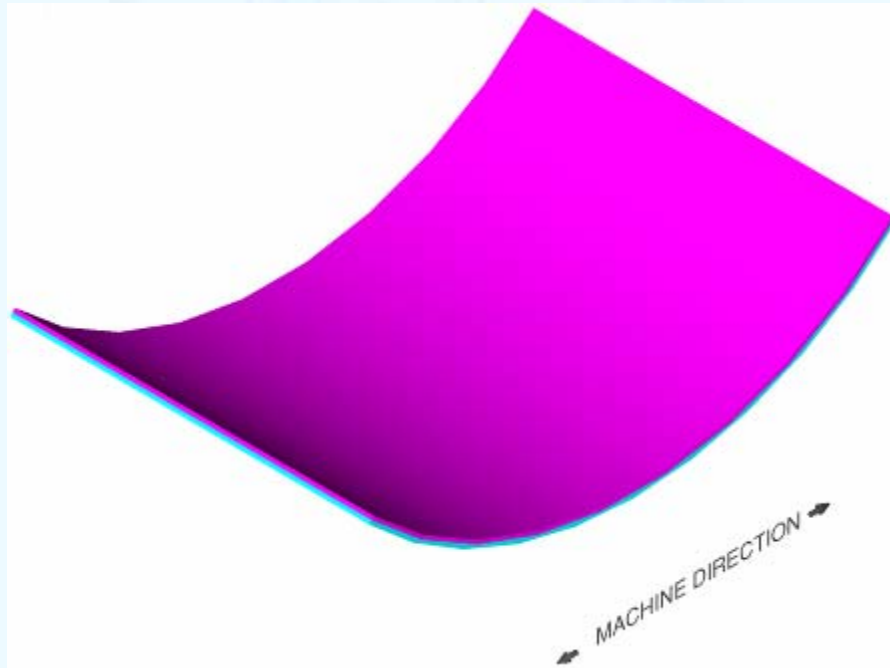
Web curl where tension in "web A" is less than "web B"

MACHINE DIRECTION

MACHINE DIRECTION
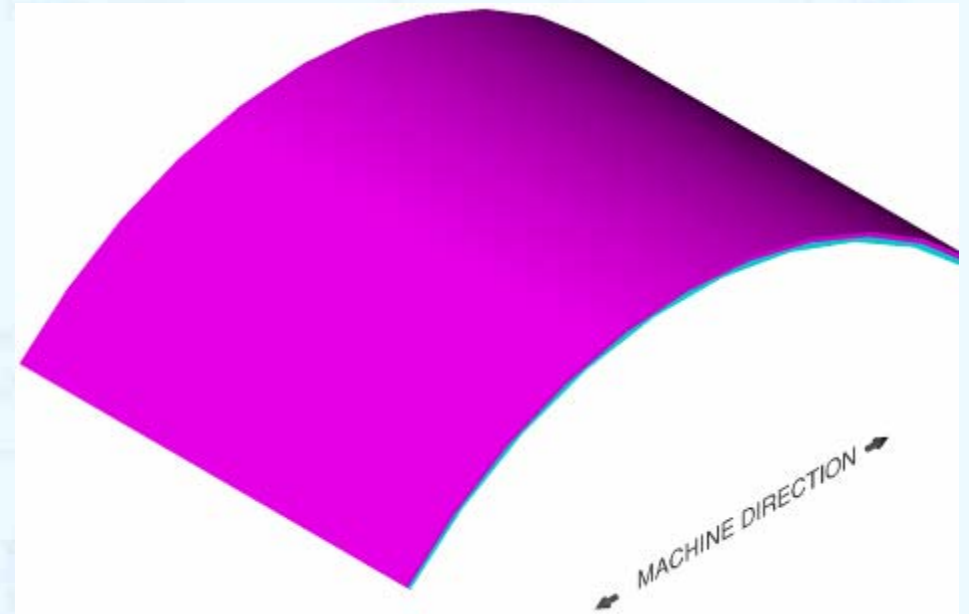
Why is tension important?

- Slit position
- Web stretch and contraction will cause wrinkles

Where is tension control important in the process?
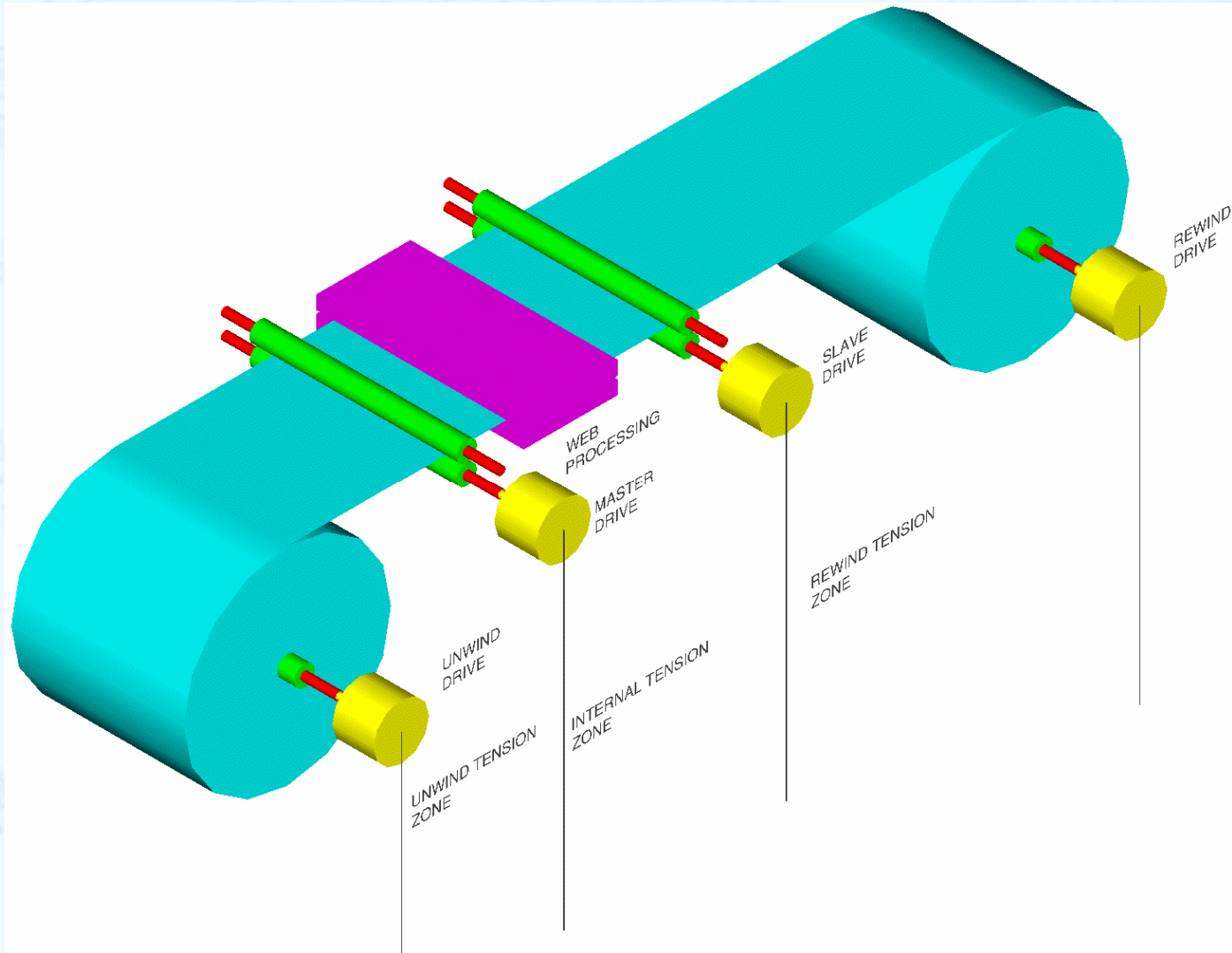
Where is tension control important in the process?

- Each zone is unique and controlled independently
- Each zone may have its own tension level
  - 1 PLI at unwind zone
  - 2 PLI at internal zone
  - 1.5 PLI at rewind zone

A word about the term - drive

- Drive is a generic term
- Used to deliver torque (power) to
  - Unwind rolls
  - Rewind rolls
  - Driven rollers
- This device could be
  - Motor
  - Brake
  - Clutch

How is tension delivered to the web?

- Torque = tension times roll radius
- For constant tension, torque must decrease at the unwind
- For constant tension, torque must increase at the rewind
- Internal zones are much more stable – roll radius does not change

How is tension delivered to the web?

Torque =
Tension X radius is linear

Torque must be decreased
at a linear rate at unwind

Torque must be increased
at a linear rate at rewind

17.5 / 1.75 Radius =
10:1 ratio

17.5" RADIUS
35" DIAMATER
ROLL

1.75" RADIUS
3.5" DIAMETER
CORE

UNWIND
DRIVE
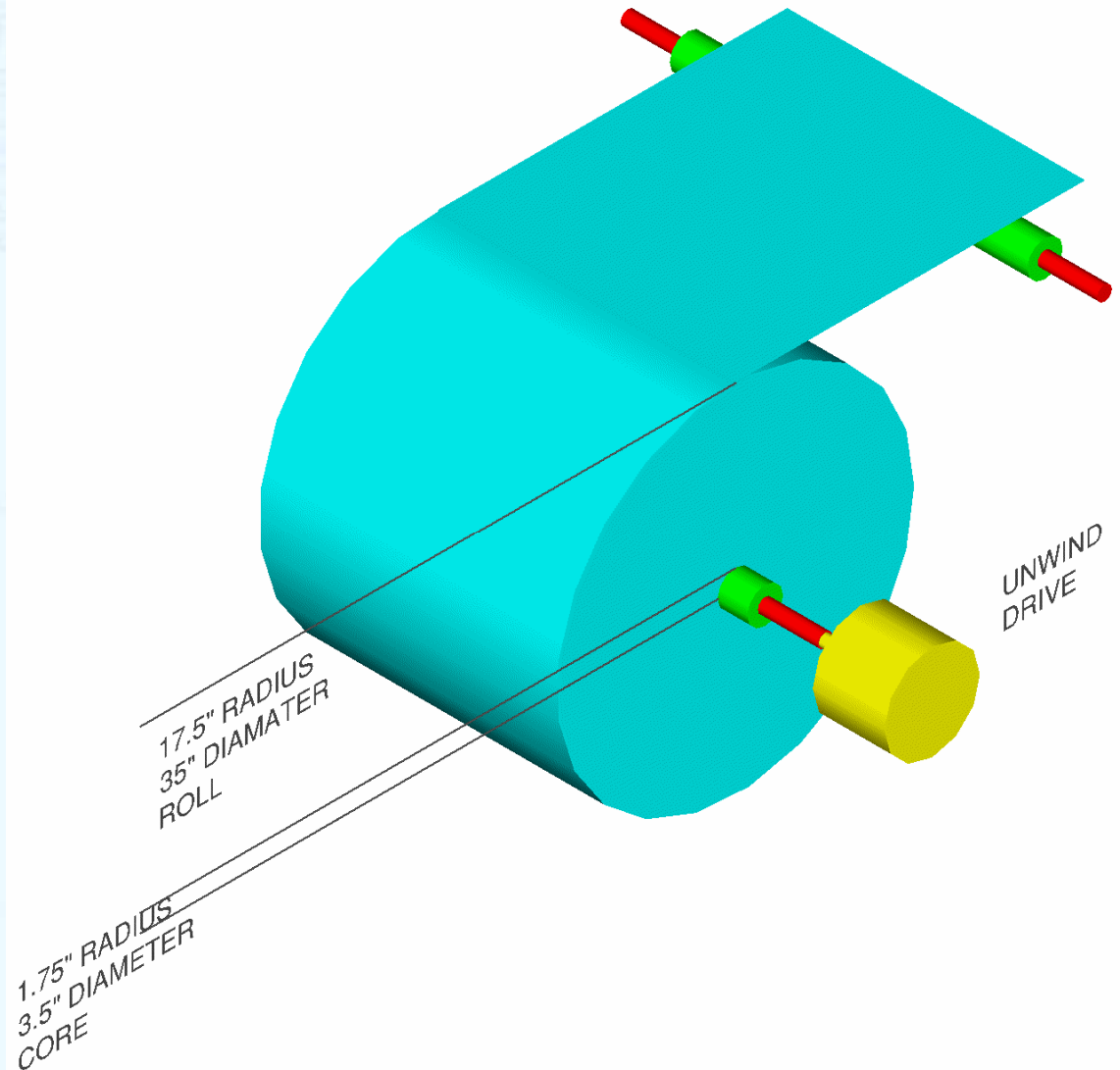
What is the right tension for me?

- Machine designers generally determine the proper tension for specific machines, based on past experience
- TAPPI (Technical Association of the Pulp and Paper Industry) publishes estimated proper tension levels for many types of materials and laminates
- Other industry resources
- General rule of thumb – 10-25% of tensile strength
- Many times proper tension for each zone can only be determined by running your process and trial and error

How do I measure tension in my existing process?

Load cell controls and displays will display actual web tension in pounds across the web

Divide total web tension in pounds by the web width in inches for PLI (Pounds Per Linear Inch)

LOAD CELL SENSOR

DISPLAY OF TENSION IN TOTAL POUNDS ACROSS THE WEB.

DIVIDE TOTAL POUNDS BY THE WEB WIDTH IN INCHES FOR PLI (POUNDS PER LINEAR INCH)
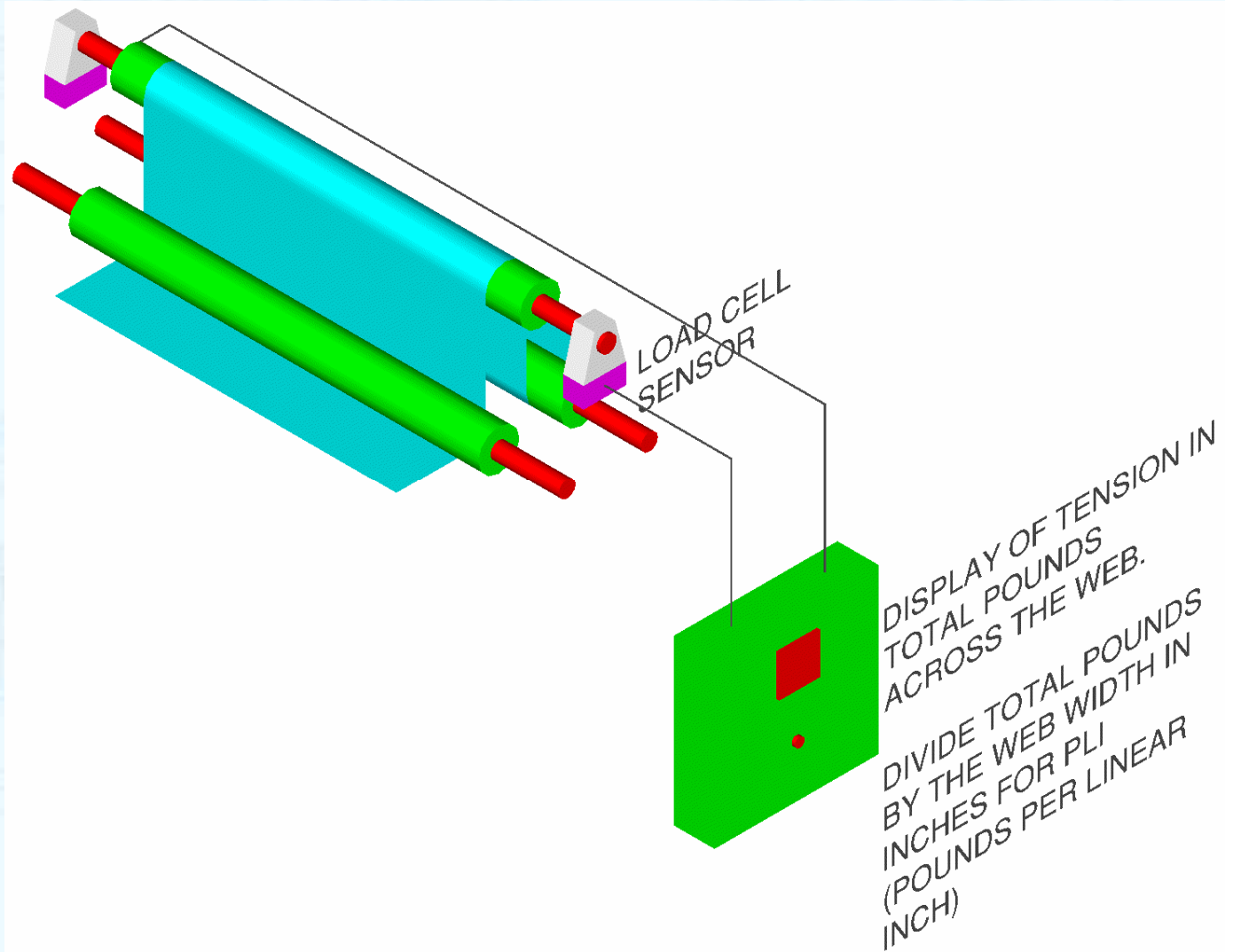
How do I measure tension in my existing process?

Tension is equal to the loading of the dancer on the web

You can calculate the loading or measure the loading of the dancer on the web
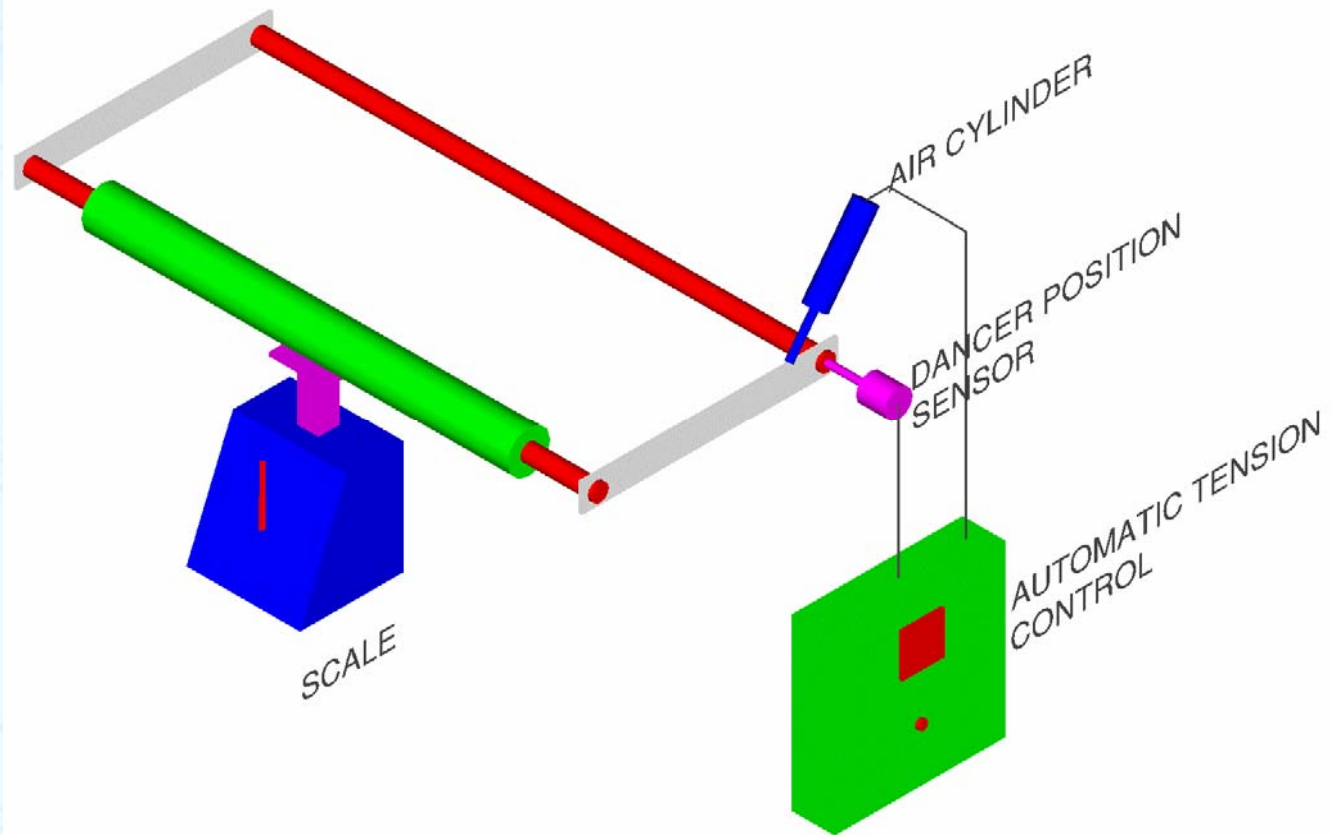
How do I measure tension in my existing process?

"Fish scale" method is crude, but effective measurement in the unwind zone controlled with a brake

DO NOT ATTEMPT THIS TEST WITH A MOTOR!!
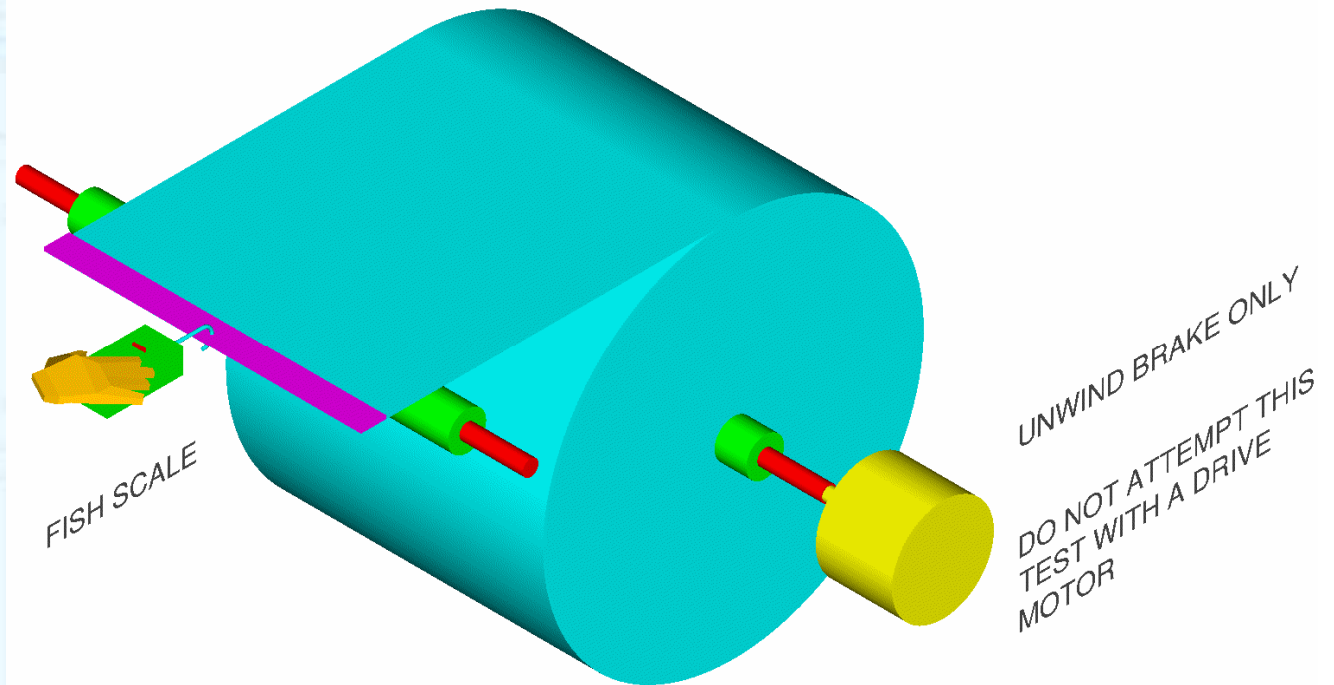
How do I measure tension in my existing process?

- Can calculate tension in unwind or rewind zone
- Model of brake or clutch
- Torque output
- Roll diameter (radius)
- Torque = tension x radius
- Tension = torque / radius

What about taper tension?

- Don't confuse constant tension and taper tension
- NEVER taper tension in unwind and internal tension zones
- Rewind zone should have taper tension capability

Why taper tension in rewind zone?

- Compressive forces in rewound layers
- Wrinkling, "starring" and crushed cores
- Taper tension relieves compressive forces by DECREASING TENSION as the roll builds (no longer constant tension)
- Taper tension is set as a percentage of tension setting
- Tension decreases at a linear rate relative to roll diameter

How do tension controls work?

- ## Manual
  - No control
- ## Diameter measurement
  - Open loop control
- ## Tension measurement
  - Closed loop control
- ## Combination
  - Closed loop and open loop control

Manual tension control

Really no control – torque setting method

Potentiometer adjusts torque of a drive or electric brake or clutch

Pressure regulator adjusts an air brake or clutch

Inexpensive

Inaccurate

UNWIND DRIVE

MANUAL TENSION CONTROL
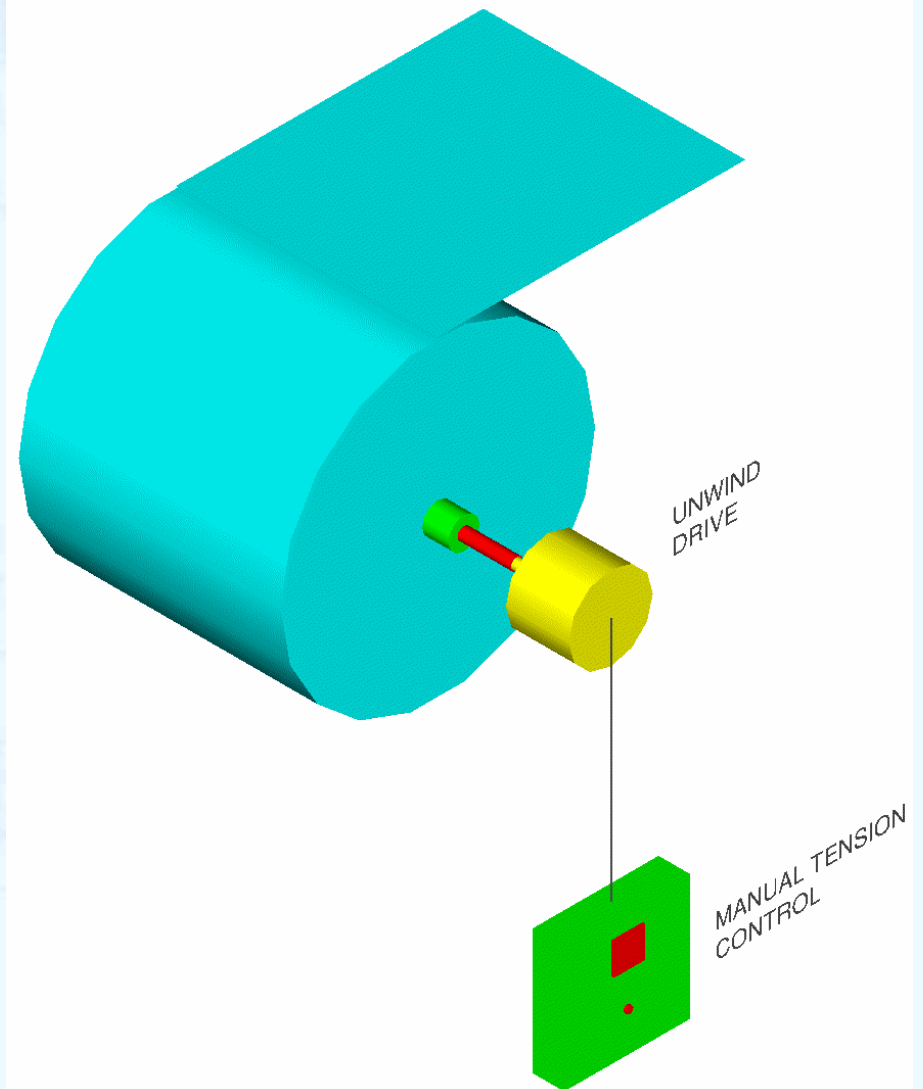
Diameter measurement control

- Three types
  - Follower arm
  - Ultrasound
  - Diameter calculator

- Controls unwind and rewind zones

- Senses roll radius
  - Decreases torque at the unwind zone
  - Increases torque at the rewind zone
  - Taper tension

- Will not control internal zones
  - Open loop

Diameter measurement control
Follower arm

- Oldest technology for measuring roll diameter
- Wheel or roll lays on roll outside
- Pivoting arm moves as roll decreases or increases in size
- Sensor detects roll radius change
- Output to drive
  – Decreases at unwind zone
  – Increases at rewind zone

Diameter measurement control
Follower arm

Follower arm – wheel type

Follower arm – roll type
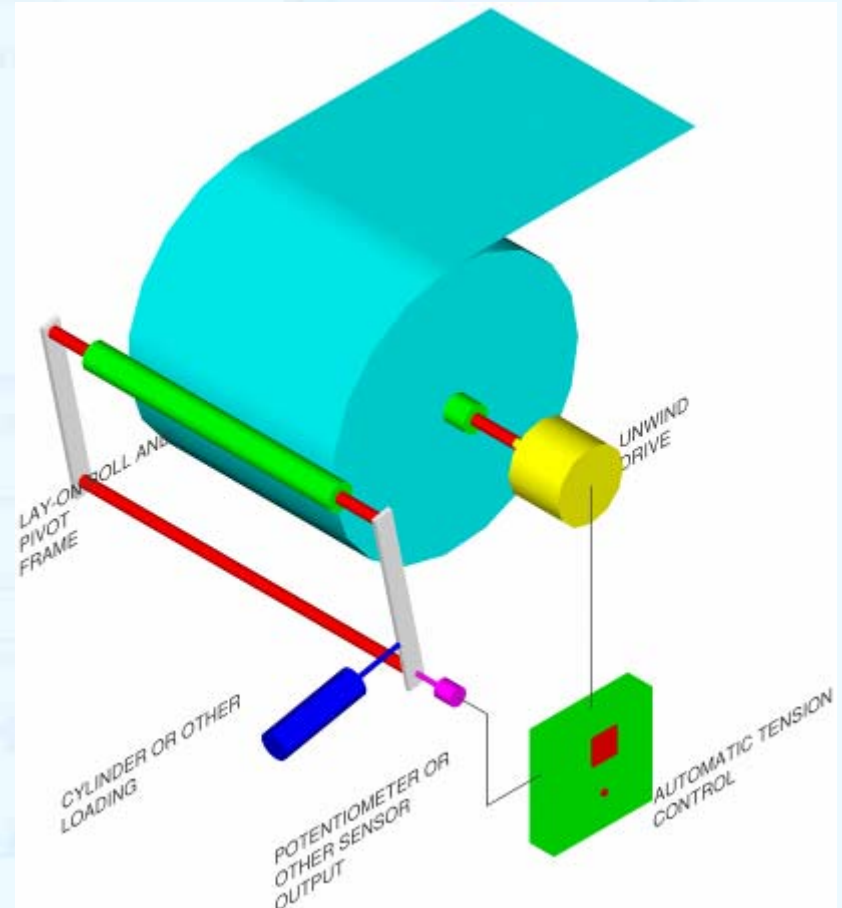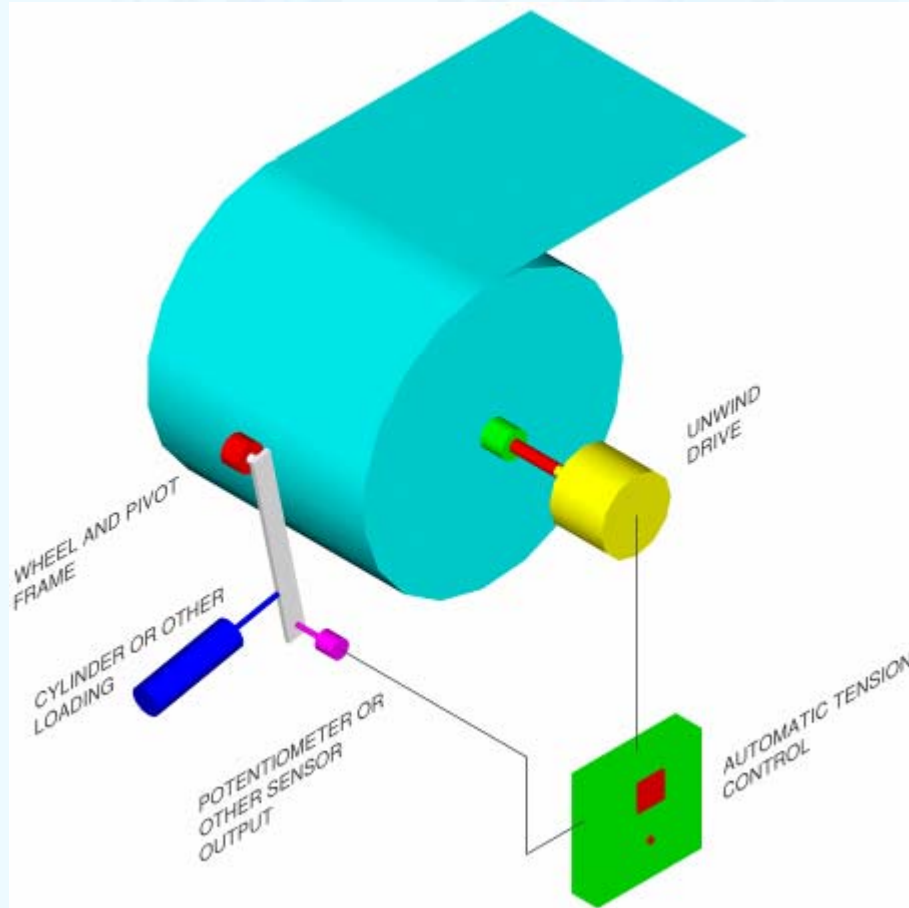
Diameter measurement control
Follower arm

Advantages

- Very simple
- Good replacement of manual control
- Inexpensive
- Easy to install

Diameter measurement control
Follower arm

Disadvantages

- Could oscillate from out-of-round rolls
- Lay on device is in the way of roll changes
- Modifications required to change capacity
- Mechanical parts need maintenance
- Open loop control – doesn't know tension
- Only controls unwind and rewind zones
- Contacts roll – problems with sensitive materials?

Diameter measurement control
Ultrasound

- Ultrasonic signal measures roll diameter

- Linear output to drive device-proportional to roll diameter change

UNWIND DRIVE

ULTRASONIC SENSOR

AUTOMATIC TENSION CONTROL
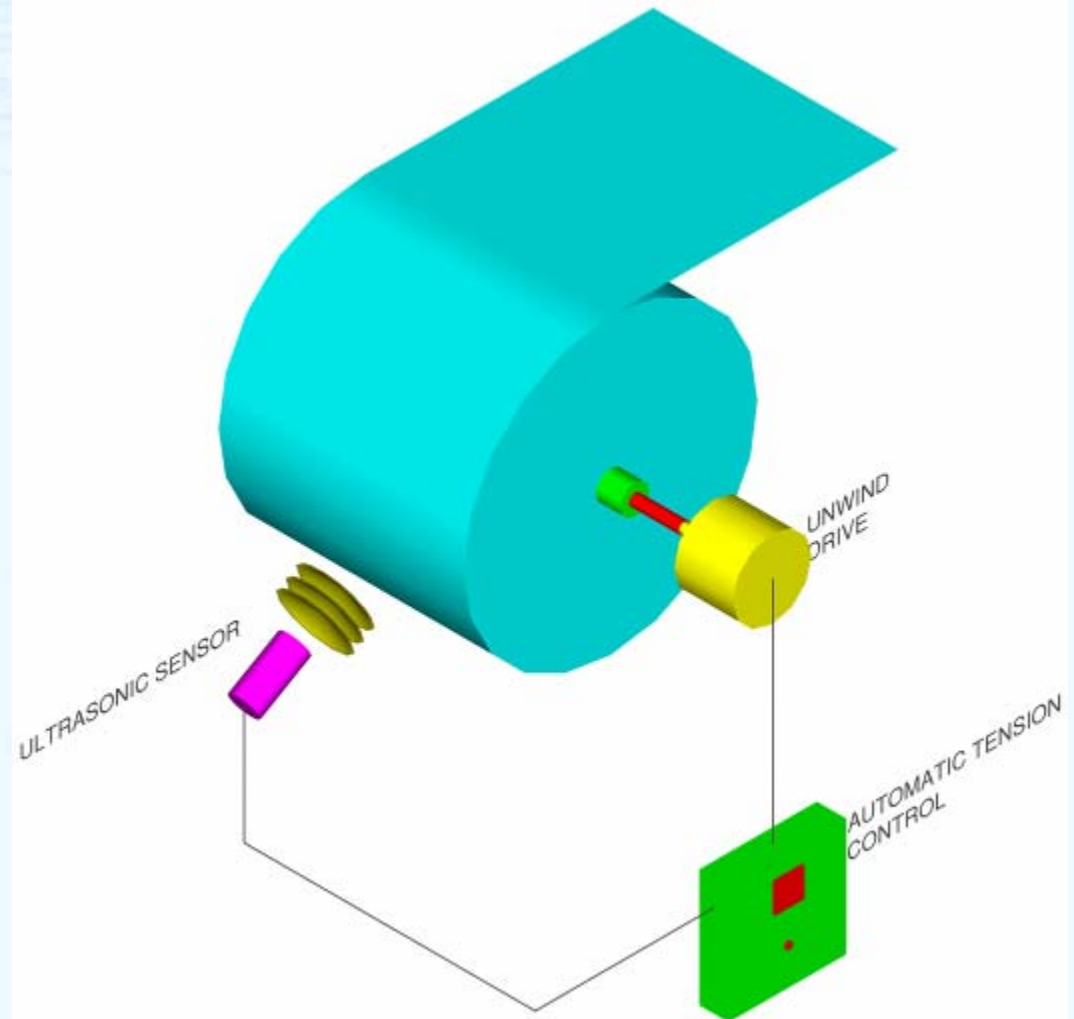
Diameter measurement control
Ultrasound

Advantages

- Very simple
- Excellent replacement of manual control
- Relatively inexpensive
- Extremely easy to install
- True linear output relative to roll diameter
- Compensation for out-of-round rolls
- Sensor can be mounted out of the way
- Unwind or rewind capacity easy to change
- No mechanical parts to wear out
- Limit alarms
- No contact for sensitive materials

Diameter measurement control
Ultrasound

Disadvantages

- Open loop – doesn't know tension
- Only controls unwind or rewind zones
- Foreign objects could be sensed
- Electronic calibration is necessary
- Signal absorption
- Perpendicular positioning of sensor is critical

Diameter measurement control
Diameter calculator

- Compares constant line speed to varying unwind or rewind speed.

- Calculates roll diameter change

- Linear output to drive
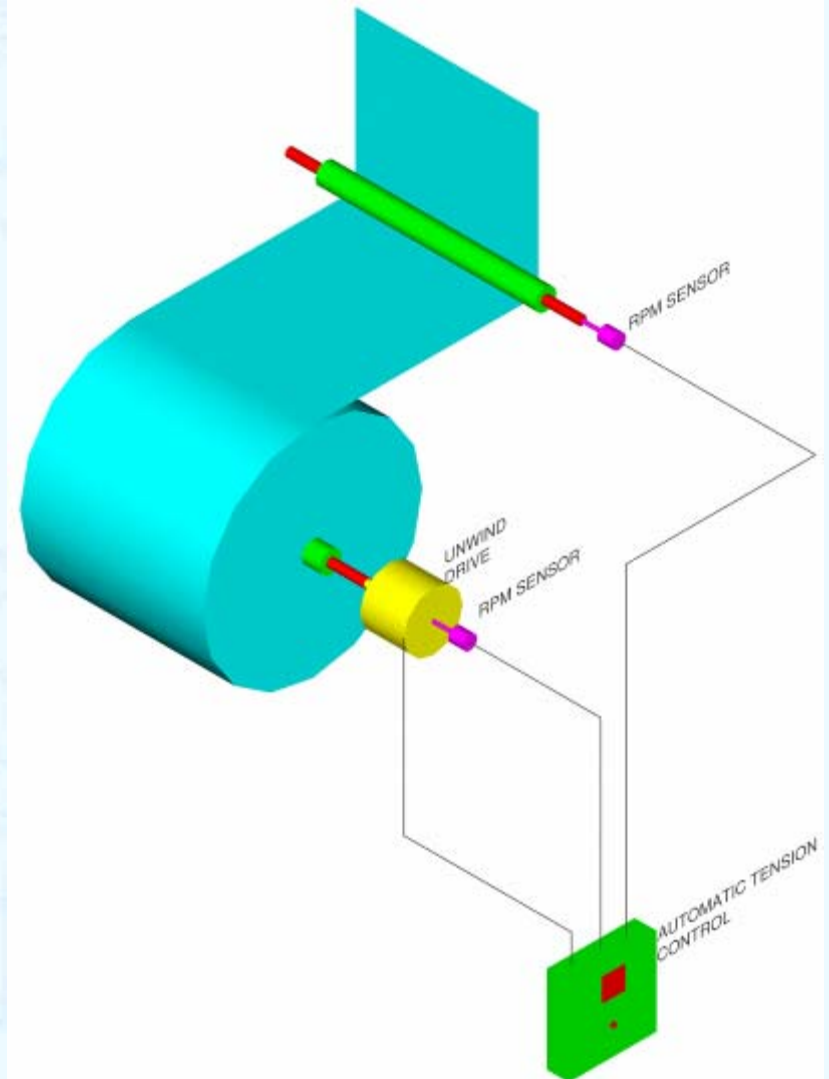
Diameter measurement control
Diameter calculator

Advantages

- Excellent replacement for manual control
- Relatively inexpensive
- Relatively easy to install
- True linear output relative to roll diameter
- Nothing in the way of roll loading / unloading
- Easy to increase roll capacity of unwind or rewind
- Minimal mechanical parts to wear out
- Limit alarms for low and empty status
- No material contact for sensitive materials

Diameter measurement control
Diameter calculator

Disadvantages

- Open loop – doesn't know tension
- Only controls unwind and rewind zones
- Control logic is complex
- Electronic calibration is necessary

Tension measurement control

- Two types
  - Dancer
  - Load cell
- Controls unwind, rewind and internal zones
- Senses web tension
  - Compensate for unplanned tension changes
  - No taper tension for rewinds without external input

Tension measurement control

Dancer
controlled
unwind

BEARINGS

DANCER POSITION
SENSOR

AIR CYLINDER

AUTOMATIC TENSION
CONTROL

UNWIND
DRIVE
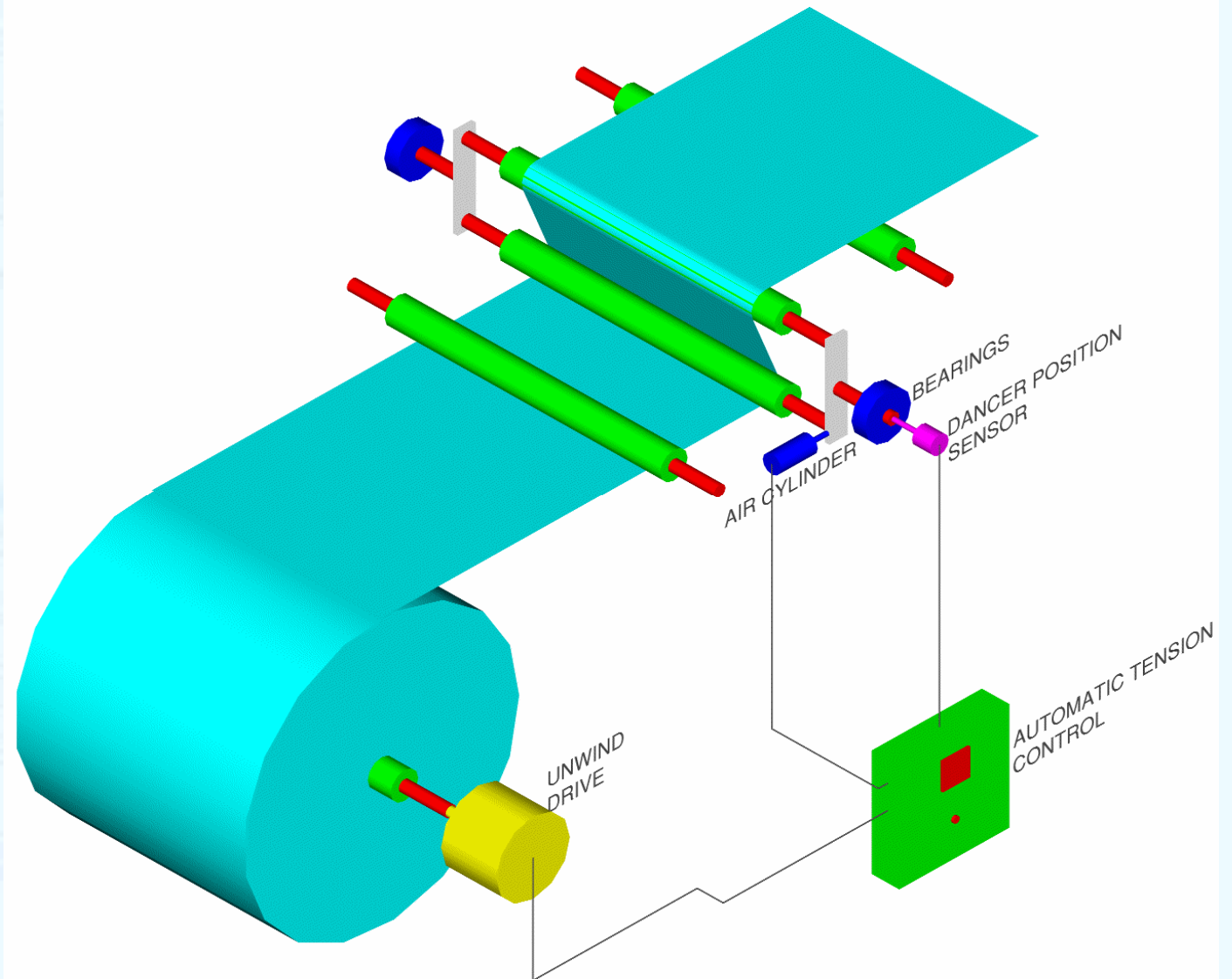
Tension measurement control

Load cell
controlled
internal
zone
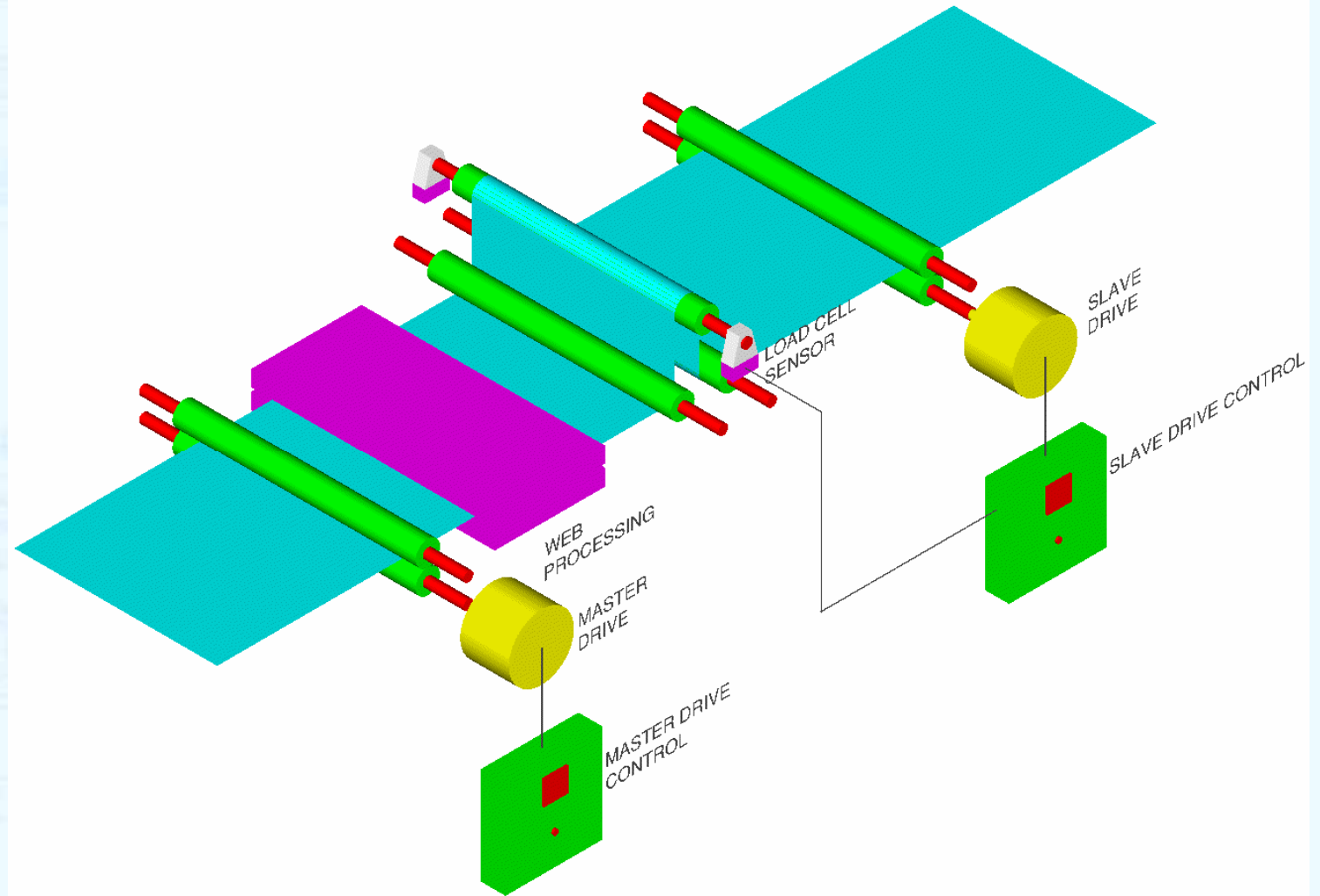
Tension measurement control
Dancer

- Many designs
  - Pivot arm
  - Linear
  - Rotational
- Common principal
  - Loaded in one direction
  - Web tends to move them in the opposite direction
  - Sensor detects dancer position
  - Control tells drive to add or subtract material from the dancer to keep position constant
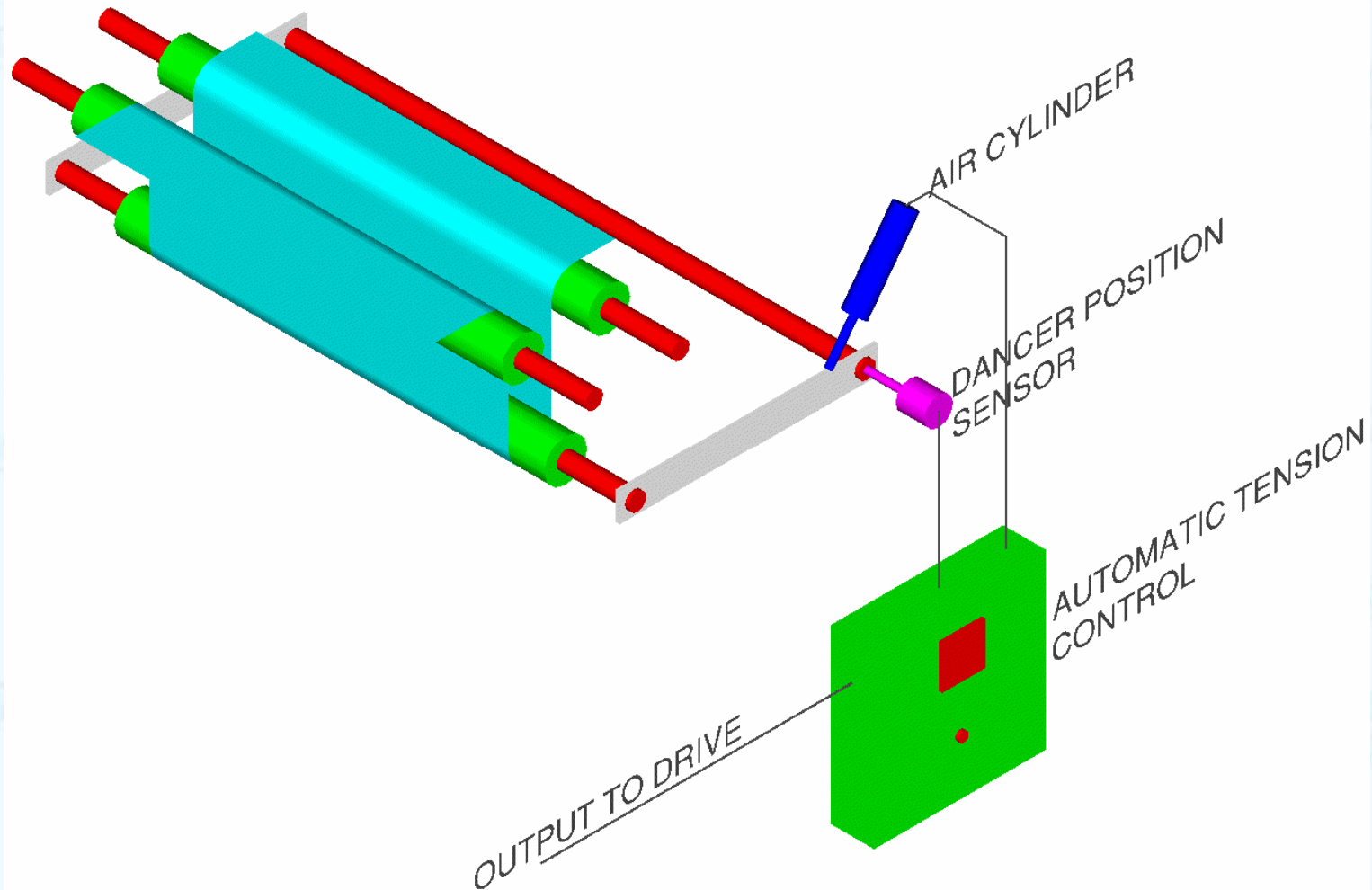
Tension measurement control
Dancer

- Dancer within travel = constant tension on web
- All dancers have web storage
- <u>Mechanically</u> stable
    - Will control drives
    - Will absorb tension fluctuations
    - Tension downstream of dancer is smooth

Tension measurement control
Pivot arm dancer

AIR CYLINDER

DANCER POSITION SENSOR

AUTOMATIC TENSION CONTROL

OUTPUT TO DRIVE

Tension measurement control
Pivot arm dancer

Advantages

- This dancer design is one of the simplest
- Most common design
- Least expensive dancer
- Can be designed with small or large amount of web storage

Tension measurement control
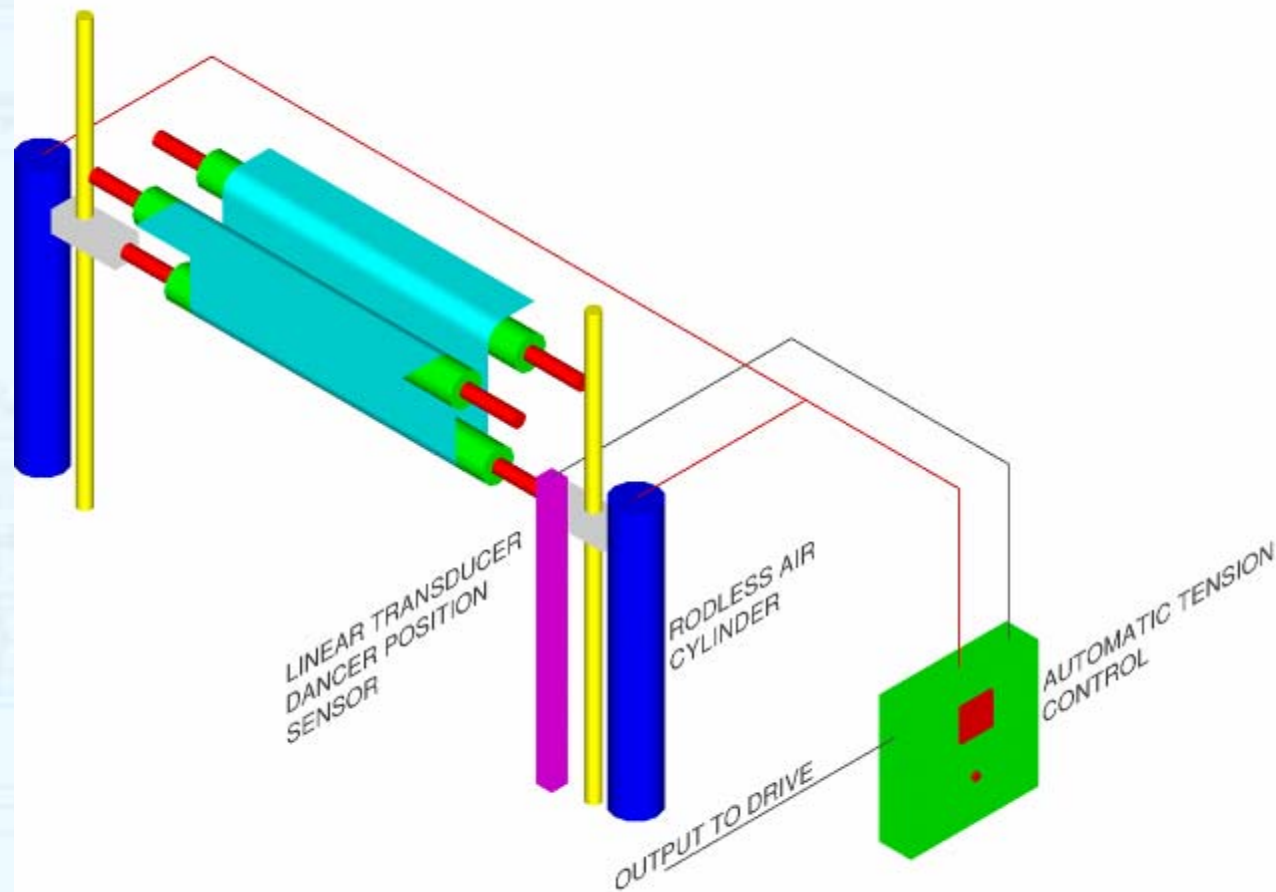## Pivot arm dancer

Disadvantages

- Gravity

- Bulky

- Momentum and inertia

Tension measurement control
Linear dancer

LINEAR TRANSDUCER
DANCER POSITION
SENSOR

RODLESS AIR
CYLINDER

AUTOMATIC TENSION
CONTROL

OUTPUT TO DRIVE

Tension measurement control
Linear dancer

Advantages

- Compact
- A LOT of web storage
- Multiple passes – accumulator
- Small package

Tension measurement control
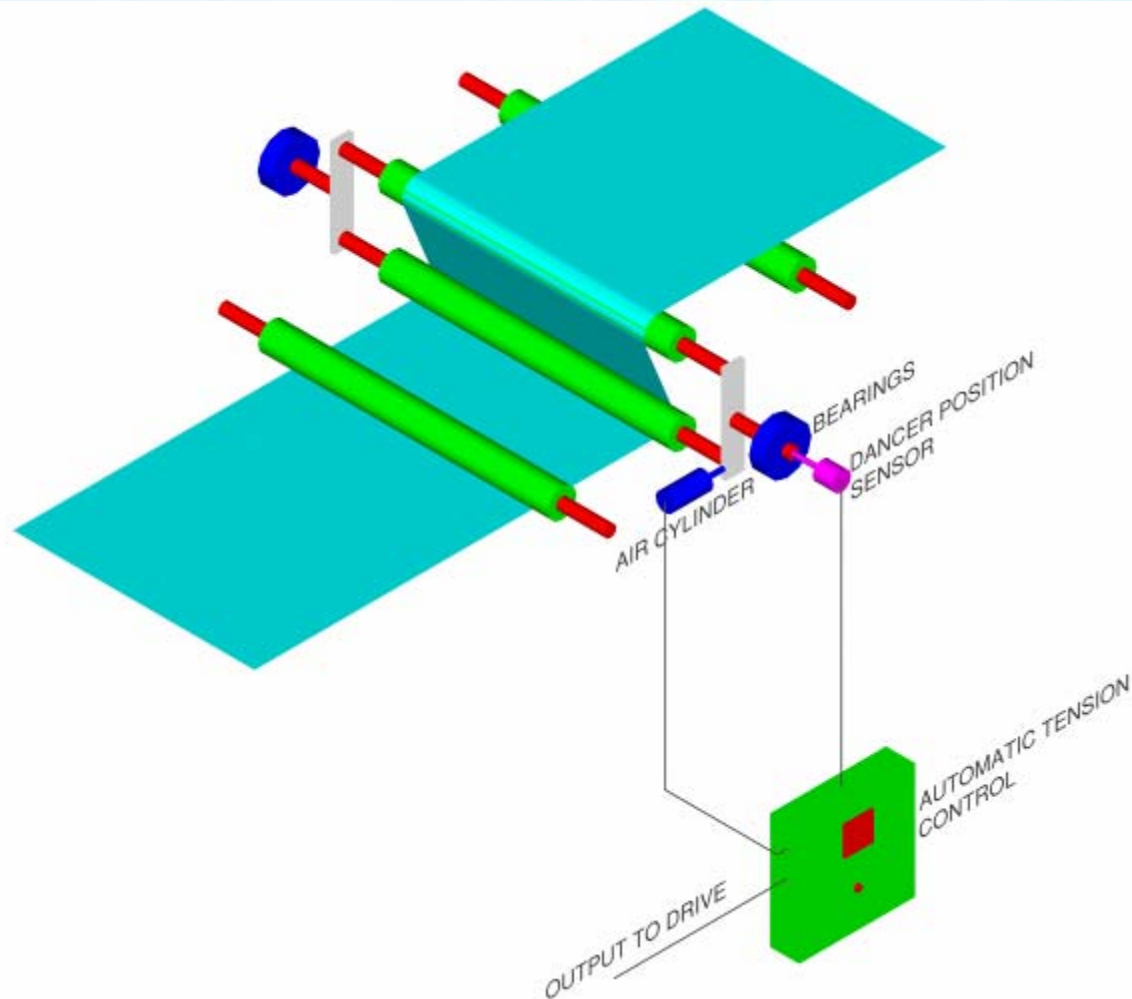## Linear dancer

Disadvantages

- Most expensive dancer design

- Gravity

- Very complex design

- Momentum and inertia

- Rodless cylinders are not low friction

Tension measurement control
Rotational dancer

Tension measurement control
Rotational dancer

Advantages

- Not effected by gravity
- Momentum and inertia greatly reduced
- Generous web storage
- Small package

Tension measurement control
Rotational dancer

Disadvantages

- Expensive
- Somewhat complex
- Increasing web storage is a new design

Tension measurement control
Dancer "enemies"

- Friction
  - Stay away from standard o-ring cylinders
  - Use low friction cylinders like glass lined or rolling diaphragm
- Momentum and inertia
  - A body in motion wants to stay in motion
  - Use light weight components
  - Stay away from weight loaded dancers

Tension measurement control
Dancer "enemies"

- Gravity
  - Use light weight components
  - Design dancers to move parallel to the floor
  - Use rotational type dancer design

Tension measurement control
Dancer design considerations

Loading

- Older units weight loaded
  - Add or subtract weight to add or subtract tension
- Newer designs use air cylinders for loading
  - Pressure regulators add or subtract tension
- Today's designs use low friction cylinders
  - Electric to pneumatic converters with closed loop pressure regulator for loading

Tension measurement control
## Dancer design considerations

Sensors

- Older units use potentiometers
  - Wearing parts will loose accuracy and need replacement
- Today's dancers use non contact sensors
  - Better accuracy
  - Long life

Tension measurement control
Load cell

- Strain gauges measure "weight" applied to idler by tension

- Control compares set value to process value – adjusts drive so process value equals set value

LOAD CELL SENSOR

AUTOMATIC TENSION CONTROL

OUTPUT TO DRIVE
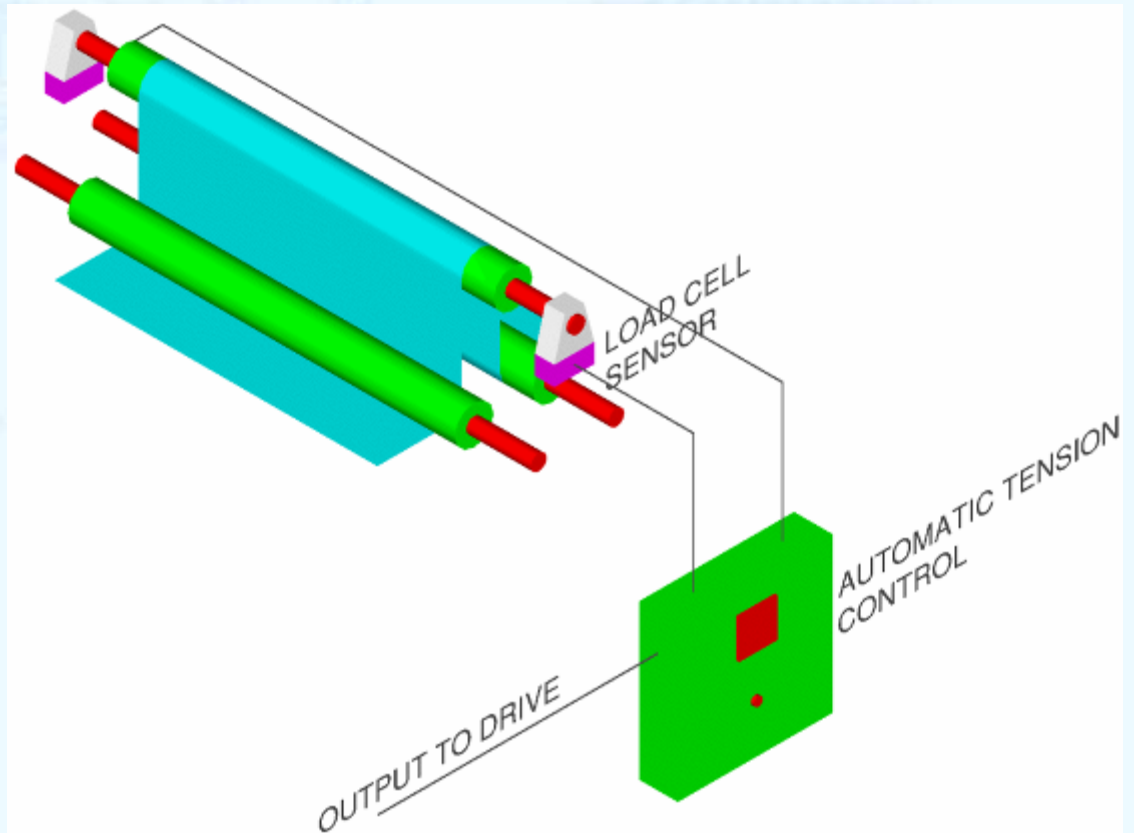
Tension measurement control
Load cell

Advantages

- Accurate tension control at the unwind, rewind or internal zones
- Many choices
- Very accepted in all facets of converting
- IO and PLC interfaces
- Auto tune simplifies calibration process
- Inexpensive, simple units available
- Easy to install at idler roll position
- Minimal modifications necessary

Tension measurement control
Load cell

Disadvantages

- No mechanical web storage
- Web tension can be unstable at unwind and rewind zones

Tension measurement control
Load cell and dancer roll

- Difficult to design with 100% control of unwind and rewind zones
- Build ratios
- Machine speed
- Elastic web
- Unstable

Tension measurement control
Open loop

- Very stable – measure distance
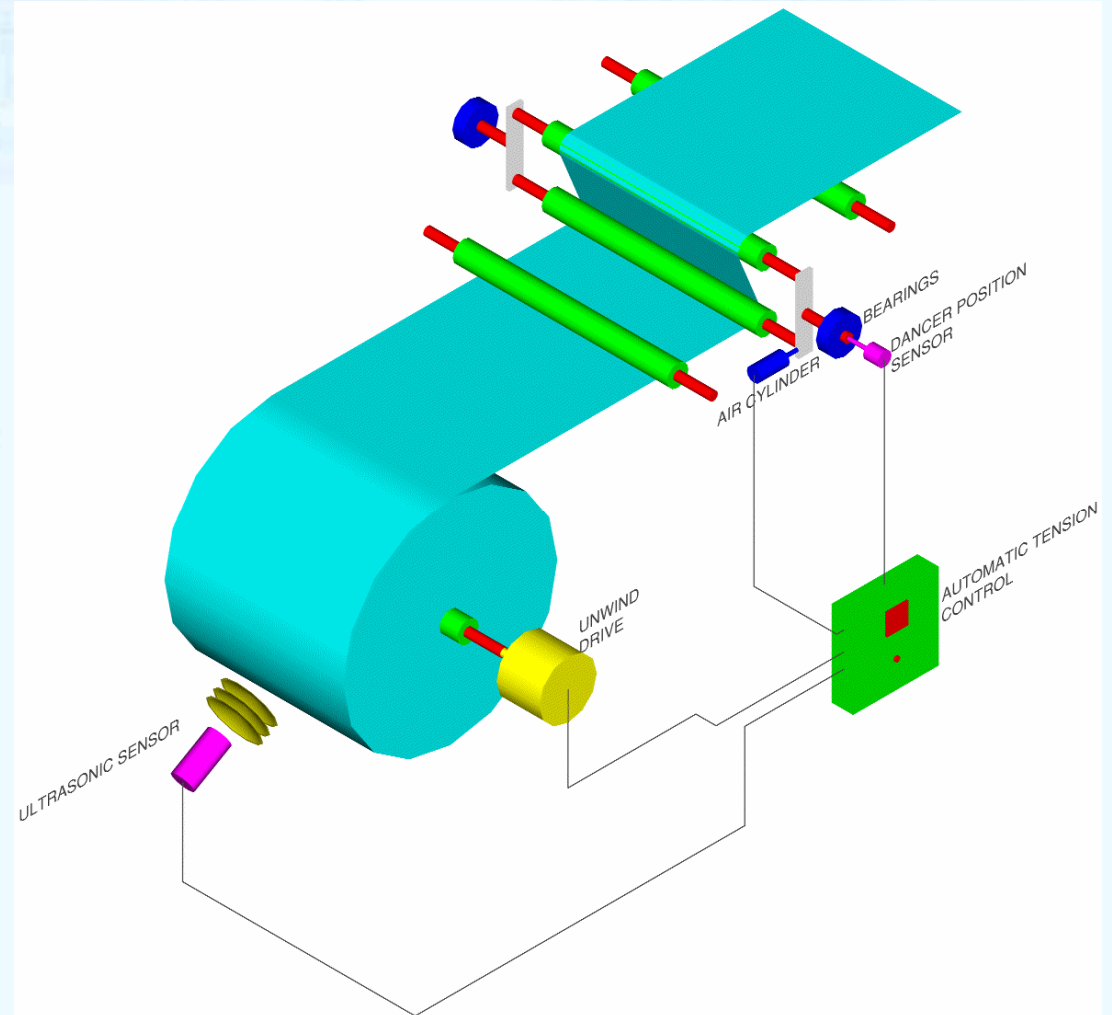- Inaccurate – do not measure web tension

Tension measurement control
Closed loop

- Unstable
  - Do not measure distance
  - Do not know roll build
- Very accurate
  - Measure web tension
  - Adjust drives relative to set point

Tension measurement control
Combination

- Stability of open loop controls
- Accuracy of closed loop controls

Tension measurement control
Combination

Advantages

- Accuracy of closed loop

- Stability of open loop

- IO and PLC interfaces

Tension measurement control
Combination

Disadvantages

- High cost
- Complex

The Mechanics of Tension Control

- Apply properly
- Decrease waste
- Can allow you to run faster
- Operators can concentrate efforts elsewhere
- Run various materials
- Essential to increase profits

The Mechanics of Tension Control

Thank you!

Omron IDM Drive Center

February 26, 2004

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