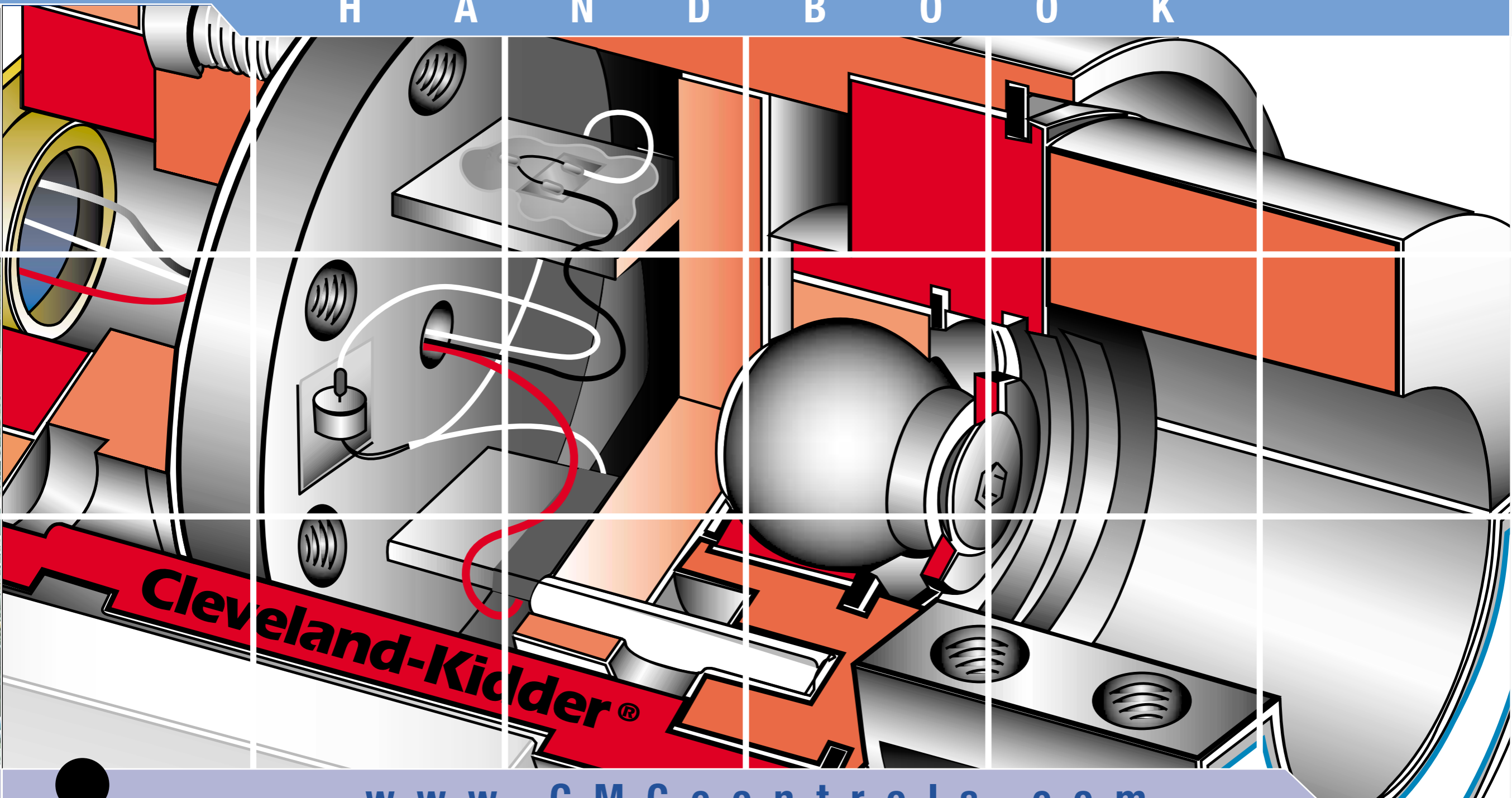


ADVANCED WEB PROCESS CONTROL

H A N D B O O K



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How to Size and Select Load Cells for Web Process Productivity

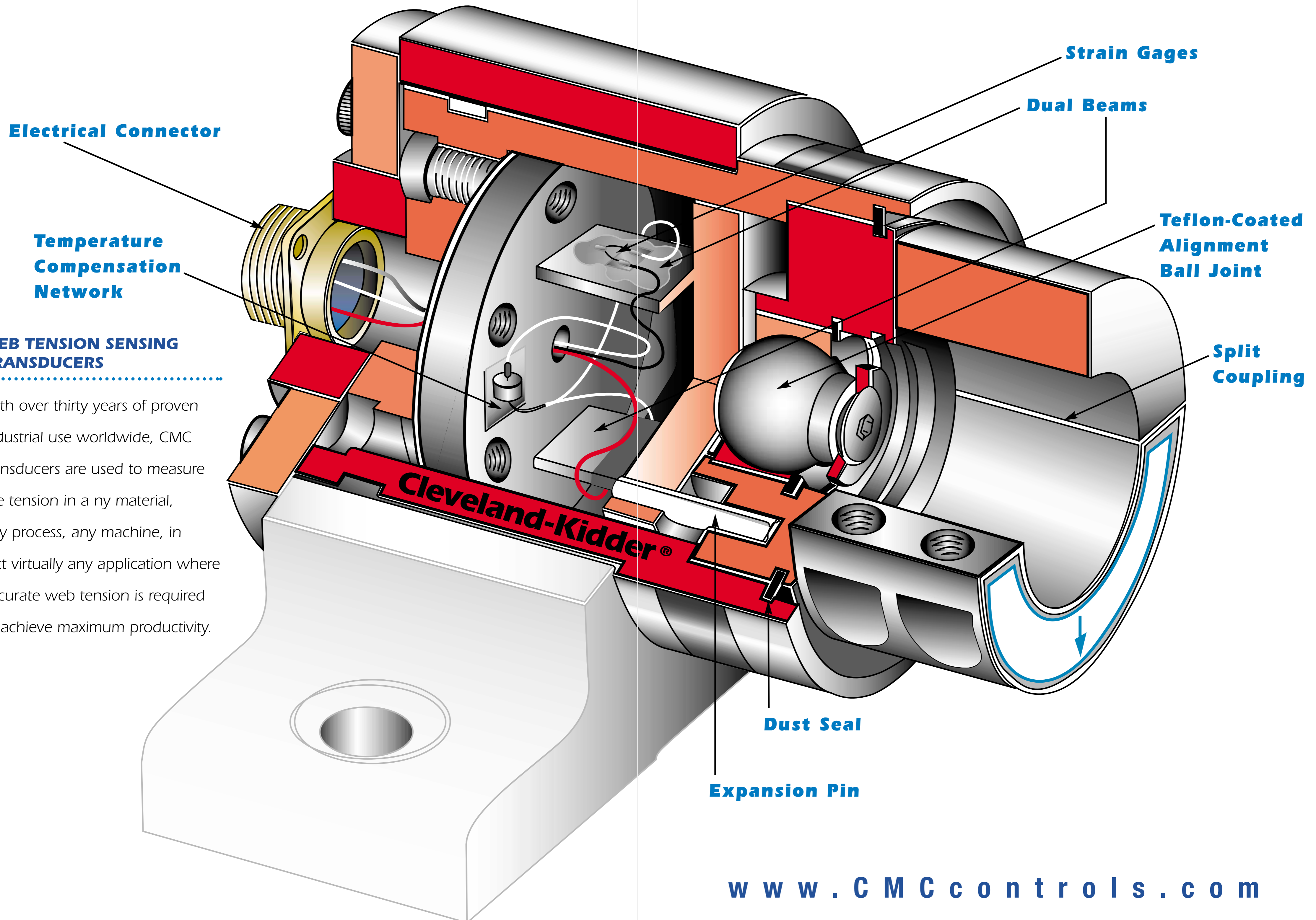
Web Tension Division

 *Improving Productivity
Worldwide*

 **Cleveland
Motion Controls**
An IMC Company

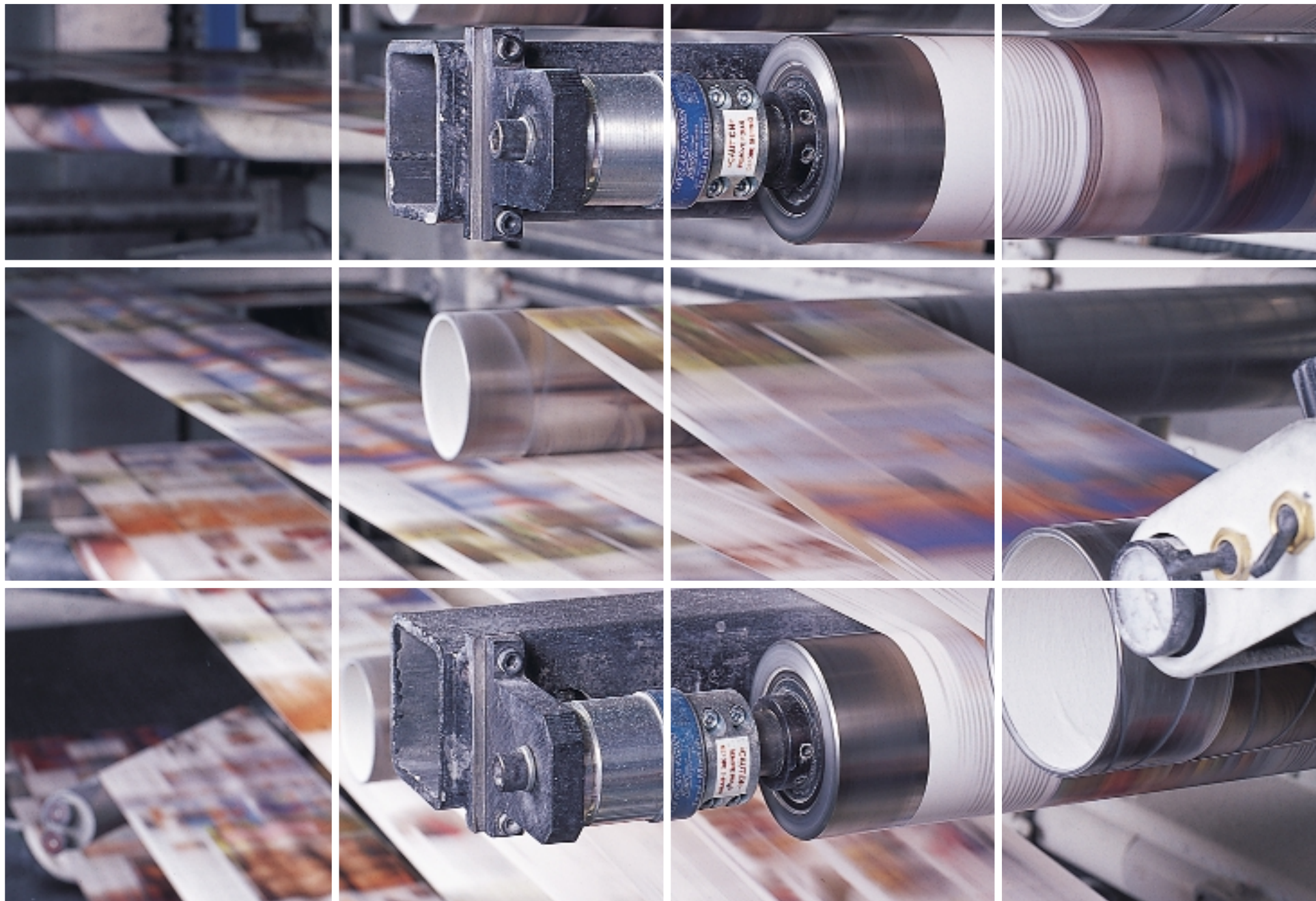


A D V A N C E D W E B P R O C E S S C O N T R O L



**WEB TENSION SENSING
TRANSDUCERS**

With over thirty years of proven industrial use worldwide, CMC transducers are used to measure the tension in any material, any process, any machine, in fact virtually any application where accurate web tension is required to achieve maximum productivity.



INTRODUCTION..... 1

THE FUNDAMENTALS OF WEB TENSION CONTROL..... 1

- What is Web Tension Control? 1
- What Requires Web Tension Control? 1
- Why Worry About Web Tension Control? 2
- What are Load Cells and Tension Transducers? 3
- Why are Load Cells Necessary? 3
- How Do Load Cells Actually Work? 6

SELECT THE LOAD CELL FOR YOUR APPLICATION..... 8

- How Do I Determine the Style Needed? 8
- Step 1-** Determine if you have a wide web, narrow web, or wire and cable application 10
- Step 2-** Determine if you have a stationary shaft or rotating shaft roller 11
- Step 3-** Determine the proper tension 12
- Step 4-** Determine space and mounting requirements 14
- Step 5-** Determine environmental restrictions 14
- Step 6-** Select the proper load cell style 14

SIZING THE TRANSDUCER FOR THE LOAD REQUIREMENTS 16

- What is the Reason for Sizing? 16
- What Formulas Are Used For Proper Sizing? 17
- How Are Sizing Formulas Applied? 18

WHAT TECHNIQUES CAN GET THE MOST FROM MY LOAD CELLS?..... 20

- Orient the Load Cell Properly 20
- Pay Attention to Roller Weight 21
- Calculate the Tare Weight and Make it Work For You 22
- Don't Ignore The Wrap Angle- Use it to Your Benefit 25
- Maintain a Fixed Angle of Wrap Throughout the Process 26
- Be Judicious in Assigning the Safety Factor 27
- Be Realistic About Tension Control and Over What Range 27
- Remove Transducers when Transporting the Machine 27

WHAT SHOULD I LOOK FOR IN LOAD CELLS?..... 29

- All Load Cells are Not Created Equal 29
- Is The Primary Technology Employed Well Accepted? 29
- Will the Load Cell Disrupt the Web Path? 29
- Will the Load Cell Allow for Shaft Misalignment? 30
- What is the Strength of the Output Signal? 30
- How Responsive is the Load Cell? 30
- Is the Load Cell's Signal Linear and Repeatable? 31
- Is the Load Cell Temperature Compensated? 31
- Will the Load Cell Accommodate Shaft Expansion? 31
- Will the Load Cell be Reliable and Durable? 32

SUMMARY..... 32

HOW TO SIZE AND SELECT LOAD CELLS FOR WEB PROCESS PRODUCTIVITY

INTRODUCTION

Many engineers and technicians are not familiar with the practical application of load cells (tension transducers) for web tension control. This handbook describes the steps required to size and select load cells for web process productivity. Through a logical progression of questions and answers, it provides fundamental background information, explains decision-making factors, and offers many useful tips and techniques along the way. Of course, when in doubt, consult with your supplier before purchasing load cells. They are the best source of application expertise and can make helpful suggestions to ensure proper configuration and sizing. The information presented in this handbook however, will enable you to have informed and meaningful discussions, resulting in the best chance of success for your application.

THE FUNDAMENTALS OF WEB TENSION CONTROL

Q: What is Web Tension Control?

Web tension control refers to the various methods used to measure and adjust tension in a moving web. In the context of this handbook, a web is any material continuously pulled from a roll through some manufacturing process. Tension is the measurable force that stretches or elongates the web. Web tension control methods range from feeling and controlling tension by hand to advanced systems that automatically measure and make adjustments to the process.

Q: What Requires Web Tension Control?

Most processes involved in the production or converting of paper, film, plastic, foil, textile, wire, and cable require some form of tension control. It is also necessary on products that require winding onto rolls, printing, coating, laminating, slitting, and extruding. This handbook only discusses continuous roll fed material, tension control of sheet fed product is outside the scope.

INTRODUCTION

THE
FUNDAMENTALS
OF WEB TENSION
CONTROL

HANDBOOK

THE
FUNDAMENTALS
OF WEB TENSION
CONTROL

Q: Why Worry About Web Tension Control?

Properly controlling web tension results in higher quality product and produces greater throughput. For instance, if the tension is not properly controlled, wrinkles in the material may occur resulting in defective or wasted product. **(Refer to Figure 1A)** If a roll of material is wound without proper tension control, the outer layers may crush the inner layers leading to starring **(Refer to Figure 1B)**, or the inner layers may telescope out resulting in ruined product **(Refer to Figure 1C)**. When printing on a roll of material, improper tension control results in smeared ink and fuzzy images from poor registration. Applying too much tension may stretch some materials beyond their elastic limit rendering them unusable. **Proper tension control allows the process to run at high speeds without sacrificing product quality.**

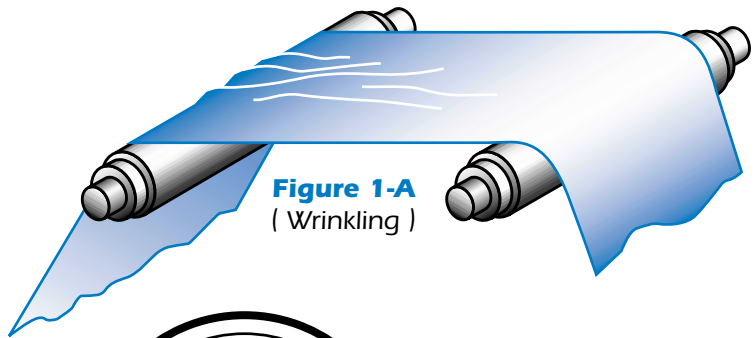


Figure 1-A
(Wrinkling)

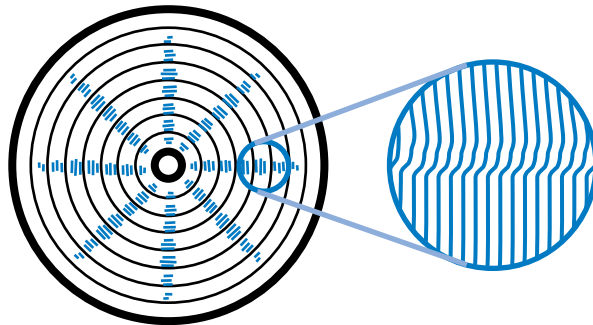


Figure 1-B
(Starring)

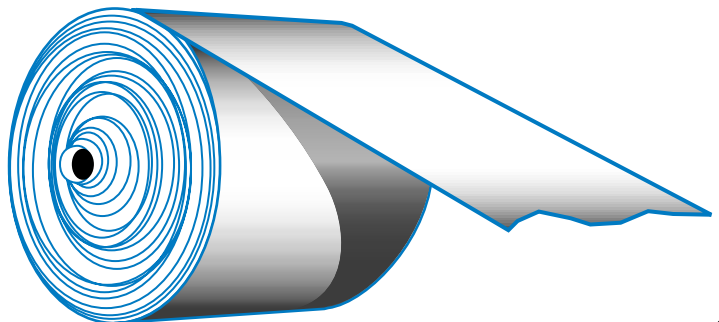


Figure 1-C
(Telescoping)

Q: What are Load Cells and Tension Transducers?

The terms "load cell" and "tension transducer" are used interchangeably to describe a sensor that accurately measures the tension in a moving web. The term "load cell" is commonly used to describe weigh scale sensors that precisely measure the force or load due to the weight of an object. The term has carried over to the web processing industry since similar sensors measure the force produced by tension in the web. The term "transducer" is defined as a device that transforms one type of energy into another. Therefore, a "tension transducer" is a sensor that measures the force resulting from tension in a web and transforms it into electrical energy.

Both terms will be used throughout this handbook.

Q: Why Are Load Cells Necessary?

Installing load cells (tension transducers) is the only accurate way to measure web tension. The measured tension value is then used to adjust the process to increase productivity.

During the manufacturing or converting process, material is generally pulled off a roll, processed, and rewound. These sections are referred to as unwind, intermediate, and rewind zones respectively. Knowing the tension value for each zone plays an important roll in making adjustments to the process. Each zone may require a unique or specific tension value. There are several methods used to measure and control tension in these zones. Some are more sophisticated than others, but once measured, the tension value is used to increase the line's productivity. Without accurate tension values, adjustments will be inconsistent and may actually reduce throughput or quality. Basic, better, and best tension measuring and controlling methods follow.

Basic Method:

The operator estimates the web tension by hand and makes manual adjustments to the process. This approach requires 100% operator intervention.

The operator taps on the web and by "feel" tries to determine the amount of tension. Appropriate corrective action is taken to change the tension by manually changing brake torques, dancer loads, gear ratios, or motor speeds. The operator continues tapping the web and making adjustments until a satisfactory result is achieved. Because this is a manual process, adjustments take time, and as a result, much wasted product is produced.

THE
FUNDAMENTALS
OF WEB TENSION
CONTROL

With this basic method, there is no consistent way of measuring or altering the tension. Attempts may be made to record the settings of the motor speeds, brake pressure, or dancer loads, but as brake pads and other machine parts wear, the settings will produce different tension levels. Temperature changes and inconsistencies in the material will also affect tension. Furthermore, different operators have differing opinions on which tension feels right. Product quality is suspect and inconsistent.

Most importantly, this method is an unsafe and unacceptable working practice.

Since the tension is unknown, so are the limits to which the line speed may be increased. Trying to run at high line speeds may produce stretch or break the web. Running at low line speeds may be required in order to produce acceptable product. This greatly limits throughput.

Better Method:

Load cells are used to measure tension and the value is displayed on an indicator. The operator still manually adjusts the tension. This requires a great deal of operator intervention.

Load cells are added to the rollers (or sheaves and pulleys) in the tension zones. The load cells measure the tension and the values are displayed on tension indicators (meters, or screen displays). The operator takes the appropriate corrective action to adjust the tension by manually changing brake torques, dancer loads, gear ratios, or motor speeds. The operator continues to read the tension values and makes the necessary adjustments until proper tension is achieved. Manual adjustments are still required, but the tension values are accurate and can now be documented. This allows for the line tension to be duplicated on the next run or when run by a different operator. There is a consistent method of measuring and displaying tension but no consistent method of controlling it. Tension control still relies on operator intervention, which takes time to correct. As a result, much wasted product is still produced. Product quality is greatly improved but is somewhat inconsistent.

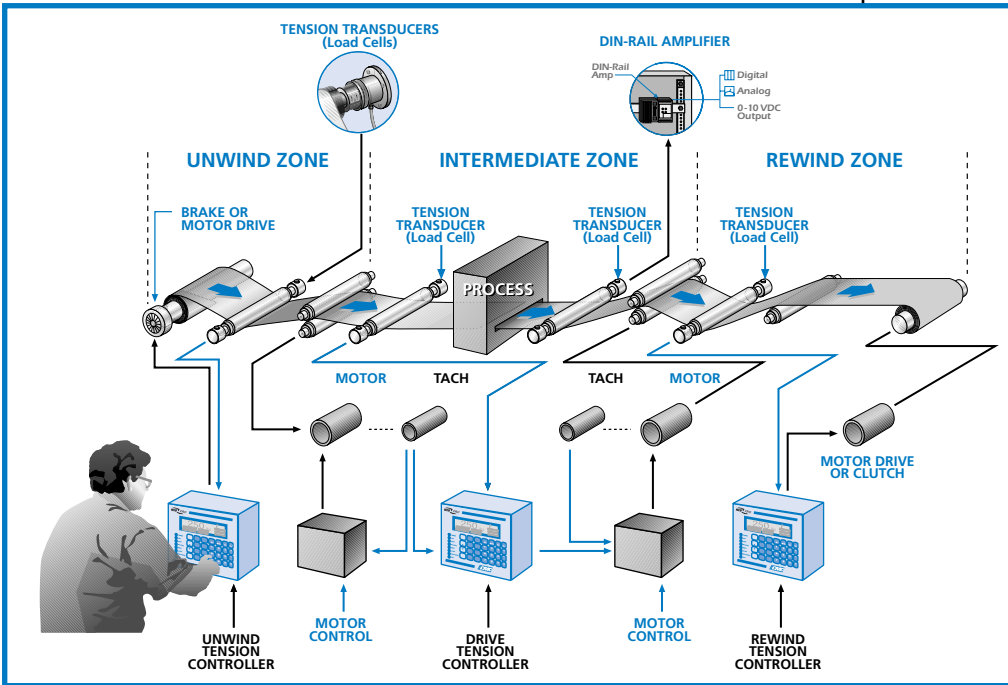
Since the tension is known, so too are the limits to which the line speed may be increased before the material stretches or web breaks. The line speed may be increased but only to the amount that it can be controlled.

Manual intervention by the operator still limits the response time and how tightly the tension values can be controlled. Though greatly improved, throughput is not yet maximized.

Best Method:

Load cells are used along with controllers and actuators to automatically measure and adjust web tension. This approach requires minimum operator intervention. (Refer to Figure 2)

THE
FUNDAMENTALS
OF WEB TENSION
CONTROL

**Figure 2**

(Complete Web Tension Converting System)

Load cells are added to the rollers (or sheaves and pulleys) in the tension zones. The load cells are connected to a device that displays the tension value and automatically controls the brakes, dancers, gear ratios, or motors. The operator enters the desired tension setting (tension set point) and the appropriate corrective action is done automatically by changing brake torques, dancer loads, gear ratios, or motor speeds. The controller may be a standalone device, PLC, or programmable drive. All perform closed-loop tension control. They continually compare the tension set point to the actual tension being measured by the load cells and automatically take corrective action to ensure that these values agree.

This method provides a consistent means of measuring and controlling tension. Tension control is done automatically and requires minimum operator intervention. Product quality is at its best and is consistent. Corrective action takes place immediately. As a result, little wasted product is produced.

THE
FUNDAMENTALS
OF WEB TENSION
CONTROL

Since the tension is known, so too are the limits to which the line speed may be increased before the material stretches or web breaks. The line speed may be increased to the amount that it can be controlled. Highly responsive automatic closed-loop tension devices tightly control tension values. Throughput is maximized. Limiting factors are only the response time of the control loop and actual process limitations.

Q: How Do Load Cells Actually Work?

Load cells employ strain gages, LVDTs (Linear Variable Differential Transformers), or some other means as their primary sensing element. In all cases, they operate as electromechanical devices. Understanding how they operate helps to apply them more effectively. Explaining Cleveland Motion Controls' (CMC) Cartridge Style Transducer illustrates the fundamentals of how a strain gage transducer operates.

The transducer is first fastened to the machine frame at one end and to a roller on the other end. Then, the web is wrapped over the roller. **(Refer to Figure 3)** Inside each transducer, strain gages have been attached to a pair of beams made of spring steel. **(Refer to Figure 4)** Referred to as dual beams, they are fixed at one end with the free end connecting to the roller. As tension is applied to the web, the force is transferred from the roller directly to the transducer.

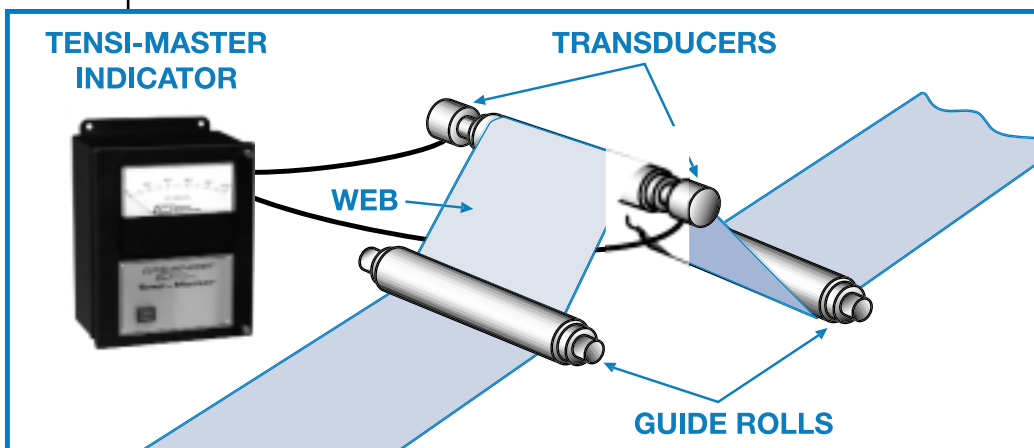


Figure 3
(Web Tension Indicating System)

The component of force applied perpendicular to the beam deflects or bends them. **(Refer to Figure 5)** This bending, typically 0.002 to 0.004 inches, creates a strain or elongation of the molecules in the beams. The strain gages measure this elongation and generate an electrical signal exactly proportional to the amount of force applied. This signal is the web tension value.

(continued page 8)

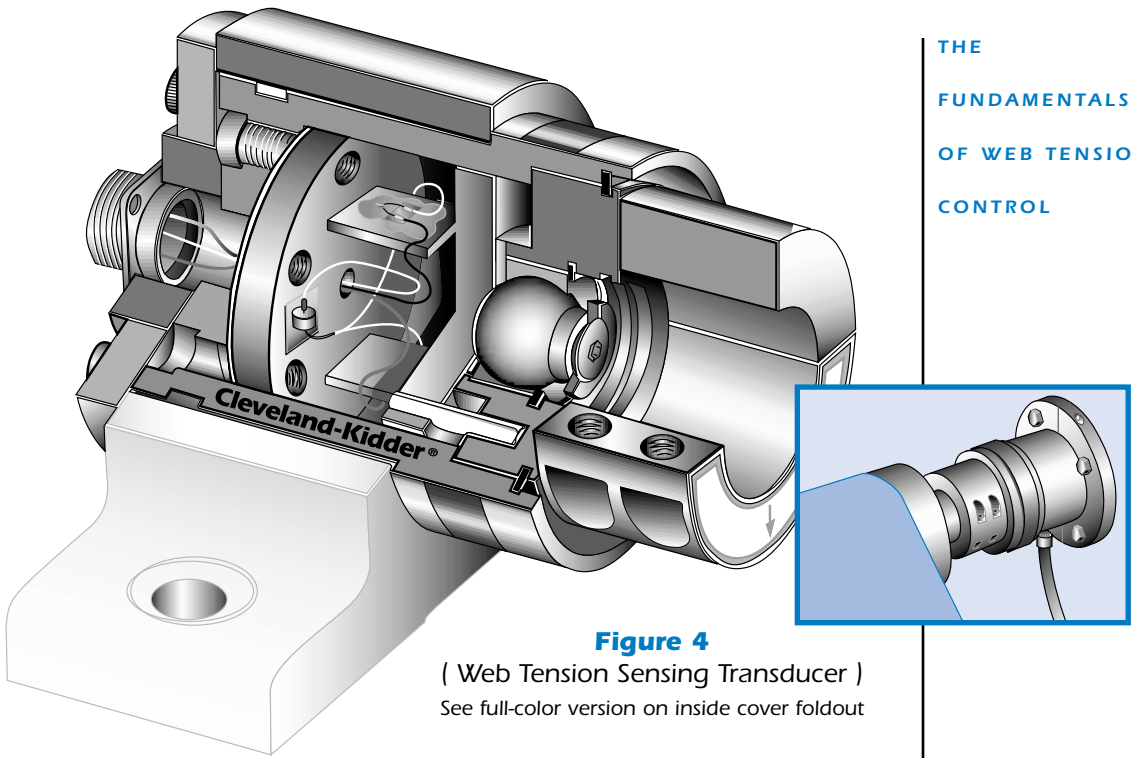
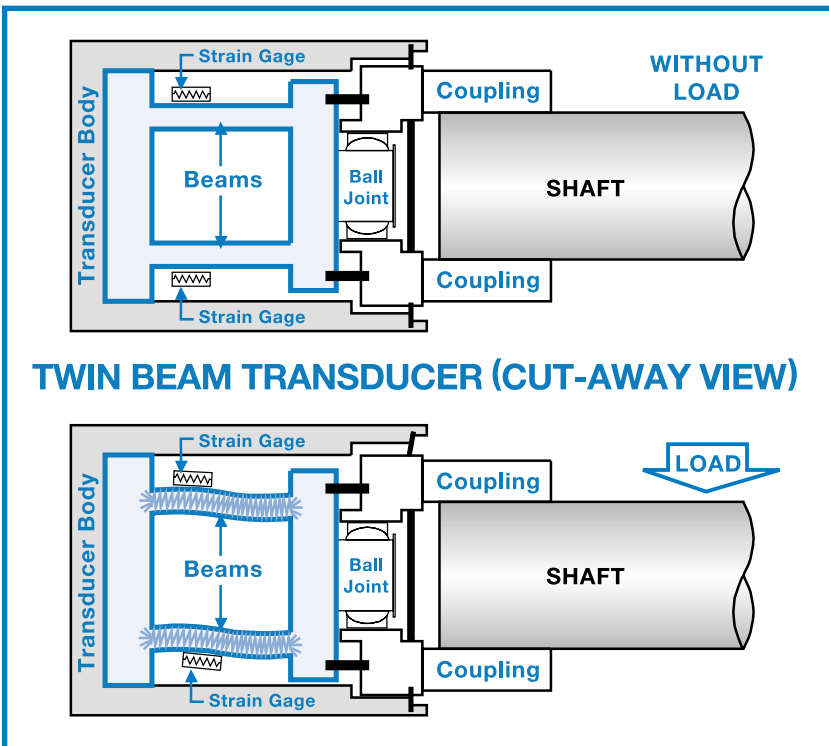


Figure 4

(Web Tension Sensing Transducer)
See full-color version on inside cover foldout



TWIN BEAM TRANSDUCER (CUT-AWAY VIEW)

Figure 5

(With Load and Without Load)

THE
FUNDAMENTALS
OF WEB TENSION
CONTROL

To accommodate a larger force, the cross sectional area of the beam can be increased by making it either wider or thicker. The greater the transducer load rating (Maximum Working Force or MWF), the larger the beam. A transducer with an MWF rating of 150 lb. has a beam both wider and thicker than one rated for 25lb. Overload stops are provided on all CMC Cartridge Style Transducers, which allow them to accommodate overloads of 150% to 300% of their rating.

SELECTING THE STYLE OF LOAD CELL FOR YOUR APPLICATION

SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION

Q: How Do I Determine the Style Needed?

Selecting a load cell first requires that the proper style be chosen. Some load cells are designed for wide webs and others for narrow webs. There are load cell designs for use with stationary (fixed or dead) shaft rollers and for rotating (live) shaft rollers. **(Refer to Figure 7)** There are load cells that are designed for use with commercially available pillow block bearings. Space limitations may be a factor so slim and low profile designs may be required. The environment may be wet or contain harsh chemicals, in which case a sealed and corrosive resistant load cell is the best solution. **(Refer to Figure 6)** Finally, different styles of load cells have different tension ranges.

Many application specific questions need to be asked and answered before choosing a load cell. The following steps contain these important questions.

(continued page 10)

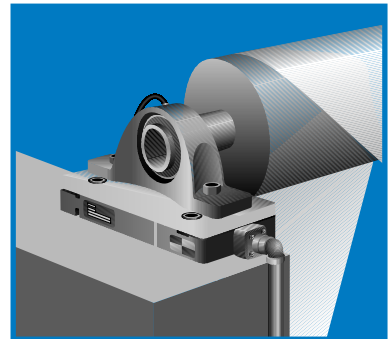
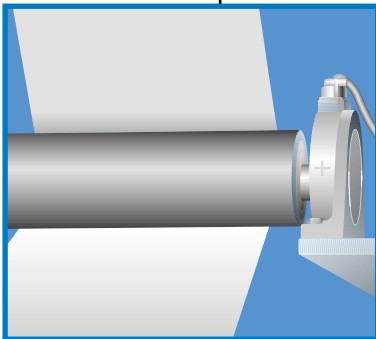


Figure 6
(Environmentally Sealed Load Cells)

Cleveland-Kidder® Transducer Styles

Wide Web Applications

Stationary Shaft Rollers

Cartridge-Style Transducers



- Wide range of maximum load ratings—from 25 lb. to 1000 lb.
- Easily oriented at any angle to accommodate all web paths.
- Wide operating temperature range.
- Negligible displacement of “twin beam” design, resulting in high level linear output signal, high frequency response and overall system stability.
- Accommodates shaft expansion & shaft misalignment.
- Wide variety of mounting options—flange mount & pillow block mounting kits.
- CE compliant.

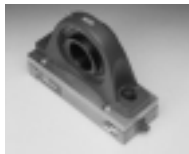
Slim Cell Transducer (Type SS)



- Low profile design reduces width requirements of machine frame.
- Available with 10 lb. to 1000 lb. load ratings.
- Extends machine’s usable tension range (by measuring low and high tensions).
- Completely sealed; corrosion, chemical and water resisting (Stainless Steel 410). Dust sealed.
- Easily oriented to any web path by merely rotating the transducer, no remounting necessary.
- 500 to 1000% Overload Ratings.
- CE compliant.

Rotating Shafts

UPB Washdown-Duty LC



- Available in a variety of load ratings (25 lb. to 30,000 lb.) and sizes (6.5 to 17 inches long).
- Resists liquids and wet environments.
- Compact low profile design fits into tight places.
- CE compliant.
- For use with pillow block bearings.
- Completely sealed; Corrosion and chemical resisting (Stainless Steel 410 or Anodized Aluminum Alloy 6061).
- Provides 500% overload protection.
- Removable mounting plate for easy installation of pillow block bearing.

Slim Cell Transducers (Type RS)



- Alternative to UPB–Low friction bearing design ideal for low tension requirements.
- See additional information shown for Type SS above.

Narrow Web Applications

Cantilevered Transducer CLT



- For use with cantilevered rollers or pulleys.
- Accommodates almost any customer roller, eliminating need & expense of integrated roller.
- CE compliant.
- Wide range of maximum load ratings – from 0.1 lb. to 500 lbs.
- Reduces maintenance costs.
- Provides flexibility of specifying almost any fixed shaft roller.
- Eliminates need for custom designed transducers for non-standard applications.
- Cylindrical body design and CMC mounting kits enables it to be oriented to any web path.

Cantilevered Tensi-Master® CR Transducer



- Wide range of maximum load ratings – from 5 lb. to 150 lb. load ratings.
- Accommodates customer-mounted pulley.
- Negligible displacement of “twin beam” design, resulting in high level linear output signal, high frequency response and overall system stability.
- Easily oriented at any angle, accommodating all web paths.
- CE compliant.

Figure 7
(CMC Transducer Selection Guide)

SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION

SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION

Step 1 - Determine if you have a wide web, narrow web, or wire and cable application

Wide Web: Typically a wide web is over 20 inches wide and utilizes a roller assembly supported on both ends. Some production processes utilizing a wide web include paper, film, foil, and plastics; printing and the converting of these products such as coating, slitting, and laminating.

CMC's standard product offerings for wide webs are the Cartridge Style Transducers, Slim Cell Transducer, and UPB Washdown Duty LC. **(Refer to Figure 7)**

Two transducers are required per roller; one mounted at each end of the roller assembly.

Narrow Web / Wire and Cable: Typically a narrow web is less than 20 inches wide and utilizes a cantilevered roller or pulley supported at one end by the load cell. Commonly, the outer sleeve rotates on bearings around a center shaft that runs the length of roller assembly. The shaft is held in place on one end and hangs free on the other. **(Refer to Figure 8)** The amount of deflection of the shaft due to the overhung tension load limits the practical length of the cantilevered roller to about 20 inches.

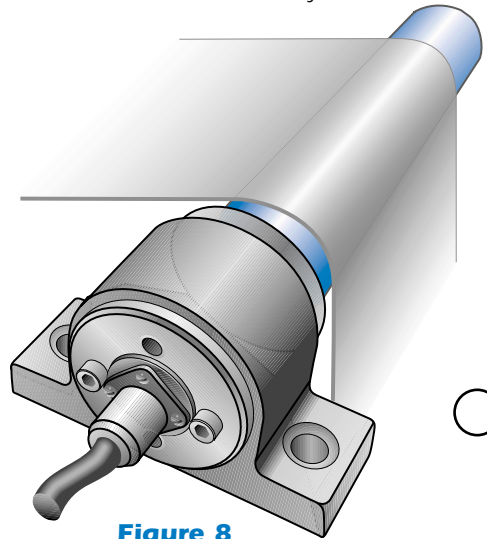


Figure 8
(Cantilevered Roller)

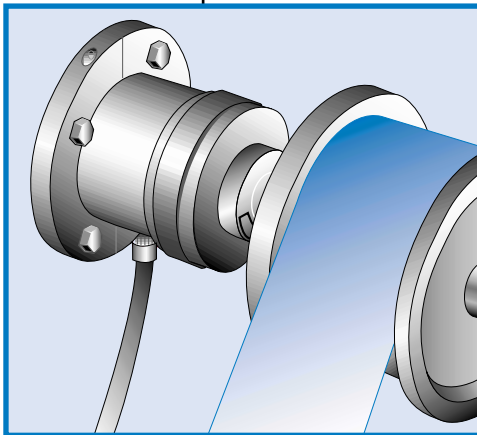


Figure 9
(Pulley)

CMC also accommodates fiber optic strands, filaments, some medical/hygienic products, as well as other very narrow width products that run over a pulley or guide roller. **(Refer to Figure 9)**

CMC's standard product offerings for narrow webs are the CLT and CR Style Transducers **(Refer to Figure 7)**. Other styles are available that have been designed for specific applications.

Only one transducer is required per roller since it supports a cantilevered roller or pulley.

Step 2 - Determine if you have a stationary shaft or rotating shaft roller

Stationary Shaft Rollers: Rollers are either stationary shaft or rotating shaft. Stationary shaft rollers have a shaft that run all the way through the assembly. The outer shell or sleeve is a cylinder that rotates around the shaft on bearings. The shaft does not rotate but remains stationary. Stationary shaft rollers are also referred to as fixed or dead shaft rollers. (Refer to Figure 10)

SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION

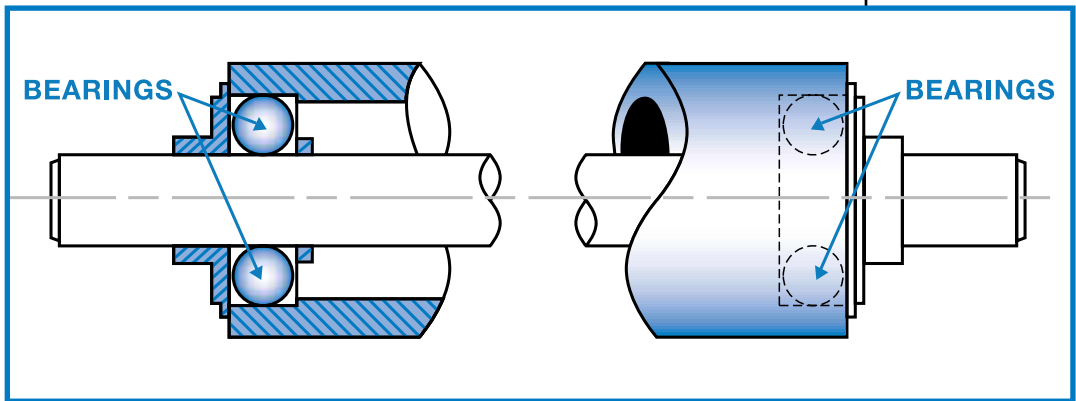


Figure 10
(Stationary (Dead) Shaft Roller)

Narrow web rollers are cantilevered or pulleys and are generally stationary shaft. CMC offers two standard styles for this application, the CLT Transducer and the CR Transducer. The CR Transducer is designed for pulleys or narrow rollers where the web, ribbon, or wire is always positioned in the exact center of the roller. The CLT Transducer, on the other hand, accommodates both pulleys and longer length rollers. The web can be positioned anywhere along the length of roller face without affecting the tension measurement.

The Cartridge Style Transducer and Slim Cell Transducers are designed for wide web rollers with stationary shafts. The Cartridge Style Transducer is very versatile since it offers a variety of mounting options—flange mount and pillow mounting kits. The Slim Cell Transducer is a low profile design and can be mounted inside or outside the machine frame. It is corrosive, chemical, and water resisting and is designed to handle high overloads.

Rotating Shaft Rollers: Rotating shaft rollers are designed so that the shaft is part of the rotating assembly. The outer shell or sleeve is integral to the shaft, there are no bearings in the assembly, and the shaft rotates. (Refer to Figure 11)

SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION

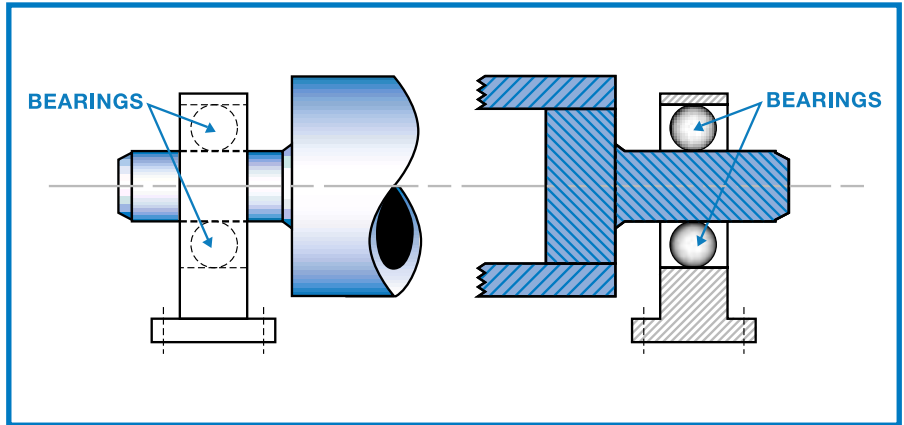


Figure 11
(Rotating (Live) Shaft Roller)

The UPB Washdown Duty LC and the Slim Cell Transducer are designed for wide web rollers with rotating shafts. The UPB Washdown Duty LC is for use with a pillow bearing which is mounted to its top plate. The Slim Cell Transducer is a low profile design and includes a low friction, maintenance free bearing.

Stationary Versus Rotating Shaft Rollers: Many times the application dictates the type of roller required. For very high speed (rpm) requirements, rotating shaft rollers are generally utilized since they exhibit higher resonant frequencies than stationary shaft rollers. Large diameter roller construction (with typically large loads) favors rotating shaft rollers that are used with under pillow block bearings. Stationary shaft rollers are used in many applications since they are relatively easy to manufacture and are readily available.

Step 3 - Determine the proper tension

Many times the process or production engineers have a good idea of what the running tensions should be. If these are not known, approximate the tension based on the thickness and type of material. **Figure 12** can be used for approximating tensions. Tensions are given in PLI, which stands for Pounds per Lineal Inch. To determine the tension in the material, multiply the PLI by the width of the web. For example, 4 mil thickness of nylon or cast propylene (non-oriented) requires approximately 1 PLI of tension ($0.25 \text{ lb./in./mil} \times 4 \text{ mil} = 1 \text{ lb./in.}$). To run a 60 inch wide web of Propylene a typical tension of 60 lb. is required ($1 \text{ lb./in} \times 60 \text{ in} = 60 \text{ lb.}$).

To estimate the load requirement for wide web transducers, use the running tension value. Ensure that the transducer you are considering is designed for this load.

To estimate the load requirement for narrow web transducers, double the running tension value. Ensure that the transducer you are considering is designed for this load.

Later in this handbook, a transducer sizing calculation will be completed to determine which load rating to actually select.

For now, use this guideline then check later against the actual calculation.

SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION

Tension Data for Typical Converting Materials

Material	Tension (lbs./inch/mil)	Paper & Laminations	Tension PLI
Note: 1 mil = 0.001"	Aluminum Foils	0.5 to 1.5 (1.0 average)	20# / R - 32.54 gm/m ²
	Cellophanes	0.5 to 1.0	
	Acetate	0.5	40# / R - 65.08 gm/m ²
	Mylar (Polyester)	0.5 to 1.0 (.75 average)	60# / R - 97.62 gm/m ²
	Polyethylene	0.25 to 0.30	80# / R - 130.1 gm/m ²
	Polystyrene	1.0	
	Saran	0.5 to 2.0 (.10 average)	
	Vinyl	0.5 to 2.0 (.10 average)	

Substrate	Approximate Tension (lbs./inch)	Substrate	Approximate Tension (lbs./inch)
Mylar, Oriental Propylene and Polyester		Paperboard	
0.0005"	0.25	8 pt.	3.0
0.001"	0.05	12 pt.	4.0
0.002"	1.0	15 pt.	5.0
Cellophane		20 pt.	7.0
0.00075"	0.5	25 pt.	9.0
0.001"	0.75	30 pt.	11.0
0.002"	1.0	35 pt.	13.0
Nylon & Cast Propylene (non-Oriented)		45 pt.	15.0
0.00075"	0.15	65 pt.	19.0
0.001"	0.25	Laminations	
0.002"	0.5	25 lb. Paper/.0005" PE/.00035" Foil/.001" PE	3.0
Paper		.001" Cello/.0005" PE/.001" Cello	1.5
15 lbs./ream (3,000 sq. ft.)	0.5	NOTE: When these substrates are coated with polyethylene, nylon, polypropylene, EVA, EAA and EEA ... add the following tension values to the values listed above for the substrate only.	
20 lbs./ream	0.75	Coating Thickness	
30 lbs./ream	1.0	Approximate Tension (lbs./inch)	
40 lbs./ream	1.5	0.0005" to 0.001	0.12
60 lbs./ream	2.0	0.0011" to 0.002	0.25
80 lbs./ream	2.5		
120 lbs./ream	3.5		
160 lbs./ream	4.5		
200 lbs./ream	5.5		
240 lbs./ream	6.5		
280 lbs./ream	7.5		

Copper Wire

AWG	Tension	AWG	Tension
8	30.0 lb.	20	5.0 lb.
10	20.0 lb.	24	4.5 lb.
12	12.0 lb.	30	1.25 lb.
14	9.0 lb.	36	0.25 lb.
16	6.0 lb.	40	0.1 lb.

Figure 12

SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION

Step 4 - Determine space and mounting requirements

Determine which of the load cells you are considering will fit your space and mounting requirements. If you are utilizing a pillow block bearing the UPB Washdown Duty LC is the proper selection. The Slim Cell Transducer is a low profile transducer for tight spaces. The Cartridge Style Transducer offers a variety of mounting options—stud mount, bearing replacement, flange mount, and PB mount. **(Refer to Figure 13)**

Check the roller shaft diameters that the load cell can accommodate. A split bushing, which the manufacturer can supply, may be required to accommodate smaller shaft diameters. You may need to turn down the ends of the roller shaft if it is larger than the load cell can accept.

Step 5 - Determine environmental restrictions

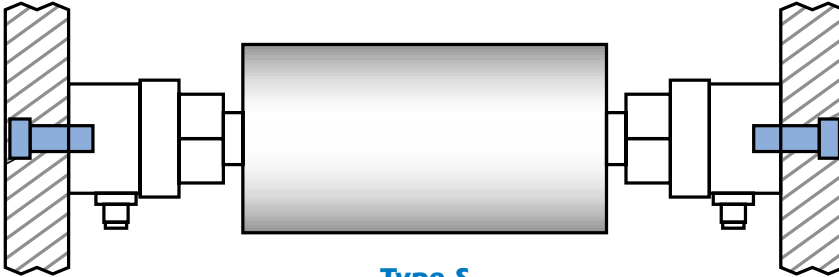
Wet environments may require a corrosive and water resisting design. Chemical environments may require a stainless steel design. Ensure that the transducer you are considering meets these requirements. The Slim Cell Transducer and UPB Washdown Duty LC can be used in these environments. In what temperature ranges will the load cell operate? Is the transducer specified for this temperature? All CMC load cells are temperature compensated so that the output does not change by more than 0.02% per deg F from 0 deg to 200 deg F. Other temperature ranges can be accommodated. Does the application require operation in a special atmosphere or vacuum? Special versions of CMC transducers are available for use in high temperature, special atmosphere, and vacuum environments.

Step 6 - Select the proper load cell style

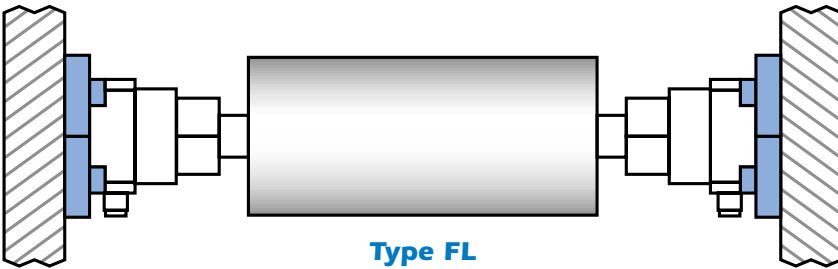
After determining the above requirements, you are in position to select your load cell. Review the load cell's data sheet, selection guide, and any other available information. **(Refer to Figure 22 for a detailed selection guide for CMC load cells)**

Make sure to consult with your supplier. They will be able to recommend the best style load cell for your application and will give you tips on how to get the most out of it. They'll recommend how it should be mounted and oriented to get the best performance. This will be useful in determining the parameters required to size the load cell to the proper load rating, which is the next step.

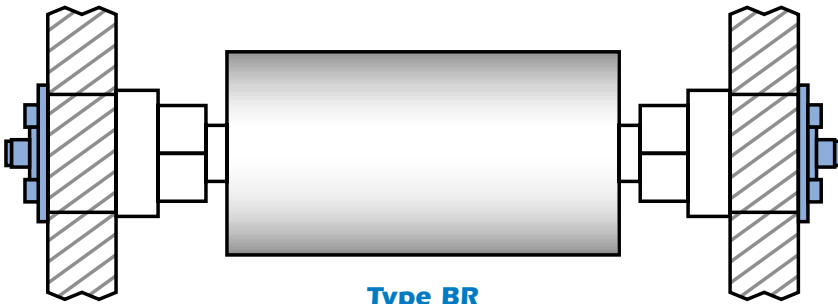
SELECTING
THE STYLE OF
LOAD CELL
FOR YOUR
APPLICATION



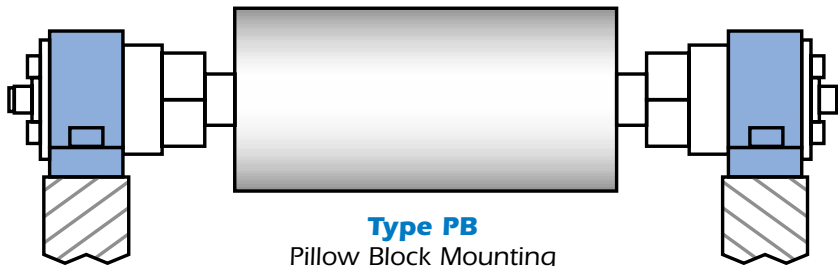
Type S
Stud Mounting



Type FL
Flange Mounting



Type BR
Bearing Replacement Mounting



Type PB
Pillow Block Mounting

Figure 13
(Cartridge Style Transducer Mounting Configurations)

SIZING THE
TRANSDUCER
FOR THE LOAD
REQUIREMENTS

**SIZING THE TRANSDUCER FOR
THE LOAD REQUIREMENTS**

Q: What is the Reason for Sizing?

Load cells (tension transducers) are electromechanical devices that have inherent design limitations. This restricts the tension (force) range over which they can operate. If the force is too high, the electromechanical elements will be overstressed and fail. If the force is too low, the signal output is too low to measure. Because of these restrictions, each style of load cell is offered with a choice of force ratings—referred to as the Maximum Working Force (MWF) rating.

The goal is to select an MWF rating that will meet the tension range requirement without overstressing the electromechanical elements. This is referred to as sizing the transducer.

DEFINITION

Tension Range is the ratio of the maximum running tension divided by the minimum running tension.

Example: What is the tension range with a max running tension of 80 lbs and a min of 10 lbs?

Answer: $80/10 = 8:1$

If the required tension range is small, 8:1 or less, this becomes less critical so the transducer can be sized for a larger load and still produce a significant signal at the low-tension requirement. If the required tension range is large, 20:1 or 30:1, the MWF rating must be as small as possible. The load cell's rating must closely match the maximum tension requirement to have enough range left to provide a significant measurement at the low end. The range over which load cells can operate depends upon its design and how it is applied.

The formulas for calculating MWF are derived from the design of the transducers themselves. These formulas are referred to as sizing formulas. Inserting values for various parameters in the formulas produce the MWF required by a specific application. Make sure your supplier reviews these calculations.

Q: What Formulas Are Used For Proper Sizing?

The sizing formulas are different for different styles of transducers. **Figure 14** shows the formulas, orientation diagrams, and the parameters required for sizing each style of transducer. The force exerted on the transducer depends upon the value and orientation of the wrap angle as well as the actual tension in the material. The key is to get the values for the minimum and maximum tension, the weight of the roller, and a sketch of the web path. From there, a supplier can determine the wrap angle, other appropriate angles, and perform the calculations.

Values for each parameter are inserted into the formula to determine the Maximum Working Force (MWF) required for the application. Select a transducer whose load rating (MWF) meets or exceeds the calculated MWF.

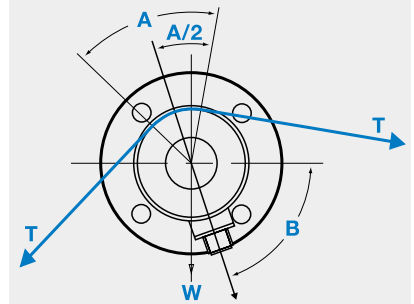
SIZING THE
TRANSDUCER
FOR THE LOAD
REQUIREMENTS

CANTILEVERED (CLT) SIZING CALCULATION

$$MWF^* = 2T \times K \times \sin(A/2) \pm W \times \sin(B)^{**}$$

- MWF** = Maximum Working Force (lbs.)
- T** = Maximum Total Tension (lbs.)
- K** = Transient Tension Overload Factor
(normally between 1.4 and 2)
- A** = Wrap Angle (degrees)
- B** = Angle of Tension Force (degrees)
- W** = Weight of Cantilevered Roller

* The MWF calculation defines the force on each individual load cell.
** If Angle B is below horizontal use + in calculation. If Angle B is above horizontal use - in calculation.



UPB SIZING CALCULATION

$$MWF^* = \frac{2KT \sin \frac{A}{2} [H \sin B + L \cos B] \pm W [L \cos C - H \sin C]}{2L}$$

- MWF** = Maximum Working Force (lbs.)
(used to select the proper force rating of the transducer)
- K** = Transient Tension Overload Factor
(normally 1.4 for most applications)
- T** = Maximum Total Tension (lbs.)
- A** = Wrap Angle (degrees)
- B** = Angle of Tension Force (degrees)
- W** = Weight of Roller
- C** = Mounting Angle (degrees)
- H** = Bearing Height + D

* The MWF calculation defines the force on each individual load cell.
** If Angle B is below horizontal use + in calculation. If Angle B is above horizontal use - in calculation.

SIZE	L (in.)	D (in.)
UPB1	2.5	0.98
UPB2	4.5	1.25
UPB3	6.5	2.10

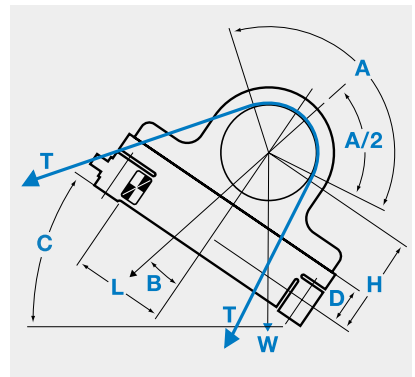


Figure 14

SLIM CELL SIZING CALCULATION

$$MWF^* = T \times K \times \sin (A/2) \pm (W/2) \times \sin (B)^{**}$$

MWF = Maximum Working Force (lbs.)

T = Maximum Total Tension (lbs.)

K = Transient Tension Overload Factor
(normally 1.5 for most applications)

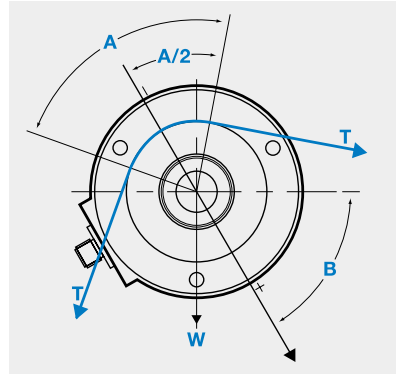
A = Wrap Angle (degrees)

B = Angle of Tension Force (degrees)

W = Weight of Roller

* The MWF calculation defines the force on each individual load cell.

** If Angle B is below horizontal use + in calculation. If Angle B is above horizontal use - in calculation.



CARTRIDGE-STYLE SIZING CALCULATION

$$MWF^* = \frac{2T \times K \times \sin (A/2) \pm W \times \sin (B)^{**}}{2}$$

MWF = Maximum Working Force (lbs.)

(used to select the proper force rating of the transducer)

K = Transient Tension Overload Factor
(normally between 1.4 and 2.0)

T = Maximum Total Tension (lbs.)

A = Wrap Angle (degrees)

B = Angle of Tension Force (degrees)

W = Weight of Roller

* The MWF calculation defines the force on each individual load cell.

** If Angle B is below horizontal use + in calculation. If Angle B is above horizontal use - in calculation.

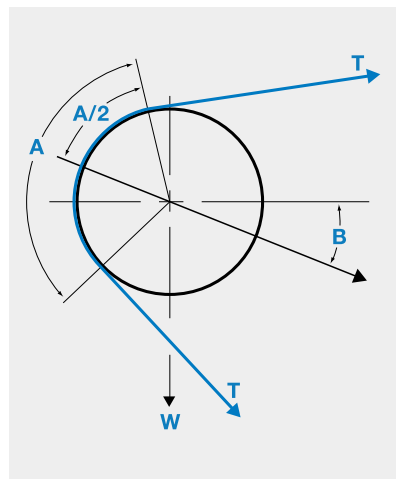


Figure 14 - Continued

-sizing the
transducer
for the load
requirements

Q: How Are Sizing Formulas Applied?

Figure 15 discusses how the sizing formula was utilized on an application for RR Donnelley and Sons. It also explains how to determine the wrap angle and angle of tension force. The initial calculation indicated that the roller weight was too heavy to take full advantage of the load cell's capability. The existing roller was replaced with a composite roller that weighed much less.

HOW TO SELECT THE RIGHT TRANSDUCERS

For RR Donnelley & Sons, two CMC SC Transducers are used on each tension roller, one on each side. The web is wrapped around the tension roller. The Transducers measure the force that is exerted on the roller by the tension in the moving web. The maximum working force (MWF) exerted on the transducers is then calculated from the following equation.

$$MWF = \frac{2T \times K \times \sin(A/2) \pm W \sin(B)}{2}$$

MWF = Maximum Working Force (lbs)

T = Maximum Total Tension (lbs)

K = Transient Tension Overload Factor (normally 1.4 to 2.0)

A = Wrap Angle

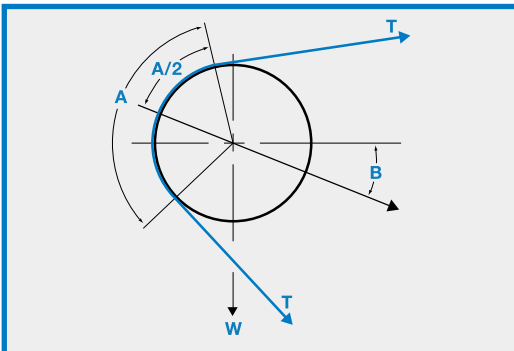
B = Angle of Tension Force

W = Weight of Roller (lbs)

According to Don Strenio, sensors and controls product manager for Cleveland Motion Controls, the user needs to proceed as follows in order to determine the parameters used in the equation:

First, make a sketch that shows where the web enters and exits as it wraps around the roller. (Refer to the diagram below). The point where the web touches the roller as it enters and exits the wrap is referred to as the tangent. Draw a radius from the center of the circle and perpendicular to each tangent at entry and exit. These lines define angle A, which is the Wrap Angle.

To determine angle B, draw a line that bisects angle A. The angle that this line makes with the horizontal is angle B—the Angle of Tension Force. If angle B is below the horizontal, use positive (+) in the calculation, if angle B is above the horizontal, use negative (-) in the calculation.



Determine the Maximum Tension T, and the minimum tension that is required for your process. If this is not known, consult your transducer supplier. The supplier should have charts that indicate typical tensions for various materials.

Weigh the roller or calculate the roller weight to determine W. K is a safety factor that is used to account for tension transient overloads (a value of 1.4 to 2.0 is typical, depending on the application.).

Insert those values into the equation to determine the maximum working force (MWF) that is exerted on each transducer. Select a transducer rating that exceeds the MWF.

The calculation should be performed using the minimum tension. The resulting value indicates what the force output will be at the lowest tension. If it is a very small percentage of the transducer rating (typically less than 1/20 or 1/30 the rating), you may need to increase the wrap angle, re-orient the web wrap, or reduce the roller weight to achieve a usable measurement at low tension.

Strenio adds, "To select and size the right transducer for the application requires careful attention to detail. You need to totally understand the application and then calculate a basic equation for each transducer. The equation is only the first step. In fact, you should never order a transducer without consulting the supplier first. The success of the application often depends on the extent to which the user and supplier work together in addressing the application. Once the supplier receives your information, you need to rely on the supplier's application experience to perform the calculations, evaluate the requirement, and if necessary, recommend machine design changes or alternate methods."

During the process, it was found that the main draw rollers (which are extremely important for maintaining steady tension on the entire web) were too heavy to take full advantage of the load cell's capabilities. The output signal would not be great enough to achieve optimal performance. Based on Strenio's recommendation, Donnelley replaced the existing roller with a composite roller, which weighed much less. By making this change, Donnelley realized a significant improvement in load-cell resolution, which resulted in a significant improvement in the overall performance of the closed-looped system.

Figure 15

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FROM MY LOAD
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WHAT TECHNIQUES CAN GET THE MOST FROM MY LOAD CELLS?

Note: These examples and explanations utilize cartridge style transducers. The formulas for other styles may be different so the specifics may change, but the principles for application are the same.

Orient the Load Cell Properly

Load cells require that they be oriented properly. This is because the force exerted on the roller due to the tension in the material must bend the transducer beam in order to produce a measurement. Refer to "How Do Load Cells Actually Work?"

The force due to the tension in the material always points along the bisector of the angle of wrap (wrap angle). The bisector is the line that splits the angle in half, also referred to as the Angle of Tension Force. If the bisector of the wrap angle is vertical and the material is pulling down on the roller, the force points straight down. If the bisector of the wrap angle is vertical and the material is pulling up on the roller, the force points straight up. Pulling horizontally on the roller is often used to negate the effect of the roller weight on the transducer—this will be discussed later. (Refer to Figure 16)

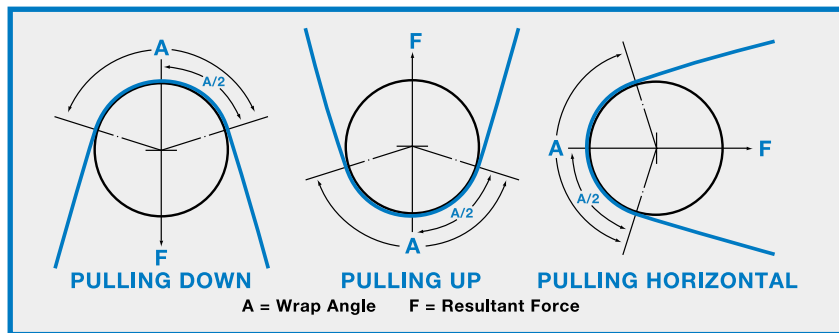


Figure 16
(Pulling Orientation)

There is an arrow on the coupling face of CMC's Cartridge Style Transducer. Installation instructions require that the transducer body be rotated so that the arrow is in line with the bisector of the wrap angle. (Refer to Figure 17) When oriented in this manner the force is always perpendicular (at right angles) to the beam. Maximum bending (deflection) of the beam occurs when the force is exerted at a right angle to the beam surface. The larger the deflection the greater the output signal (measurement). When the transducer is oriented in this manner, the output signal is always at its strongest (maximum) for a given force. This means that for a given tension and wrap angle no other orientation will yield as strong a measurement.

A lower output signal results if the transducer is not installed so that the arrow is aligned with the bisector of the wrap angle. Generally, "eyeballing" is sufficient to achieve proper alignment. The resultant signal output is a function of the sin of the included angle between the direction of the force and the surface of the beam. Being 5 degrees off in alignment results in less than a 1% drop in signal strength from the maximum. Being 15 degrees off results in only a 4% drop and 30 degrees results in 13% drop.

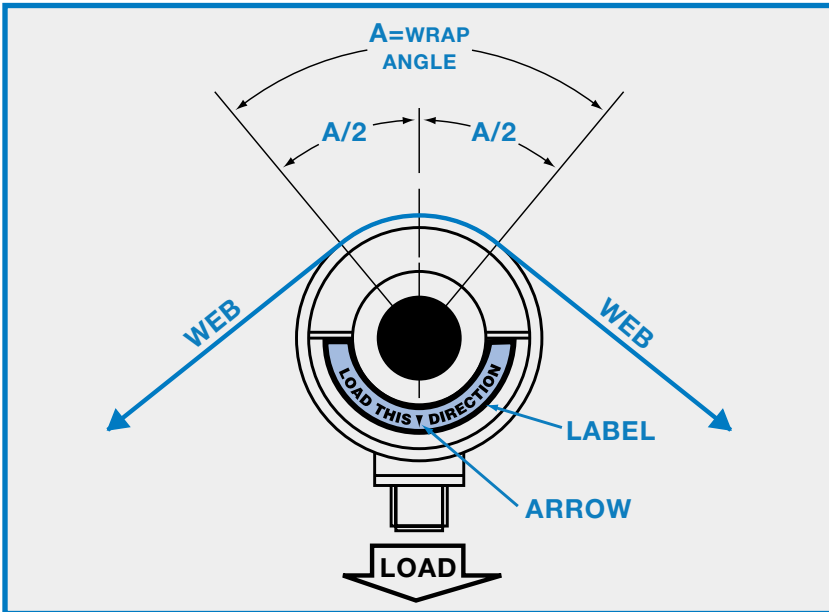


Figure 17
(Transducer Mounting Orientation)

Pay Attention to Roller Weight

The load cell not only measures the force due to the tension in the material but also due to the mass of the roller. The force measured by the transducer due to the mass of the roller is known as the tare weight. The tare weight is a function of the roller mass and the orientation of the transducer with respect to the gravitational force. Gravity always pulls a mass toward the earth so the force due to gravity (weight) is always pointing vertically downward.

The force of gravity bends (deflects) the transducer beam the most when it is perpendicular to it. The greater the deflection, the greater the output signal. When the transducer is oriented in this manner the output signal due to gravity is always at its strongest (maximum) for a given mass. In this situation the tare weight is the weight of the roller. For the Cartridge Style Transducer this occurs when it is oriented so that the arrow on the coupling face is pointing vertically up or down.

WHAT
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CELLS?

WHAT
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CELLS?

The tare weight adds or subtracts to the output signal produced by the tension force. As part of the calibration procedure the tare weight is zeroed out so that only the signal due to tension is measured. This is accomplished by various means in the electronic amplifiers or controllers, either automatically or by adjusting a potentiometer.

If the output signal due to the tare weight is too great, less of the total transducer output signal can be utilized for measuring the tension force. This is especially important to consider when the roll weight is large when compared to the required tension.

As a rule of thumb the tare weight should be no greater than 2/3 of the transducer load rating (MWF). This leaves enough signal to measure the tension load. There are exceptions to this if the tension range is small (2:1, 4:1). For a large tension range (20:1, 30:1) the tare weight must be reduced to zero or used to extend the transducer range by working in the opposite direction of the load.

If the tare weight is too large, either the roller weight must be reduced or the web path changed so that the transducer can be oriented differently. Constructing the roller from aluminum or composite material will reduce the roller weight.

Calculate the Tare Weight and Make it Work For You

The tare weight calculation is part of the sizing formula. Refer to the sizing formula and orientation diagram for the Cartridge Style Transducer in **Figure 14**. The term in the equation $\pm W \sin(B) / 2$ is the gravitational force exerted on the transducer beam due to the roller mass and is referred to as the tare weight. There is an arrow on the coupling face of the cartridge transducer. During installation the transducer is rotated so that the arrow is in line with the bisector of the wrap angle. This bisector is the line from which the Angle B (Angle of Tension Force) is determined. The other side of angle B is the horizontal line. W is the roller weight. For any orientation Angle B can always be referenced from the horizontal, so B is between 0 and 90 degrees.

Pull up on the roll to extend the range of the transducer (Refer to Figure 16). When B is 90 degrees, the force is either pulling straight up or straight down on the roller. The sin of 90 degrees is 1. Inserting $B = 90$ degrees into the equation yields a tare weight of $\pm W/2$. This is half the weight of the roller. The weight of the roller, W , is divided by 2 since there are two transducers supporting this roller.

When the tension pulls down on the roller the tare weight $W/2$ acts in the same direction as the tension force and is positive. It adds to the tension force to increase the total load on the transducer.

By pulling up on the transducer, the roller weight can work for you. When the tension pulls up on the roller the tare weight $W/2$ acts in the

opposite direction of the tension force and is negative. It subtracts from the tension force to decrease the total load on the transducer.

Example:

The maximum tension in the material is 50 lb. and the roller weight is 60 lb. The wrap angle is 180 degrees. Select the Cartridge Style Transducer. Calculate the MWF for different orientations. Ignore the safety factor, K, by making $K=1$.

If the force is pulling straight down, a Maximum Working Force (MWF) of 80 lb. per transducer is calculated. 50 lb. is the force due to the tension and 30 lb. is the tare weight. The tare weight is in the same direction as the tension force, so it is added. The closest transducer rating that meets or exceeds the MWF is 100 lb.

If the web path is changed so the force is pulling straight up, a Maximum Working Force (MWF) of 20 lb. per transducer is calculated. 50 lb. is the force due to the tension and 30 lb. is the tare weight. The tare weight is in the opposite direction of the tension force, so it is subtracted. The closest transducer rating that meets or exceeds the MWF is 25 lb. Pulling up on the roll allows a lower MWF rating to be selected which results in a higher transducer output and more sensitivity. However, the 25 lb. MWF transducer is not acceptable because the tare weight of 30 lb. exceeds the transducer rating of 25 lb. Never choose a load cell rating that is less than the tare weight it supports, otherwise overloading may damage it. A 50 lb. MWF rating is the next available size so it is selected.

By pulling up instead of down on the roll the transducer size has been reduced from 100 lb. to 50 lb. The sensitivity has increased twofold and we have increased the ability to measure lower tensions thus increasing the range of tensions that we are able to measure. A transducer with a lower MWF force rating is more sensitive to lighter loads than one with a higher MWF rating. **For the greatest possible tension range choose the transducer with the lowest possible force (MWF) rating.**

If the force is pulling up, the beam moves downward from its neutral position when the 30 lb. roll weight is applied and then moves upward past its neutral position when the 50 lb. tension force is applied. **(Refer to Figure 18)** The strain gages are bipolar and give a signal (the signal can be offset or zeroed with the electronics) if the beam is deflected down or up. The transducer can operate at up to + 50 lb. or -50 lb. By pulling against the roll weight we can extend the effective measuring range of the transducer up to double its rating in some situations.

The recommended orientation for most applications is a 180-degree wrap angle pulling straight up on the roller. This gets maximum utilization from the transducer. **(Refer to Figure 16)** Following this rule is generally a good idea. However, many times its is not possible to achieve this orientation or wrap angle.

WHAT

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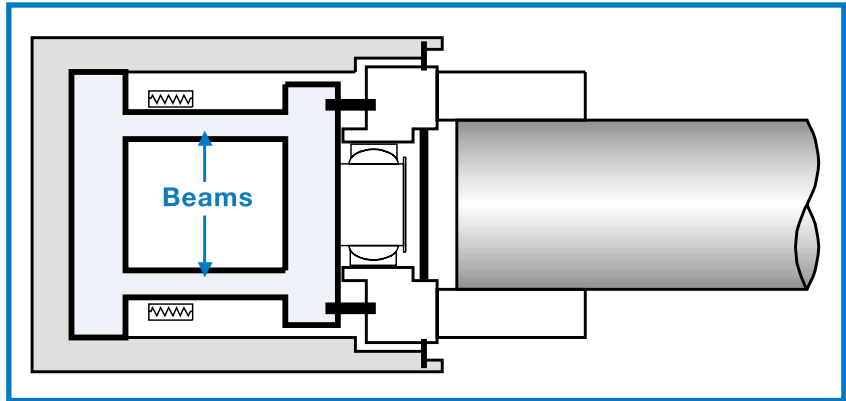


Figure 18-A
(Neutral Position)

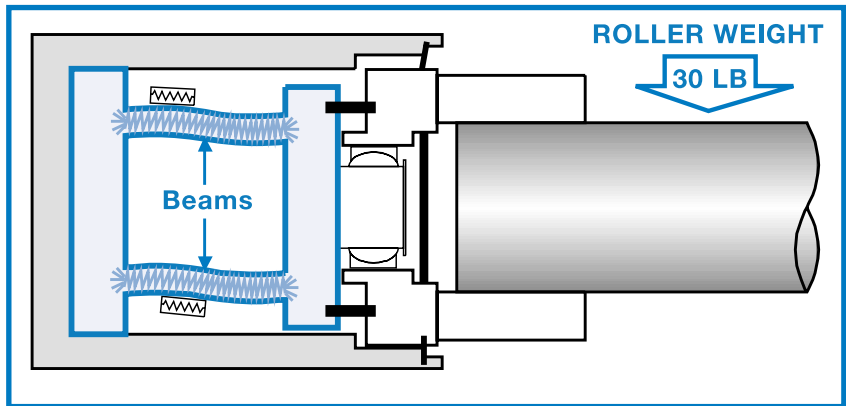


Figure 18-B
(30 LB Roller Weight Only)

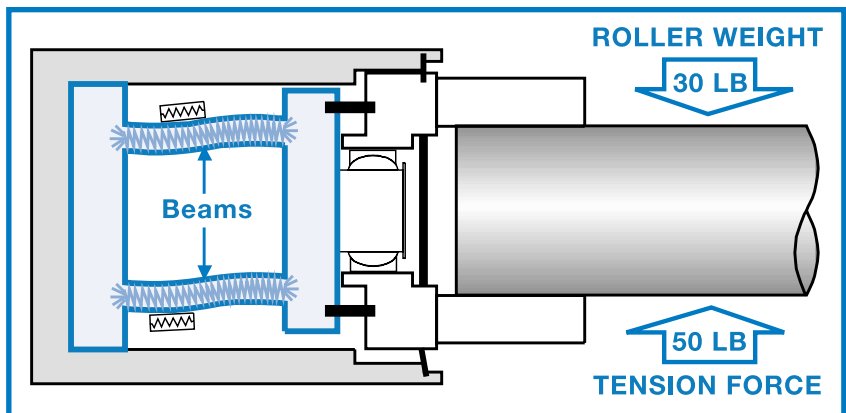


Figure 18-C
(30 LB Roller Weight and 50 LB Tension Force)

When B is 0 degrees the force is pulling horizontally on the roller. **(Refer to Figure 16)** The sin of 0 degrees is 0. Inserting B = 0 degrees into the equation yields a tare weight of 0. **Pulling horizontally against the roller negates the effect of the roller weight.**

Example:

The maximum tension in the material is 5 lb. and the roller weight is 25 lb. The wrap angle is 180 degrees. Select the Cartridge Style Transducer. Calculate the MWF when the material is pulling horizontally against the roller. Ignore the safety factor, K, by making K=1.

A Maximum Working Force (MWF) of 5 lb. is calculated. 5 lb. is the force due to the tension and 0 lb. is the tare weight. The closest transducer rating that meets or exceeds the MWF is 25 lb. The output signal will only be that due to the tension force. Only 20% (5 lb.) of the available transducer output signal (good to 25 lb.) is being utilized for the maximum tension measurement, but there is no output due to the roller weight. This means that everything being measured is actual tension signal. This technique improves the ability to recognize a small signal when the roll weight is appreciably larger than the tension.

Even though the tare weight is zero, the transducer will be subjected to the weight of the roller while it is being installed and rotated into position. As a general rule, the transducer MWF rating should not be less than the weight it might support. Otherwise, you could damage it by overloading or be unable to zero out the roller weight in the electronics.

Don't Ignore The Wrap Angle—Use it to Your Benefit

The force due to the tension and wrap angle is part of the sizing formula. Refer to the sizing formula and orientation diagram for the Cartridge Style Transducer in **Figure 14**. The term in the equation $2T \times \sin(A/2)/2$ is the force exerted by the tension in the material as it wraps around the roller. (The term is divided by 2 since there are two transducers supporting this roller which divides the total load. Ignore the safety factor, K, by making K=1.

The tension, T, pulls in opposite directions away from the roller, and this puts double the load or 2T on the roller. The portion of tension that is transmitted to the roller and the transducer is dependent upon the amount of wrap around the roller. **The amount of wrap is referred to as the wrap angle.** This angle is determined by drawing a line from the center of the roller perpendicular to where the web first touches the roller as it enters and another where it last touches as it exits. The angle in between is defined as A, the wrap angle.

WHAT

TECHNIQUES

CAN GET THE MOST

FROM MY LOAD

CELLS?

HANDBOOK

WHAT
TECHNIQUES
CAN GET THE MOST
FROM MY LOAD
CELLS?

The portion of tension through the wrap angle is $\sin (A/2)$. The maximum value for the sin is 1 and this occurs when the angle A is 180 degrees ($\sin (180/2) = \sin (90) = 1$). **The largest amount of tension is transmitted to the roller when the wrap angle is 180 degrees.** When A is 0 degrees there is no wrap around the roller and the tension force is zero.

For typical applications, and especially for low tension, it is desirable to make the wrap angle as large as possible. This produces the greatest tension force giving more signal output resulting in a better measurement.

Many machine designers use a minimum of 30 degrees of wrap as a rule of thumb. A wrap angle of 30 degrees transmits 25% of the line tension to the transducer. This is still a significant value so they know the signal will be manageable. In most cases, this also gives enough wrap to ensure that the material stays in contact with the roller surface. With light material, running at low tension and at high speeds, air may draft under the material causing it to rise and lose contact with the roller surface. Transducers are applied at much lower angles of wrap, but the application requires scrutiny to ensure proper performance.

For some applications it is desirable to slightly decrease the wrap angle in order to use a smaller transducer (smaller MWF rating). This is generally considered when large tension ranges are required. In this case, we want to use the entire transducer output signal in order to get maximum resolution.

Maintain a Fixed Angle of Wrap Throughout the Process

If the angle of wrap varies, the tension force on the transducer changes. This results in inaccurate measurements. Only use transducers on a roller where the wrap angle is fixed. **(Refer to Figure 19)**

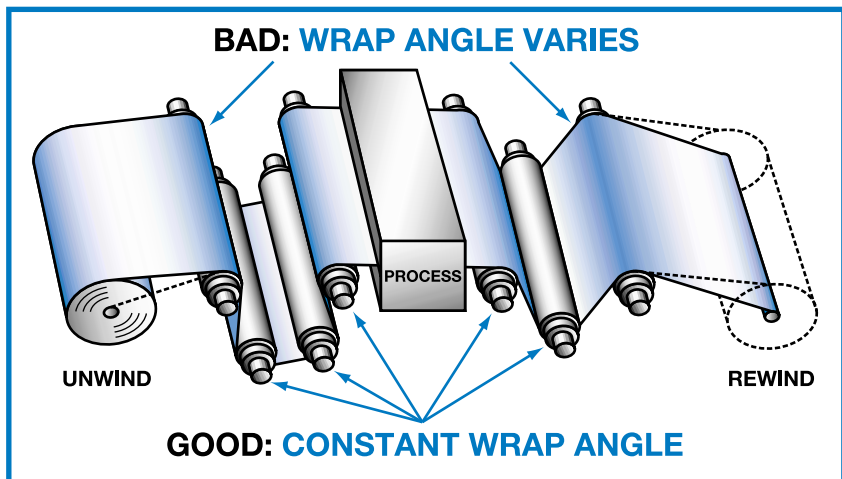


Figure 19
(Where to Mount Tension Transducers)

Be Judicious in Assigning the Safety Factor

The K factor is assigned to ensure that the MWF rating of the transducer is high enough to protect it from transient overloads. Overload conditions may damage the transducers. Some transducers are rated for higher overloads than others. The recommend overload rating to use for the Cartridge Style Transducer is 150% of the MWF. A K of 1.4 to 2 is typically used for these transducers, which extends the overload protection to 210% and 300% effectively. It is not always necessary to assign a K value greater than 1; it depends upon the application and the transducer overload rating. Overload limits for the UPB Washdown Duty LC are 500% and the Slim Cell Transducer are as high as 1000%.

The amount of conservatism that is placed on the maximum tension value and the method in which the machine is controlled needs to be taken into consideration when assigning the K value.

Making the K value too large may oversize (too large of a MWF) the transducer limiting the low end of the effective tension range. Of course, undersizing (too small of a MWF) can lead to damaged transducers. When a large tension range is required (20:1, 30:1), oversizing the transducer limits its low-end performance. When a small tension range is required (2:1, 4:1), oversizing the transducers gives it extra protection.

Be Realistic About Tension Control and Over What Range

How well tension can be controlled and over what range depends upon many factors other than how well the load cells perform their measurements. Some of these factors are the mechanical design of the machine, mechanical wear of the components, line speed, and the system response (mechanical and electrical). All systems have natural resonant frequencies that limit their ability to be controlled and to respond to corrective changes. **(Refer to Figure 20)** System engineers explain that attempting to control tension above a 20:1 or 30:1 range and achieve acceptable tolerances is extremely difficult. Some system integrators won't accept jobs specifying a tension range over 10:1. Although the load cell signal output is linear all the way down to zero, CMC doesn't recommend exceeding a 20:1 or 30:1 tension range from an individual load cell. These applications require special attention. Steps can be taken to extend the measuring range such as routing the web over an idler roller to change the wrap angle. **(Refer to Figure 21)** Most applications require much less range than this—4:1, 8:1.

Remove Transducers when Transporting the Machine

Exceedingly high shock overloads occur while transporting machinery. Remove the transducers BEFORE transporting machinery or they will become damaged. Pack each one in its own container.

WHAT

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FROM MY LOAD

CELLS?

HANDBOOK

BANDWIDTH AND RESPONSE

Two quantities – bandwidth and response – quantify a system’s capability to react to command changes.

Bandwidth for any system is the maximum frequency at which a system can be excited and still remain stable. The value of this bandwidth is less than the natural frequency of a system. For example, in a mechanical system, the natural frequency of a mass attached to a spring is expressed by: $w = \sqrt{K/m}$, where **w = natural frequency in radians/second, K = spring stiffness in Newtons/meter, and m= the inertial mass in kilograms**. If this type of system is excited at its natural frequency, the system will oscillate uncontrollably and become unstable.

Electrical systems operate in a similar manner. For a servo system, the bandwidth is the frequency of small signal change (10% or less) that can be applied to the input and the output will drop to 0.707 (-3dB) of the input. Servo bandwidth is expressed in Hertz (cycles per second) and radians per second. To convert from Hz to rad/s, multiply the Hz value by 2π . For example, a hypothetical servo system has a bandwidth of 100 Hz. This can also be expressed as 628 rad/s.

Response time indicates the time (usually expressed in seconds or milliseconds) for the output to reach the speed or position commanded by a small input change (usually 10% or less of the maximum). For slightly underdamped systems, and most servo systems fall into this category, the response time is approximately three times the reciprocal of the bandwidth when expressed in rad/s.

For example, the servo with a 100 Hz (628 rad/s) bandwidth has a response time of $3(1/628) = 0.005s$ (5ms). Thus, the servo will reach the full value of a small input change in 5 ms.

Typically, for small input changes, ac brushless servo drives have a bandwidth of 100 Hz and response times of 0.005s. By comparison, standard industrial adjustable speed drives have bandwidths of 3 Hz and response times of 0.16s.

For systems where a large change (more than 10%) is required, the system response must usually be added to the acceleration time, because load inertia, maximum accelerating current, and other factors must be considered.

WHAT
TECHNIQUES
CAN GET THE MOST
FROM MY LOAD
CELLS?

Figure 20
(Bandwidth and Response)

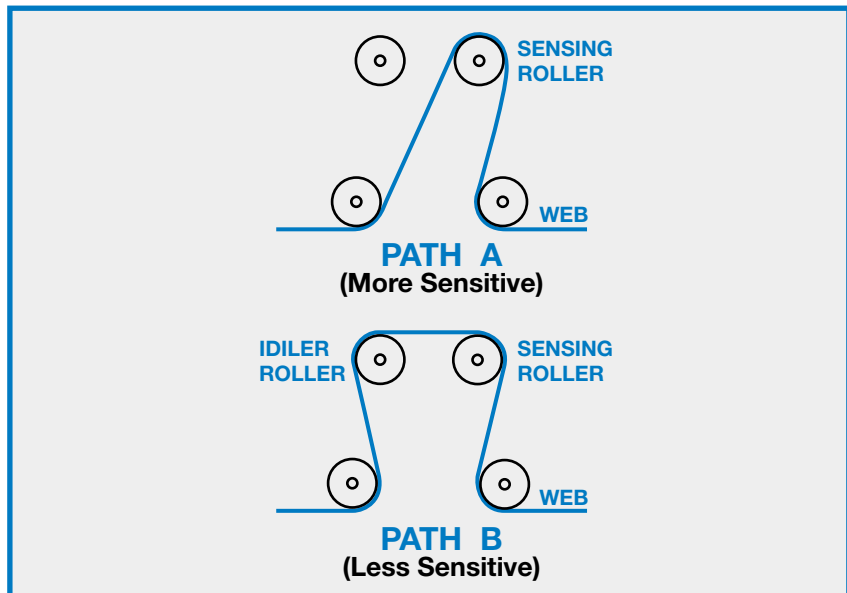


Figure 21
(Method to Double the Tension Range of a Sensing Roll)

WHAT SHOULD I LOOK FOR IN A LOAD CELLS?

All Load Cells are Not Created Equal

Many times users regard load cells as generic because they don't have the knowledge to distinguish one from the other. As a result, their load cells may be under performing yet they are unaware of the problem. The following questions should be considered when comparing load cells.

CMC's Cleveland-Kidder transducers will be used as the standard for comparison. This is because they have been used worldwide for over 40 years in a variety of applications and are known for their high performance and reliability.

Q: Is the Primary Technology Employed Well Accepted?

Load cells are offered with the primary sensing element as strain gages, LVDT's, magnetoelastic effect, or others. One could argue over the merits of each, but further investigation reveals that claims made by some are unfounded. CMC utilizes strain gages as the primary measuring element. They are extremely linear in their response, reliable, and are a well-proven technology. **Strain gages are the primary technology used world wide in load cell applications.** They are also utilized in all kinds of highly accurate applications including weigh scales, Formula One and NASCAR racing, and aerospace and defense.

Q: Will the Load Cell Disrupt the Web Path?

A primary consideration in tension sensing is that the path of the moving web be disrupted as little as possible as the measurement is being taken. This means that the deflection of the load cell must be minimal. The more deflection the more likely the web path will be disturbed and not track properly. **CMC load cells exhibit very little deflection at the rated tension load, typically only between .002 to .004 inches.** In addition, their twin beam design (**Refer to Figure 4**) ensures that any beam deflection is perpendicular to the web path to prevent steering to one side. Brands from some manufacturers typically allow as much as .10 inches deflection at full load. Also, load cells using strain gages have significantly less deflection than those using LVDTs.

WHAT SHOULD
I LOOK FOR IN A
LOAD CELL?

WHAT SHOULD
I LOOK FOR IN A
LOAD CELL?

Q: Will the Load Cell Allow for Shaft Misalignment?

In a perfect world, all rollers in the web line would be perfectly aligned from end to end and with respect to their neighbors. Even with the best attempts to ensure alignment, misalignment occurs. In the case where the roller is mounted to a pillow block bearing, the bearing chosen must be one that is designed to accommodate shaft misalignment. When the load cell is coupled to the roller shaft, the load cell must be able to accommodate the shaft misalignment. **CMC load cells are designed to accommodate up to +/-1 degree of misalignment from one end of the roller shaft to the other.** This is achieved by using an alignment bearing of aircraft grade quality that is Teflon coated (**Refer to Figure 4**). The Teflon coating eliminates the possibility of fretting corrosion. Fretting corrosion occurs when two metal surfaces are repeatedly knocked together due to vibration. This corrodes the metal over time, weakening it, and creating a rust-like condition.

Not all manufacturers offer load cells that accommodate for shaft misalignment. In these cases, binding may occur and the load cell measures this stress as a force that interferes with the true tension measurement. Some designs use a diaphragm to accommodate for misalignment. Over time, diaphragms weaken due to repeated bending, eventually crack, and break.

Q: What Is the Strength of the Output Signal?

The signal output of the load cell must be large enough for it to operate over a large tension range—typically 20:1 to 30:1. CMC utilizes semi-conductor strain gages that have a very high gage factor (100) and provide high signal output at small deflections. **CMC load cells typically provide a 100MV to 250MV output at rated load. Load cells from some manufacturers provide as little as 21MV at rated load.**

Q: How Responsive is the Load Cell?

The load cell must respond quickly to tension changes. This is especially true when it is being utilized in closed-loop applications. **CMC load cells are designed to have a high natural frequency; they respond quickly to changing tension in the web.** CMC electronics such as amplifiers, indicators, and controllers are also designed to accommodate this rapid response. Brands from other manufacturers have high inertia, which limits their response capability. The supplier should be able to calculate the response of their load cell in your application. Stay away from designs that require movement of substantial mass; they will yield a sluggish response.

Q: Is the Load Cell's Signal Linear and Repeatable?

Look for a combined non-linearity and hysteresis of +/- 0.5 % maximum of rated output, and repeatability of +/- 0.2% maximum of rate output. Manufacturers provide specifications for these ratings. They are not consistent on how they present their ratings so take this into account. CMC is conservative in their ratings and provides them as maximum tolerance limits—performance is typically much better.

All systems have natural resonant frequencies that limit their ability to be controlled and to respond to corrective changes. Beware of this when evaluating load cell specifications. Actual design limitations of the machine and system response (mechanical and electrical) limit how well tension can be controlled. These are typically the limiting factors of performance, not the load cells.

Q: Is the Load Cell Temperature Compensated?

Look for a sensitivity change (in the output signal) due to temperature of less than 0.02% per degree Fahrenheit. CMC incorporates a temperature compensation network (**Refer to Figure 4**) in their load cells in order to achieve this result. It is important that temperature changes have minimal effect on the output signal. **Not all brands compensate for temperature changes.**

Q: Will the Load Cell Accommodate Shaft Expansion?

The roller shaft grows or expands in length as the temperature increases. This creates a stress on the mounting components. If not properly relieved, the load cell measures this stress as a force that interferes with the true tension measurement.

In the case where the roller is mounted to a pillow block bearing, the bearing that is chosen must be one that is designed to accommodate shaft expansion. When the load cell is coupled to the roller shaft, the load cell must be able to accommodate the shaft expansion due to temperature changes. **CMC load cells are designed to accommodate 0.10 inches of shaft expansion per transducer (Refer to Figure 4).** Where two load cells are utilized, shaft expansion of 0.20 inches can be accommodated.

Many manufactures require that one end of the roller shaft be tightened to a transducer coupling and the other end be free to float in the transducer coupling. While this may relieve the stress due to shaft expansion it requires special mounting procedures and the use of "feeler gages" to set the appropriate gaps. Insuring that the gap is even may require the use of shims. Having to adhere to these requirements places much responsibility on the expertise and judgment of the installer. This can lead to improper installation or inconsistencies especially if the transducers are removed and then reinstalled (for roller maintenance—replacing bearings in the rollers) by someone other than the initial installer.

WHAT SHOULD

I LOOK FOR IN A

LOAD CELL?

HANDBOOK

WHAT SHOULD
I LOOK FOR IN A
LOAD CELL?

Q: Will the Load Cell be Reliable and Durable?

Look at the construction of the load cell. Is it open or sealed? Dust entering into the sensing elements can shorten the operating life. Is the body cast, machined, or is it made from sheet metal. Sheet metal designs are not nearly as rugged. Does the design require moving parts, mechanical springs, or offsets? These wear over time and present calibration problems. How reputable is the load cell manufacturer? How long has the manufacturer been in business? Who have the best companies been using? A good reputation is generally derived from producing a reliable product.

CMC constructs their transducers from cast or machined bodies and seals them against dust. Water resisting designs are also available. Most CMC load cells have NO moving parts and require NO maintenance. It is not uncommon for the Cleveland Kidder load cells to last 20 years or longer. All CMC transducers are designed to meet high performance standards. **CMC has been manufacturing tension transducers for over 40 years. The longevity and outstanding reputation of the Cleveland- Kidder brand attest to the superiority of their product.**

SUMMARY

SUMMARY

The more you know about selecting and sizing load cells the better your chance for success in your web tension application. It is important to understand why and how load cells are to be applied in your control scheme. Select the style that best fits your requirements. Use the appropriate techniques to get the most out of your load cell. Size the transducer to determine the load rating that best meets your tension range. Ensure that it has been designed to meet your performance requirements and will be both reliable and durable. Doing all of this will give years of outstanding, reliable performance from your load cell.

Cleveland-Kidder® Tension Transducer (Load Cell)

Load Cell Style	Web Width		Tension Roller Shaft		* Load Ratings			**Mounting		
	Used for Wide Webs (Over 20 in.)	Used for Narrow Webs (Under 20 in.)	For use with Stationary (Dead) Shafts	For use with Rotating (Live) Shafts	Min. Load Rating Offered (LB.)	Max. Load Rating Offered (LB.)	Typical Overload Rating (%)	Inside Machine Frame (Stud or Flange Mount)	Outside Machine Frame	Above Machine Frame (Pillow Block Mount)
Cartridge-Style	■		■		25	1,000	150 - 300%	■		■
Slim-Cell	■		■	■	10	1,000	500 - 1,000%	■	■	■
UPB Washdown Duty	■			■	25	30,000	500%			■
Cantilevered CLT		■	■		0.1	500	150 - 300%	■		■
Cantilevered CR		■	■		5	150	150 - 300%	■		■

Figure 22
Standard Features for all Transducers:

- Typical Tension Range- 20/1 to 30/1 (Based on Proper Load Cell Sizing)
- Temperature Range -0-200 degrees F
- Load Cells can be oriented to measure the tension force in any direction
- UL certified for Intrinsically Safe applications
- CE label

Selection Guide

Special Environments			Key Considerations			
Washdown-Duty, Corrosive and Chemical Resisting	For use in Vacuums (Modified)	For use in High Temperatures (Modified)	Why would I Select this Transducer over the Others?	Typical Applications	Price Comparison *Low End ** Mid Range ***High End	
			Industry Standard, Variety of Mounting Styles, Good Value	Flexographic Presses, Extruder Lines, Laminators and Coaters	*	
○	■	■	Slim Profile-Advanced Design, For use where Mounting Space is Tight - Reduces Machine Frame Width, Outside Frame Mounting Available, Light Tensions, Extended Tension Range, Retrofits, Special Environments	State of the Art Equipment for Printing , Flexible Packaging, Converting, Coating/Laminating where wide tension ranges and high performance are required. Very good for plastic and aluminum films, foils, and laminates	**	
	■	■	For use with Pillow Block Bearing, Low Height Profile, High Tensions, High Temp., Special Environments	Paper Mills, Steel Mills, Textiles, Tire Cord Machines, Dryer Drums, Paperboard, Machine Retrofits	***	
			For use with Cantilevered Rollers-Unique design eliminates affects of shifting cantilevered load, Pulleys, Both Extremely Light Tensions and High Tensions	Label Presses, Very good for use on equipment producing multi-laminate materials used in Hygienic & Medical Products, Light Wire and Heavy Cable	**	
			For use with Cantilevered Pulleys, Good Value	Wire and Cable, Ribbon, Textiles	*	

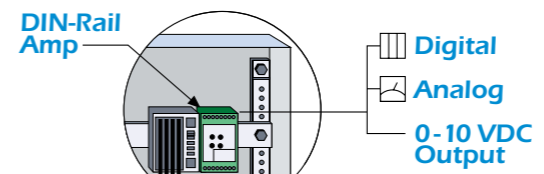
* Transducers are offered in variety of load ratings. They must be properly sized for the tension load. Refer to the appropriate transducer data sheet for sizing formulas and available load ratings.

** Mounting kits are required for some mounting configurations. Refer to the appropriate transducer data sheet.

Figure 22

TENSION TRANSDUCERS
(Load Cells)

DIN-RAIL AMPLIFIER



UNWIND ZONE

INTERMEDIATE ZONE

REWIND ZONE

BRAKE OR
MOTOR DRIVE

TENSION
TRANSDUCER
(Load Cell)

TENSION
TRANSDUCER
(Load Cell)

TENSION
TRANSDUCER
(Load Cell)

PROCESS

MOTOR

TACH

TACH

MOTOR

MOTOR DRIVE
OR CLUTCH

WEBPRO
UNWIND
TENSION
CONTROLLER

MOTOR
CONTROL

WEBPRO
DRIVE
TENSION
CONTROLLER

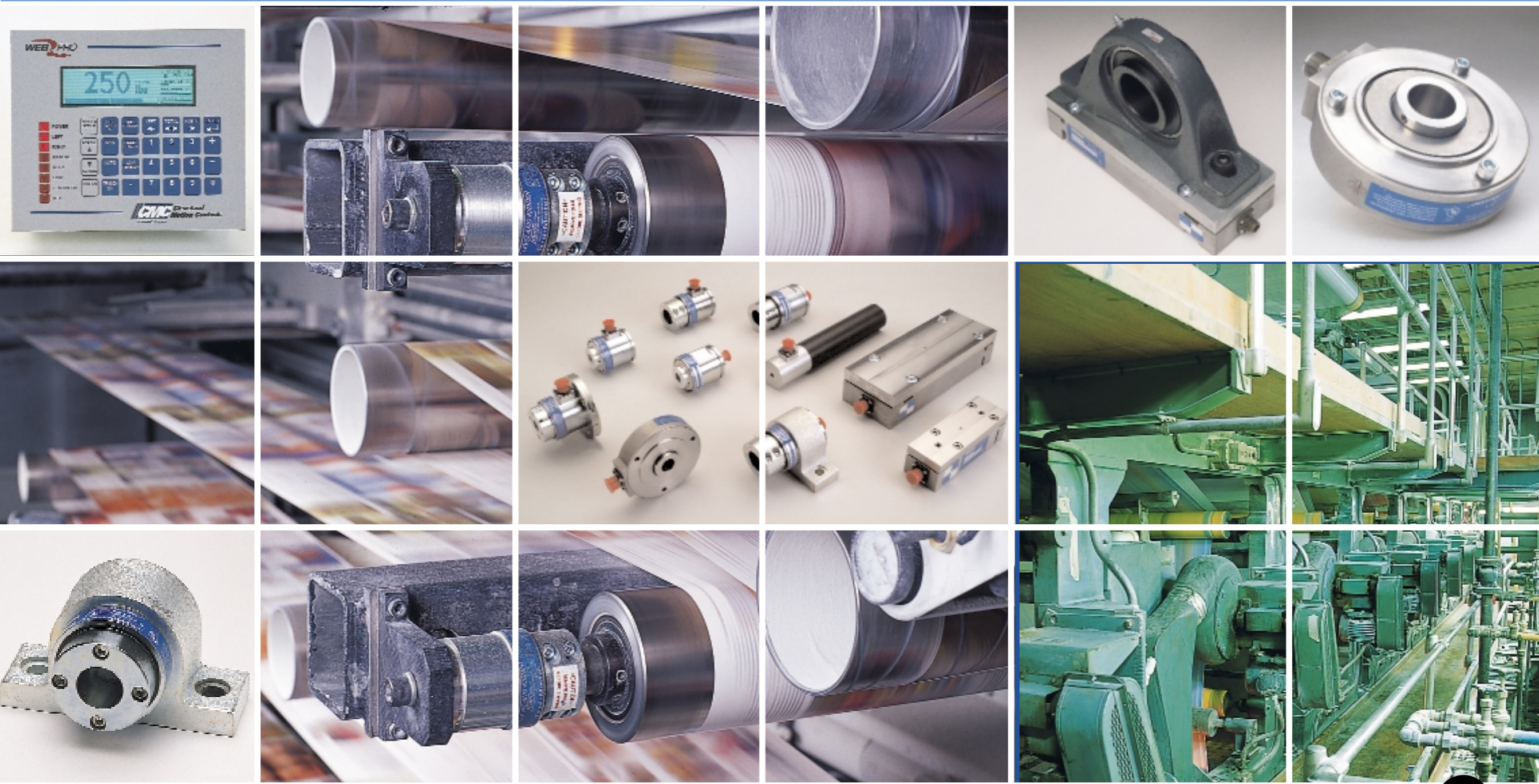
MOTOR
CONTROL

WEBPRO
REWIND
TENSION
CONTROLLER

ADVANCED WEB PROCESS CONTROL

Your
Single
Source
For
Web
Tension
Solutions

Your Single Source For Web Tension Solutions



www.CMCcontrols.com

All CMC Web Tension data sheets and manuals are available on our website.



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