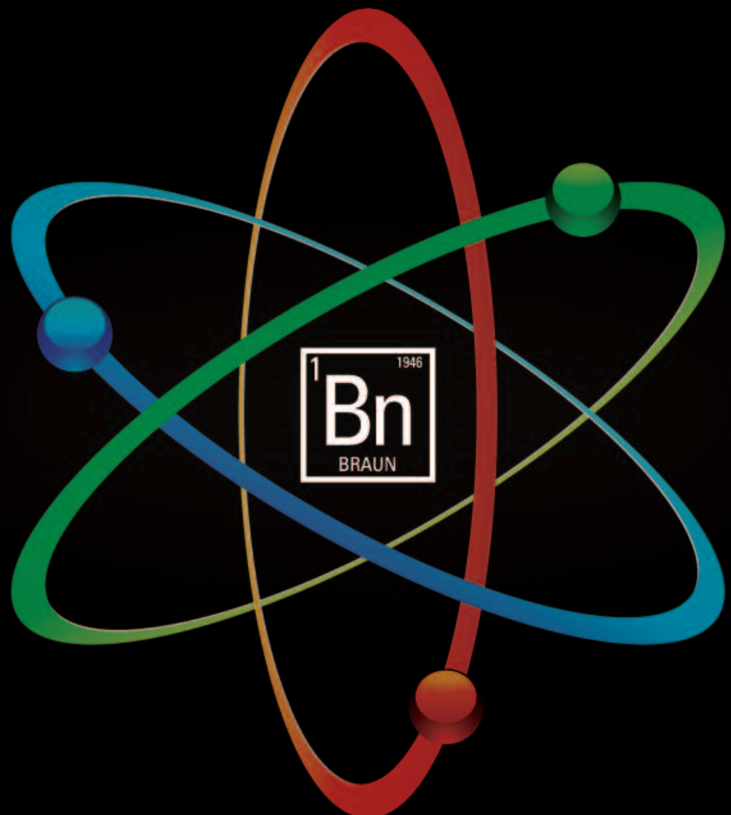

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ENERGY EFFICIENCY FROM WASH TO FINISH®

BRAUN

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Overview

The purpose of this publication is to familiarize you with the science behind batch tunnel washing systems, specifically Braun Batch Tunnel Washers (BTW). This includes the mechanical operation and features, process flow and control, chemistry, time, sizing and throughput considerations; as well as the wide range of goods classifications that can be processed.

Machine Features

Braun Batch Tunnel Washers are designed to provide users with an efficient processing solution that is easy to operate and simple to maintain. This is accomplished by a robust heating and energy recovery system as well as a mechanical design philosophy centered on reliability, durability and simplicity.

The batch tunnel washer has two classifications available, 100 – 150 pound class and 200 – 220 pound classification (These weights are based on the clean dry weight of linen). Within each weight classification, there are three compartment configurations available. These are an 8 compartment, 11 compartment, and 14 compartment.

A model of the 150 BTW-11 is shown in **Figure 1** as an example of the tunnel washer.

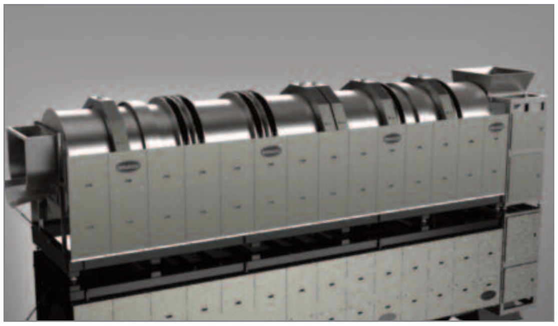


Figure 1—150 BTW-11 model

Each Braun BTW has five zones: prewash, wash, post wash bath exchange, rinse, and finish. The different compartment sizes will offer the same general functionality, with slight differences in the function of each chamber. The following defines the functionality and features that are common to each zone:

Zone 1: Prewash zone

- Function is to provide initial wetting of goods, application of heat and chemistry early in the process, and to remove as much soil as possible from goods prior to entering the wash zone
- Process water to feed the prewash zone is from the wetout tank
- Reclaimed wetout tank process water is made up of reclaimed rinse and press water
- Drains from the prewash zone are to the floor or to an installed heat and waste water reclamation system

Zone 2: Wash zone

- Function is to provide application of heat, chemistry and mechanical action to thoroughly remove any remaining soil from goods after the prewash section
- Process water fed to the wash zone is from the rinse reclaim tank. It is fed continuously to the last wash chamber and counterflows to the wash drain
- Rinse reclaim tank process water is made up of reclaimed rinse water, press hydraulic cooling water, and post wash bath exchange reclaimed water
- The main wash zone can be drained to the floor or to an installed heat and waste water reclamation system

Zone 3: Post wash bath exchange zone

- Function is to provide rapid removal of spent wash process water, coupled with refill volume using finish water, to aggressively initiate the rinsing operation
- Process water is drained from the post wash bath exchange to the rinse reclaim tank
- Bath exchange is refilled from the final rinse reclaim tank
- Final rinse reclaim process water is made up of reclaimed post rinse bath exchange water
- There are no drains to the floor in this zone

Zone 4: Rinse zone

- Function is to remove all residual alkali, detergent, and/or bleach from the goods after the wash process
- Process water fed to the rinse zone is a combination of fresh and press reclaim water, it is fed to the last rinse zone and counterflows to the first rinse zone
- The main rinse drain is drained to the rinse reclaim tank
- There are no drains to the floor in this zone

Zone 5: Finish zone

- Primary function is to neutralize residual wash chemistry using sour and antichlor (for chlorinated bleach applications); additionally, softener is applied in this zone and if desired starch can be also applied
- Process water is drained from the finish bath exchange to the final rinse reclaim tank
- Process water fed to the finish zone is a combination of fresh and press reclaim water used for bath exchange refill and finish zone level control
- There are no drains to the floor in this zone

To define the operations for each chamber, a waterway functionality matrix is used to map all of the transfer, injection, and heating processes. Waterways are discussed later in this technical bulletin in more detail. They provide a means for the transferring of fluids, steam and chemicals to the internal areas of the BTW cylinder. This allows the Braun BTW to avoid the use of a maintenance intensive external "double drum" design. These charts are shown in **Table 1** for each compartment configuration.

Table 1—Waterway matrices

Legend for BTW zone identification:

Prewash	
Wash	
Post Wash Bath Exchange	
Rinse	
Finish	

	Steam Zone Designations
S1	Wetout tank steam
S2	Wetout feed line steam
S3	Bath exchange #2 feed line steam
S4	Wash zone sparge steam
S5	Wash zone sparge steam
S6	Wash zone sparge steam
S7	Finish zone sparge steam
S8	Final rinse reclaim tank steam
S9	Wash zone feed line steam

BTW-8 Waterway Functionality Matrix

Chamber	# Waterways	Drain	Drain Type	Process Fluid In	Fluid Type	Spade Type	Heat In	Chemical injection Capable	Chemicals Injected
1	1	Yes	Programmable Rapid drain #1	Yes	Programmable Bath exchange #1 refill	Process feed to chute; chemical ports on chute; Blank on waterway	S1 S2	Yes	Alkali, Detergent
2	1	Yes	Wash drain	No		Blank		No	
3	1	No		No		Chemical	S4	Yes	Alkali, Detergent, Peroxide
4	1	No		Yes	Wash flow	Chemical/ Water	S9	Yes	Alkali, Detergent, Peroxide
5	1	Yes	Programmable Rapid drain #2	Yes	Programmable Bath exchange #2 refill	Chemical/ Water	S8	Yes	Alternate Bleach
6	1	Yes	Rinse drain	No		Chemical		Yes	Alternate Bleach
7	1	No		Yes	Rinse flow, press reclaim makeup	Chemical/ Water		Yes	Bleach
8	1	No		Yes	Fresh water, press reclaim makeup	Chemical/ Water	S7	Yes	Sour, antichlor, softener

BTW-11 Waterway Functionality Matrix

Chamber	# Waterways	Drain	Drain Type	Process Fluid In	Fluid Type	Spade Type	Heat In	Chemical injection Capable	Chemicals Injected
1	1	Yes	Programmable Rapid drain #1	Yes	Programmable Wetout feed Bath exchange #1 refill	Process feed to chute; chemical ports on chute; Blank on waterway	S1 S2	Yes	Alkali, Detergent
2	1	Yes	Programmable Rapid drain #2	Yes	Programmable Bath exchange #2 refill	Chemical/ Water	S3	Yes	Alkali, Detergent
3	1	Yes	Wash drain	No		Blank		No	
4	1	No		No		Chemical	S4	Yes	Alkali, Detergent, Peroxide
5	1	No		No		Chemical	S5	Yes	Alkali, Detergent, Peroxide
6	1	No		Yes	Wash flow	Water	S9	No	
7	1	Yes	Programmable Rapid drain #3	Yes	Programmable Bath exchange #3 refill	Chemical/ Water	S8	Yes	Alternate Bleach
8	1	Yes	Rinse drain	No		Chemical/ Water		Yes	Alternate Bleach
9	1	No		Yes	Rinse feed/ press reclaim alternate rinse feed	Chemical/ Water		Yes	Alternate bleach
10	1	Yes	Programmable Rapid drain #4	Yes	Programmable Bath exchange #4 refill	Chemical/ Water		Yes	Sour, Antichlor, softener, starch
11	1	No		Yes	Press reclaim	Chemical/ Water	S7	Yes	Starch

BTW-14 Waterway Functionality Matrix

Chamber	# Waterways	Drain	Drain Type	Process Fluid In	Fluid Type	Spade Type	Heat In	Chemical injection Capable	Chemicals Injected
1	1	Yes	Programmable Rapid drain #1	Yes	Programmable Wetout feed Bath exchange #1 refill	Process Feed to chute; chemical posts on chute; Blank on waterway	S1 (tank) S2	Yes	Alkali Detergent
2	1	Yes	Programmable Rapid drain #2	Yes	Programmable Bath exchange #2 refill	Chemical/ Water	S3	Yes	Alkali Detergent
3	1	Yes	Wash drain	No		Blank		No	
4	1	No		No		Chemical	S4	Yes	Alkali Detergent Peroxide
5	1	No		No		Chemical	S5	Yes	Alkali Detergent Peroxide
6	1	No		No		Blank	S6	No	
7	1	No		Yes	Wash feed	Chemical/ Water	S9	Yes	Akali/Detergent
8	1	Yes	Programmable Rapid drain #3	Yes	Programmable Bath exchange #3 refill	Chemical/ Water	S8	Yes	Alternate Bleach
9	1	Yes	Rinse drain	No		Chemical		Yes	Alternate bleach
10	1	No		Yes	Alternate rinse feed Press reclaim	Chemical/ Water		Yes	Bleach
11	1	No		Yes	Rinse feed	Chemical/ Water		No	Bleach
12	1	Yes	Programmable Rapid drain #4	Yes	Programmable Bath exchange #4 refill	Chemical/ Water		Yes	Sour
									Antichlor
									Softener
13	1	No		Yes	Press reclaim	Chemical/ Water	S7	Yes	Finish-starch
14	0	No		No				No	Finish dwell only

Cylinder

There are two prevailing designs for the cylinder of a Batch Tunnel Washer. These are referred to as single drum and double drum. Some Batch Tunnel Washers have portions of their cylinder that are single drum and portions that are double drum. This is referred to as combination drum. Single drum cylinders are a single, solid weldment with external waterways and seals. Double drum cylinders are essentially a tube within a tube. The internal tube is perforated to allow water to flow in and out. The external tube is stationary without perforations and is a means for water and chemical input. Each design has advantages and drawbacks. See **Appendix 1** for a more direct comparison of the two designs.

The Braun BTW is a single drum design. The cylinder is a solid weldment constructed of 10 gauge 304 stainless steel. This simple and rugged design is the backbone of the machine. The internal members are precisely designed to provide optimum washing and transfer capability.

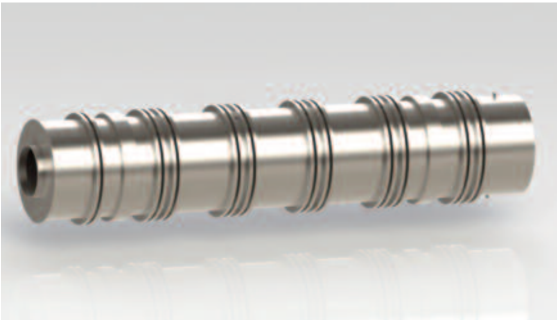


Figure 2—BTW cylinder (11 Chamber)

The cylinder chamber sizing is based on the ability to contain a load both statically (cylinder stopped) and dynamically (during oscillation). While the cylinder is stationary 40% of the volume of the cylinder is used to contain the goods and keep chamber isolation. While the cylinder is oscillating, 70% of the volume of the cylinder is used for the same purpose. This can be seen in **Figure 3,** which identifies the cylinder use from both a static and dynamic perspective.

During transport, the entire cylinder volume is used to move the contents of one chamber to the next chamber, keeping the contents separate from all other chambers.

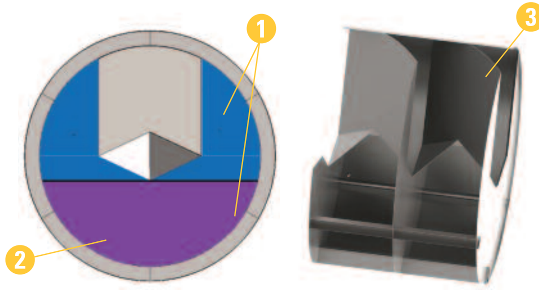


Figure 3—model of static/dynamic chamber volume

1. Dynamic Volume (blue & purple area)
2. Static Volume (purple area)
3. Open area for transfer

Seals

The type of seals used on a tunnel washer is dependant on the cylinder design. With a single drum design, all seals are external and easily accessible. Seals on a double drum cylinder are between the two drums, which make access and functional visibility very difficult.

Due to its single drum design, all seals on the Braun BTW are external to the machine. The seals provide a water tight barrier for the perforated waterways of each chamber. All water, chemical, and steam injections, as well as drains, are accomplished via affecting a small opening in the seal at the desired location and chamber for the transfer of aqueous material. The seals are made of an engineered polymer that is suitable for hot water, chemical, and steam contact.

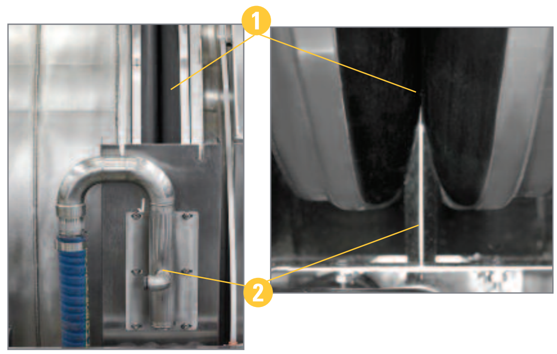


Figure 4—Tunnel seals

1. Seals
2. Injection Spade

Drive System

The Braun BTW is powered by a simple, rugged friction drive system. It consists of four drives that act on the two cylinder drive rings. Each drive has a three sprocket setup, which is composed of a gear motor driving two pairs of drive wheels through a carbon fiber belt. The gear motors are controlled with individual variable frequency drives (inverter) that precisely control the rotation of the machine during the washing and transport process. All bearings used in the drive system are sealed spherical roller bearings. The structure of the drives is provided by ductile iron castings.

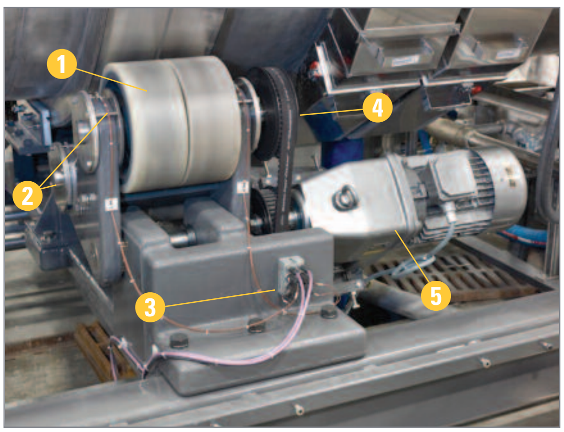


Figure 5—Drive System

1. Drive Wheels
2. Sealed Spherical Roller Bearings
3. Thermocouples
4. Belt/Sprockets
5. Gearmotor

The Braun BTW can operate if one gearmotor fails. This allows plant operations to unload the machine prior to maintenance.

Some drive systems employed on tunnel washers have large chain and sprocket design. This is normally associated with an automatic oiler or greaser that is critical to provide lubrication to the drive mechanism. Additionally, a drive failure with this system will result in the tunnel washer being inoperable until the drive can be repaired.

Chemical Injection

Chemicals are introduced into the Braun BTW via injection spades that penetrate the chamber seals above the water line. Through these spades, chemicals are rinsed thoroughly into the tunnel cylinder with water and/or chemical flush streams. Injection spades can be set up for any chamber on the BTW. **Figure 6** shows a chemical injection spade with a fresh water flush:

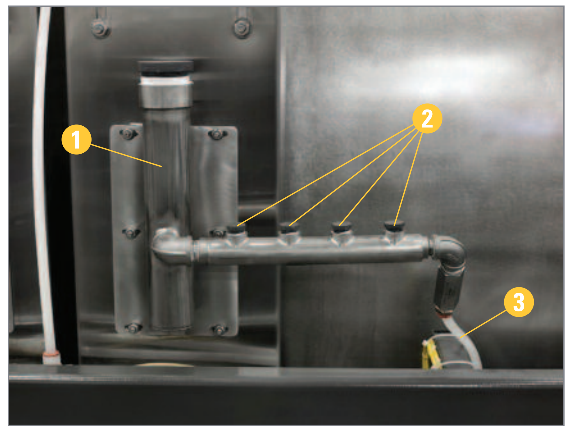


Figure 6—Chemical injection manifold and flush water

1. Injection Spade
2. Chemical Injections Ports
3. Flush Water Line

Machine Features (continued)

Rapid Drains

Rapid Drains are located in each bath exchange chamber. They consist of pneumatically actuated pistons that, when extended, penetrate the chamber seal creating a 80-100 GPM drain. The duration of the drain and the number of drain events per cycle are programmable. **Figure 7** shows an external view of the rapid drain, while **Figure 8** shows an internal model of the rapid drain in both the extended and retracted position.

Figure 7—Rapid drain

1. Rapid Drain
2. Shroud Drain

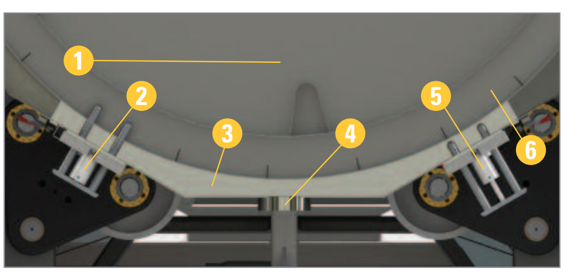


Figure 8—Rapid Drain

1. Wash Chamber
2. Rapid Drain Extended
3. Shroud
4. Drain
5. Rapid Drain Retracted
6. Waterway

Heating System

The heating system on the Braun BTW is designed for the application of steam to the machine in three different ways. Each of the heat applications on the machine are designed for the highest energy efficiency conversion, as well as for the quickest ramp up to operating temperature. The methods of heating are noted below including heating applications of each method:

1) In-tank Heating

- utilized for heating reclaimed water in the wetout tank and final rinse reclaim tank
- heating system sized to meet all industry demands
- energy efficient direct steam tank injection
- temperature probe in tanks for indication feedback
- precision temperature control

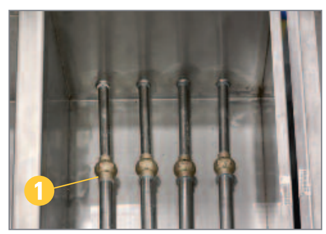


Figure 9—In-tank heating

1. Steam Injectors

2) In-line Heating

- utilized for heating all prewash compartments and main wash flow can be used for supplemental or primary heating of prewash compartments
- primary heating for main wash flow
- energy efficient direct steam line injection in process line while fluid being transferred
- temperature probe in pipelines for indication feedback
- precision temperature control

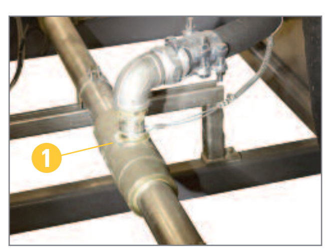


Figure 10—In-line heating

1. Steam Ring

3) In-shell Heating

- **patent pending** technology
- utilized for heating all necessary wash compartments
- energy efficient direct steam injection in BTW cylinder to get direct delivery of heat to process
- temperature probe in shell for indication feedback
- precision temperature control
- provides heating capability in one finish compartment for improved extraction and/or starch applications

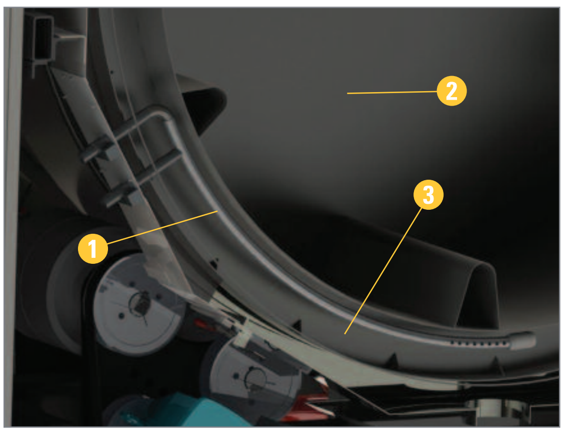


Figure 11—Sparge tube in tunnel waterway

1. Sparge Tube
2. Tunnel Chamber
3. Waterway

Water and Heat Recovery

The Braun BTW is supplied with internal heat and water recovery systems. Some of these features have already been noted in the overview section. Much of the recovered water is heated, so a by product of this is a reclamation of the heat from the machine also. Braun's total water recovery system (BTWRS) recovers seal wetting water, all process water, press cooling water, as well as other controlled cylinder overflows on the machine. The tanks and recovery equipment noted below are designed entirely for reclamation of process water and heat:

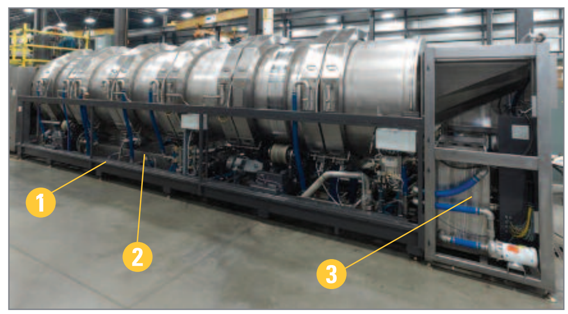


Figure 12—Entire tunnel with tanks shown

1. Final Rinse Reclaim Tank
2. Rinse Reclaim Tank
3. Wetout Tank

1) Wetout tank (recovers press and rinse process water and feeds to prewash zone)

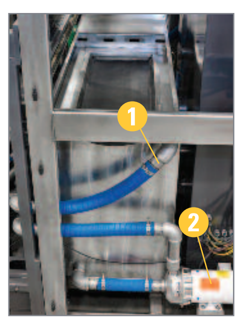


Figure 13—Wetout Tank

1. Process Water Add
2. Bath Exchange Supply Pump

2) Rinse Reclaim Tank (recovers rinse process water and post wash bath exchange process water and feeds to wetout tank and wash zone)

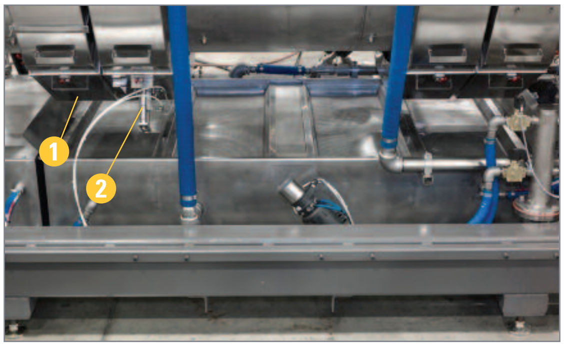


Figure 14—Rinse Reclaim tank

1 Rinse Drain
2 Post Wash Bath Exchange

3) Final Rinse Reclaim Tank (recovers finish process water and feeds to post wash bath exchange)

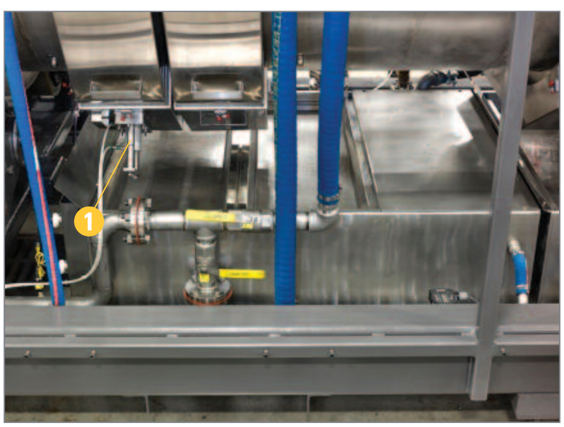


Figure 15—Final Rinse Reclaim tank

1 Post Rinse Bath Exchange

4) Press Water Recovery Tank (recovers press process water and feeds to wetout tank, rinse zone and finish zone)

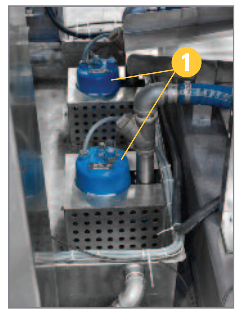


Figure 16—Press moat with pumps

1 Press Water Pumps

In addition to the meticulous design for water and heat recovery, tools are provided on the Braun BTW to measure and monitor water and steam usage in the field. Each machine is supplied with a total water flow meter to capture all fresh water used in the machine. The total water consumption is measured and used to calculate a gallons per pound ratio in the PLC processor. There is also an optional total steam flow meter to quantify all steam used in the machine. This number is converted from pounds per hour (measured) to BTU/hour (calculated in PLC processor). Field performance data for the Braun 150/220 BTW shows usages in the following ranges:

Water usage: 0.5 – 0.8 gallons per pound of linen
Steam usage: 300 – 400 BTU per pound of linen

The Braun BTW's open helicoid design, coupled with the bottom transfer process, results in the transfer of both water and goods from one chamber to the next without plugging and roping.

Transfer Method and Wash Process

Defined as the means in which a tunnel washer transfers a load of goods from one chamber to the next. There are two main types of transfer methods: *bottom transfer* and *top transfer.* Defined further, there are two different techniques used in bottom transfer: *open helicoid* and *Archimedean screw.* This section describes the transfer method of the Braun BTW and the differences between each method. A direct comparison of the three methods are in **Appendix 1.**

Logically, bottom transfer gets its name because the goods are transferred from chamber to chamber along the bottom of the tunnel cylinder. Similarly, a top transfer tunnel achieves this transfer by scooping the goods up and advancing them through a restrictive opening that runs through the center of the tunnel. There is a clear difference in philosophy between the two main transfer types, but there is also a stark difference in the two types of bottom transfer methods (*open helicoid* and *Archimedean screw*).

The Braun BTW uses an open helicoid design. Helicoid is defined as follows:

"A surface generated by a curve which is rotated about a straight line and also is translated in the direction of the line at a rate that is a constant multiple of its rate of rotation." [1]

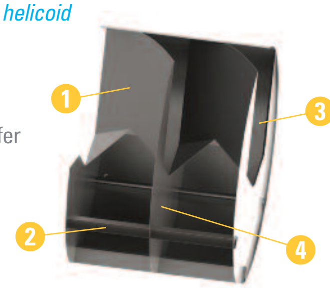
The BTW open helicoid members have a low angle curvature and large open area near the centerline of the machine. This combination allows free transport of the chamber contents without interference.

The transfer members do not contact the goods until the wash cycle time is complete, and when the transport operation is initiated they will be rotated into position to move the goods and water from one chamber to the next. **Figure 17** shows both the internal dividers and transfer helicoid members.

Figure 18 demonstrates the actual transfer process.

Figure 17—Internal open helicoid

1. Helicoid
2. Rib
3. Open Area for Transfer
4. Divider



Worth noting beside the large open area for transfer are the straight chamber dividers. The design of these dividers and ribs create a washing environment similar to that of an open pocket washer. This is a main difference between the Braun BTW open helicoid and the Archimedean screw. The Archimedean screw is designed like a corkscrew with angled dividers, which causes the goods to move axially throughout the process time. Additionally, for structure, the Archimedean screw features a large center shaft that runs the entire length of the cylinder. The axial movement of goods, coupled with the restrictive chamber volume caused by the center shaft, creates a greater probability of goods roping and tangling.

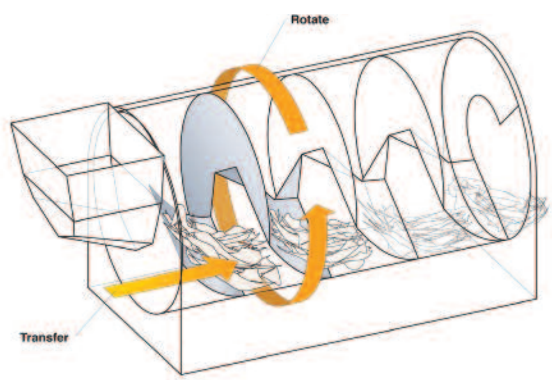


Figure 18—Bottom transfer/open helicoid

The Braun BTW's open helicoid design, coupled with the bottom transfer process, results in the transfer of both water and goods from one chamber to the next without plugging and roping. Additionally, all of the energy in the rotational operation goes into agitating the goods in solution as there is no axial movement of the laundry during the washing process (as is seen in the Archimedean screw machine types).

1 McGraw-Hill Dictionary of Scientific and Technical Terms, Fifth Edition; New York, 1994 (pg. 918).

Washing and Rinsing Processes

There are a number of parameters that are important for effective washing. These are mechanical action, temperature, chemistry, and time. This is commonly referred to as the *wash pie* and will be discussed in more detail as this section develops. Another important factor is adequate dilution. Dilution is the weakening of the soil concentration in the goods through the addition of cleaner water. This is important for the washing process as well as the rinsing process. Different tunnel designs try to accomplish dilution in different ways. This section explains how the flows in the tunnel washer are designed to achieve the greatest washing and rinsing effectiveness.

Counter Flow

Braun's BTW process includes what is known as counterflow. This is more commonly known as cascade flow and the concept is that cleaner process water is forced in the opposite direction of the main flow of material. Cascade flow has been proven to be an effective mode of rinsing and washing, and is often the method of choice when designing process plants. To gain an appreciation for cascade technology a definition of cascade mixing-settling is noted below:

"Series of liquid holding vessels with stirrers, each connected to an unstirred vessel in which solids or heavy immiscible liquids settle out of suspension; light liquid moves through the mixer-settler units, counterflowing to heavy material, in such a manner that fresh liquid contacts treated heavy material, and spent (used) liquid contacts fresh (untreated) heavy material." [2]

Counterflow is also a process that varies depending on the cylinder design of the tunnel washer. In a bottom transfer single drum design, the internal chamber dividers in the counterflow zones are perforated. This allows water to flow freely, by gravity, through the goods in each chamber of the zone. The necessity of water to pass through the goods creates an environment which ensures thorough dilution. This type of counterflow is called direct counterflow. In a top transfer double drum design, water is piped externally from the bottom of the outer drum in one chamber to the bottom of the outer drum in the next chamber. By introducing the water in the bottom of the chamber, the water must act against gravity to try and penetrate the perforated inner drum as well as the goods. This need to defy gravity runs the risk of a counterflow in which the wash liquor does not fully enter the washing chamber (the inner drum), resulting in poor dilution. This type of counterflow is called indirect counterflow. See **Appendix 1** for a direct comparison of the counterflow processes.

Direct counterflow is used in both the wash and rinse zones in the Braun BTW and is noted in the previous overview section. Water is injected in the last chamber of a given zone and flows to the first chamber of the same zone. The counterflow transports the dissolved and suspended soil in the water stream in the direction of the most contaminated process water, towards the drain in that given zone. Using counterflow in both the wash and rinse zones is known as dual counterflow.

Figure 19 depicts the effect of dual-direct counterflow:

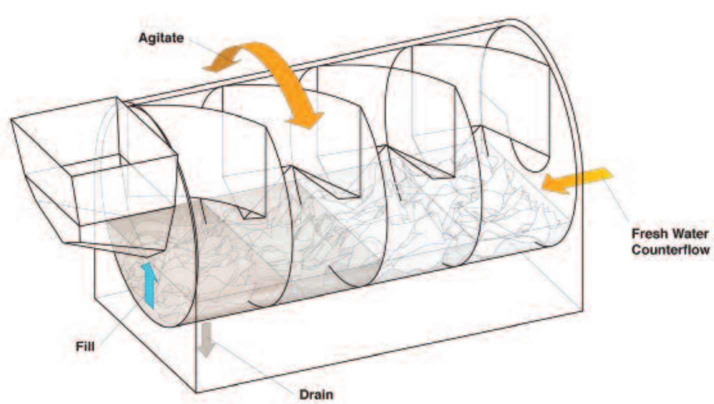


Figure 19—Counterflow diagram

2 McGraw-Hill Dictionary of Scientific and Technical Terms, Fifth Edition; New York, 1994 (pg. 320).

Important features about dual-direct counterflow:

1) Process water at the back end of the machine is the cleanest and moves dissolved and suspended solids (soil) to the front of the machine in both the rinse and wash zones.

2) Process water is forced through all of the goods mass over the entire length of the given chamber in both the rinse and wash zones.

3) Process water flows through the compartment walls, the only entry in the compartment, which eliminates the need for internal seals.

4) The result of dual-direct counterflow is a more consistent chemical gradient within each zone which minimizes linen damage and redeposition.

Another benefit to the Braun BTW is that the wash and rinse flows can be set and controlled by formula to provide the optimum process flow for each goods type. If process flows are minimized, cost savings in water as well as chemicals that are discharged down the drains can be realized.

The combination of flow control, Dual Counterflow, and Direct Counterflow makes for an effective rinsing and washing process, allowing plant operations flexibility for any application.

Bath Exchanges

Braun's bath exchange technology is important for tunnel processing. There are bath exchanges strategically placed in the prewash, post wash, and finish sections on all Braun BTW's. The bath exchange is a dual use chamber consisting of rapid drain and refill capabilities. They provide breaks between zones to remove spent process water prior to entry to the next zone.

The quantity of bath exchanges and their functions will depend on the number of chambers in the BTW. Each bath exchange and its functions and benefits are summarized below:

1) Pre wash bath exchange:

- removes soil laden process water early in process for heavy soiled goods to jump start the washing process
- refills with wetout water after initial draining of soiled process water
- programmable times for flexibility in processing needs
- up to 3 drain and refill events can be programmed for each tunnel transport cycle

2) Post wash bath exchange:

- removes alkali laden process water after the wash zone
- refills with final rinse reclaim water after drain to initiate rinsing process
- programmable times for flexibility in processing needs
- up to 3 drain and refill events can be programmed for each tunnel transport cycle

3) Finish bath exchange:

- removes rinse water prior to application of finishing chemicals to save chemistry
- refills with fresh water to remove finish chemicals towards end of cycle
- programmable times for flexibility in processing needs
- up to 3 drain and refill events can be programmed for each tunnel transport cycle

Wash Pie

The washing process is a combination of a number of controlled factors that are balanced. This is commonly known as the *wash pie* and is defined in the TRSA's Textile Laundering Technology.[3] An equally balanced wash pie is shown in **Figure 20** (adapted from TRSA by Braun):

As the wash process discussion develops, scenarios will be presented that alter the individual contributions of each component. This will be to demonstrate the flexibility offered by a Braun BTW to accomplish the washing process objective effectively.

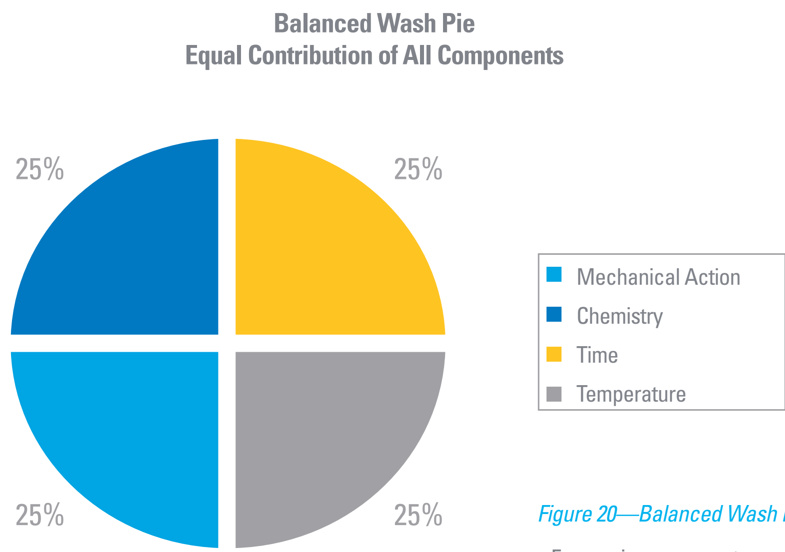


Figure 20—Balanced Wash Pie

- Four main components required for proper linen processing
- Changes in processing for any one component will require compensation by one or more other components
- This is representative of an ideal process with optimum balance of all four components

3 Riggs, Charles L., Ph.D. and Klipper, Michael, Textile Laundering Technology, Alexandria: 2005 (pp. 24-27.).

Chemical Profile

Chemistry is the first piece of the Wash Pie and is an integral part of the wash process. It also represents a large part of the monthly expense of processing laundry. The Braun BTW process flow and control features discussed will result in a consistent chemical profile throughout the wash zone. This is due to the bottom transfer design combined with the direct counterflow through the goods. Consistent alkali gradients are favorable for less damage to the linen being processed, specifically polyester based linen. A top transfer tunnel washer demonstrates more variability in alkali concentration, specifically high concentrations early in the wash zone.

Figure 21 contrasts a typical alkali concentration gradient in the wash zone for a Braun BTW and a top transfer tunnel. The Braun BTW curve is based on a model validated with field test data. After the wash zone in the BTW, the bath exchange is employed to drain and refill the chamber to aggressively begin the rinsing process.

If alkali concentrations are excessive; alkali hydrolysis may occur, which is an attack of the caustic material on the fibers. This is described as follows:

"Polyester, on the other hand, can be damaged in strong alkaline solutions. The fiber surface becomes pitted and/or the fabric loses strength-a chemical process termed ***alkaline hydrolysis.*** *All the conditions that lead to alkaline hydrolysis haven't been firmly established, but a combination of higher pH and temperature causes the greatest damage and in some cases, can destroy the polyester fiber. 'Spike' alkalinity, immediate concentrations after chemical dosing, may produce an adverse effect, and considerations should be taken. In any case, alkalinity should be thoroughly rinsed from the fabric and final pH adjusted so no residual is left in the fabric where it can be exposed to high heat from ironers or dryers."* [4]

The above excerpt not only discusses the importance of low alkali concentrations, but also the importance of rinsing for minimizing goods damage. Test results from a leading chemical supplier in a field healthcare environment independently verified an excellent BTW rinsing process with a combination of dual counterflow and bath exchange technology as shown in the test data below:

Residual iron: Negative
Residual softener: Negative
Residual bleach: Negative
pH of fabric: 7
Note: A pH of 7 is neutral

BTW vs. Transfer Alkali Gradient

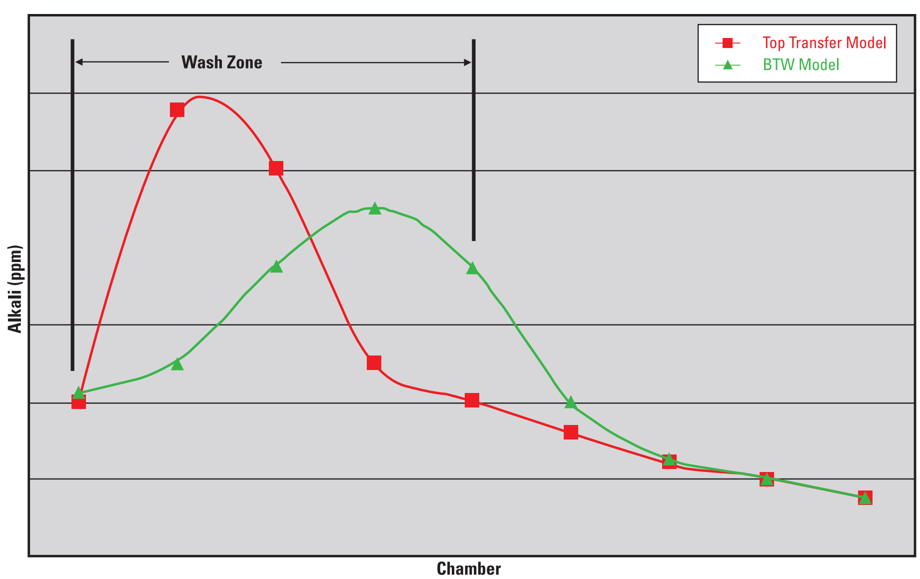


Figure 21—Typical Chemical Gradient in Braun BTW and top transfer tunnel

4 Riggs, Charles L., Ph.D. and Klipper, Michael, Textile Laundering Technology, Alexandria: 2005 (pg. 186).

Mechanical Action

The combination of flow control, Dual Counterflow, and Direct Counterflow makes for an effective rinsing and washing process, allowing plant operations flexibility for any application.

Mechanical action is an important component in the wash pie. Braun's BTW is designed for robust and adjustable mechanical action. We have taken our industry leading washer extractor technology and applied this to the cylinder design of the tunnel washer. Each chamber washes with a similar level of mechanical action to a conventional washer-extractor for exceptional wash quality. Each chamber has three ribs that are spaced 60 degrees apart from each other to cover a third of the chamber circumference. The center rib is the tallest of three ribs and as the goods come into contact with this a lift and drop action is affected, similar to a conventional washer extractor. To fine tune this component of the wash pie, an adjustable wash angle is also a feature on the machine. The wash angle can be adjusted to optimize the action desired for the tunnel processes.

The wash angle setting correlates to a rotational angle as noted in **Figure 22:**

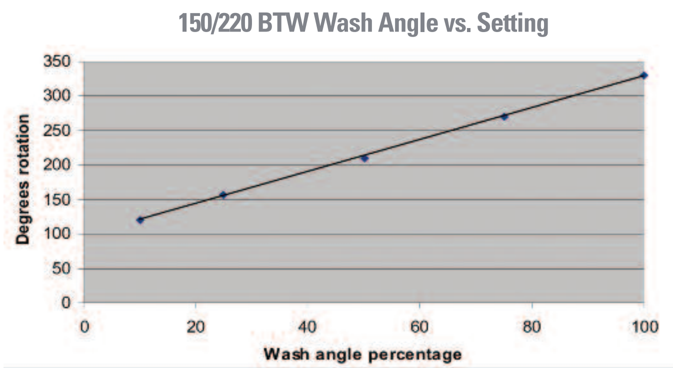


Figure 22—Wash angle percentage setting and actual wash angle

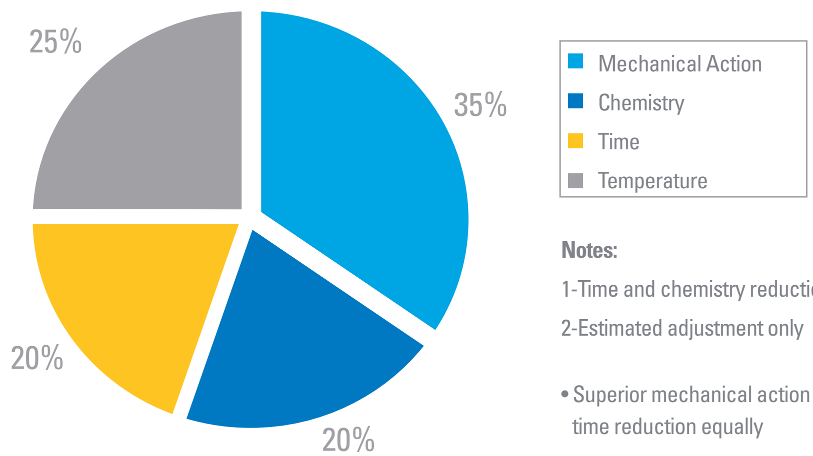
There is also a long and short wash angle setting so specific goods types can be programmed with an intentional gentle angle so as not to over agitate and damage the goods and/or redeposit removed particulate. Degradation in whiteness can be seen if there is too much mechanical action. Field testing on Braun BTW's has shown that the whiteness retention is better than typical standard samples. Testing results are summarized below. Test 1 was conducted independently by a leading chemical vendor and test 2 was carried out using Laundry Performance Evaluation test pieces from the Dry-cleaning and Laundry Institute (DLI):

	Test 1	Test 2
Industry standard	100.0	100
Braun average	104.9	103

The fact that Braun BTW's have robust as well as adjustable mechanical action (i.e. a wide process window), allows plant operations latitude to tune the process to that which best meets the requirements of the facility. This flexibility allows the operator to slightly adjust the wash pie segments to best suit the processing needs. The Textile Laundering Technology handbook demonstrates wash pie segment shifts emphasizing reduced time, temperature, and chemical costs.[5] The Braun adjustable BTW mechanical action allows the operator the luxury of widening the process window to reduce other segments of the wash pie. Temperature is typically not an option due to minimum activation energy required for many chemical reactions. Peroxide bleaching is an example of this. Two scenarios are demonstrated in **Figure 23;** reduced time and concentration, and reduced time only:

5 Riggs, Charles L., Ph.D. and Klipper, Michael, Textile Laundering Technology, Alexandria: 2005 (pp. 25-26.).

Braun Mechanical Action—Scenario 1



Notes:

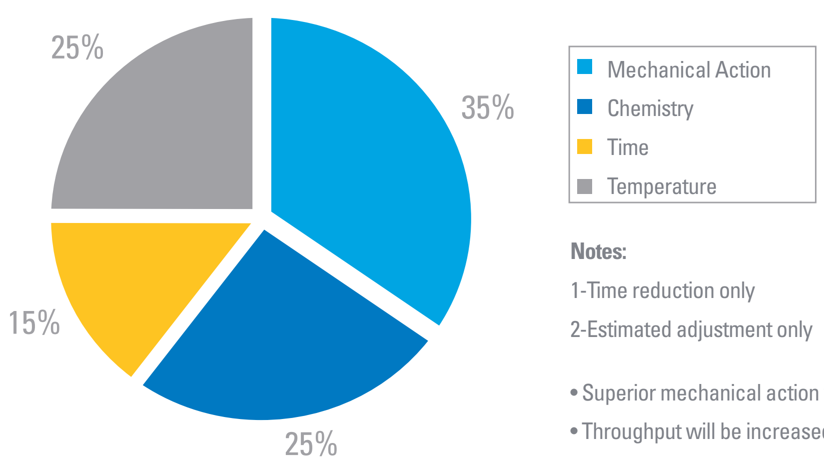
1-Time and chemistry reduction

2-Estimated adjustment only

- Superior mechanical action allows chemistry and time reduction equally
- Shift in pie works to a cost and throughput advantage
- No additional cost as inherent feature of machine
- Controllable parameter with wash angle adjustment capability

Figure 23—Modified Wash Pie Scenarios

Braun Mechanical Action—Scenario 2



Notes:

1-Time reduction only

2-Estimated adjustment only

- Superior mechanical action with wash pie adjustment in time only
- Throughput will be increased at no additional cost
- Controllable parameter with wash angle adjustment capability

Wash Testing Results

Results for whiteness retention testing performed on Braun BTW's were already discussed previously. Additional field testing using Laundry Performance Evaluation test pieces from DLI has been performed to evaluate the wash quality of the Braun BTW process with the following results (compared with Industry standard):

Percent better than standard.	
Tensile strength loss	62.0%
Yellowness	90.0%
Soil removal	24.3%
Bleach effectiveness	5.8%

Table 2—Batch tunnel washer production rates

	BATCH WASHER PRODUCTION RATES				
Number of chambers	8	10	11*	12	14
Total wash time (min)	Production Rate (lbs/hr @ 100% efficiency)				
14	5,143	6,429	7,072	7,714	9,000
18	4,000	5,000	5,500	6,000	7,000
22	3,273	4,091	4,500	4,909	5,727
26	2,769	3,462	3,808	4,154	4,846
30	2,400	3,000	3,300	3,600	4,200
34	2,118	2,647	2,912	3,176	3,706
38	1,895	2,368	2,605	2,842	3,316
42	1,714	2,143	2,357	2,571	3,000

* Constructed based on data for an 11 chamber tunnel washer

5 Riggs, Charles L., Ph.D. and Klipper, Michael, Textile Laundering Technology, Alexandria: 2005 (pp. 25-26.).

Sizing

Correct tunnel sizing is paramount to an efficient and successful operation. Many factors need to be evaluated in this decision. One essential factor is desired throughput and how that relates to quality. The recommended throughput differs with the size of the machine.

Braun offers three sizes for both tunnel washer classes; an 8 chamber, 11 chamber, and 14 chamber. There are target cycle times and ranges for each of these machines based on total dwell time in the machine. The ranges can change based on soil level.

When choosing a tunnel, it must be remembered that the less compartments a tunnel has, the greater the cycle time needed to achieve effective washing. Choosing to run a smaller compartment tunnel with cycle times lower than the recommended ranges leads to issues with quality and longevity of goods, as well as increased operating costs. This is a direct result of the wash pie discussion in the previous section. Because of the reduced wash time available in a smaller tunnel coupled with short processing times, higher chemical usage is required.

Textile Laundering Technology defines tunnel throughput based on size and total wash time. Average production rates for 150 pound batch sizes are shown in **Table 2 (on page 16).** An additional column was constructed based on the data for an 11 chamber tunnel washer.[6]

The cells that are within the setup range for typical light to medium soil for a bottom transfer washer are highlighted in grey for reference. These are taken from a table of industry standard process times for hotel sheets, hotel and hospital linen, and general hospital linen.[7] The tunnel washer should be sized based on these throughput numbers to best insure success for the overall tunnel system productivity.

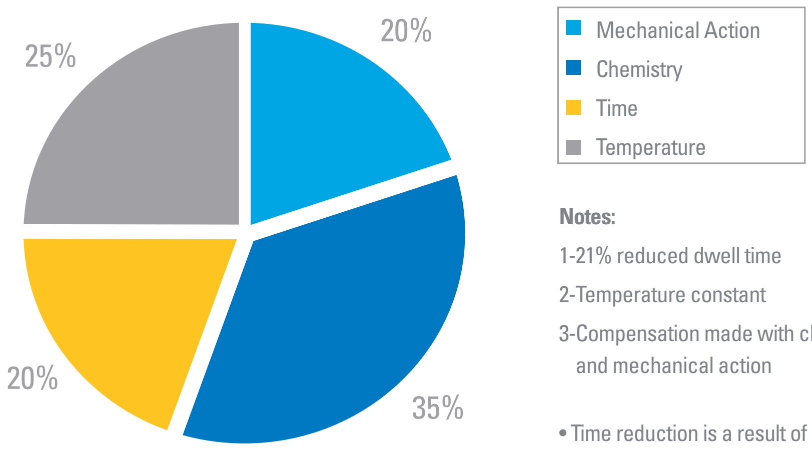
Undersizing any type of tunnel will lead to unachieved throughput goals and excessive operating costs. To better understand these consequences the pie chart is used as the foundation for this discussion. To achieve satisfactory washing, based on the wash pie chart **(Figure 20),** if time is sacrificed then other areas of the chart must increase. A by product of the reduced time is also a reduction in mechanical action since there will be less oscillations in a given tunnel cycle. It has also been mentioned in this technical bulletin that temperature is typically not an option to adjust due to minimum activation energy required for many chemical reactions. The only option this leaves is to increase chemical concentration in order to establish wash quality.

With an undersized tunnel, the dwell time in both the wash and rinse zones decreases. To combat this, some rinsing needs to start at the end of the wash zone, which lessens washing effectiveness. To compensate for this reduced dwell in the wash zone higher chemical concentrations at the beginning of the wash cycle are employed. This chemical *spike* has two direct consequences. First, the higher concentrations lead to greater chemical costs for the life of the machine. Secondly, as referenced earlier in this technical bulletin, the higher concentrations reduce the tensile strength and life of the goods, which also results in a greater linen replacement cost.

6 Riggs, Charles L., Ph.D. and Klipper, Michael, Textile Laundering Technology, Alexandria: 2005 (pg. 157).
7 Riggs, Charles L.' Ph.D. and Klipper, Michael, Textile Laundering Technology, Alexandria: 2005 (pg. 155).

The two graphs in **Figure 24** show how this scenario skews the wash pie and the adjustments that are required as a result:

**Adjustments required for improper sizing from balanced model—
Large vs. Medium Chamber Numbers (1.5 minute cycle)**



Notes:

1-21% reduced dwell time

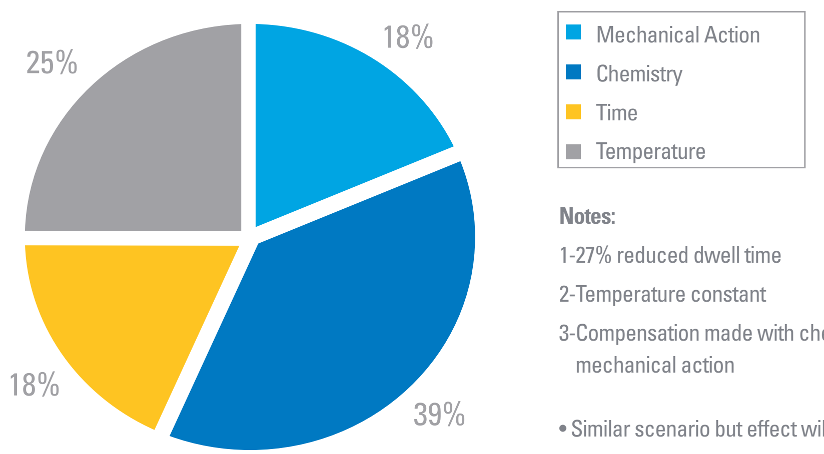
2-Temperature constant

3-Compensation made with chemistry to offset reduced time and mechanical action

- Time reduction is a result of less number of chambers at fixed cycle time
- To maintain desired throughput an increase in chemical concentration will be required
- A secondary effect will be an increase in rinsing required to remove additional chemicals required for processing

Figure 24—Adjustment scenarios required for improper sizing

**Adjustments required for improper sizing from balanced model—
Medium vs. Small Chamber Numbers (2 minute cycle)**



Notes:

1-27% reduced dwell time

2-Temperature constant

3-Compensation made with chemistry to offset reduced time and mechanical action

- Similar scenario but effect will be greater based on greater percentage
- Chemical concentration increases will be forced even higher than larger machine scenario
- Rinsing will need to be increased in this scenario to a higher level than smaller machines

Overall System and Processing Considerations

The tunnel washer is the backbone of the tunnel washing system and has been the topic of discussion in this technical bulletin. That being said, each of the individual components in the system has an important role in the overall system processing capability. When the tunnel washer is setup with reasonable wash processing times, if the other components are not setup or tuned properly, the overall system will not perform as expected. System efficiency of 100% is not realistic and must be tempered by real life factors. Textile Laundering Technology notes four factors that are *qualifying considerations* for the throughput numbers shown in the batch tunnel washer production rate table as[8]:

"- Rates shown..... require that sufficient capacity of downstream equipment such as extraction and/or drying be available.

- Production may be less due to NOG goods creating more under loaded batches

- Production may be less if empty pockets are required between greatly dissimilar batches.

- Production or Wash Quality may be reduced, and costs increase, if efficient sequencing is not maintained."

These are very important factors that are often overlooked when designing and specifying a tunnel system. An article in Textile Rental Magazine states this well as when it notes that:

"There is a long history in our industry of continuous batch washing systems not performing to their maximum capabilities for one simple reason: They weren't designed with the concept of linear (series) production as the primary focus of the design" [9]

The article goes on to identify two of those downstream components that hinder performance as *"not providing adequate high-pressure extraction time"* and *"not providing adequate drying capability"*.[10] This section will address the overall system operation.

The components of the system that need to be addressed individually for a tunnel washing system are noted in **Table 3 (on the next page).** In the table the specific considerations that have to be taken into account are identified.

When the overall system is setup and operated properly, testing can be performed after initial ramp up to determine if productivity can be improved beginning with the tunnel cycle time reduction. As an example of this, at an operating plant with a 150 BTW-11 tunnel washer system, tunnel cycle time was able to be reduced well below the lower limit setup targets for an 11 chamber machine. Tunnel transport time was ultimately lowered to 103 seconds (35 transfers/hour) for a hospitality linen plant. The recommended setup time for an 11 chamber machine based on table 2 is a minimum of 22 minutes. The machine runs a total process time of just under 19 minutes for most of the goods types processed. The throughput achieved was a bonus and due to proper tunnel system design and excellent operations management. The results of these improvements are noted as follows:

- Excellent goods quality
- Process balance
- Process throughput efficiency
- Cost parameter control (natural gas, water, and chemicals)

8 Riggs, Charles L., Ph.D. and Klipper, Michael, Textile Laundering Technology, Alexandria: 2005 (pg. 158).
9 Curiale, Jim. Textile Rental, February 2009 (pg. 64).
10 Curiale, Jim. Textile Rental, February 2009 (pp. 64-65).

Table 3—Tunnel system component optimization

Component	Options	Considerations
Load device	Sling	-generally less labor intensive after slings are loaded in soil sort area -less interference at ground level with operation -goods cueing and staging based on cycle times, goods type is important for overall operation
	Conveyor	-manually loading requires adequate labor resource management to not slow system down -goods cueing and staging based on cycle times, goods type is important for overall operation
Tunnel	General	-tunnel considerations discussed extensively in the applications section -heat application in finish end will reduce moisture in pressed cakes -do not necessarily want to run the tunnel as fast as possible for overall system performance optimization -transport time is an important component in addition to cycle time (may not be included in overall tunnel cycle) -although the key piece of equipment in the system, do not neglect importance of each other component
	Number of modules	-specify number of modules on the conservative end of throughput requirements -tunnel considerations discussed extensively in the applications section and always lean towards slight over capacity side for safety
Press	General	-understand moisture extraction curve performance to assess minimum time under high pressure -poor moisture extraction is very costly as water removal in dryers requires more energy per pound -tamping feature can be beneficial for low permeability goods types (gowns, high fiber count sheets, etc) -dead time parameters should be adjustable for press-tunnel cycle optimization matching
	Pressure	-pressure at the membrane is actual pressure on the linen matrix, measurement and control of pressure at the membrane is the preferred method -40 bar and above units provide more than enough extraction force
	Basket diameter	-larger diameter is desirable -use height to area ratio as a rule of thumb for sizing as the lower this ratio is the better the extraction becomes
Cake handling shuttle	Single Bed	-limits buffer capability for press-dryer interface -simpler operation
	Double Bed	-best for double cake dryer setup -best for buffer capability for press-dryer interface -front end goods cueing is more important for matched goods
Cake storage elevator	Single Bed	-limits buffer capability for press-dryer interface -simpler operation -does not use shuttle movement as efficiently with full travel for every cake
	Double Bed	-best for double cake dryer setup -best for buffer capability for press-dryer interface -front end goods cueing is more important for matched goods
Sheet by pass station		-option provides additional system capacity to mitigate system from becoming dryer bound
Clean side rail storage		-Braun Patent Pending technology provides rail storage and chute loading of dryers -provides additional storage buffer capacity to eliminate process flow bottlenecks
Dryers	Single cake	-reduced opportunity for mixed cake loads -adds more time per cake for ancillary operations (load, lint blowdown, unload) -design system with correct number of dryers with additional if possible (downtime, unforeseen issues)
	Double cake	-more sensitive to mixed loading issues -less time per cake for ancillary operations (load, lint blowdown, unload) -design system with correct number of dryers with additional if possible (downtime, unforeseen issues)
Unload conveyor		-clearing of goods either manually or automatically is primary concern -labor resource management important to ensure operation is not a bottleneck

Goods Processing Flexibility

The Braun BTW can be utilized in most any processing application. Due to its design, process control features, multiple heating zones, and chemical injection flexibility, it can be setup to effectively process a wide range of classifications. As a result, any laundry processing plant can benefit from Braun's technology. A brief summary of which features would be used for five main types of processing plants is noted below:

Heathcare:

- flexible front end temperature for lower prewash temperature requirements
- can use trim heat in prewash if chemistry warrants additional front end heat
- high or low temperature wash zone capabilities:
    - easily can reach 180°F for peroxide bleaching
    - lower temperature control excellent for PAA and enzyme washing chemistries (120 - 140°F)
    - heat control and/or indication in every wash zone chamber
- multiple rapid drain and refill capabilities in the prewash zone for heavy soil products
- post wash bath exchange for aggressive pre rinse and/or application of rinsing chemicals
- finish heat for reduced moisture in pressed cake

Hospitality:

- trim heating in prewash section for higher heat application:
    - can hit up to 190°F with trim heating
- high or low temperature wash zone capabilities:
    - easily can reach 180°F for peroxide bleaching
    - lower temperature control for chlorine bleaching (140 - 160°F)
    - heat control and/or indication in every wash zone chamber

Hospitality (continued):

- flexibility with goods type shifts:
    - prewash and post wash bath exchanges for rapid drop of undesired process water
    - can program to allow empty pockets before and/or after goods needing segregation
- post wash bath exchange for aggressive pre rinse and/or application of rinsing chemicals
- finish heat for reduced moisture in pressed cake and starch applications

Food and Beverage:

- multiple rapid drain and refill capabilities in the prewash zone for heavy soil products including heavily soiled and stained table linen and bar mops
- flexibility with goods type shifts:
    - prewash and post wash bath exchanges for rapid drain of undesired process water
    - can program to allow empty pockets before and/or after goods needing segregation
- finish heat for reduced moisture in pressed cake and starch applications

Industrial:

- trim heating in prewash section for higher heat application:
    - can hit up to 190°F with trim heating
- multiple rapid drain and refill capabilities in the prewash zone for heavy soil products including industrial wipes

Scour Bleaching:

- high temperature capability in prewash for scour processing (up to 190°F)
- high temperature capability in wash for peroxide bleaching process (up to 205°F)
- finish heat for reduced moisture in pressed cake and softener process

Summary

Batch tunnel washers are an excellent option for high volume, efficient goods processing. Braun BTW's are designed to be flexible, simple and effective to meet any plant processing needs. The machine operation and process flow is designed for optimal wash processing of any goods type desired. Water and heat reuse is applied throughout the machine, resulting in a cost effective use of natural resources. Simplicity and durability are the key words when describing the machine features. The cylinder, drives, seals, heating system, and water and heat recovery systems are designed to ensure high quality processing at the lowest costs, ease of maintenance and long life expectancy.

The *open helicoid* internal cylinder design allows for optimum washing as well as hindrance free transport. This is not only key to trouble-free processing, but ensures that personnel do not have to enter the tunnel to unplug jams. The cylinder volume is used efficiently for all rotational processes during the wash cycle.

Superior wash and rinse processing is mainly due to dual-direct counterflow and superior mechanical action. A result of this is a uniform alkali concentration gradient in the wash, rapid and effective rinsing, and increased throughput due to wash pie time reduction. It also allows for efficient use of chemicals and utilities thus minimizing plant operational expenses.

A properly sized tunnel will demonstrate excellent production throughput. Additionally, Braun's flexible machine features allow efficient processing in any of the five major goods classification type plants.

Science is the foundation for the development, design and validation of the performance of the Braun BTW.

It stands the test of time!

Appendix 1—Technology Comparison Table

	Transfer Method			Shell Construction		Counterflow Process		Drive Configuration	
	Bottom Open Helicoid	Bottom Archimedean Screw	Top	Single	Double	Direct	Indirect	Friction	Chain Around Perimeter
Pros:	Large open area between chambers	Smooth flow of goods and water between chambers	Less water transferred with goods for improved rinsing	Robust weldment with no moving parts	Chambers can be separate operations	Forces counterflow through goods matrix		No auto greasers or oilers	Single motor for drive
	Smooth flow of goods and water between chambers		No axial movement of goods during wash cycle closely simulating conventional washers	External seals easy to access	More bath exchanges possible to remove unwanted process water	More efficient rinsing		Easier drive or component replacement	
	No axial movement of goods during wash cycle closely simulating conventional washers				Easier for chemistry sampling			Multiple motors for drive allows operation when one motor or gearbox fails	
					More flexible for processing colored goods mix				
Cons:	None	Less open area due to center shaft and more propensity for goods jamming and roping	Less water transferred with goods causes high concentration spikes	Less flexibility for machine setup with fixed zones	Internal seals difficult to change and to determine if there are failures		Paths to by pass goods matrix are possible		Automatic greaser or oiler
		Axial movement of goods during wash cycle making less effective rib contact and mechanical action	High propensity for plugging and roping	Machine needs to be placed in standby for sampling	Long-term wear and potential component failure due to modular design		Less efficient rinsing		Major maintenance for drive and/or chain replacement
			More sensitive to water level effects on transfer of goods	Need to have empty pockets between colored goods and effects process time	Modular design can present a problem for movement and relocation of machine				


BRAUN

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