Practical Applications of Unwind Systems for Converting Lines & Slitter Rewinders

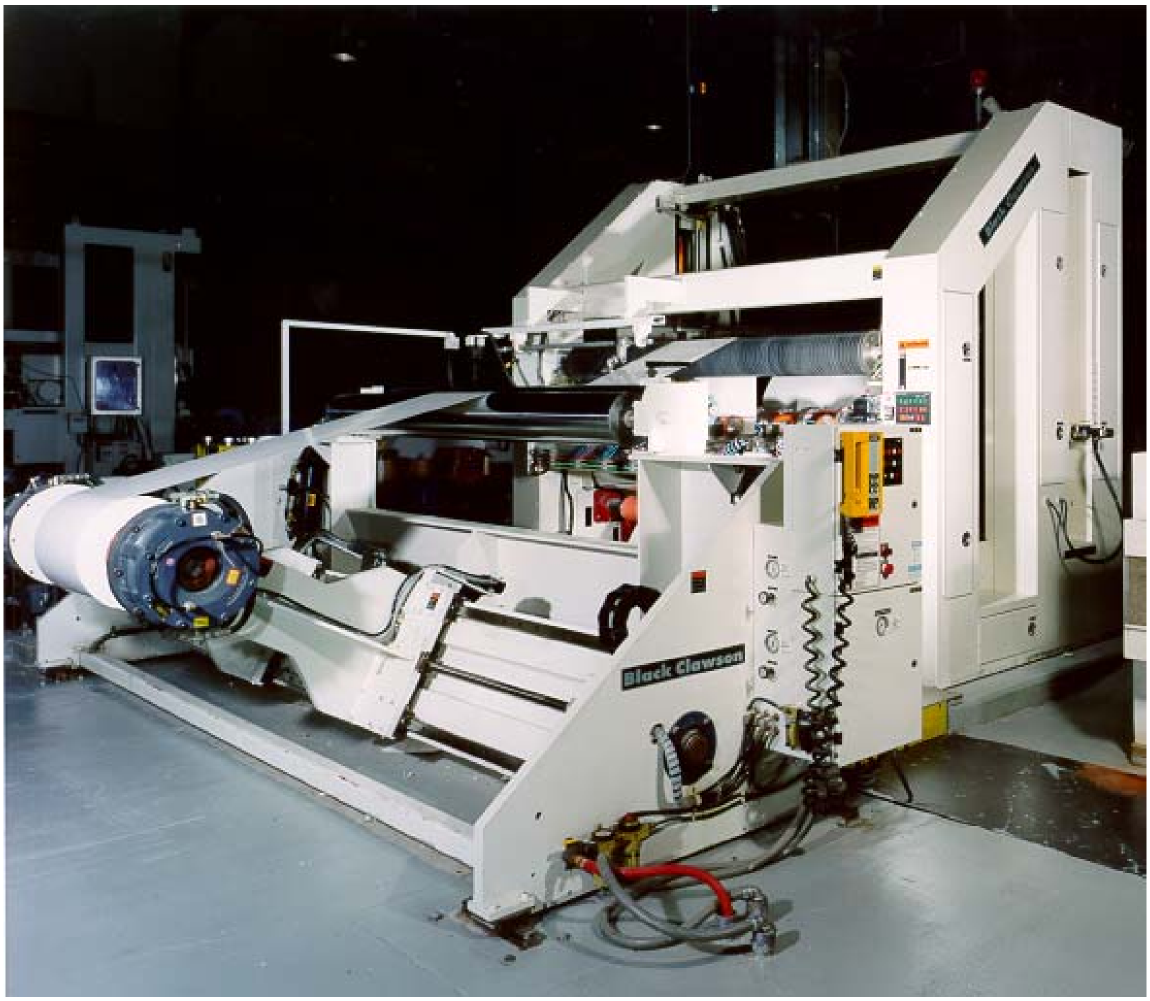

Photo Courtesy of Black Clawson

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Abstract

All converting lines and slitter rewinding operations require an unwinding system. Typically the unwinding system is the Rodney Dangerfield on a line or slitter rewinder. The slitting system and the winding system are considered with great importance but the unwinding system does not get the respect it deserves. Although often considered a simple function, the selection of a proper unwinding system is extremely important to the overall productivity of the converting or slitting and rewinding operation.

This paper is a Practical Guide for selecting the right unwind and related equipment to best match the unwinding system's Cost verses Efficiency to ensure the maximum performance and productivity from a converting line and/or slitter rewinder.

Design Criteria - The first thing that must be established is the basic design criteria. This basic design criteria will help select the design of unwind best suited for the application. The variation of these parameters dictate the flexibility required, and therefore the complexity and cost of the system.

The following must be determined:

1. Materials to be processed:
   - Types - composites, extensible, non-extensible
   - Basis weight range
   - Thickness range for each material and basis weight
2. Roll diameters and weights
3. Speed of operation
4. Tension - Tensile strength of materials
5. Core materials and sizes:
   - Length variations
   - Inside diameter and tolerances
   - Outside diameters
6. Roll delivery systems

The old rule "jack of all trades and master of none" applies to the unwind operation so be realistic when specifying the required range for best value and performance of the unwinding system.

Frame Construction – A major factor in an unwinds cost is the material and construction of the framing. The frame construction for unwind stands on typical converting lines and slitter rewinders can range from machine mounted plate steel for lower speed and light weight rolls applications to separate unwind stands fabricated from heavy weldments or castings. Heavier roll weights and higher speed operations require separate rigid frame construction for quick acceleration and deceleration rates, smoother unwinding of "out of round" rolls at the higher speeds and precise web guiding without vibrations or tension upsets.

Edge Guiding – One of the key functions of the unwind in a converting operation is to guide the edge and/or to provide oscillation of the web into the process.

The framing of the unwind is typically mounted to the floor on cross direction slides. Roll weight and speed determine the type of slides. Lightweight units may be as simple as sleeve bearing, nylon races or cam followers. In high speed and heavy roll applications, the framing is rigidly mounted to the floor and side shifted on linear bearings and hardened rails.

For automatic edge guiding, a lead-out idler roll must be connected to the side shifting unwind frame. This idler roll (depending on tension) should have a non-slip surface and provide for a constant web lead into a floor mounted edge position sensor, which is part of the edge guiding system. The sensor may be a pneumatic, infrared, ultrasonic, or a color- line design. The pneumatic is commonly supplied for dusty environments and lower accuracy requirements; the infrared for opaque materials; color-line sensors for guiding with reference to printed lines, and an ultrasonic edge sensor is the solution for transparent films. To ensure the best operation of the edge guiding system, the sensor must be located as close to the lead-out roll as possible.

The side shifting mechanism is typically a hydraulic cylinder or a servomotor. Both systems work well on most applications, but each has its own specific benefit. The pneumatic/hydraulic system is typically less expensive and can provide the greatest shifting force. The electrical/mechanical servo system is cleaner and more accurate on a critical high-speed edge alignment application.

Oscillation of the unwind may also be required when handling web materials that have higher caliper bands in localized areas in the cross machine direction. These thicker bands cause ridges in the rolls when they are wound one layer on top of another to the full roll diameter. By oscillating the unwinding web before the slitting operation, these high caliper bands are randomized in the roll. Typically the edge guide sensor is moved back and forth during the unwinding operation to accomplish this randomization. This requires taking wide trim, which is greater than the amount of oscillation. The suggested oscillation speed is 1" per minute per 500 FPM of winding speed.[1]

Shafted Operation - The simplest and least expensive unwinds are of a shafted design.
For shafted operations, the core diameters and roll weight must be limited for narrow widths wound on wider machines. Narrow widths cannot be unwound on small diameter shafts without excessive deflection at higher speeds. Shafted unwinds normally require an overhead hoist for loading the shafted rolls into the frames.

The selection of shaft type is critical for optimum unwinding operation. For each core size the required criteria for selection is:

- Shaft load capacity
- Shaft torque capacity
- Shaft speed capacity

- Shaft weight
- Shaft tolerance to poor quality cores
- Shaft cost

Most shafts are pneumatically expanding and the expanding elements are either lug, button, leaf, or strip. A comparison of these factors for different shaft types has been done by Tidland and is summarized below in chart A[2]:

SHAFT TYPE COMPARISON

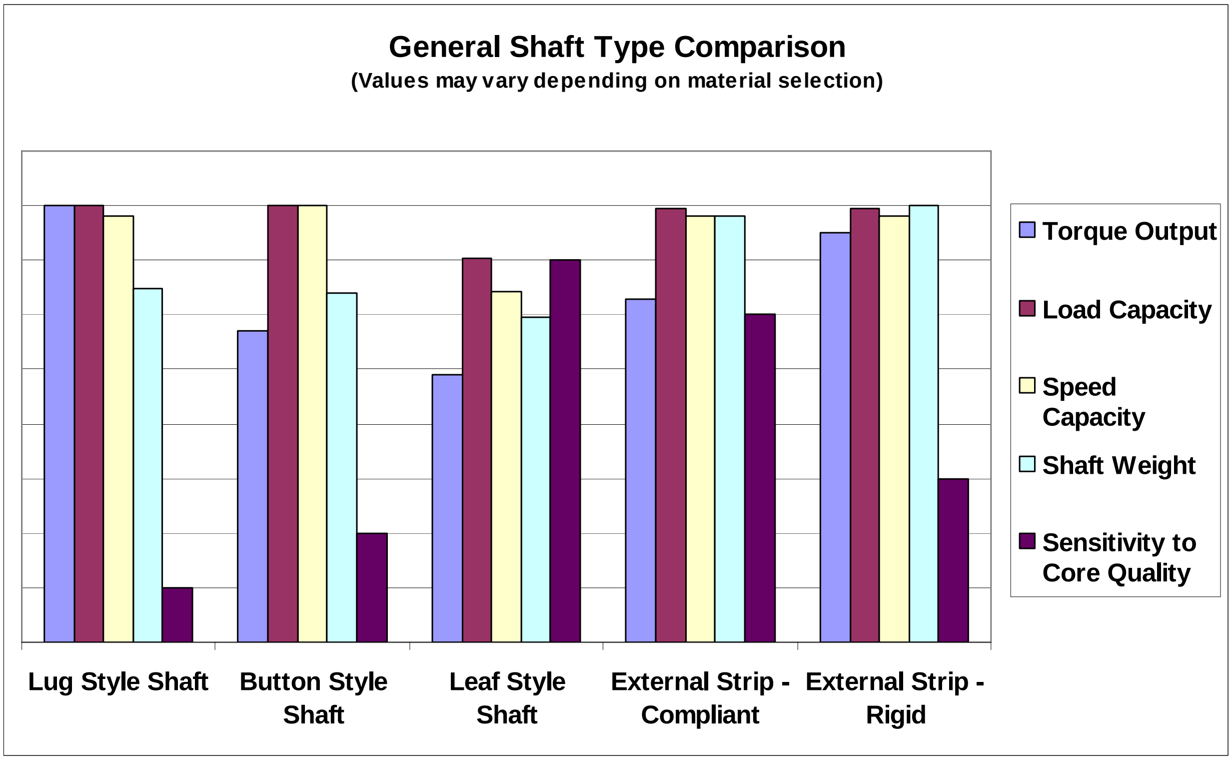


Chart A

Since load, torque and speed are generally the most critical factors, either a lug or external strip shaft is preferred for an unwinding application.

The type of material for the shaft then must be selected. The three most common materials are steel, aluminum and carbon fiber composite shafts. This selection is based on shaft load capacity vs. shaft weight and cost. Steel shafts have high load capacity and are relatively cost effective. However, steel shafts often require special shaft handling equipment or additional personnel. Normal aluminum shafts are a lighter weight alternative but can't support heavy loads and are not as durable. Newer aluminum extrusions have a higher load capacity and greater stiffness for higher operating speeds (greater critical speed). These extruded aluminum shafts provide an economical alternative to steel shafts relative to the ergonomic handling (weight) challenge. Titanium aluminum materials are ultimate in terms of load capacity and durability but are also very expensive and relatively heavy for their stiffness. In recent years, carbon fiber composite shafts have significantly come down in cost and increased in popularity. When the selection driving factor is the strength and stiffness (critical speed) relative to desirable shaft handling weight (ergonomics) then carbon fiber composite is the shaft material of choice. For a comparison of shaft materials, see Chart B.[2]

COMPARISON OF SHAFT HOUSING MATERIAL

5 = High
4 = Moderate to high
3 = Moderate
2 = Low to moderate
1 = Low

	Material Properties				
	Tensile Strength (PSI) → Load Capacity	Material Density → Shaft Weight	Modulus of Elasticity → Stiffness (Speed)	Resistance to Impact → Durability	Cost
Mild Steel (1018,1020,1026)	4	5	5	3	1
Alloy Steel (4130,4140)	5	5	5	4	2
Aluminum (6061T6)	1	2	1	1	2
Aluminum (2024T3)	2	2	1	1	3
Aluminum Extrusion (6061T6)	2	1	2	1	2
Titanium (Ti6al4v)	5	3	3	5	5
Composite/Carbon Fiber (15 MSI)	4	1	3	2	4
Composite/Carbon Fiber (28 MSI)	3	1	5	2	4

Chart B

Carbon fiber composite shafts are proving to have longer useful lives compared to aluminum shafts. Typical wear on an air shaft occurs in the holes in the shaft body. The buttons or lugs tend to wear the holes larger due to continuous movement while transmitting torque from the roll to the drive or brake. Aluminum tends to wear rapidly in this situation whereas composite bodies seem to become polished by this movement and not much wear occurs.

Latching - Shafted unwinds need to have secure latching, the capability to support the shaft's and roll's weight and to transmit the braking torque. This may be done by shaft clamps around bearing housings and a sliding coupling or by pneumatic latching. Pneumatic latching must have safety latches to prevent accidental unlatching while unwinding. Today the most common shaft latching is mechanical safety latches which automatically close as the roll is rotated. For a typical mechanical safety latch and capacity, see Photo and Chart #1.[4]

Shaft deflection is a major concern to insure that the latch will provide long term performance. For any shafted unwinding operation, determine the maximum shaft deflection from the shaft manufacturer and then be sure that the latching system can withstand this deflection.

The concentricity of the shaft and latches is also important, especially on higher speed unwinding applications. Newer safety latches incorporate round seats that ensure good concentricity between the shaft and the latches. See Photo #1.

MECHANICAL SAFETY LATCHES

Photo and Chart courtesy of Boschert

MECHANICAL SAFETY LATCH APPLICATION CHART										
Max. Sq. Opening - in.	**.75”**	**1”**	**1.25”**	**1.5”**	**2”**	**3.12”**	**4.75”**	**7”**	**7.9”**	**9”**
- (mm)	**20**	**25**	**30**	**40**	**50**	**80**	**120**	**180**	**200**	**230**
Load Capacity/Pair - lbs.	330	880	1,760	3,520	6,200	15,400	26,450	48,500	70,500	141,000
- (KG)	(150)	(400)	(800)	(1,600)	(3,800)	(7,000)	(12,000)	(22,000)	(32,000)	(64,000)
Torque Cap./Latch - in. lbs.	348	1080	1560	3000	9600	20,400	87,600	177,800	222,000	363,600
- NM	(38)	(120)	(170)	(330)	(1,060)	(2,260)	(9,700)	(19,700)	(24,000)	(40,400)
Max. RPM	**1350**	**1350**	**1350**	**1350**	**1350**	**1100**	**900**	**700**	**500**	**500**

PHOTO AND CHART #1

Shaftless Operation - For applications where there is a wide variation in web widths on smaller diameter cores - typically 3” (76 mm) or there is a wide variation of core sizes, then a shaftless unwind operation is preferred. Shaftless unwinds are more complex with a greater number of moving parts, take-up greater amounts of space and are more expensive. However, they are typically much more versatile and productive than a shafted operation. Typically, the rolls are brought to the unwind from the floor and no overhead hoist is required. The arms move in and out on a shaftless unwind to accommodate various widths and to chuck a new roll and unchuck an empty core. Many shaftless unwinds provide the ability for the arms to move down and pick-up the roll from the floor or a loading cart. The arms then lift the roll to the unwinding and guiding position. (See photo on cover page.

In a shaftless unwinding operation, the shaftless chuck selection is as critical as the shaft selection in a shafted operation. For each core size required, the selection criteria is:

- Chuck load capacity
- Chuck torque capacity

- Chuck roll centering capability
- Physical space available
- Ease of making core size changes
- Core I.D. tolerances
- Cost

There are basically two types of shaftless chucks which are commonly used in unwinding applications. These are pneumatically expanding chucks and mechanically expanding chucks. The expansion is for centering the roll and transmitting the braking torque.

Pneumatic chucks can provide positive locking and roll centering on both sides even if the torque is being transmitted on only one side. Pneumatic tire type chucks are the least expensive and the most forgiving for loose core I.D. tolerances. However, they generally are not as durable or maintenance free as an all metal chuck. They also have limited torque capacity and roll centering capability. The limited roll centering is a concern for higher speed unwinding applications.
For typical pneumatic chucks and capacity, see Photo and Chart #2.[5]

PNEUMATIC TIRE TYPE CHUCKS

APPLICATION CHART
Torque Capacity / Chuck in Fiber Cores*

Core Size	60 PSI (4.1 bar)	90 PSI (6.2 bar)
4" (100mm)	3,100 in-lb. (350 NM)	3,820 in-lb. (431 NM)
5" (120mm)	3,580 in-lb. (404 NM)	4,060 in-lb. (458 NM)
6" (150mm)	4,310 in-lb. (487 NM)	5,390 in-lb. (608 NM)
8" (200mm)	14,900 in-lb. (1,690 NM)	20,100 in-lb. (2,275 NM)
10" * * (250mm)	10,900 in-lb. (1,235 NM)	15,200 in-lb. (1,722 NM)
12" (300mm)	28,800 in-lb. (3,250 NM)	39,200 in-lb. (4,424 NM)

* Torque in metal core is about 10% higher
** Lower torque due to internal design

Photo & Chart courtesy of Tidland

Photo and Chart #2

Air power lug chucks are self centering and provide a uniform radial grip with alloy steel lugs. Torque capacity is limited only by the strength of the core or roll into which the chucks are inserted and the available air pressure. Core size changes are quick and easy with adapter rings. Air power lug chucks also have much better roll centering capability for more concentric unwinding for higher speed applications. The major drawbacks to this style chuck are cost and physical size. For a typical air powered lug chuck and adapter ring and capacity, see Photo and Chart #3[6].

Air Powered Lug Type Chuck

Photo courtesy of Goldenrod

Pneumatic-Mechanical Chucks (leaf or lug expanders) APPLICATION CHART							
Core Size (I.D.)	**3"**	**4"**	**5"**	**6"**	**8"**	**10"**	**12"**
Max Roll Weight per pair (lbs)							
Heavy Duty	5400	7000	8700	10500	12400	14600	17000
X-Heavy Duty	8000	9700	11400	13300	15300	17600	20000
Torque per chuck (in-lbs)							
Heavy Duty-cardboard cores	5400	7300	8900	11000	13300	15700	18200
Heavy Duty-metal cores	3600	4700	5900	7300	8900	10500	12200
X-Heavy Duty-cardboard cores	6500	8800	10700	13200	16000	18800	22000
X-Heavy Duty-metal cores	4350	5900	7100	8800	10600	12500	14600
Information is approximate only--all chucks are designed to handle the customer's application.							
Max roll weights are based on the expanders lifting the roll.							

Chart provided By Goldenrod

Photo and Chart #3

A drawback for pneumatically actuated chucks is that operators must be sure sufficient air pressure is applied to the chucks and air leaks will result in loss of torque.

Mechanically expanding chucks use torque to automatically expand the chuck and grip the cores. They have good torque capacity and centering capability. The expansion does not require operator interaction and insufficient air pressure or air leak problems do not exist. Mechanically expanding chucks are, by their mechanical design, concentrically expanding. This helps to ensure much better roll centering capability for higher speed unwinding without tension waves. The maximum core I.D. tolerances and compressibility of the cores are important considerations as after the chucks expand to their limit, they can no longer transmit torque. Also, releasing the mechanical expanding lugs may be a problem on this style chuck for automatic unlatching unwinds.

For applications using predominately two core sizes, stepped chucks may be a good solution for ease of making core size changes. For typical mechanically expanding and stepped mechanically expanding chucks and capability, see Photo #4 and Chart #4. When converting existing unwinds to stepped chucks, you need to check the load capacity of the bearings and spindles. Heavy rolls supported on the smaller size chucks produce high over hung loads and high bending stress on the spindles.

MECHANICALLY EXPANDING TYPE CHUCK

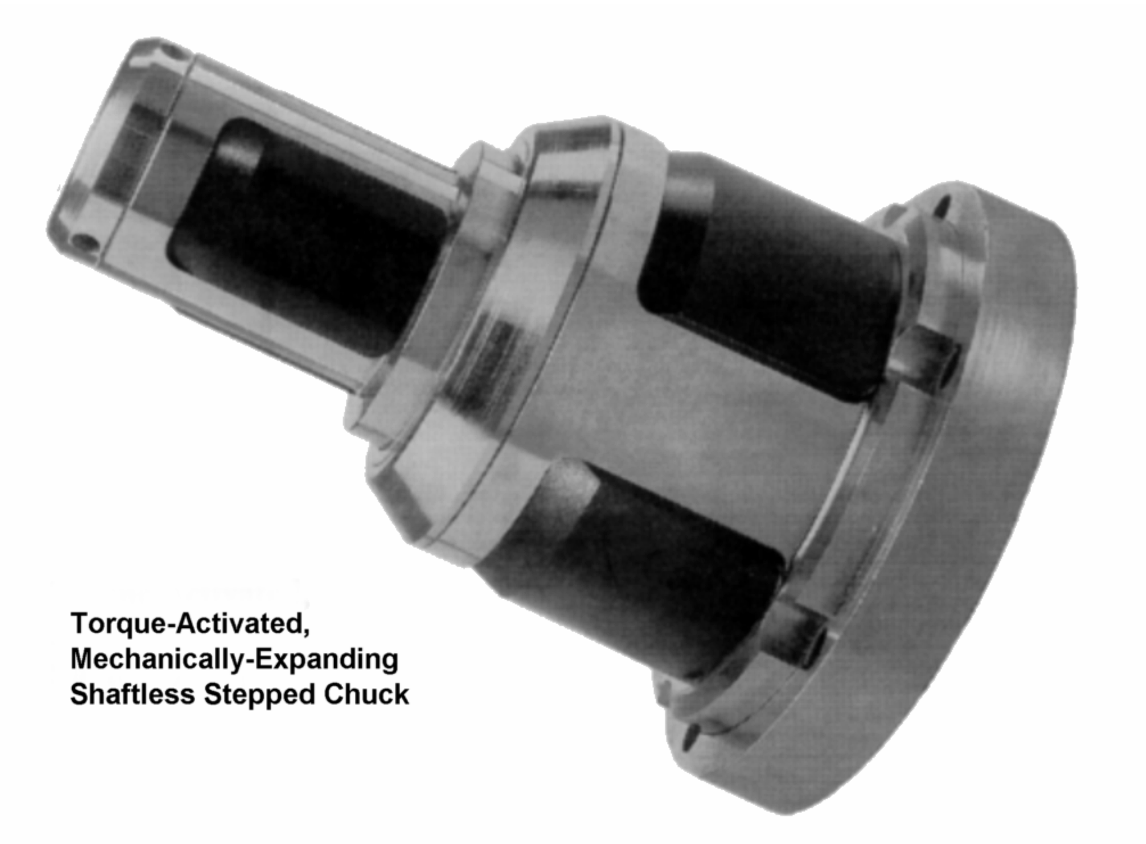


Photo courtesy of Double E

PHOTO #4

Mechanically Expanding Type Chucks APPLICATION CHART							
Core Size	**3” (76mm)**	**4” (102mm)**	**5” (127mm)**	**6” (152mm)**	**8” (203mm)**	**10” (254mm)**	**12” (305mm)**
Load Capacity/Pair							
Standard - lbs. - (KG)	4,550 (2,100)	6,100 (2,8600)	17,400 (7,900)	9,500 (4,300)	15,500 (7,100)	16,500 (7,500)	17,500 (8,000)
Standard (Heavy Duty) - lbs. - (KG)	7,100 (3,300)	9,600 (4,400)	17,400 (7,900)	15,000 (9,000)	20,000 (9,000)	20,000 (9,000)	20,000 (9,000)
Long - lbs. - (KG)	6,800 (3,100)	9,200 (4,200)	9,500 (4,300)	14,500 (6,600)	X X	X X	X X
Torque Capacity/Chuck							
Standard - in.lbs. - (NM)	5,600 (630)	8,600 (980)	12,000 (1,400)	18,000 (2,000)	24,000 (2,700)	28,800 (3,300)	36,000 (4,100)
Long - in.lbs. - (NM)	6,300 (710)	12,000 (1,400)	18,000 (2,000)	18,000 (2,000)	X X	X X	X X

Chart courtesy of Double E

CHART #4

X – Not Available

<u>Brake Applications</u> - The unwind must provide web tension for web tracking, spreading, stability of cross machine web width and wound roll density. Low modulus or highly extensible materials want to be unwound with as little tension as possible. For these materials, a belt tension unwind is preferred with draw or speed control between the unwind and rewinder. For higher modulus or relatively non-extensible materials, the suggested winding tension is 10% to 25% of the yield strength.[8] Chart #5 gives the suggested tension per mil (.001”) of thickness for a number of common materials. It is important that the roll is never unwound at a tension level higher than the roll was previously wound at to prevent cinching and/or telescoping. When tension isolation between the unwind and rewind is provided, it is suggested unwinding at 60% of winding tension.

Winding Tension vs. Material and Thickness[9]	
Paper and Paperboard	**0.55 #/in./mil.***
Polyester (Mylar)	**1.0 #/in./mil.**
Nylon	**0.25 #/in./mil.**
Polypropylene (unoriented)	**0.25 #/in./mil.**
Polypropylene (oriented)	**0.5 #/in./mil.**
Polyethylene	**0.25 #/in./mil.**
Polystyrene	**1.0 #/in./mil.**
Cellophane	**0.75 #/in./mil.**
Acetate	**0.5 #/in./mil.**
Aluminum Foil	**1.0 #/in./mil.**
Highly Extensible Materials	**Speed Control**

* Conversion factor kn./m/mm = #/in./mil x .0043

CHART #5

The selection and size of the unwind brake is made from the maximum torque requirements and the tension horsepower = web width (in.) x tension (pli) x speed (fpm) / 33,000. For low tension and horsepower applications, magnetic particle brakes provide excellent braking and smooth control. Most converting applications use air cooled disc brakes. These brakes are easy to maintain and do not require external cooling. Shaftless unwinds typically have brakes on both sides which allow distributing the torque to both ends of the core and provides roll centering on both sides. On floor pickup unwinds, this also allows using smaller diameter brakes so smaller diameter rolls can be picked up off the floor. However, for higher tension horsepower applications, especially when operating at slower speeds, the heat dissipation of these brakes may not be adequate. Water cooled disc brakes are then required. It is important that the cooling water is automatically shut off at zero speed to prevent sweating problems. For applications for high winding speeds and fast acceleration rates and light tensions, regenerative D.C. or A.C. Vector braking systems must be supplied. Although these systems are initially expensive, they provide excellent tension control, faster acceleration capability and web payout and take-up functions. Regenerative tension control systems also provide savings in power consumption and maintenance costs which over the long term can be significant.

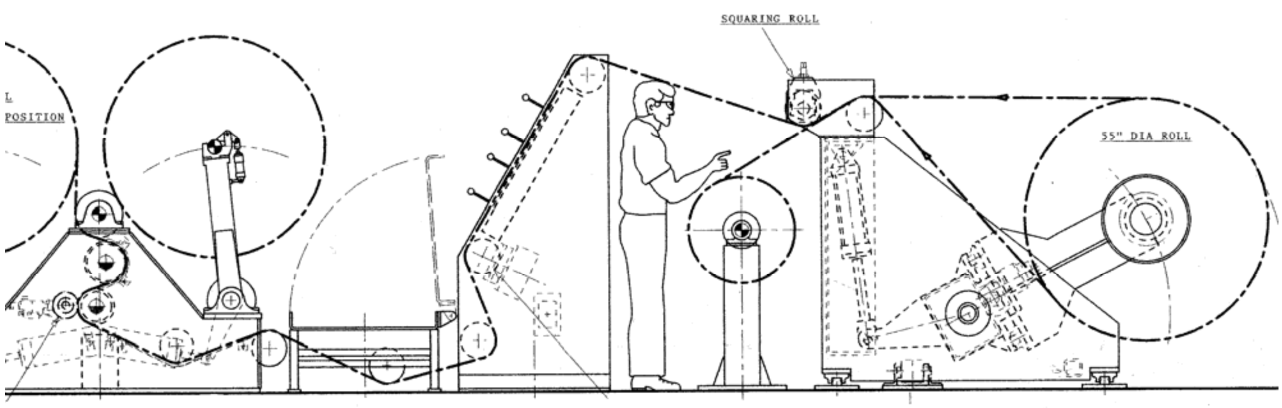
Tension Control Systems - All converting unwinds need to have a tension control system which controls the brake's torque as a function of the unwind's diminishing diameter, compensates for the roll's inertia during acceleration/deceleration and compensates for winding and friction losses to achieve constant web tension. Dancer control systems are preferred for slitter rewinders where the unwind tension is isolated from the winding tension. A dancer system is more expensive than a transducer system and web threading is generally more complicated. However, dancers allow unwinding out of round rolls at higher speeds. Electronic transducer control systems are preferred when the winding tension is being controlled from the unwind. Transducers provide faster response to tension upsets and provide a direct readout of the winding tension. Roll centering and roundness are critical for high productivity of smooth sided rolls when unwinding and winding tension isolation is not provided.

Web Squaring - Even cross machine web tension is important for proper spreading and good winding. When caliper or moisture variations occur across a roll being unwound, skewing of the unwind or one of the rolls after the unwind is required to even out the tension from one side of the web to the other. The important consideration is to provide a scale so the unwind or roll can be brought back to the center position after the problem roll has been processed.

Operator Control Stations - Another important consideration for an unwinding system is the placement of the operator controls. For safe and efficient operation, the control stations need to be within easy reach of the area where the operator is performing a function. On a shaftless floor pick-up unwind, the arms should have the controls to chuck a roll, raise and lower the arms and to sidelay the unwind. The ability to turn on and off the stall tension should also be provided at the arms to allow making a splice at the unwind and tightening the web before starting the rewinding operation. An operator station should also be provided at the unwind. This station should have speed control and stop/start pushbuttons to allow slowing down and stopping the operation for inspection or cutting out off quality material. This operator station should also have an edge guide auto/manual selector if this function is not automatic. Also, it requires an emergency stop mushroom head pushbutton.

Splice Table and Scrap Winders - Rewinding operations require the splicing of webs due to web breaks, cutting out bad material in the roll being unwound or rewinding a large diameter roll from multiple smaller rolls. A splice table between the unwind and slitters provides the ability to consistently produce quality butt splices which are made at an angle from the perpendicular to the edge of the web. The angular splice is important for the next process for the rewound roll. It allows introducing the splice into a nip in a wedge fashion rather than causing a severe bump when the splice enters nipped rolls.

When rewinding rolls containing large amounts of material that needs to be cut out, a scrap winder also increases the efficiency, helps prevent operator fatigue and increases safety of the operation. These small winders are located between the unwind and splice table "packaging" the scrap rather than manually rolling it and loading it into carts. See Figure #6.



Splice Table and Scrap Winder
Figure #6

In Conclusion - The Rodney Dangerfield of a slitting and rewinding operation is typically the unwinding system. How many times have you heard this operation called the unwinding, slitting and rewinding operation? Proper selection of an unwind and auxiliary equipment is very important to insure the maximum performance and productivity of a slitter rewinder. I hope that you found the information presented in this paper both practical and useful in getting the unwinding system the respect it deserves.

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