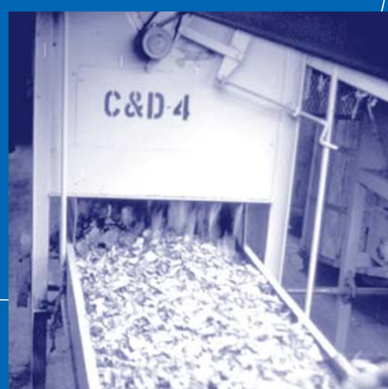

The Art and Science of Processing Tobacco

Universal Leaf Tobacco Company Incorporated

Acknowledgments

This booklet is a compendium of information gathered from various sources and prepared by the following persons:

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Contents

As processing tobacco is not an exact science, some of the statements in the booklet are not matters of proven fact, but rather opinions based on experience and consultation with many processing and technical personnel. It is accepted that in certain instances there will be differing opinions. This booklet is not intended to be an in-depth explanation of the stemming process, but rather a broad overview to give interested individuals a basic understanding of the system.

Overview

Tobacco is indigenous to North America and was introduced to the western world by the Indians in the late 16th century. It is a hardy weed which flourishes in the sandy soils of the eastern United States and other countries with similar soils and climatic conditions. The typical tobacco plant consists of a central, fibrous stalk about 4–5' high which supports 18–22 large leaves.

Originally, tobacco was sold by the farmers in "hands", which consisted of 10–30 leaves of tobacco tied together at the stalk end by another leaf wrapped around the stalks and tucked under itself. This was because the farmer meticulously graded the tobacco by stalk position and color, and then packed his crop in hogsheads (large wooden barrels), for transport to market. The merchant who purchased the tobacco then had to employ a large number of people to manually remove the leafy portion from the stem before packaging the tobacco for its various uses. It became apparent that the tobacco tasted better if it was not smoked immediately after curing, but allowed to age for at least one year, like a good wine. During the year, the tobacco went through a slow fermentation process known as a sweat, after which its characteristics were considered much improved.

There were pitfalls to this system, for if the tobacco were left to age when its moisture was above a certain threshold, the fermentation process would get out of control, and the tobacco would simply carbonize. In extreme cases, spontaneous combustion could occur. The merchants concluded that it would be prudent to ensure that tobacco was never stored above the critical moisture content of about 13%. Thus the processing industry was born, when former brokers of tobacco had to start investing in machinery to safeguard their product.

The first processing plants were set up in warehouses in which tobacco from the farms was stored after purchase. The tobacco was re-inspected for quality, and the hands (or bundles) were draped across sticks and loaded on to chains to be slowly transported through a drying machine. This was a slow process, but the emerging tobacco could be packed into hogsheads again and stored indefinitely without fear of carbonization. The tobacco brokers could sell the product immediately after the drying process, and thus take a quick turnaround on the merchandise. The manufacturers of tobacco products stored the leaf tobacco and after the fermentation, stripped the leaves and cut and packaged it for the retail market.

As the cost of labor steadily increased in the western world, the continuation of the industrial revolution led inventors to look at methods of mechanizing the tobacco business. Instead of manually stripping the leaf from the stem, a variety of machines were developed to perform this function. Thus the leaf merchants were compelled to increase their services to include mechanical threshing of tobacco prior to drying, so that the manufacturers could purchase the leaf product ready for use after aging. As the capitalization, wage structure and geographical considerations were quite distinct between manufacturer and tobacco merchant, the industry became clearly partitioned in terms of scope. The merchant handled the process from buying and grading the product until packaging in dried form, and the manufacturer undertook the storage, aging and manufacturing functions.

The threshing process is required as an essential step in the preparation of tobacco leaves to be processed into cigarettes, cigars, pipe and chewing tobacco. Originally done by hand at considerable cost, it has evolved over the last fifty years into a fairly sophisticated art and science.

Today's modern cigarette makers require the raw material supplied to them to be in a special size range for optimum utilization. A major criterion is to have the required cigarette firmness with the lowest possible weight. The critical size appears to be in the areas of 1 x 1" and ½" x ½", with a minimum of particles below ¼" x ¼". The stem content for cigarette tobacco is a trade-off between lamina particle size and problems in the makers and final product. In general, the higher the stem content, the larger the lamina size and the higher the yield. However, the price for this is lower maker utilization and higher reject percentage. The industry seems to believe that an objectionable stem target of 0.25% and a total stem content of 2–2.5% is the best compromise.

Tobacco is a most variable plant and it is not possible to have a single strategy to handle different crops and different growths. However, by grouping similar types we believe a system of statistical process control can be used to set up the equipment for the required results.

The typical processing system involves ten steps:

1. **Preconditioning.** This is the process that adds some moisture and heat to the farmer package prior to entering the main system.

2. **Blending.** This is the process of feeding the tobacco into the system. Different grades are combined at specific rates to accomplish the required blend of tobaccos.

3. **Picking.** This is the manual inspection process to remove non-tobacco products and undesirable leaves from the product.

4. **Conditioning.** The controlled addition of moisture and heat to the leaves. This is the single most important step in preparing the tobacco for threshing. The threshing action is influenced by a number of factors, but having the correct moisture and temperature is vital.

5. **Feed Regulation and Transport.** Feed regulation is critical to obtaining maximum efficiency and consistent ordering, threshing and separation.

6. **Threshing.** The mechanical removal of the lamina portion of the leaf from the stem.

7. **Separating.** Once the lamina is free from the stem, it must be separated from the stem.

8. **Scrap Removal.** The mechanical removal of small particles from the main strip product.

9. **Drying.** The drying of the stems and lamina to uniform moistures

10. **Packing.** The packing of the end-products in bales, cases or hogsheads.

Preconditioning

The single most important factor in the successful stemming of leaf tobacco is the condition it is in prior to entering the system. Cold, dry tobacco is very fragile and if subjected to any mechanical action it will shatter easily. This causes dust and scrap generation which affects size and yield adversely. Over the years, therefore, various methods have been developed to condition the tobacco prior to entering the main stemming system. The oldest and simplest is a "sweat" room which is an enclosed area maintained at 75–80°F and 80–90 °F humidity. It must be sufficiently large to accommodate 24–48 hours of production and is operated on a FIFO basis to give each bale or sheet a residence time of 24–48 hours.

Whereas this system is simple and effective, depending on the sizes of the packages and the degree of compaction, the conditioning may not be uniform throughout the package unless a very long residence time is used. Also, there is quite a bit of handling involved going in and out of the sweat room.

Vacuum conditioning is another alternative to precondition tobacco. It has been used for many years, and relies on the principle of evacuating a closed chamber containing batches of tobacco and then injecting steam and water to raise the temperature and humidity. The thermodynamics of this process are quite complicated, but the principles are readily understandable. The vacuum system, if used correctly, gives good penetration and is controllable to give ranges of exit temperatures and moistures. Normal cycle time is in the region of thirty minutes, so no large quantities of conditioned tobacco need to be accumulated. The vacuum system also has the capability to cool and reduce moisture which is useful for stabilizing green tobacco too hot or wet or for correcting finished product packed too high in moisture.

The third method gaining popularity is the direct cylinder conditioning, where leaf tobacco packages are sliced and fed directly into large conditioning cylinders. In this case there is no preconditioning and the system relies on the slices being exposed to steam as soon as they enter the cylinder. As they are tumbled, they quickly break apart and each particle is exposed to the humid environment.

Vacuum Conditioning

There are two basic means of accomplishing penetration of steam into packages or homogenous masses of material. The most common is the pressure method, used domestically in the pressure cooker and commercially by means of autoclaves. In this method, a closed chamber containing the product is pressurized by means of live steam injection or by boiling water already in the chamber. As pressure increases, heat and moisture are forced into the cells of the leaves. This does a fine job of penetration, but a large pressurized vessel has a higher risk factor, is very expensive and high pressures can cause cell collapse which is detrimental.

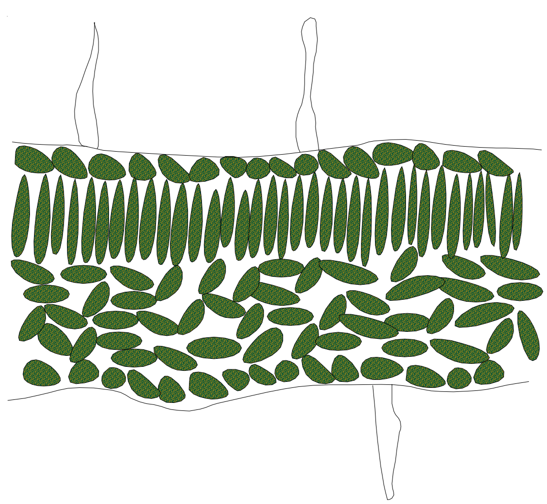
The other method is to place the product in a sealed chamber and evacuate it. As the evacuation process progresses, non-condensibles (mainly air) are removed from the chamber and the pressure drops. At the point where the pressure is equal to the saturated vapor pressure of water at the loading temperature of the product, water molecules within the cells start to vaporize and boil off, thus cooling the product and driving out any pockets of non-condensible gases.

The next step is the injection of steam into the vessel. The steam must be in the saturated condition to give maximum humidifying effect, this being accomplished by means of a de-superheater or water atomizers. Saturated steam raises the pressure in the vessel and the vapor penetrates the cells and condenses, raising both the moisture and the temperature. If any pockets of non-condensible gases are trapped within the packages, they will impede the penetration of moisture. Thus it is important that the initial evacuation be continued to the lowest practical limit (usually 0.2" HG or 35°F wet bulb) in order to remove these pockets. Any leaks in the chamber will allow the ingress of air and have a similar detrimental effect.

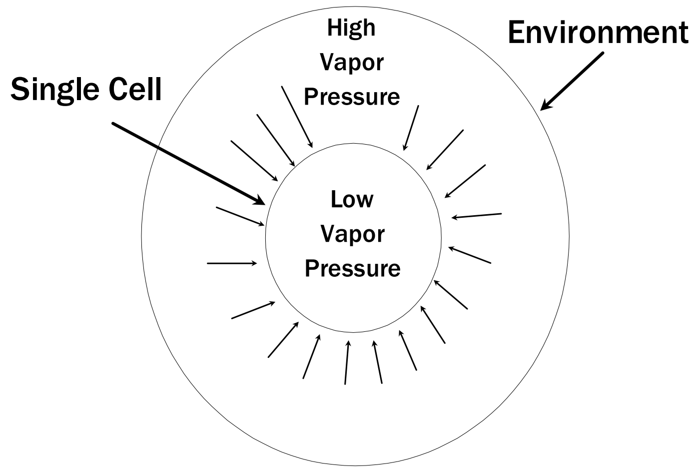
The Basic Tobacco Leaf

Tobacco leaves, like all organic material, are made up of cells. The cells are made up of a cellulose outer layer and a liquid interior. The cell boundaries are permeable and moisture can move across these boundaries according to the pressure difference from one side of the boundary to the other. The movement always takes place from the high to the low pressure and under constant conditions, pressures will eventually equalize.

Cross Section of Tobacco Leaf



Moisture moves from high to low vapor pressure regions across cell walls



Vapor Pressure

Vapor pressure is the pressure caused by molecules of water in a gaseous environment (in this case). Water, as defined by the molecule H_20 (two atoms of hydrogen combined with one of oxygen) can exist in three phases. The first is solid (ice) which is the lowest energy level. As energy is added in the form of heat or pressure or both, the molecules become more active and the ice melts to become a liquid (water). In changing phases, energy is added without a temperature change and this energy is defined as the latent heat of fusion. Once all the solid has become liquid, temperature starts to rise again until there is enough energy for some of the molecules to break loose from the surface of the liquid to become gaseous. Again, once this process starts, energy must be added for it to continue and temperature will not change until all the liquid has turned to vapor. The energy required to go from liquid to vapor stage is known as the latent heat of vaporization.

Conversely, if vapor is condensed to liquid or water frozen to ice, heat must be removed. For water, there is a unique relationship between boiling point and pressure, as listed in Figure 1. This shows that at any given pressure, there is a unique temperature at which the water will boil. The lower the pressure, the lower the boiling point. For this reason it is impossible to brew hot drinks on top of high mountains. At low pressure, the water boils at a low temperature and *it is impossible* to get the temperature any higher in an open container.

Saturated vapor pressure is the pressure caused by the energy of the water molecules in a saturated environment. When there is no other gas present, the only pressure in a vessel is caused by vapor pressure. Saturation is when the atmosphere cannot hold any more vapor without condensation occurring.

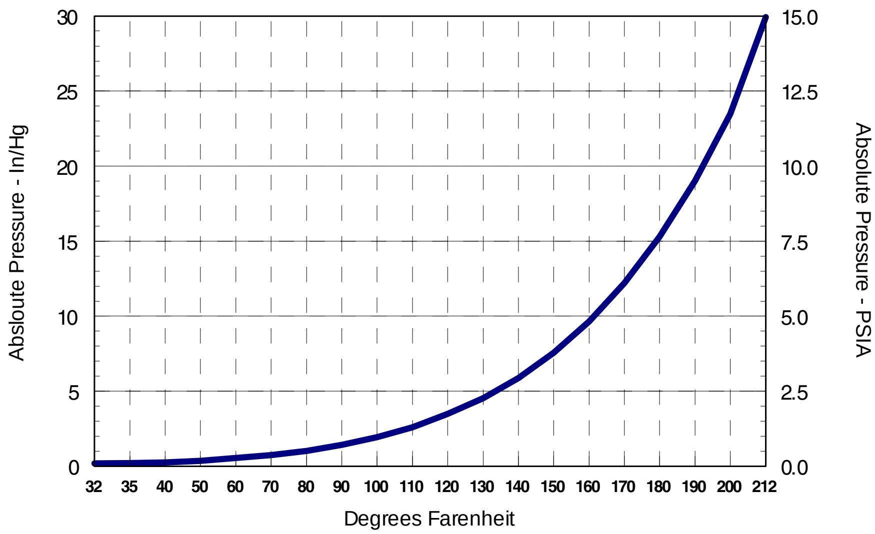
From examining the saturated vapor pressure / temperature tables in figure 1, it can be seen that at atmospheric pressure (14.7 PSIA) pure water boils at 212°F. As the pressure is reduced (by evacuation)

Figure 1

Saturated Steam Chart

Saturated Steam Table

Temp. F.	Press. In/Hg	Press. PSIG
32	0.1803	0.0885
35	0.2040	0.0100
40	0.2480	0.1217
50	0.3630	0.1781
60	0.5520	0.2563
70	0.7390	0.3631
80	1.0320	0.5069
90	1.4220	0.6982
100	1.9330	0.9492
110	2.5960	1.2748
120	3.4660	1.6924
130	4.5250	2.2225
140	5.8810	2.8890
150	7.5690	3.7180
160	9.6520	4.7410
170	12.1990	5.9920
180	15.2910	7.5100
190	19.0140	9.3390
200	23.4670	11.5260
212	29.9210	14.6960



the boiling point drops. Thus if tobacco is loaded into a chamber at 70°F, when the absolute pressure reaches 0.37 PSIA (0.75 INS HG) the water contained within the cells will start to boil. If no further evacuation takes place, the pressure in the vessel will rise slightly and the tobacco will cool slightly (due to latent heat of vaporization) until equilibrium is reached again. If evacuation continues, more water will evaporate from the cells and the tobacco will continue to cool. The practical limit of our normal evacuation systems is 0.2" HG, at which point water boils at 35°F. If evacuation occurs rapidly, evaporation will be so intense that the mechanical energy of the molecules leaving the surface will entrain others with them and cause the liquid temperature to drop below saturation point. Ice will form where any pools of liquid have been in the chamber.

It is important to note the tremendous increase in volume which occurs when water turns to vapor. At 35°F and 0.2" of HG., the liquid volume is 0.016 FT^3/LB. If this liquid is all boiled off into vapor at the same temperature and pressure, it will have a specific volume of 2947 FT^3/LB. For this reason, a dry, empty chamber will pull down very rapidly to 0.2 HG, whereas a loaded chamber with standing water on the floor will take much longer, as the evacuation system must remove all the water vapor produced by the drop in pressure. For best results, chambers must be well drained to minimize standing water after each cycle.

The Vacuum Cycle

The vacuum cycle is best understood from the pressure/temperature chart shown in Figure 2. This shows the various steps of evacuation, steaming, re-evacuation, final steaming and back to atmospheric pressure at the end of the cycle. The temperatures are the saturation temperatures at the various pressures as measured by the wet bulb and the tobacco may be at different temperatures depending on the amount of moisture present and the soak time for each step of the cycle. The atmosphere within the chamber is saturated when the wet and dry bulb temperatures are the same. The two basic steps in the vacuum cycle are evacuation and steaming.

Figure 2

Saturated Steam Table

Temp. F.	Press. In/Hg	Press. PSIA
32	0.1803	0.0885
35	0.2040	0.0100
40	0.2480	0.1217
50	0.3630	0.1781
60	0.5520	0.2563
70	0.7390	0.3631
80	1.0320	0.5069
90	1.4220	0.6982
100	1.9330	0.9492
110	2.5960	1.2748
120	3.4660	1.6924
130	4.5250	2.2225
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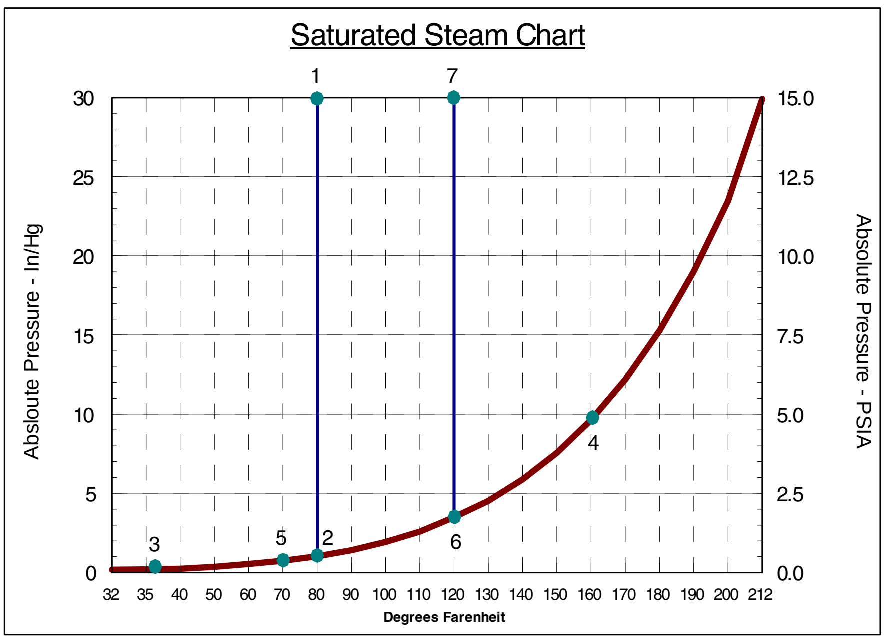


1 - 2: Evacuation to Saturation Point
2 - 3: Evacuation and Evaporation
3 - 4: Steaming and Condensation
4 - 5: Re-Evacuation and Evaporation
5 - 6: 2nd Steaming and Condensation
6 - 7: Vent Back To Atmospheric Pressure

Vacuum Conditioning Cycle - 2 Step

Evacuation

An evacuation system normally consists of three parts:

1. Vacuum pumps
2. Steam ejector
3. Condenser with cooling tower.

Whereas small units and older units operate with two or three stages of steam ejector, this is very inefficient from the energy standpoint and, therefore, the initial evacuation is normally accomplished by means of vacuum pumps.

Vacuum pumps are essentially compressors which operate in the range from 0–15 PSIA. Although reciprocating pumps can be used, the liquid ring pump is more popular as it can handle large quantities of vapor and liquid and also condenses any vapor in the inlet stream. The principle of the liquid ring pump is simple, as illustrated in Figure 3. It can be single or multiple stage depending on the application, but two stages are more popular in the tobacco industry. The limitation of the pump is dependent on the temperature of the seal-water, as this cannot be above the saturation point at the pump suction pressure. Thus, if seal-water temperature is 80°F, the lowest pressure the pump can pull to would be 1.0320" HG (from table–Figure 1). In practice, unless the water is refrigerated, pumps can only reach 1.5–2 HG reliably.

Once the pump has reached its limit, the next step is the steam ejector. This operates by forcing steam through a nozzle at high velocity, thus causing a local pressure-drop and subsequent entrainment of the gas around the nozzle. The nozzle is directed into a converging/diverging diffuser and from there into a condenser where any vapor is condensed. The condenser is connected to the vacuum pumps and is maintained at about 2" HG.

A typical ejector is illustrated–Figure 4. The liquid-ring pump/ejector combination can handle larger volumes of vapor and reduce pressure to 0.2" HG in 6–8 minutes if sized correctly. Although reciprocating or vane vacuum pumps are capable of reaching very low pressures without the aid of ejectors, the volume of vapor generated by the evaporation of water in the tobacco is so great that it would require huge pumps to accomplish the task and this method is generally considered impractical.

The condenser is a very effective means of reducing the volume of water vapor, thus leaving the pumps to handle mostly non-condensable gases. It is also essential to condense the steam from the primary ejectors and reduce back-pressure on the ejector. In order for the ejector to function correctly, the condenser must have adequate water flow, the flow must be well diffused within the vessel and the temperature must be well below the saturation temperature of the pressure within the condenser.

This is accomplished by circulating water through the condenser from the cooling-tower, which removes the latent heat gained in the condenser. The cooling-tower works using both sensible heat removal and latent heat removal via evaporation. It must be sized to handle the maximum heat load under the worst ambient conditions of high temperature and humidity. Although water is added to

Figure 3

Liquid-Ring Vacuum Pump

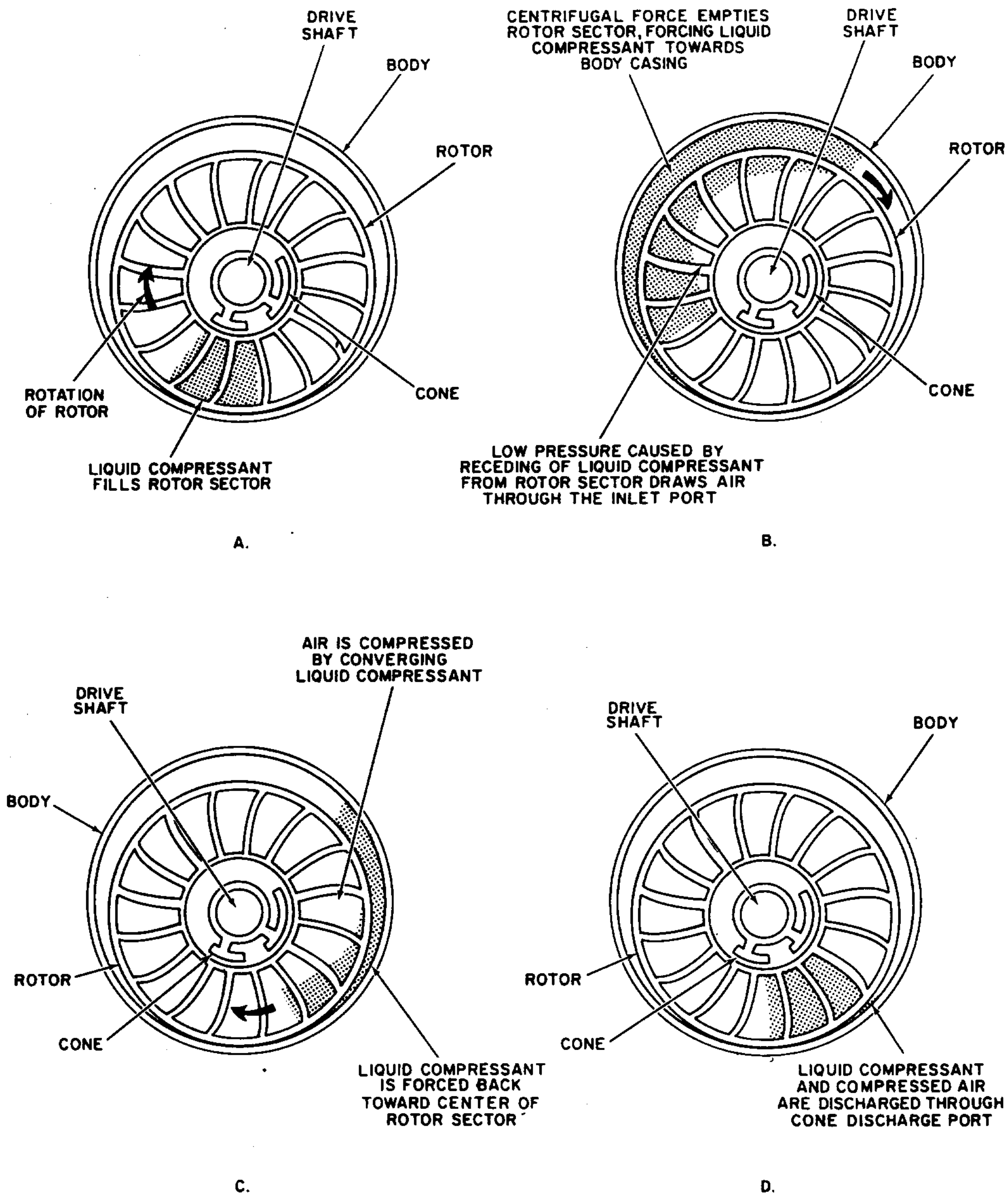


Figure 4

Steam Ejector

OPERATING PRINCIPLE

Motive fluid expands through a nozzle converting pressure to velocity energy. The motive stream contacts the fluid to be evacuated or pumped at the end of the nozzle in the suction chamber of the ejector. The resulting mixture enters the diffuser where velocity is reconverted to pressure at the ejector discharge.

Efficient use of ejectors may require the use of more than one stage of compression. Low absolute suction pressure, high discharge pressure, and/or low motive pressure may result in the use of multi-stage ejectors.

In a multistage ejector, the total amount of compression is divided between ejectors operated in series. The ejector into which gases first enter is called the first stage, and subsequent stages are numbered in succession. It is desirable to connect a condenser to the discharge of each ejector to reduce all condensable gases to the liquid state. Subsequent stages then compress only those gases which are non-condensable. Condensers between stages are intercondensers. A condenser at the discharge of the final stage is known as an aftercondenser. Inter- and aftercondensers may be either barometric or surface type.

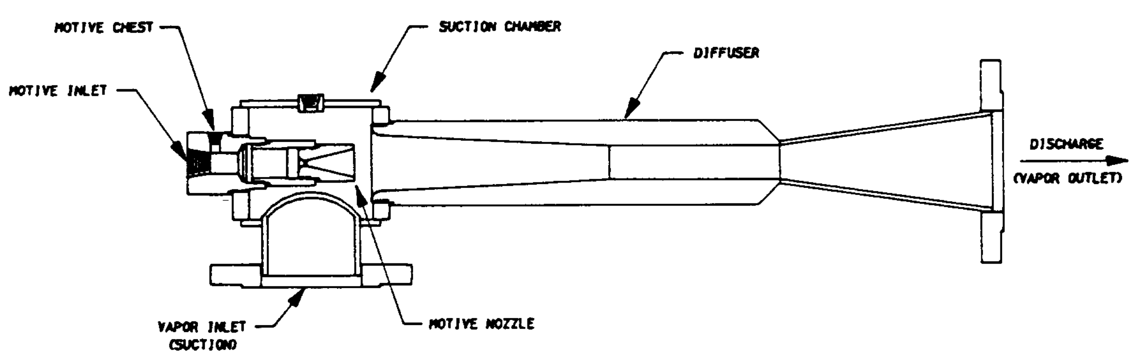
With a single stage ejector an aftercondenser may be used.

A two-stage ejector usually has an intercondenser between stages, and may have an aftercondenser. Where the desired capacity is small, or the motive consumption is not important, or space limitations exist, two-stage non-condensing ejectors with the discharge of the first stage connected to the suction of the second stage can be installed.

Three or more stage ejectors employ two intercondensers and possibly an aftercondenser. For limited capacity or hot water the intercondenser between the first and second stages of a three-stage ejector may be omitted and the discharge of the first stage connected directly to the suction of the second stage. For very low capacities or where motive consumption is of little importance both intercondensers may be omitted.

Intercondensers operate at sub-atmospheric pressures. It is necessary to provide means for draining the mixture of condensed fluids in a surface condenser and the mixture of the condensed fluids and cooling water in a barometric condenser.

An aftercondenser operates at atmospheric pressure and is provided with a vent to allow the air and non-condensable gases to escape. The aftercondenser will not improve the economy, but is used to recover the heat, condensate, or to prevent final stage discharge from being a nuisance.



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the system as the steam and vapor in the condenser are cooled to the liquid phase, the loss in the cooling tower through evaporation may be more or less than this. Therefore, depending on operating conditions, the tower may need water make-up or may overflow. As the tower operates continuously, water make-up is normally necessary except in very cold weather.

The cooling tower is also commonly used to cool the seal-water for the vacuum pumps. As the pumps rely on close tolerances to perform efficiently, seal-water must be filtered to remove any contaminants from the cooling tower. Normally a back-up supply of city-water is also available so that during filter changes or in very hot weather the pumps can continue to run efficiently. If seal-water gets too hot, boiling will occur within the pump and cause cavitation, recognizable as the sound of pebbles in the pump. Not only does this cause a loss in efficiency, but the rapid decompression during cavitation causes severe damage to the pump rotors.

Evacuation is normally controlled by wet bulb temperature within the chamber, but it can also be done by direct absolute pressure sensing. As the practical limit of the vacuum pump is about 2" HG absolute, a pressure sensor cuts in the steam ejector at this point. The ejector continues the evacuation process until an absolute pressure of 0.2" HG or 35°F on the wet-bulb sensor. This is the practical limit in a tight chamber.

Steaming

Once the evacuation process is complete, the chamber isolation valve closes and the ejector cuts off. The vacuum pumps continue to run to maintain condenser vacuum and to assist the water-flow from the cooling-tower. The steam valve now opens at a controlled rate and if saturated steam is required (normal) then the desuperheater operates to cool the steam to saturation point. This is important, as if superheated steam enters the chamber it will not condense immediately and have the effect of heating the tobacco and raising the pressure without adding moisture. Under certain conditions this is desirable, but normally the interior of the chamber, when viewed through the portholes, should appear to be fogged.

The desuperheater is mounted in the main steam line downstream of the control valve. Its function is to add finely atomized water to the steam to cool it to the saturation point. Although this is a precise requirement, in practice excess water is added to give slightly wet steam. The correct amount of water can be automatically controlled by measuring the downstream temperature and pressure and conforming to the saturated vapor tables.

A maximum temperature for steaming is normally set in the range of 140–160°F. There is no scientific formula for this, it is really a concern for staining and discoloration that dictates it. Once the set-point has been reached, a soak-time of 1–5 minutes is set. This gives the steam time to fully penetrate the package without raising the temperature further. If moisture is gained or lost by condensation or evaporation alone, the rule of 1% moisture change fore each 20°F temperature change applies. Thus, if tobacco enters at 75°F and is cooled to 35°F, it will lose 2% moisture. If it is then steamed to 155°F, it will gain 6% moisture, or compared to original conditions, the net gain will be 4% moisture.

Depending on the density of the package, the ambient conditions, the type of the tobacco and the initial condition of the tobacco, more than one cycle may be required to adequately condition. In this case, after an initial steaming and soak period, the steam supply is closed and the chamber re-evacuated, usually down to about 75°F to drive out any trapped non-condensables. A second steaming then occurs, usually to a lower temperature in the region of 120–130°F. This process may be repeated up to 4 or 5 times if necessary, but normally two cycles are sufficient. In each steaming cycle, once the set temperature is reached, the automatic control system supplies only enough steam to maintain that temperature for the duration of the soak period.

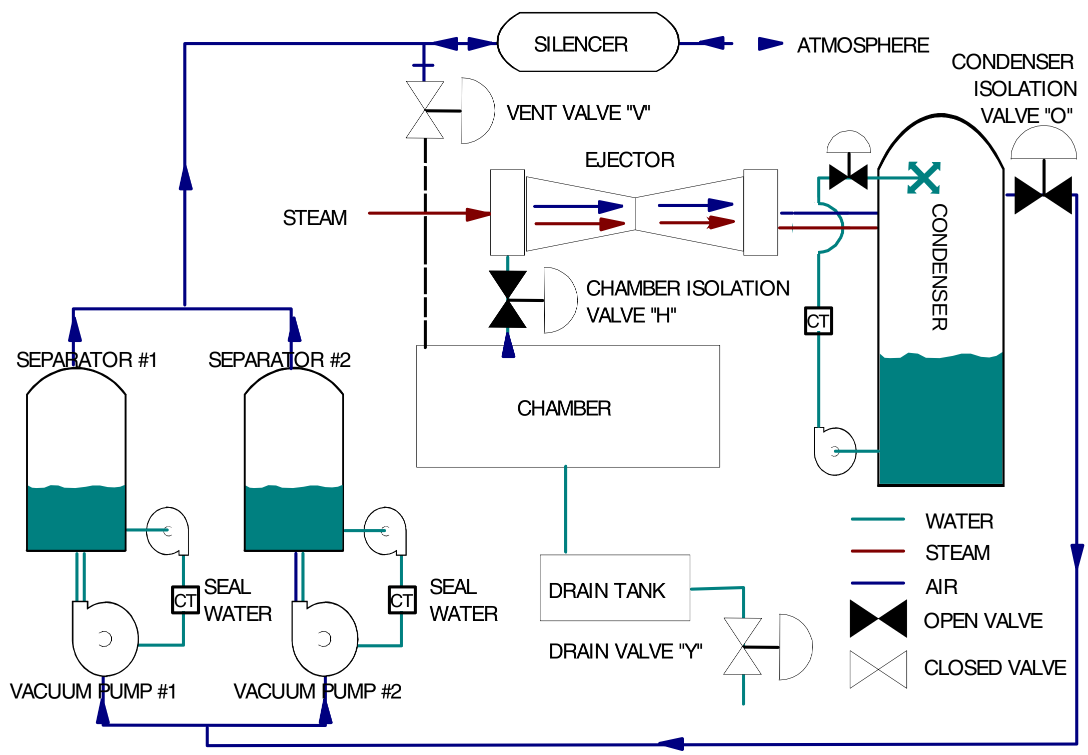
Note that the higher the final temperature of the tobacco, the more flash-off will occur when it is removed from the chamber. Flash-off is the limited evaporation of water caused by moving air currents and ambient conditions. Unless ambient conditions are at 100% relative humidity, some flash-off will always occur. Flash-off obeys the 20:1 rule for loss of temperature and moisture. If cold, dry ambient conditions prevail, the conditioned package should not be opened until it is ready for use, as the more surface area exposed, the more flash-off will occur.

Most of our vacuum chambers function without probes. Probes are stainless-steel perforated spikes which are driven down into the tobacco to assist both the evacuation and the steaming process by getting to the center of the package. Whereas they do accomplish this, for most purposes the benefits do not justify the additional mechanical complications presented and they are only used when very stringent bug-kill requirements must be met.

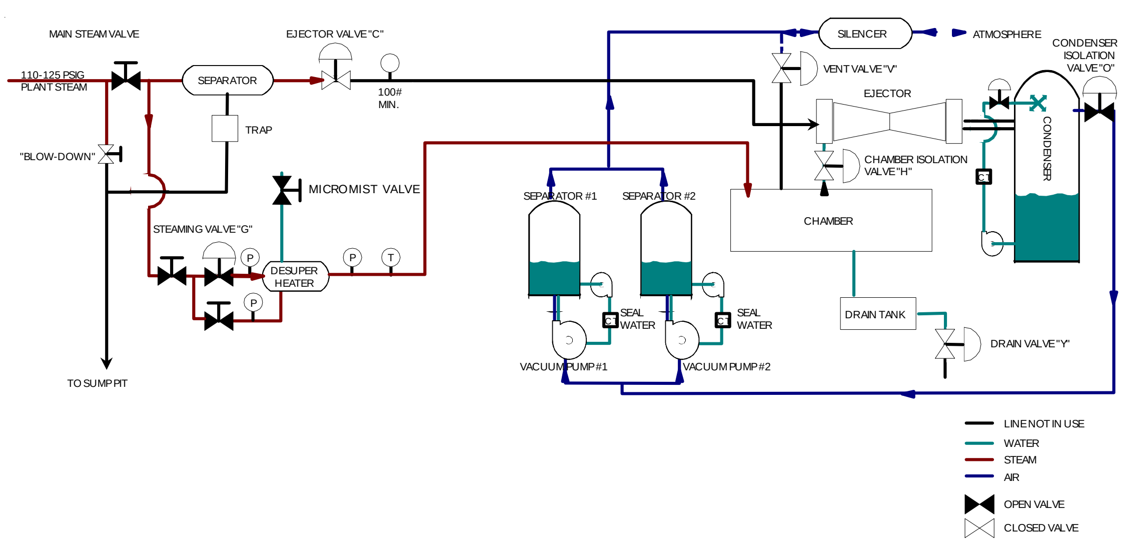
In recent years the trend in the primaries has been away from vacuum conditioning in favor of direct conditioning cylinders. This is because of the high operating costs and complexity of the vacuum system. In countries where tobacco is sold in loose-leaf form and bulk-fed into the system, this technique has been tried with promising results in stemmeries, but at this time it is not widely used.

Diagram—Vacuum System

Evacuation



Steaming Cycle



Blending

There are various methods of introducing the tobacco into the system once it has been preconditioned or otherwise prepared. The method is dictated by the type of package the product is packed in at the farm, whether it is in tangled leaves, straight-laid or tied, and whether tipping is required. These criteria are influenced by many factors including labor costs, type of tobacco, tradition and country of origin. However, there are really only 3 popular techniques:

Bulk-Blending

This is used in the U.S. and Europe where labor-costs are high, tobacco is mainly delivered in tangled-leaf form and tipping is impractical. It involves removing whatever covering there is on the tobacco and then placing the entire package on a conveyor-belt or dump-feeder to be broken apart and metered into the system. No real blending takes place in this system, although if the dump-feeder is large and tobacco is allowed to accumulate in it, some mixing occurs. Sometimes the package of tobacco is split mechanically or manually before the feeder so that graders can check for quality and foreign-matter.

Manual Feeding

When the farmers sort the tobacco by grade and straight-lay or tie the leaves in bundles, the option to tip is available. Tipping is the mechanical slicing of the leaves so that the tips can be handled differently from the butts. This has some advantages, because generally the heavy, objectionable portion of the stem is confined to the butt portion of the leaf. Tipping enables a large slice of the leaf to be salvaged with no further trauma and an acceptable fraction of objectionable stem. This contributes to the size of the final product while also reducing the load on the threshing line. When large leaves are tipped, the tip may be sliced into two or three pieces so that the final product does not contain objectionably large pieces. When feeding manually, accurate blending can be accomplished by having each blending person feed a specific grade. However, when tipping, most of the stem in the final product is contributed by the tips, so the threshing-line must be run relatively free of stem. Most tipping-tables consist of a conveyor portion about 50-100' long followed by the cutting assembly. This is normally a series of circular overlapping rotating blades and a chain or belt clamping mechanism to secure the leaves. If the tobacco is tied, the butt portion of the bundle then passes through a drum-type cutter which cuts the tie-leaf.

Slicing with direct cylinder conditioning

This method is still under evaluation, but demonstrates certain advantages. For small farmer bales (<150LB) no slicing is required, and unconditioned tobacco which is not tied can be fed directly to the DCC. For larger packages, the package is first sliced into 150–200LB slabs by means of a vertical or horizontal slicer and then fed to the DCC.

After the tobacco is broken down into individual leaves by one of the above systems, except for the case of the DCC, it is further conditioned in an ordering cylinder, goes through a control feeder/weighbelt to picking, and is ordered one more time before threshing. The reason for the three steps in conditioning is because in each interim step the tobacco cools off and dries out.

Picking

Some years ago picking was a major part of any leaf-tobacco processing facility. Great emphasis was placed on color and stalk-position and in a typical plant, 40–80 people were involved in meticulously inspecting each leaf. The rising cost of labor led cigarette manufacturers to re-examine the benefits of this, bearing in mind that almost none of the picked leaves was ever discarded but simply reclassified to another grade or packed until its color improved. The first change to address this was the incorporation of electronic pickers instead of humans, and most U.S. and European plants were equipped with these in the early 1970s. They did a surprisingly good job at rejecting specific colors, but were no better than the operator set them to be and required meticulous maintenance. With the increasing pressure on the tobacco industry and potentially damaging lawsuits, the emphasis has now shifted to inspecting the product at various points to make sure no non-tobacco material is left in it. Although manual inspection at each point in the process is still the most effective means, this has been reinforced with strong farmer and employee awareness programs, magnets, metal-detectors and more sophisticated electronic scanning devices. However, the main searching area is still at the point after primary ordering. Most plants have now abandoned the concept of dividing the flow over multiple parallel conveyors in favor of a series of wider conveyors handling the full flow. Although the carpet of tobacco is deeper, the attractions are less space, less equipment, less downtime and the fact that several people look at the same tobacco, so what the first may miss, the second should get.

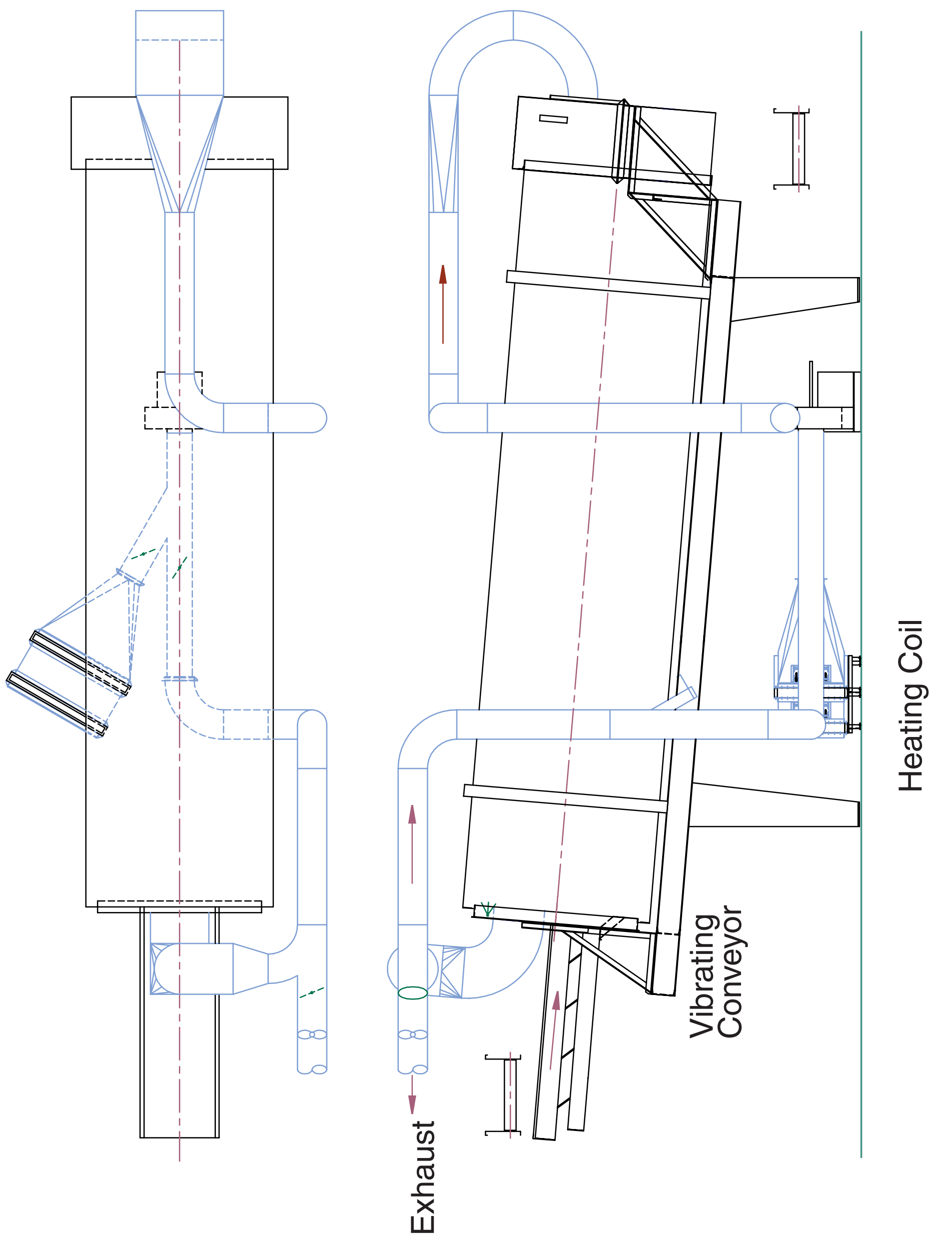
Conditioning

The final ordering is the critical step before threshing. The ordering cylinders are sized to give a specific residence time and fill ratio. Most cylinders are inclined downhill, at 5° and rotate at 14–16 RPM. For a 32' cylinder of 6' diameter, the residence time is 4.1 minutes. The fill ratio at 15,000 LB/HR is 56%. For smaller flows, smaller cylinders are used and for high flows, larger. If the cylinder is too empty, the steam tends to condense more on the cylinder than the tobacco, and if it is too full, there is poor exposure and roping problems may occur.

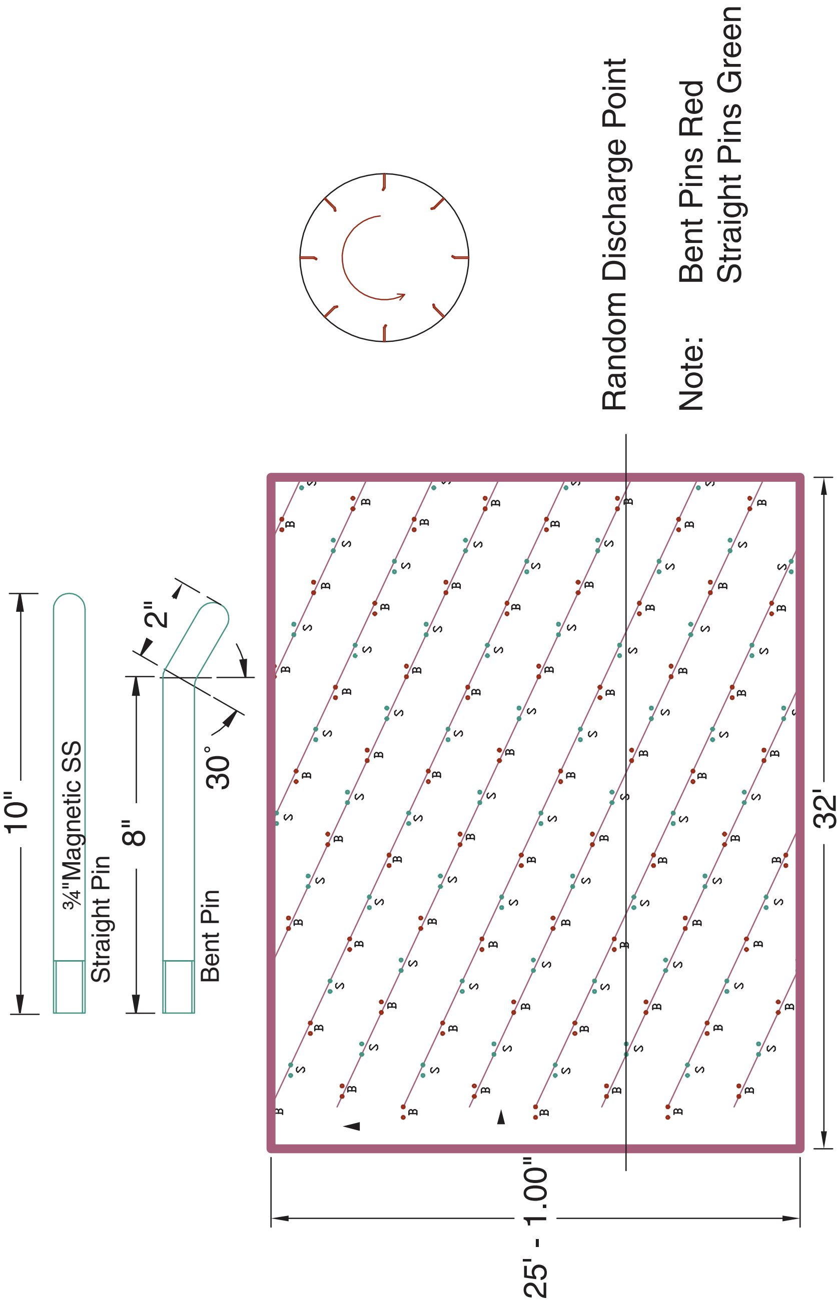
The principle of the ordering cylinder is very simple. The tobacco is lifted and dropped by the pins as the cylinder rotates and the humid environment inside the cylinder causes each leaf to absorb moisture and gain heat. If this is accomplished by steam alone, the 20:1 law applies. If atomized water is added, this does not hold true anymore.

The arrangement of pins is important. The objective is to have only a small amount of tobacco falling away at any given angle of the drum rotation. In this way, each leaf is separated and acted upon individually and the stem has an adequate amount of exposure. This gives an exit product in which the lamina and stem moisture are fairly close. As the tobacco travels from the cylinder to the thresher, moisture flashes off the lamina faster than off the stem due to the different surface areas. Within the thresher, the stem is pliable enough not to break and the lamina pliable but not soaked. This threshes well, and makes the job of separation easier as the surface-area to weight ratio difference between lamina and stem is quite distinct.

Ordering Cylinder



Ordering Cylinder Pin Arrangement



The atmosphere within the ordering cylinder is controlled by temperature and humidity. For different products, different atmospheres are required. By varying this atmosphere, the tobacco moisture can be increased or reduced and the final temperature can be controlled.

The environment within the cylinder is affected by the amount of steam injected, the amount of atomized water added and the amount of heat added via a heat exchanger. It is also affected by the direction of air flow in the cylinder and the amount of fresh air vs. recirculated air used.

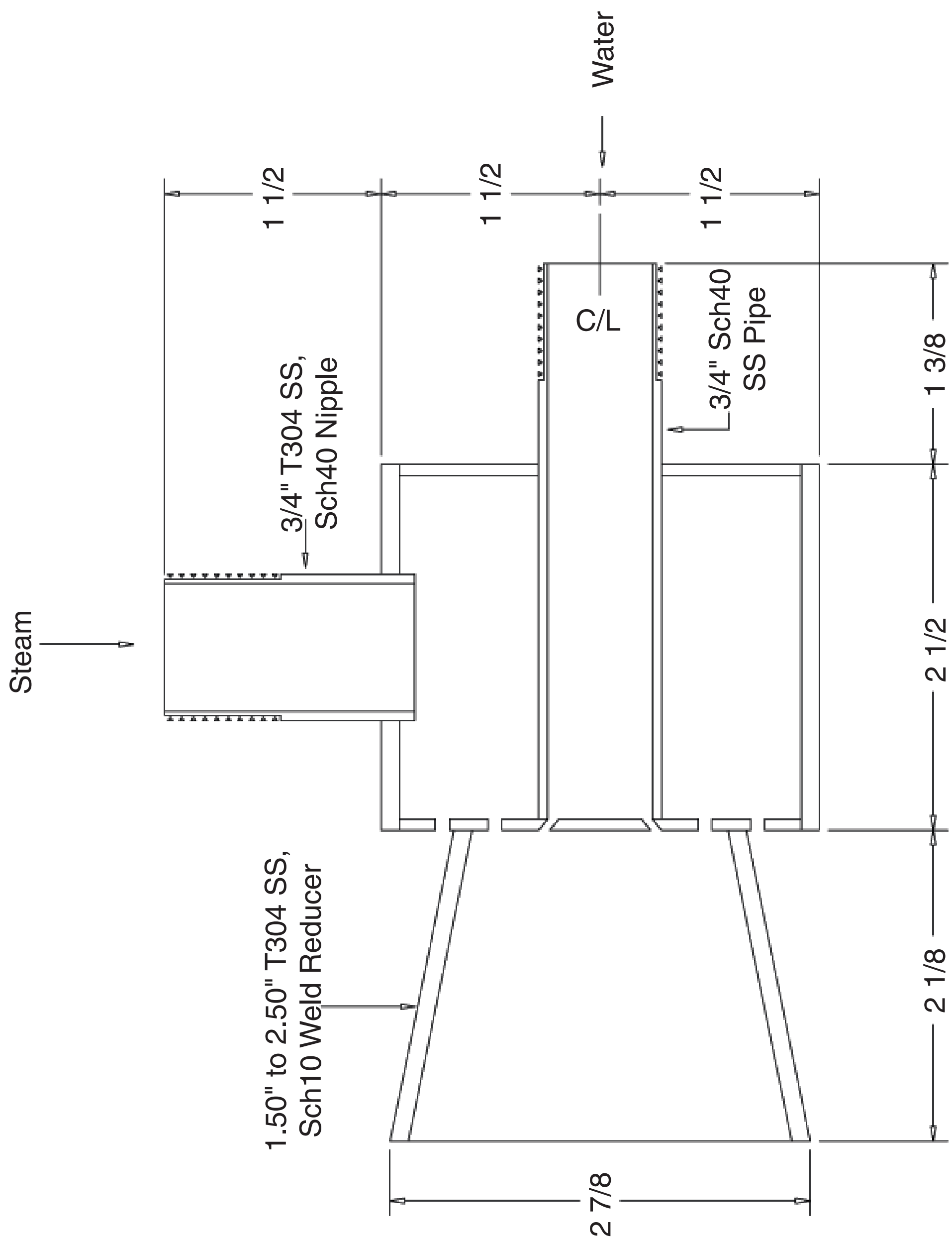
For normal conditioning of flue-cured tobacco, for a typical moisture gain of 2–3%, the latent heat of condensation from the steam is sufficient to raise the temperature to 130–140°F. In this case the heat exchanger is only necessary to preheat the drum to avoid excessive condensation on start-up.

In the case of burley tobacco which often arrives very cold with an excessively high moisture, the drum actually becomes a dryer. In this situation, the heat exchanger draws fresh air and heats it to 250–300° F, providing a hot, dry atmosphere to heat and dry the tobacco. Moisture-laden air is removed via an exhaust.

In the cases where a high moisture gain is required without getting too hot, water is added to the atomizers to provide moisture with low heat gain.

Atomizers are normally placed at both ends of the drum, directed along the axis of the drum. In

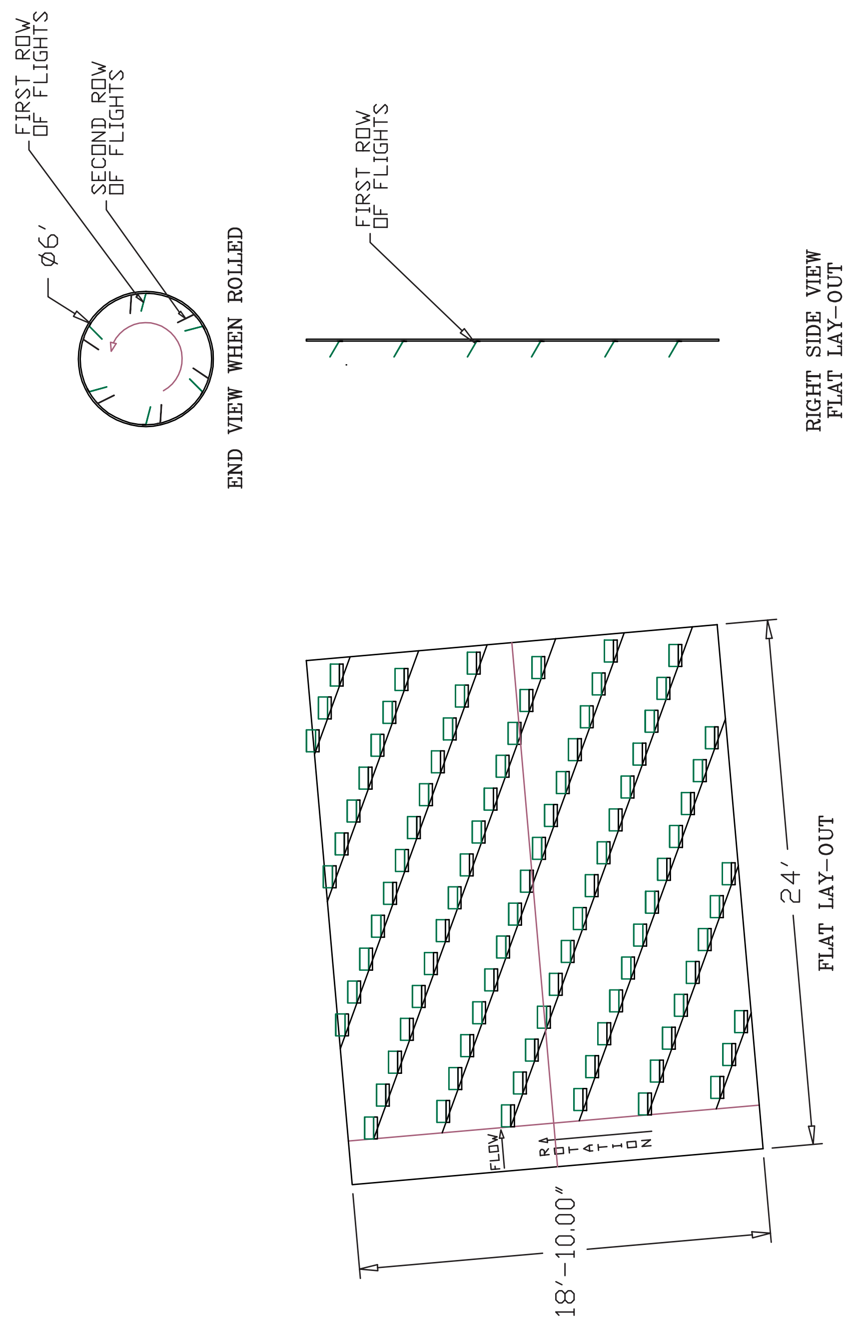
Rosemond Nozzle



recent years most drums have been equipped with the PM Rosemond atomizers. These have the advantage of giving good atomization of the water without the clogging problems encountered with the traditional Cardwell atomizers.

There continues to be controversy regarding the correct air flow direction through the drum. The air flow is required to give a uniform environment within the drum and in drying mode, to dry and remove moisture. Most existing drums have air flow direction opposite to the tobacco flow, i.e., the hottest air encounters the hottest tobacco, giving a higher exit temperature. However, in instances where it is necessary to heat the tobacco immediately to avoid breakage, a concurrent air flow is preferable. This has the added advantage of reducing scrap entrainment and allows a higher moisture gain without excessive exit temperatures. The higher the difference between the exit temperature and the environment outside the drum, the more flash-off will occur, causing the lamina to dry and cool according to the 20:1 ratio.

Tip Drum Flight Arrangement

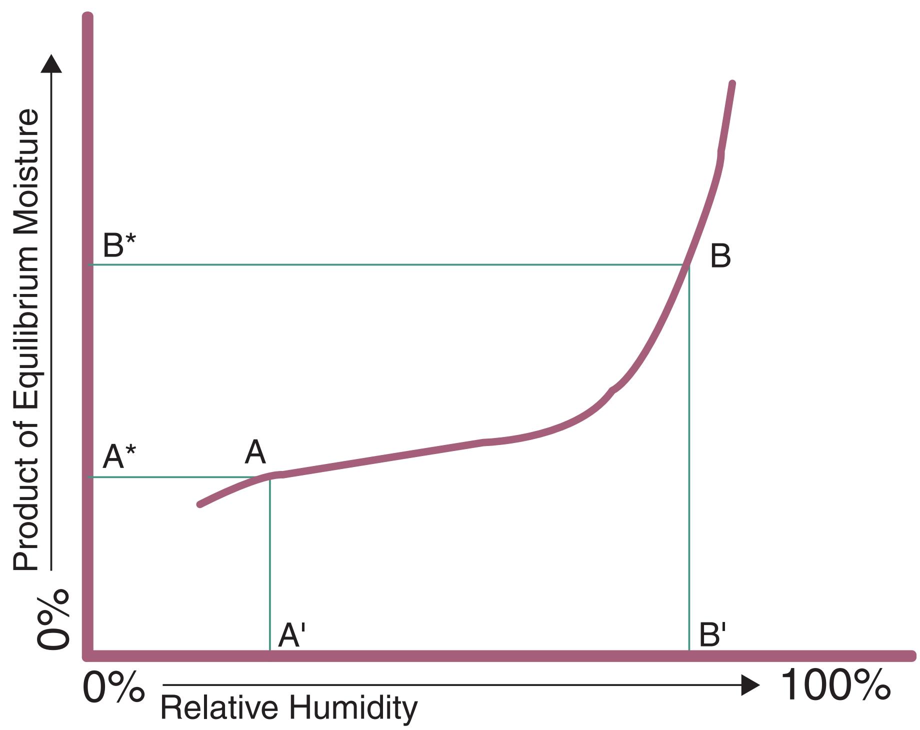


Moisture Equilibrium in Cylinder Conditioning

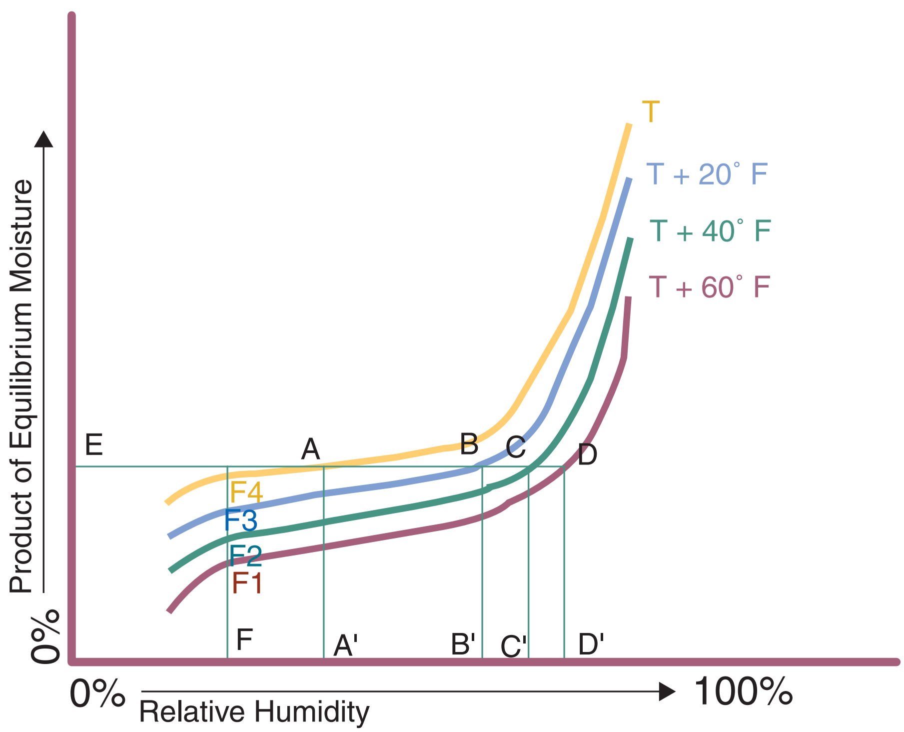
Tobacco is a material that absorbs or gives off moisture depending on the environment. The main factors affecting this environment are temperature and relative humidity. For a given temperature and relative humidity the lamina and stem will eventually come to an equilibrium moisture, such that no further changes in moisture will occur. Different stalk positions, varieties, and individual components of the leaf have different equilibrium moistures.

In the case of conditioning, the leaf absorbs moisture, for the environment around the leaf is laden with moisture. In the case of drying, the environment around the leaf is low with moisture. The basic mechanism for determining conditioning or drying is the water vapor pressure differential between the environment and the tobacco. When the water vapor pressure is greater in the environment than the tobacco, conditioning occurs; and when the water vapor pressure in the tobacco is greater than the environment, moisture moves from the tobacco to the air and drying occurs. The speed, or how quickly the moisture change occurs, depends on the quantity of the differential and the surface conditions of the tobacco component. Most changes in moisture at a stemmery occur within minutes. This is not enough time for the product to come into true "moisture equilibrium." However, if a few fundamental concepts are considered, then one may be able to move the process in the desired direction as far as moisture gain or loss is concerned.

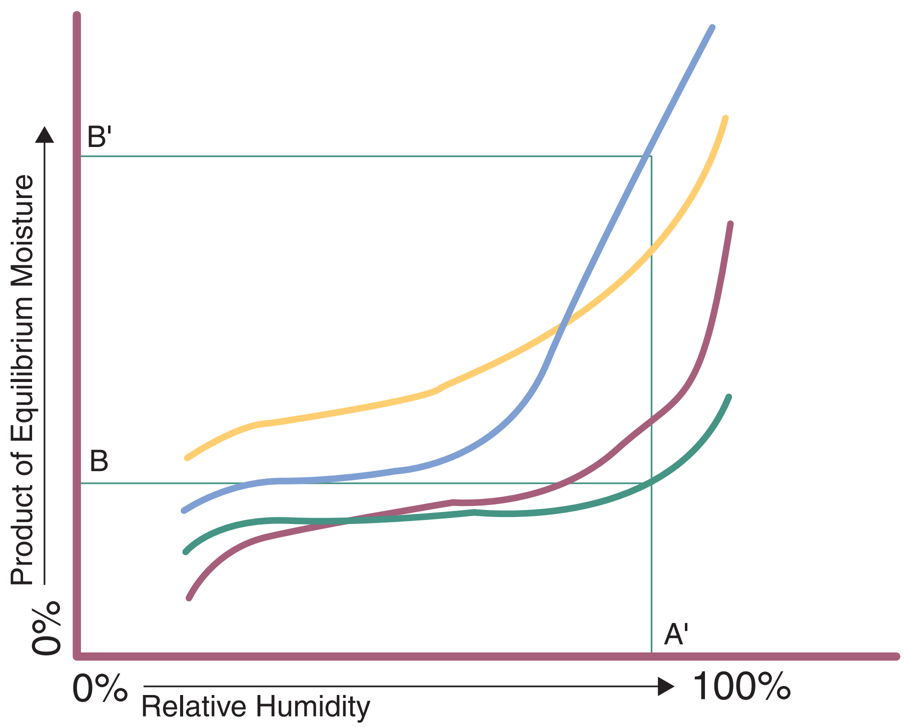
Typical Equilibrium Moisture for Tobacco at Constant Temperature



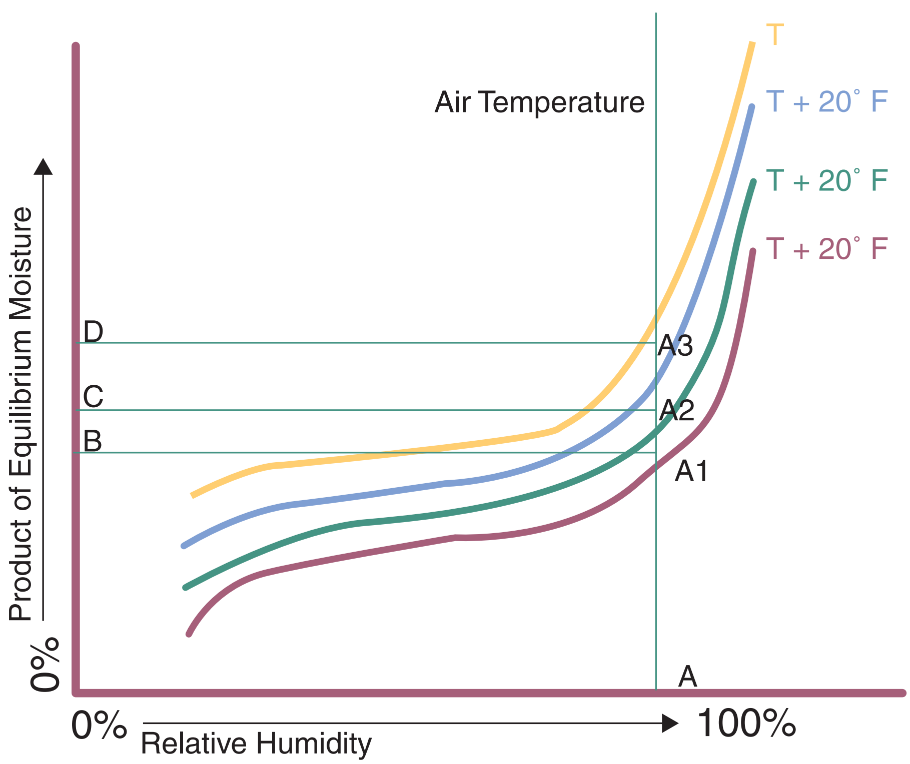
Typical Equilibrium Moisture for a Tobacco Component at Different Air Temperatures



Typical Equilibrium Moistures at One Temperature for Real Life Stemmery Production Runs



Typical Equilibrium Moisture at Different Air Temperatures



Feed Regulation

For any device to work at peak efficiency, it is necessary to have consistent operating conditions. Ideally, tobacco should enter the system at a uniform rate. The flow at the start of the system is controlled by a weighbelt and feeder combination, but in going through the picking and re-ordering processes, flow disruptions occur. In order to smooth these out again, another feeder is necessary just prior to the threshers. This serves two purposes:

1. To provide a consistent flow to the threshers.
2. To spread the tobacco uniformly into the threshers.

Various spreading devices are used, depending on the width of the system. The most effective to date has been the sweep feeder, which wipes the tobacco off a troughed belt at regular intervals. This must be precisely synchronized to function correctly, and the tip speed of the sweep must be in the range of 150–200 feet per minute in order to get a clean sweep. Depending on the width of the system and the flow rate, single and double sweeps of different diameters are required.

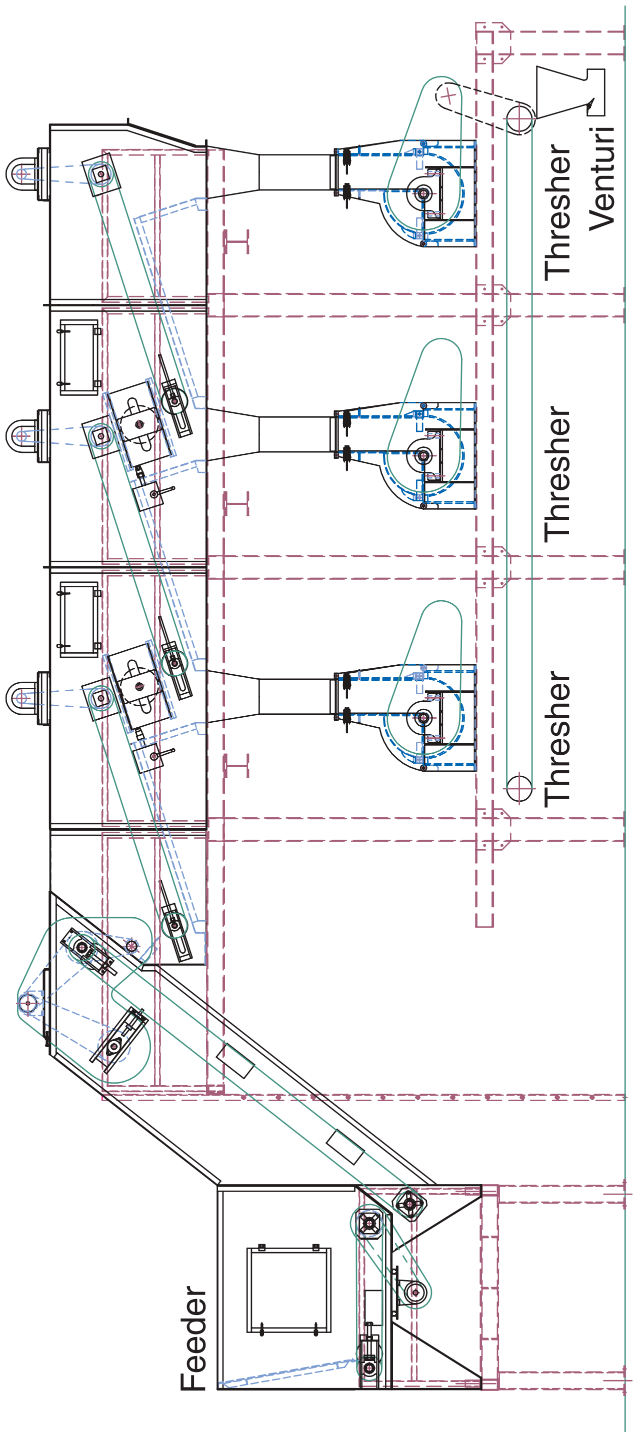
Silo/feeder systems controlled by weighbelts prior to the picking systems are very useful in controlling feed, blending and equilibrating moisture.

Regulating feeders have a small hopper section to provide a reservoir of tobacco and an incline section fitted with rakes to lift the tobacco. A doffer wipes back excess tobacco to theoretically provide a carpet of constant width and depth. The two feeder belts are variable speed systems so that the flow is proportional to the speed for any given doffer setting. In order to function correctly, there should always be enough tobacco in the feeder to provide full coverage of the incline belt and some contact with the doffer. This is accomplished by matching the speeds of the belts to the production coming from the blending line. Once set up, these speeds should not be changed unless there is a problem with one of the threshers and production must be reduced. Feeders running too fast with bare spots on the incline will not give a consistent flow to the threshers. Feeders running too slowly will build up tobacco against the doffer and will eventually choke or trip.

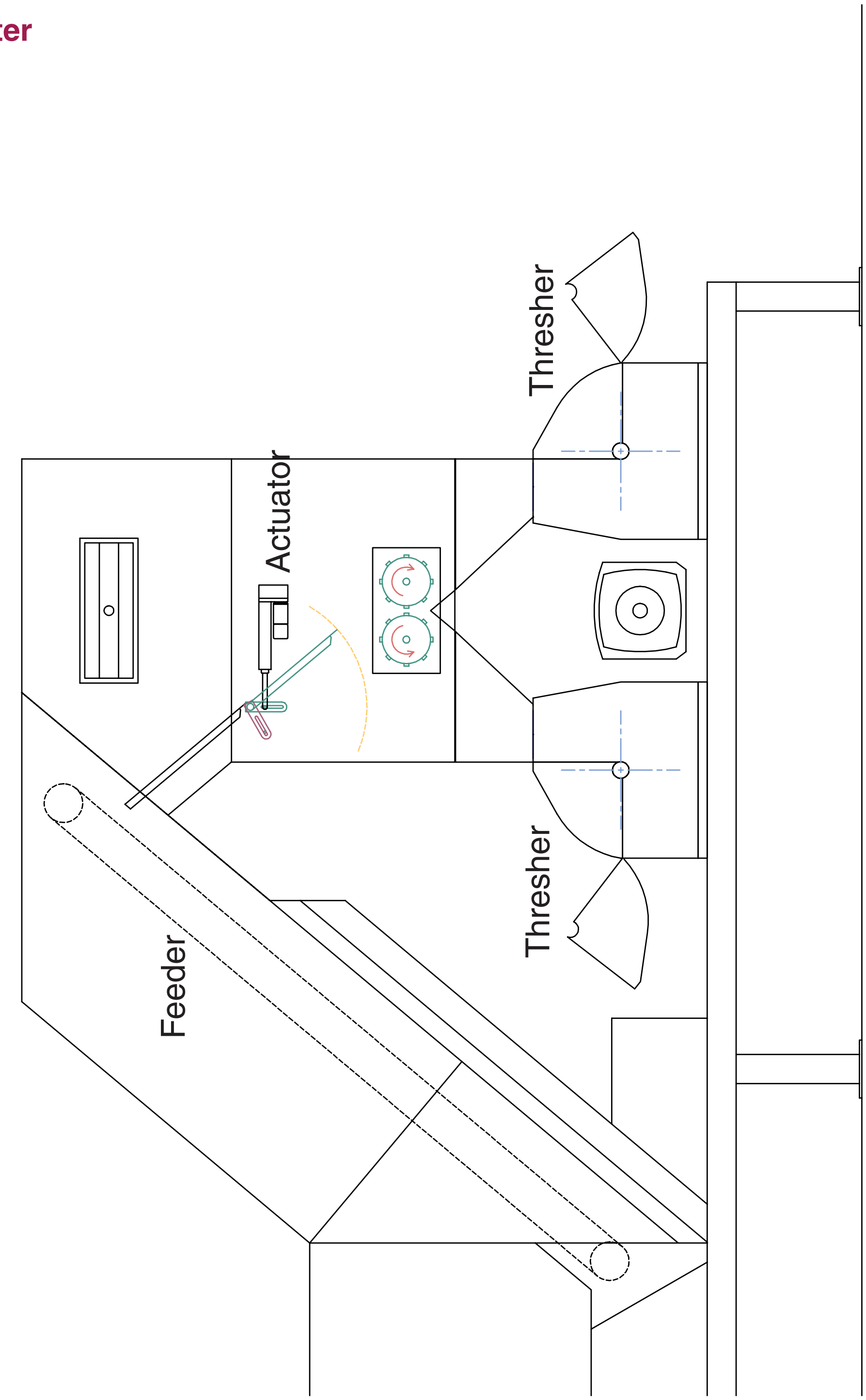
The feeders themselves must be designed correctly. The normal degree of inclination to give a clean roll back of excess tobacco is 50–55°F. The pins on the rakes must be properly spaced at about 3–4" and about 2½–3" long. The pin bars must be spaced at about 6", giving a large enough "pocket" for the tobacco to fall into but a small enough interval between bars so that the discharge is not intermittent. When multiple lines are being fed from one supply system, care must be taken to ensure that each line receives an equal flow. Also, when one feeder supplies multiple threshers, the flow must be divided equally. This is difficult to judge by eye or by monitoring motor power usage, but a combination of both methods is the best that can be used in the existing set-ups. Ideally each thresher should be fed by a separate weighbelt system.

In multi-line systems, the doffers in all feeders should be set at the same height and an accurate means of measuring incline belt speed should be supplied. The most accurate speed measure is via a motion detector device fitted to the tail roller of the incline belt. The vital importance of consistent feed cannot be overemphasized.

Proportional Feeder/Splitter



2 Doffer Splitter



Transport Systems

There are various methods of transporting solid particulate products. The conventional conveyor belt is excellent, but in threshing lines, except in the case of our new Multiseparator system, takes up too much space. Most threshing lines rely on pneumatic transport systems to convey product from one machine to the next.

The typical pneumatic transport system has three basic components:

1. The loading device (venturi or airlock).
2. Power system (centrifugal fan).
3. Unloading device (screening separator or tangential separator).

These must all be designed and sized correctly for the particular conveying requirements. As a rule of thumb, for most leaf tobacco an air speed of 4,000 to 4,500 feet per minute is necessary, and a loading factor of 1 LB/HR of tobacco per 1 cubic-foot per minute (CFM) of air. Tobacco will remain in suspension at lower speeds and higher load rates if its size and moisture are appropriate, but to handle the ranges required for all conditions, the above guidelines have proven true.

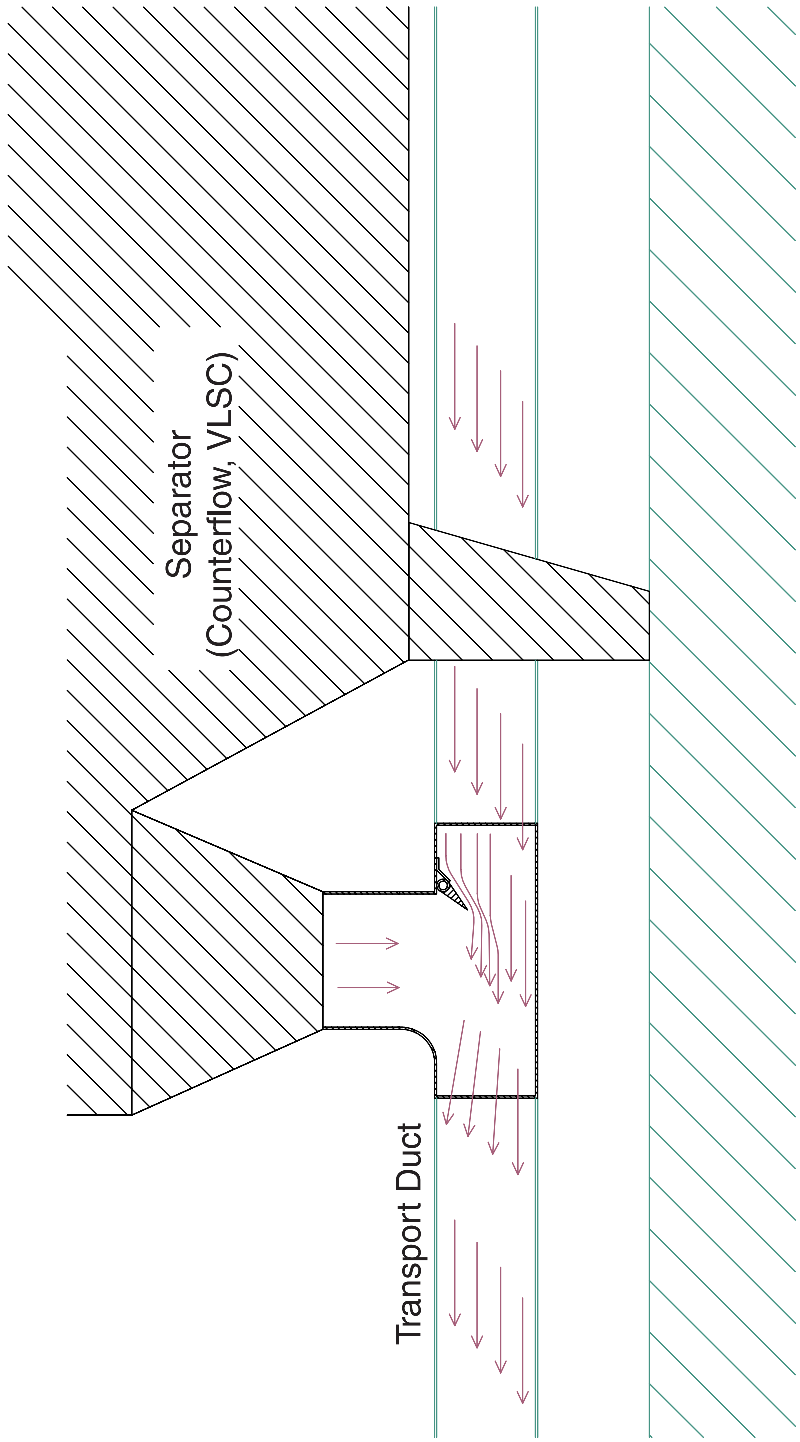
The Loading Device

The loading device design is most important. The venturi system is most commonly employed, and utilizes the basic fluid dynamic principle of increasing velocity to lower pressure. When correctly set up, the pressure in the throat of the venturi is negative compared to the ambient above it, which causes a flow of ambient air into the system. This gives a smooth loading device which induces the tobacco into the recirculating air path. The relationship between the width and depth of the duct, the length of the venturi deflector blade and the depth of the throat are critical and must be carefully designed. Also, the ductwork carrying the tobacco must be correctly sized and equal in area for the route. Any sharp edges, poor alignment or tight radius elbows are potential problems.

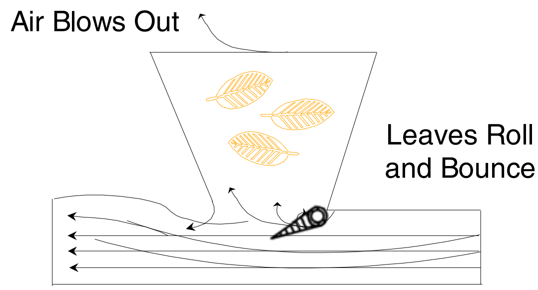
As the venturi induces ambient air, this must be removed again somewhere in the circuit. This is accomplished by means of the bleed-off system, which serves this purpose and also removes fine sand and dust from the circuit. The bleed-off is normally mounted tangentially on the fan scroll in order to take advantage of the cyclone effect within the fan, which forces all solid particles to the outer perimeter. As air is being removed from the transport loops, if they are all interconnected via separators, a net removal of air from the system occurs. Except for the first-stage threshers, the system is not open to the atmosphere. Therefore, to avoid air being induced via the airlocks and/or an excessive negative pressure, it is desirable to provide some means for ingress of fresh air. This keeps the system cooler and cleaner and does not lower the density of the separation air. Air is normally introduced in the plenum chamber of the separator in order to avoid extreme temperatures in the separator and to assist with airflow from the separator to the transport circuit.

Airlock loading can be accomplished without a venturi, as no air is induced and the system is not open to atmosphere. However, it is wise to provide a small "kicker" before the loading point to avoid system back-pressure on the airlock. This is necessary when the static pressure in the duct below the airlock is higher than the ambient pressure above the airlock.

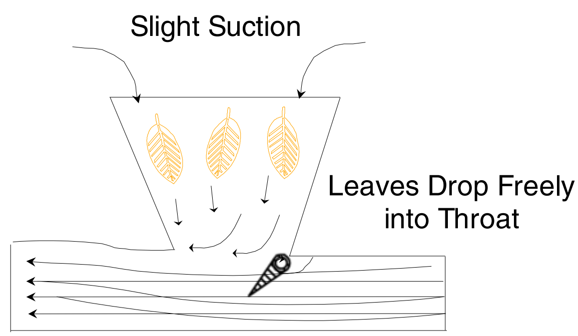
Typical Venturi Loading System



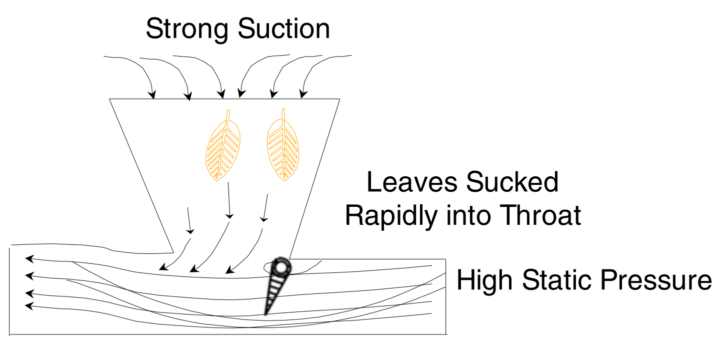
Typical Venturi Adjustments



Venturi with Damper Too Far Open

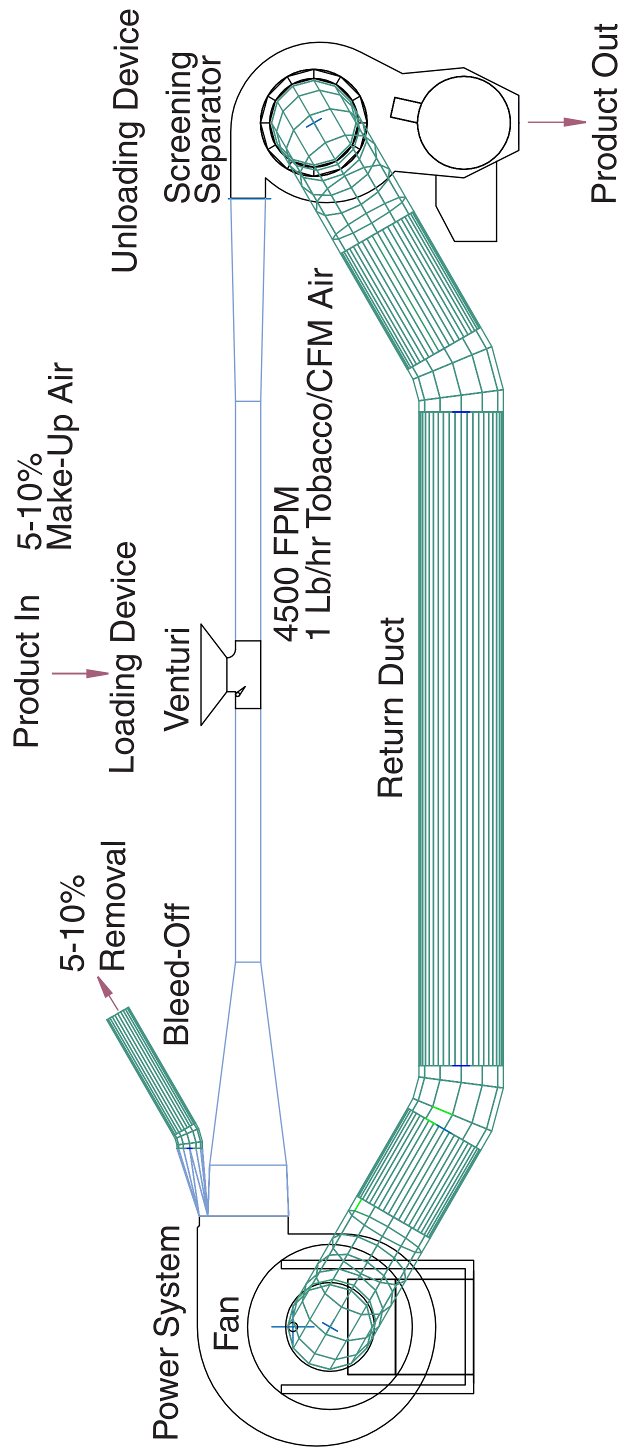


Correctly Adjusted Venturi



Venturi with Damper too Far Closed

Typical Air Transport Circuit



The Power System

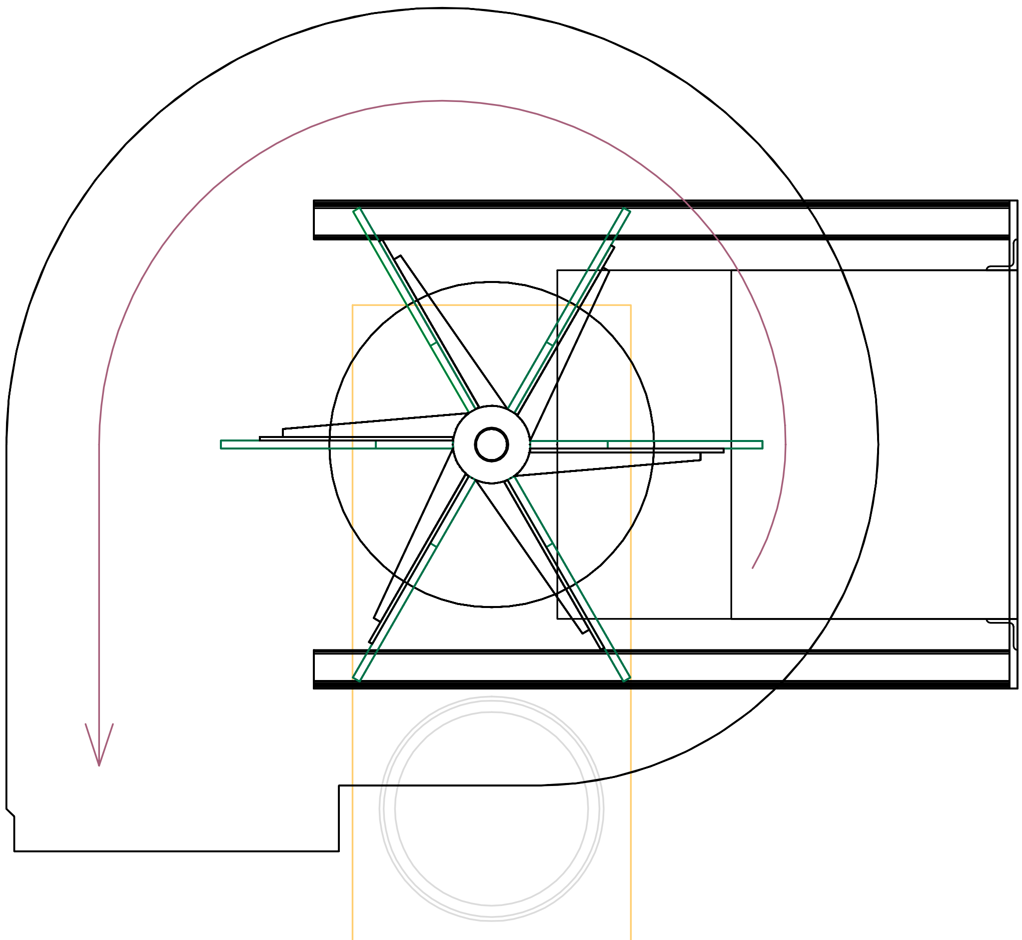
The fan is the power system which provides the energy to transport the tobacco. All conventional systems are powered by centrifugal fans, which work on the slingshot principle. There are various impellers available for centrifugal fans and the correct impeller must be chosen for the application required. The most efficient impellers are the closed type with reverse swept airfoil blades. However, the clearances in these are tight and they can only be used where there are no large particles in the air-stream. The more popular type is the paddle wheel, which is far less efficient, but is able to handle particulate up to two or three inches in size without problems. As for one reason or another there is always the possibility of large particles entering the fans, the paddle wheel is the most widely used. However, in cases where the particle size is small or the fan is handling filtered air, the closed impeller is used to save energy. Fans are in many ways comparable to centrifugal pumps. As the resistance to flow increases, the flow decreases and the power used decreases at any given speed. It is most important that these fans are fitted with the correct impeller for the housing and that they rotate in the correct direction. Fans running backwards are a major cause of choke-ups, as they deliver only a small percentage of the design flow.

Fans are normally sized according to the flow and static pressure requirements of the system. Whereas the objective is to pick the fan which is the most efficient under these conditions, in order to standardize as much as possible we allow some flexibility here.

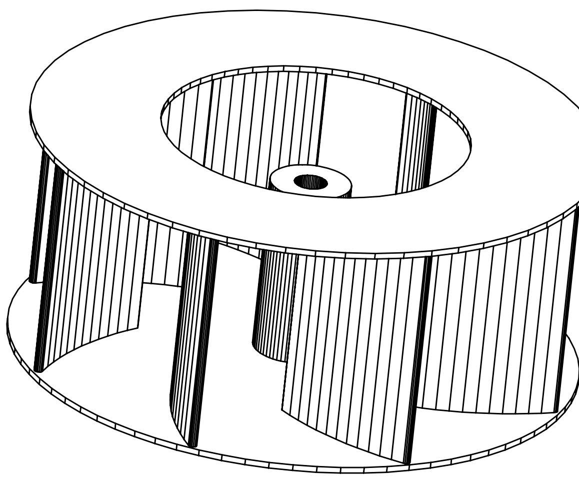
The criterion for lifting or carrying tobacco particles by air is the velocity pressure of the air. This is directly proportional to the air density and proportional to the square of the air velocity. Thus when fan speed calculations are made, the altitude and operating temperature must be taken into account in order to arrive at the required velocity to give the necessary velocity pressure.

The most important factor affecting fans is balance. A well balanced fan will give years of trouble free service, but even a slight imbalance will place severe stresses on the bearings and drive components.

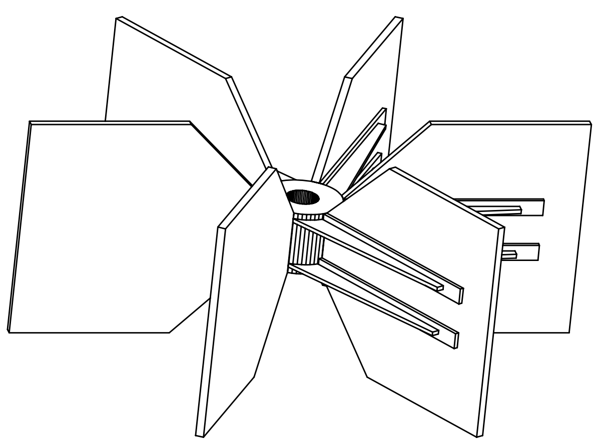
Typical Centrifugal Fan



Fan Rotation

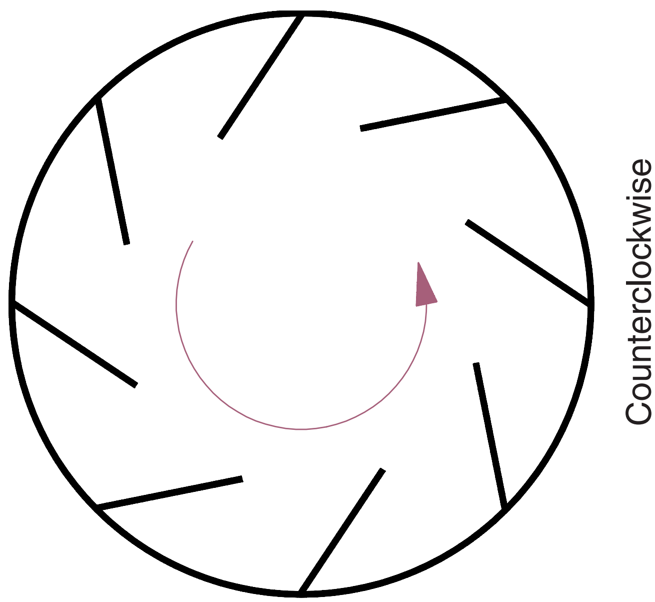


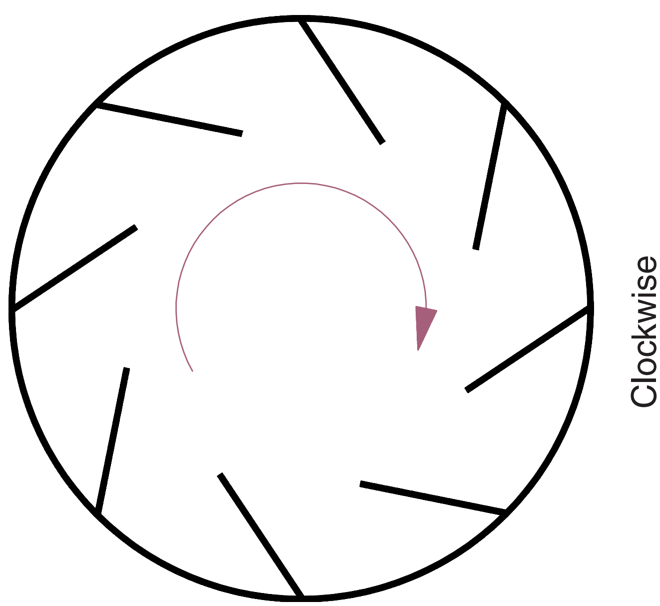
Closed Impeller



Paddle Wheel

Fan Rotation—Looking at Suction Side





The Unloading System

The unloading system is the device which removes the tobacco particles from the high velocity air stream of the transport duct. Almost all unloading devices work on the cyclone principle, i.e., centrifugal force causing heavier particles to be moved towards the outside of a rotating air stream.

The two common devices used for this purpose are the tangential separator and the screening separator. These are effectively horizontal cyclones with an airlock placed tangentially to skim off the solid particles.

The tangential separator has only one moving part, the airlock. The air enters tangentially and is forced to rotate by the housing curvature. The exhaust is via a system of blades or baffles in the center of the machine which straightens the air out again before it enters the fan.

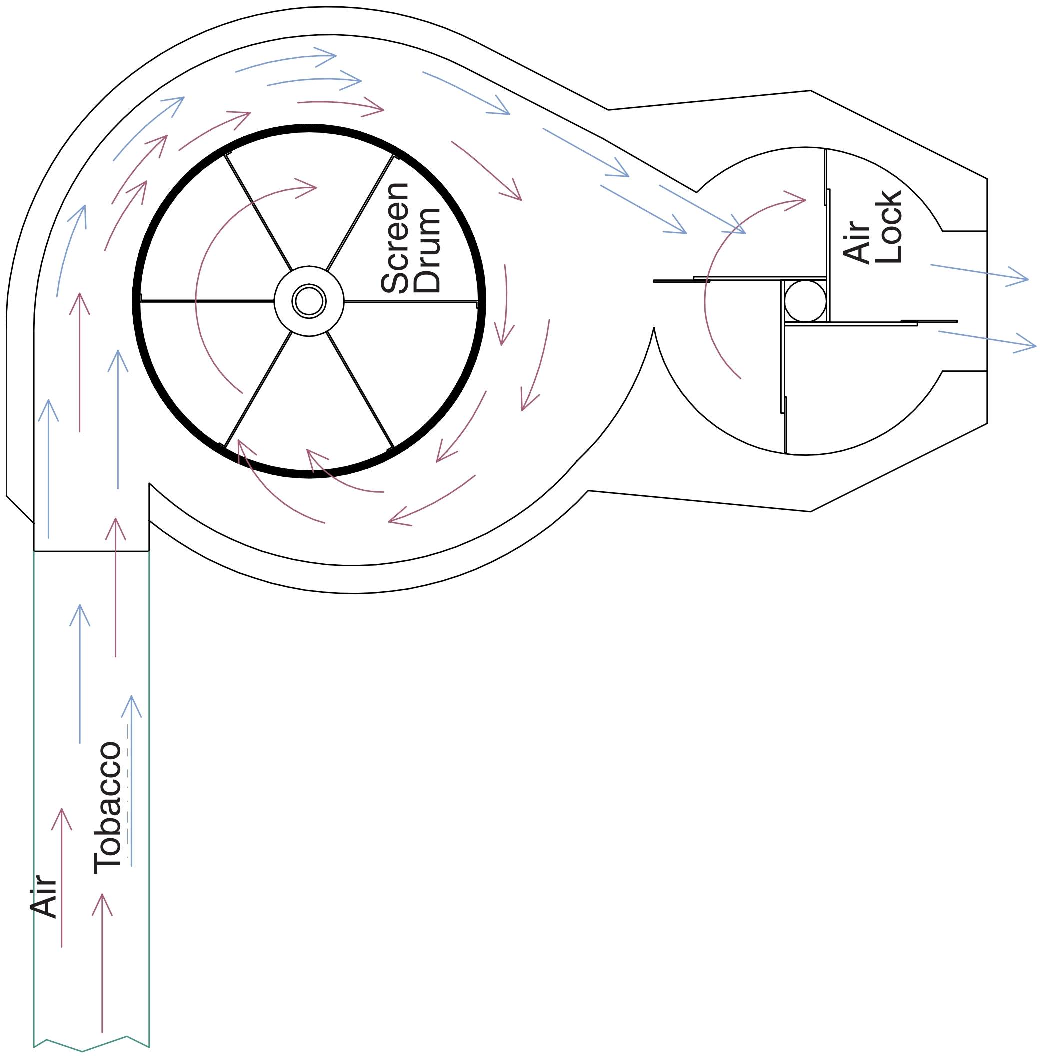
The design of the straightening devices affects the efficiency of the machine and also the resistance to the airflow. The double-air-diffuser (DAD) unit is the least efficient (in terms of solid particle retrieved) but has the lowest pressure drop. The "rosebud" is in the middle, and the "squirrel cage" is the most efficient with the highest static loss. Most of our applications employ the rosebud, but care must be taken to get the rotation correct. Installing a left-hand rosebud in a right-hand position will raise the static loss tremendously.

In recent years the screening separator has replaced the tangential separator in all new installations. It is more efficient in particle removal and has a lower static loss. It does have two moving parts, the screen and the airlock, normally driven from the same motor. It is also lower in profile, allowing it to fit in tighter spaces than the tangential separator. The one drawback is that the screen must be fitted with one or two rotating seals (depending on width) and these wear, allowing particulate matter to enter the fan which causes yield loss, wear, contamination of downstream devices and choke-ups.

The screening separator also works on the cyclone principle, but the perforated rotating screen prevents solid particles larger than the perforations from entering the fan. As the screen rotates, the flow of incoming product continuously wipes and cleans the screen and the rotary motion also makes it difficult for particles to build up on the screen. The standard screen has perforations of ⅛" Ø at 3/16" centers. For scrap applications, this is reduced to 1/16" at 3/32" centers.

Most problems in transport systems are caused by insufficient air flow. This can be due to low fan speed, belt slippage on fan drive, holes in the duct work or obstructions in the duct. Other causes are misalignment of mating flanges or clean-out doors, incorrect damper settings in venturi(s) or insufficient bleed-off.

Screening Separator



Threshing

This is the mechanical means of removing the lamina portion of the leaf from the stem. Over the years a multitude of ingenious and amazing devices have been invented to do the job, but to date nothing has been found to beat the conventional rotary thresher/basket combination that has been used for many years.

We have done a great deal of tinkering and testing on conventional threshers, including high speed filming of the action. From these high speed films, a number of conclusions can be drawn:

A. The threshing action appears to occur when the moving tooth strikes the stationary leaf. This is a tearing or ripping action and does not appear to be significantly affected by the design of the tooth as long as the corner is square and the thickness is ¼" or less.

B. On initial impact, the tooth throws the leaf against the flat door of the thresher, where it stops and falls vertically until it enters the pinch-point where the tooth strikes it again and drags it across the basket. Further tearing and ripping occur here.

C. The basket does not appear to play much part in the threshing action. Its primary function is to act as a screen to determine the size of particles that leave the thresher and cause the larger particles to be recirculated for further threshing. This basket size of course also determines the amount of product which is resident within the thresher at any time. The more product within the thresher, the more grinding rather than tearing will occur, resulting in more scrap generation.

D. The stationary, or door teeth, do not appear to play a large part in the threshing process, but they do serve to break up pads and prevent basket damage. In some respects they are detrimental, as the combing action tends to break stems which make separation more difficult.

As described earlier, the two most important criteria in threshing effectively and consistently are conditioning and flow. In order to tear rather than shatter, the lamina portion of the leaf must be soft and pliable. There is no magic formula for this, as each leaf behaves differently. However, as a general guideline, the lamina should be in the 18–22% moisture range and the 100°–120°F temperature range entering the thresher. The stem should be moist enough to bend freely without breaking. Under these conditions the impact of the tooth on the leaf tears the lamina off the stem without breaking the stem. If the leaf is too wet it will become heavy and sticky and tend to agglomerate in lumps, resulting in choking and grinding.

As the thresher is very sensitive to loading, it is vital to load it at the optimum rate consistently and also uniformly across its width. Any fluctuations in flow and/or distribution will cause problems down the entire line. Thus the feeder loading the thresher(s) must have tobacco spread across its full width and must run at a constant speed.

There have been thousands of tests done on threshers to determine efficiency and particle size. Again, there is no magic formula or setup. As a general statement it is true to say that efficiency increases with loading and particle size decreases. However, different crop years and stalk positions are affected more than others.

Tooth spacing is also a subject of considerable discussion. The feeling is that the first-stage rotor teeth should be spaced 2½ - 3" CC, going down in ½" increments to the fifth-stage at 1½" CC. We have some rotors with 4½" tooth spacing and it is difficult to prove that this has a beneficial or detrimental effect. The tooth arrangement in the rotor has some effect if fixed teeth are used. In order to avoid build-up on the fixed teeth, at least one row of rotor teeth must wipe the fixed teeth closely on each side.

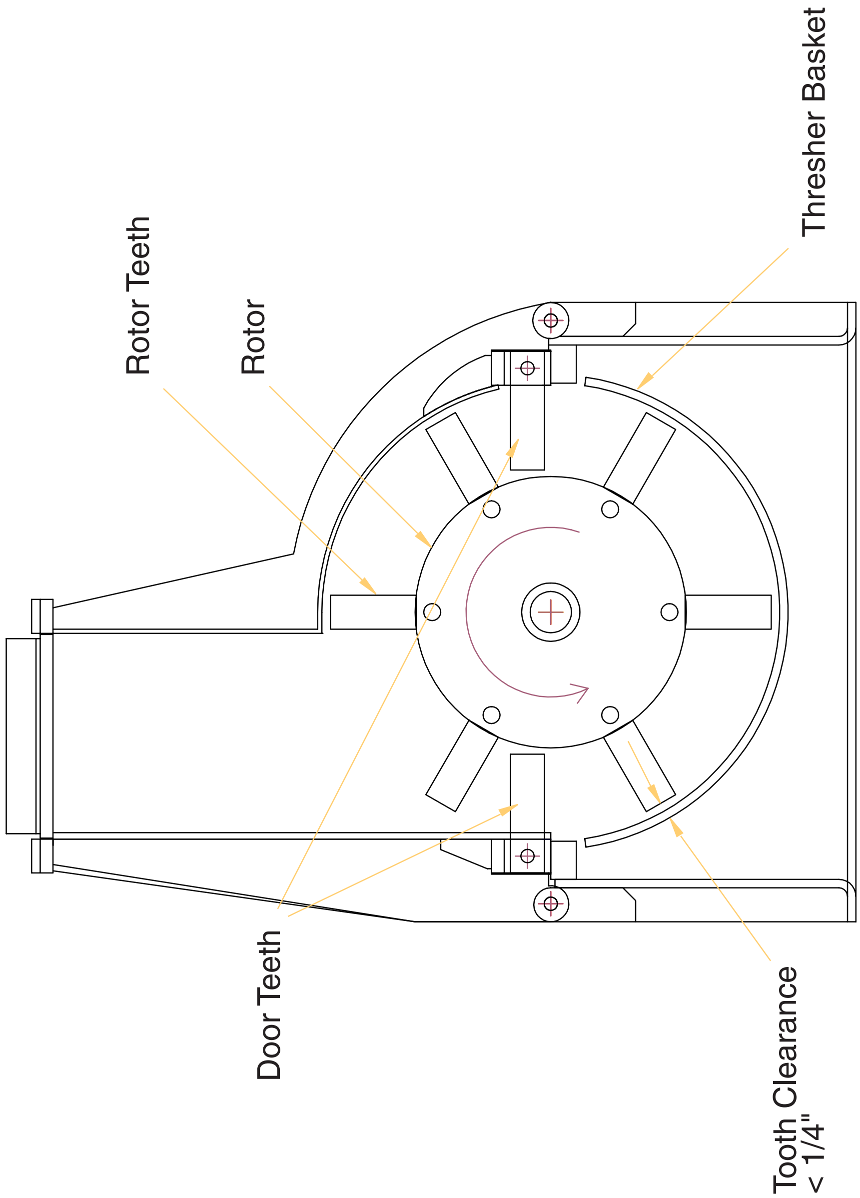
The normal set-up is to stagger the teeth in two or three sets, if possible avoiding the ribs on the basket. The clearance between the tip of the tooth and the basket should be ¼–⅜" in order to keep the basket clean. If this clearance is too great, the tobacco is not wiped off the basket and builds up, causing grinding and choke-ups. Diamond basket size is normally defined by the perpendicular distance between two diamond edges. This determines the size of the gap through which the threshed tobacco must pass to get out of the thresher. It also determines the open area of the basket. Normally the first-stage uses baskets in the range of 2–5" depending on leaf size and type. The diamond itself is normally 7½–8" from tip-to-tip, giving long angle edges and sufficient gap at the tip for stems to escape.

A multitude of different basket designs have been tried over the years. The diamond system has proved to be the most trouble free and effective in the first-stage to fourth-stage, with the fifth-stage normally carrying a 1½" or 2" round hole basket to clean and break up the stems. It is important that the basket is accurately cut and rolled and certainly in the first-stage is well supported under each rib to avoid flexing under heavy loads.

Our tests have not shown any particular differences between sharp and smooth edges to the diamonds. If we believe that the basket mainly acts as a sizing screen then this makes sense. Badly worn and rounded teeth however do have a detrimental effect as they cannot tear the leaf effectively and have an excessive tip-to-basket clearance. We have also tried twelve rows of teeth as opposed to the standard six rows and cannot see any measurable benefit to the twelve row setup.

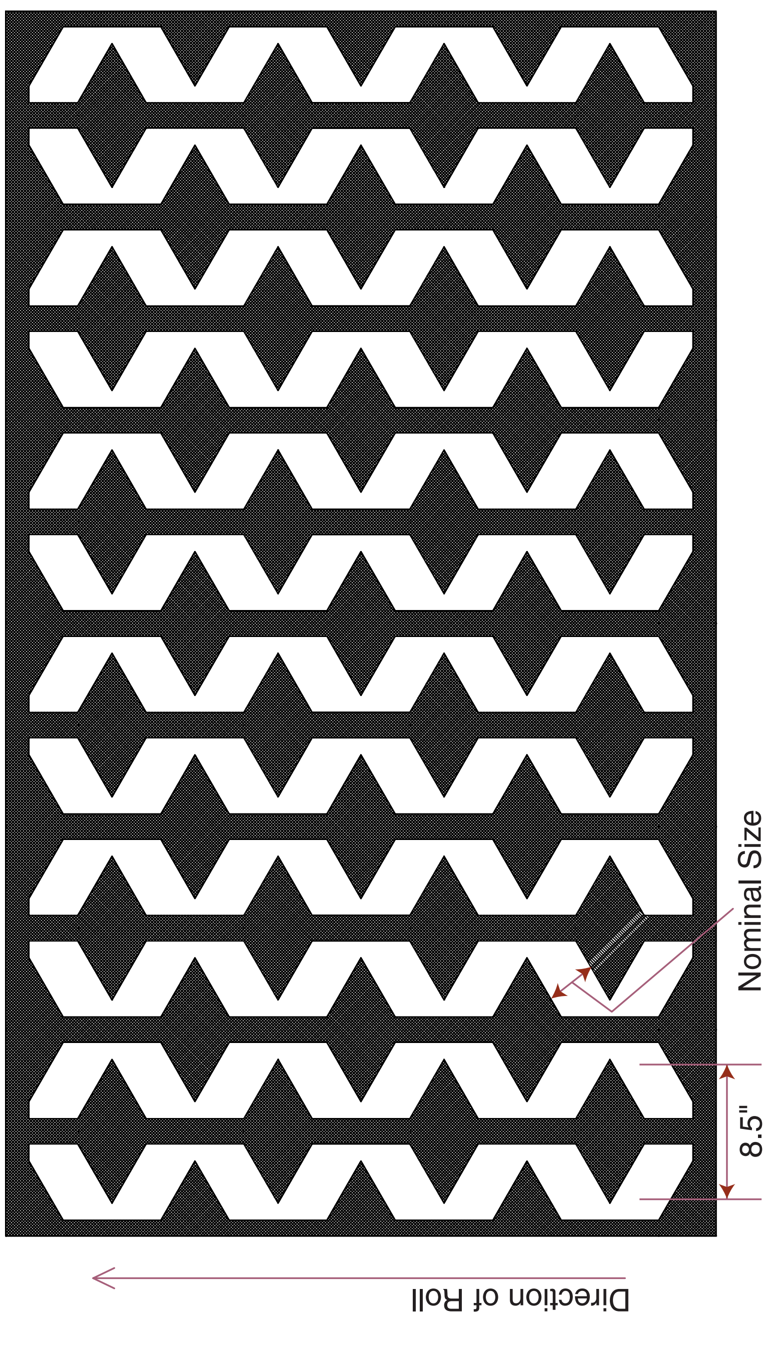
Thresher speed has an effect on efficiency and particle size and in general the lower the speed, the larger the size and the lower the efficiency. This has a lower limit of course, because below a certain speed no threshing will occur and the thresher will choke up. Normal speeds range from 400 RPM in the first-stage to 1,000 RPM in the fifth-stage.

Thresher

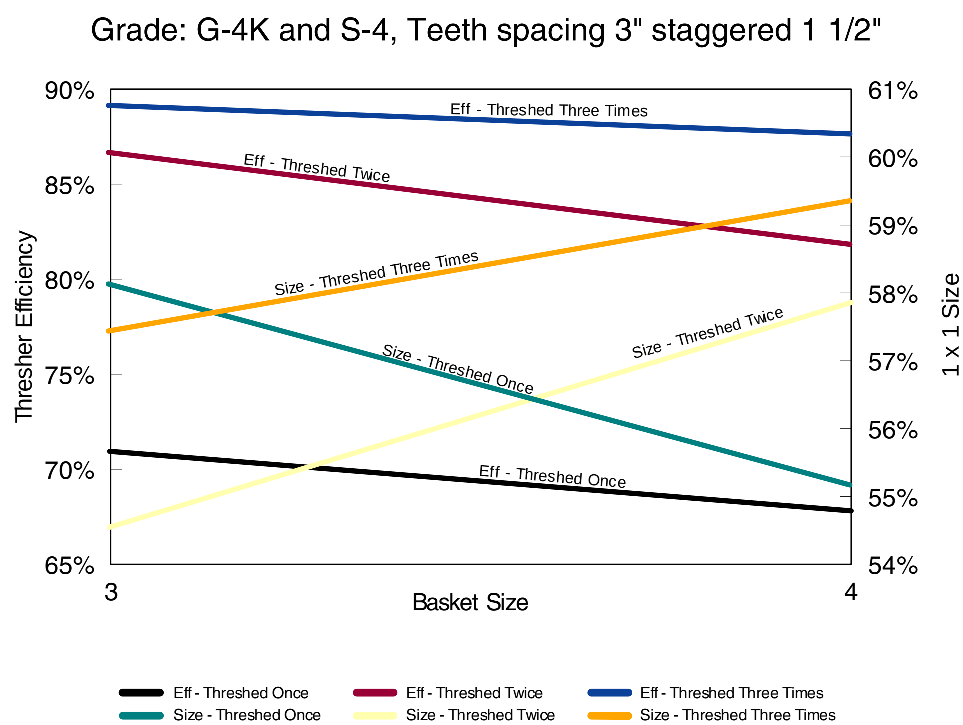


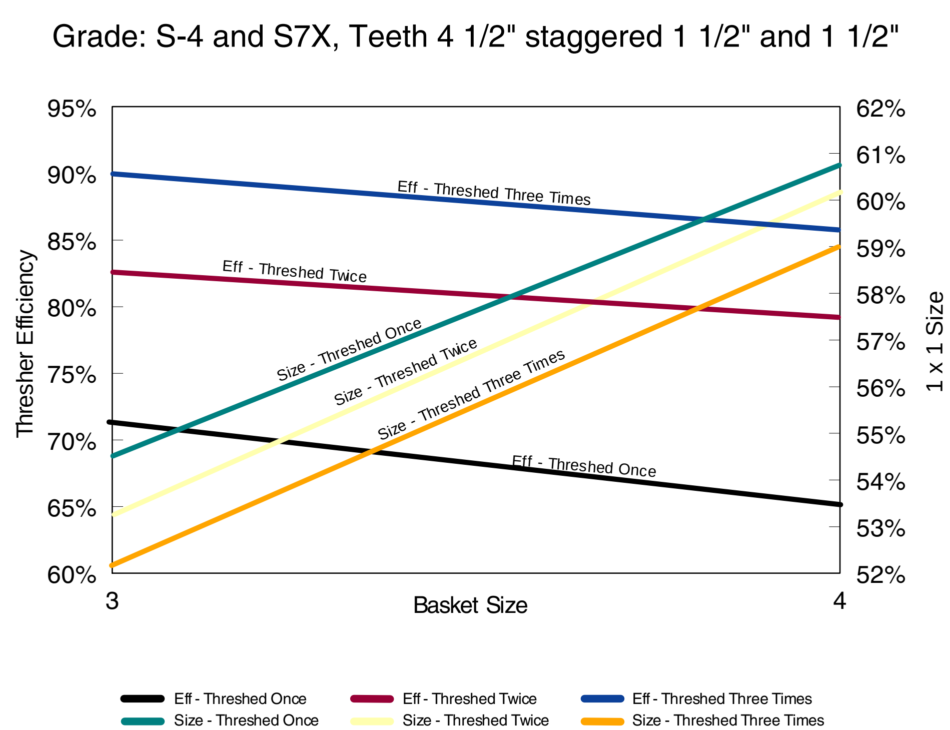
Rotor Teeth
Rotor
Thresher Basket
Door Teeth
Tooth Clearance
< 1/4"

Thresher Basket Flat Layout



Evaluation of Running 42" Thresher in Series





Thresher Efficiency

This is the ratio between the lamina removed by the thresher and the total lamina presented to the thresher. It is normally expressed as a percentage based on the following formula:

$$\text{Thresher Efficiency} = \frac{\text{Weight of Free Lamina x 100}}{\text{Weight of Free and Attached Lamina}}$$

Depending on the leaf and position, this will vary from 50–75%. The efficiency is affected by order, loading, speed, tooth condition and basket size. The optimum conditions for efficiency are not normally the same for the large product size, thus the thresher setup is normally a trade-off between efficiency and size.

Over the years it has been discovered that size is maximized at a loading of around 50 LB/HR. INCH on the first-stage threshers for flue cured tobacco and 35–40 LB/HR. INCH for burley. This varies from grade to grade and year to year and is also dependent upon the strength of the rest of the system. Thresher loading factor is defined as follows:

$$\text{Thresher Loading Factor (TLF)} = \frac{\text{Flow Into Thresher (LB/HR)}}{\text{Width of Thresher (INCHES)}} \quad \frac{\text{lb}}{\text{inch-hr}}$$

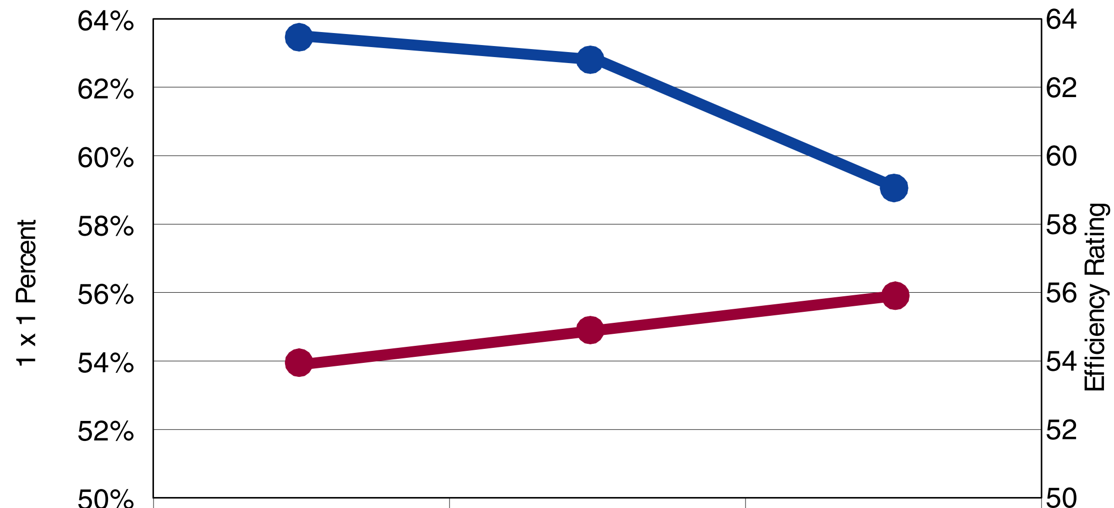
The loading factor for the second through third-stage threshers is a subject of considerable controversy. One theory is that the loading should stay even down the line and thresher inches should be proportional to the product flow at each stage. The other theory is that as lamina is removed from the stem, it is necessary to thresh harder to remove the remaining lamina. Many tests have been conducted on this but again, results are inconclusive to date and the normal setup is to size the threshers to be loaded more at each stage.

Other Means of Removing Lamina

ULT and other companies have experimented with other means of removing the lamina from the stem. These methods employed the basic principle of securing the lamina with carding belt or wire brushes and pulling the stem free. Whereas this does work when the leaves are open, aligned and separate from one another, it is not efficient with the range of products we handle at the volumes at which we need to run. We have also tried various configurations of dual rotor thresher and cutting devices but again, they do not out-perform the traditional machine.

Thresher Loading Effect

Grade: S-4 and S7X, Teeth 4 1/2" staggered 1 1/2" and 1 1/2"



	120	80	40
Efficiency	63.5%	62.8%	59.1%
1 x 1	53.9%	54.9%	55.9%

Thresher Loading
Lb/Inch-Hr

Evaluation of the Different Flow Rate in 42" Thresher

Date: Nov 02, 1993 Grade: E45K Basket: 3" Diamond Teeth: Regular

Thresher rotor RPM: 450 Spacing: 2 1/2" Staggered 1/2"

Flow Rate: 120 LBS/IN-HR

Test#: R3-1 **Total Weight** 109.2 Oz. **Free Lamina** 53.41 Oz. **Attached Lamina & Stems** 54.59 Oz.

Temp: degrees F Moisture Before: % Moisture After: %

Weight of Attached Lamina at 2 1/2 min 30.76 Oz. Weight of Attached Lamina at 4 1/2 min 33.01 Oz.

SIZE in Inches	1 x 1	1/2 x 1/2	1 + 1/2	1/4 x 1/4	1/8 x 1/8	PAN
WEIGHT in Oz.	28.8	16.9	45.7	5.1	0.81	1.09
%	53.9%	31.6%	85.6%	9.5%	1.5%	2.0%

EFFIC. AT 2 1/2: **63.5%** ***EFFIC. AT 4 1/2:*** **61.8%**

Flow Rate: 80 LBS/IN-HR

Test#: R3-2 **Total Weight** 132.2 Oz. **Free Lamina** 62.81 Oz. **Attached Lamina & Stems** 67.89 Oz.

Temp: degrees F Moisture Before: % Moisture After: %

Weight of Attached Lamina at 2 1/2 min 37.21 Oz. Weight of Attached Lamina at 4 1/2 min 39.49 Oz.

SIZE in Inches	1 x 1	1/2 x 1/2	1 + 1/2	1/4 x 1/4	1/8 x 1/8	PAN
WEIGHT in Oz.	34.5	19.2	53.7	5.7	1.03	1.44
%	54.9%	30.6%	85.5%	9.1%	1.6%	2.3%

EFFIC. AT 2 1/2: **62.8%** ***EFFIC. AT 4 1/2:*** **61.4%**

Flow Rate: 40 LBS/IN-HR

Test#: R3-3 **Total Weight** 82.74 Oz. **Free Lamina** 36.85 Oz. **Attached Lamina & Stems** 45.17 Oz.

Temp: degrees F Moisture Before: % Moisture After: %

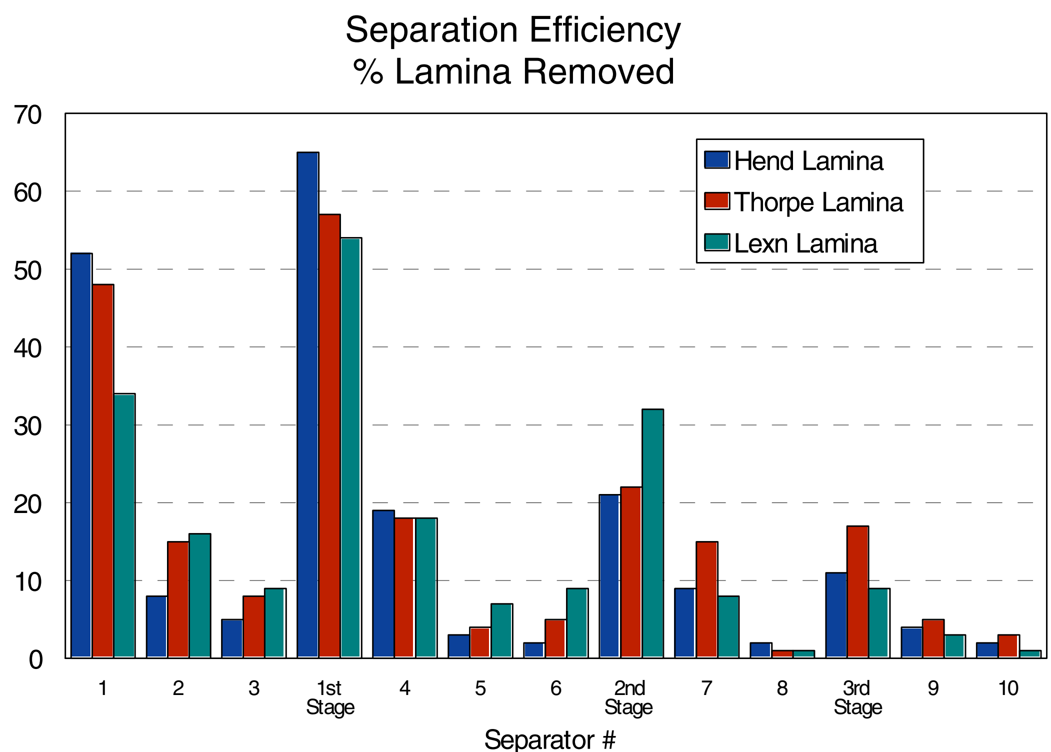
Weight of Attached Lamina at 2 1/2 min 25.47 Oz. Weight of Attached Lamina at 4 1/2 min 27.13 Oz.

SIZE in Inches	1 x 1	1/2 x 1/2	1 + 1/2	1/4 x 1/4	1/8 x 1/8	PAN
WEIGHT in Oz.	20.6	11.5	32.1	3.1	0.5	0.69
%	55.9%	31.2%	87.1%	8.4%	1.4%	1.9%

EFFIC. AT 2 1/2: **59.1%** ***EFFIC. AT 4 1/2:*** **57.6%**

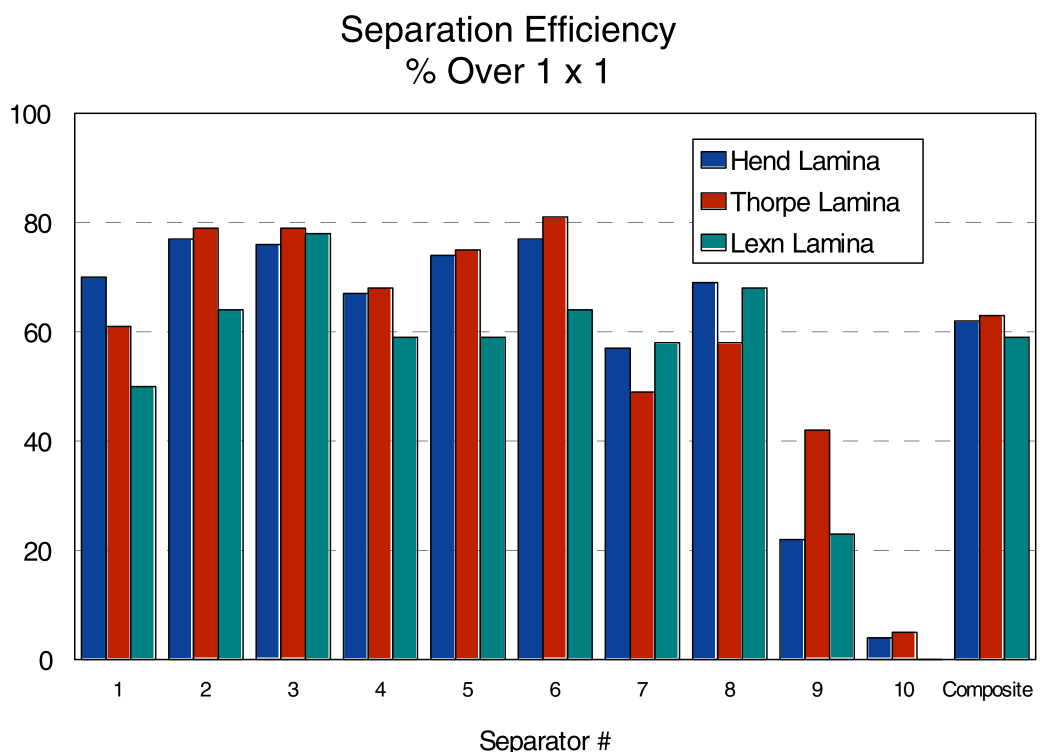
Note: Flat door teeth spacing 5"
Curved door teeth spacing 2 1/2"

Separation Efficiency
% Lamina Removed



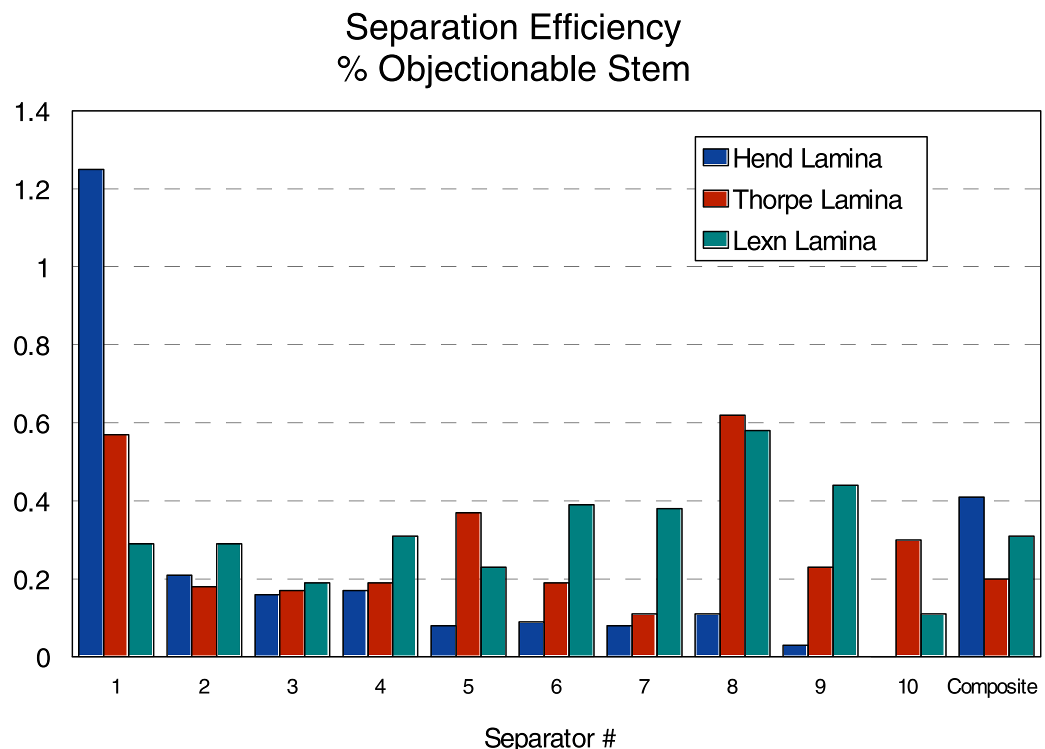
Hend = 33.3 lbs/hr/inch
Thorpe = 27.7 lbs/hr/in
Lexn = 52.7 lbs/hr/in

Separation Efficiency
% Over 1 x 1



Hend = 27.7 lbs/hr/inch
Thorpe = 33.3 lbs/hr/in
Lexn = 52.7 lbs/hr/in

Separation Efficiency
% Objectionable Stem



Hend = 27.7 lbs/hr/inch
Thorpe = 33.3 lbs/hr/in
Lexn = 52.7 lbs/hr/in

Separating

Again, a multitude of separating devices have been tried over the years. The common basis to all of them relies on the difference in surface-area to weight ratios of the stem and lamina. This leads to separation by means of some form of flotation. As liquids are really not practical, the flotation medium is air.

There are four requirements critical to the efficiency of a typical flotation separator:

1. A constant product flow.
2. A well distributed product flow.
3. A projection mechanism to deliver the product into the separation chamber in a well dispersed form.
4. A uniform air flow through the chamber.

The flotation can theoretically be accomplished vertically or horizontally, but practical experience has shown that vertical flotation is simpler and more effective.

The separator can be loaded via conveyor or pneumatically. It is essential that the flow is consistent and spread evenly across the full width of the projecting mechanism. Varying flow conditions and side-loading will severely limit the efficiency of the machine. The projecting mechanism is normally some type of rotary winnower. The objective is to project the leaves at the desired angle across the chamber in a smooth and continuous flow. The speed and diameter of the winnower determine the projection velocity and this is normally set so that the heavier particles strike the far wall of the separating chamber. If this velocity is too low, the leaves will not disperse well and if it is too high, the forward momentum of the leaves will make it more difficult for the vertical air stream to peel the lighter lamina free.

Good dispersion is essential to good separation, as ideally each particle needs to be acted upon separately by the air stream. Again in theory, the longer the chamber, the better the dispersion as the same surface-area to weight ratio determines how far a particle moves horizontally before falling to the apron or being lifted by the vertical air stream. However, a very long chamber would require a much larger air flow with accompanying energy cost. We have therefore tended to compromise in chamber length to get good dispersion with acceptable horsepower. This is normally in the 60" range.

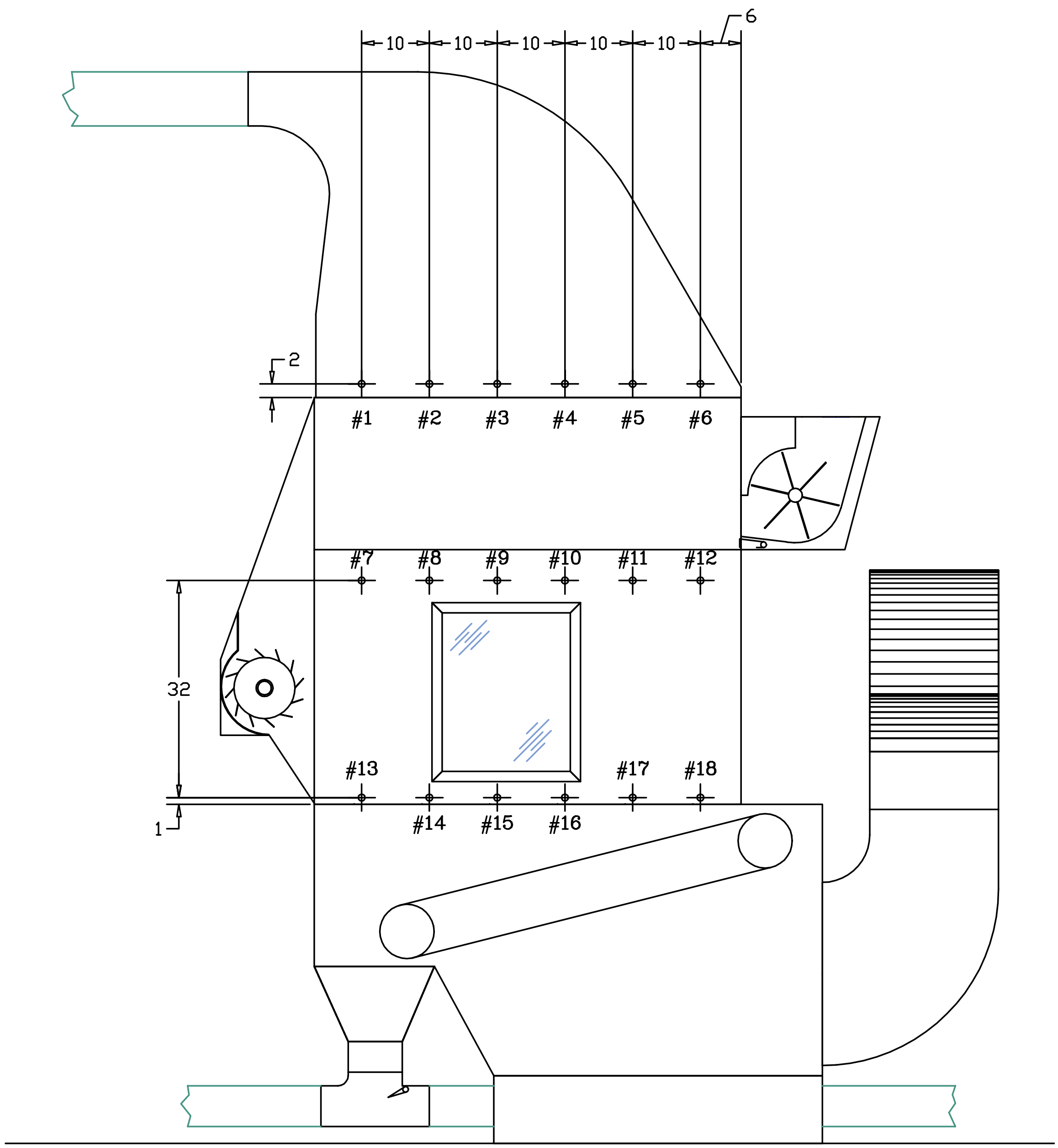
For the winnower to function correctly, the paddles must be closely spaced to avoid pulsing and be rigid enough to move the tobacco positively but flexible enough to give when leaves become trapped between the paddle and the housing. In recent years we have found that 1/8" UHMW polyethylene is best suited for this purpose. Worn or limber paddles adversely affect projection velocity. Most inlet winnowers have six paddles.

Flotation separation balances the upward force on the leaf caused by the vertical air stream against the downward force caused by gravity. The upward force is dependent upon the density of the air, the square of the velocity of the air and the surface-area of the leaf. It is not possible to have 100% efficiency because some free lamina is balled up and has a low surface-area to weight ratio and some large open lamina will have a short piece of stem in it giving it a high surface-area to weight ratio. In practice, holding a 0.25–0.5% objectionable stem content, the best that can be expected is to recover 85–90% of available free lamina. This normally requires several separators in series, depending on load and position.

The air flow through the machine is generated by a centrifugal fan or fans. It is difficult to obtain completely uniform air flow in the chamber because of the practical limitations involved with trying to diffuse the air uniformly without creating pockets where tobacco accumulates. The most effective strategy to date has been to have the inlet ducting and plenum chamber under the apron large enough so that the velocity of the inlet air is low. High velocity pressure is the major cause of non-uniform air flow, and as velocity pressure is proportional to the square of the velocity, lowering velocity helps exponentially.

The other means of controlling velocity fluctuations is to create a pressurized plenum by providing a perforated apron with a low open area. Again, this has a down side in that the lower the open area, the greater the horsepower required to obtain the required flow. Thus the practical result of these strategies has been to have a large inlet duct system, a large plenum and an apron with an open area sufficient to pass the required air volume with acceptable horsepower.

Modified Counterflow Measuring Points



Counterflow Air Profile Test

Date: May 12, 1993 Location: J. P. Taylor Co., Inc., R & D Center, Wilson, NC

Counterflow Set-Up: Modified 2nd winnower counterflow set-up. Fan on right side with ABB controller. New apron with 3/32 dia. holes. New, large size elbows for separation air.

Total amount of separation air		13.457	CFM
Cardwell fan size 400 running at		989	RPM
Static pressure:	bottom chamber	+.60	in of water
	main chamber	+.02	in of water
	across fan	6.5	in of water
Power usage:		24.6	KW
ABB controller:		60.7	Hz (Equivalent of modutrol position of 14 degrees)
Separation air temp.:		109.9	F degrees

Air Flow Velocities at the Hood Level in FPM: (10 sec mean readings)

from left side	6" in	12" in	18" in	24" in	30" in	36" in	42" in	48" in	54" in	60" in	66" in	Avg
Hole #1	591	488	471	549	513	476	234	377	400	457	413	452
Hole #2	671	650	641	639	683	663	648	651	677	663	543	648
Hole #3	630	656	642	626	560	462	399	518	590	595	527	564
Hole #4	526	552	550	546	538	476	514	532	457	496	461	513
Hole #5	463	483	470	471	469	468	462	484	530	530	504	485
Hole #6	182	165	328	267	165	148	101	268	316	285	370	236
Avg	511	499	517	516	488	449	393	472	495	504	470	483

Air Flow Velocities at the Inlet Winnower Level in FPM:

from left side	6" in	12" in	18" in	24" in	30" in	36" in	42" in	48" in	54" in	60" in	66" in	Avg
Hole #7	656	460	357	299	276	272	173	151	386	448	421	354
Hole #8	649	532	592	704	693	678	695	665	614	675	504	636
Hole #9	633	656	662	644	635	618	632	653	658	682	660	648
Hole #10	545	570	580	597	534	494	519	496	445	402	369	505
Hole #11	476	473	486	494	475	472	514	508	523	519	499	494
Hole #12	354	399	411	394	389	382	325	414	470	469	399	401
Avg	552	515	515	522	500	486	476	481	516	533	475	507

Air Flow Velocities at the Lower Winnower Level in FPM:

from left side	6" in	12" in	18" in	24" in	30" in	36" in	42" in	48" in	54" in	60" in	66" in	Avg
Hole #13	474	157	382	646	474	472	665	770	767	275	136	474
Hole #14	340	448	351	402	442	466	472	476	650	652	660	487
Hole #15	516	511	513	506	518	525	487	515	537	533	517	516
Hole #16	534	532	513	525	519	457	390	443	506	478	351	477
Hole #17	477	432	415	436	451	487	529	560	588	611	608	509
Hole #18	647	568	425	535	533	548	581	574	626	569	783	581
Avg	498	441	433	508	490	493	521	556	612	520	509	507

Summary

Equivalent to modutrol position of 10 degrees

	Set-up	Hood Avg	Hood Std	Inlet Winnower Avg	Inlet Winnower Std	Lower Winnower Avg	Lower Winnower Std
Test #1	Standard	492	262	520	325	543	102
Test # 2	Extended Winnower	490	165	502	225	509	162
Test #3	Extended Winnower ABB Controller	494	189	502	243	542	151
Test #4	Extended Winnower ABB Controller Apron with 3/32 dia. holes	467	170	483	150	494	94
Test #5	Extended Winnower ABB Controller Apron with 3/32 dia. holes Large separation elbows	483	142	507	130	507	116
Test #6	Extended Winnower ABB Controller Apron with 3/32 dia. holes Large separation elbows Clean-out chute open	455	242	435	199	464	320

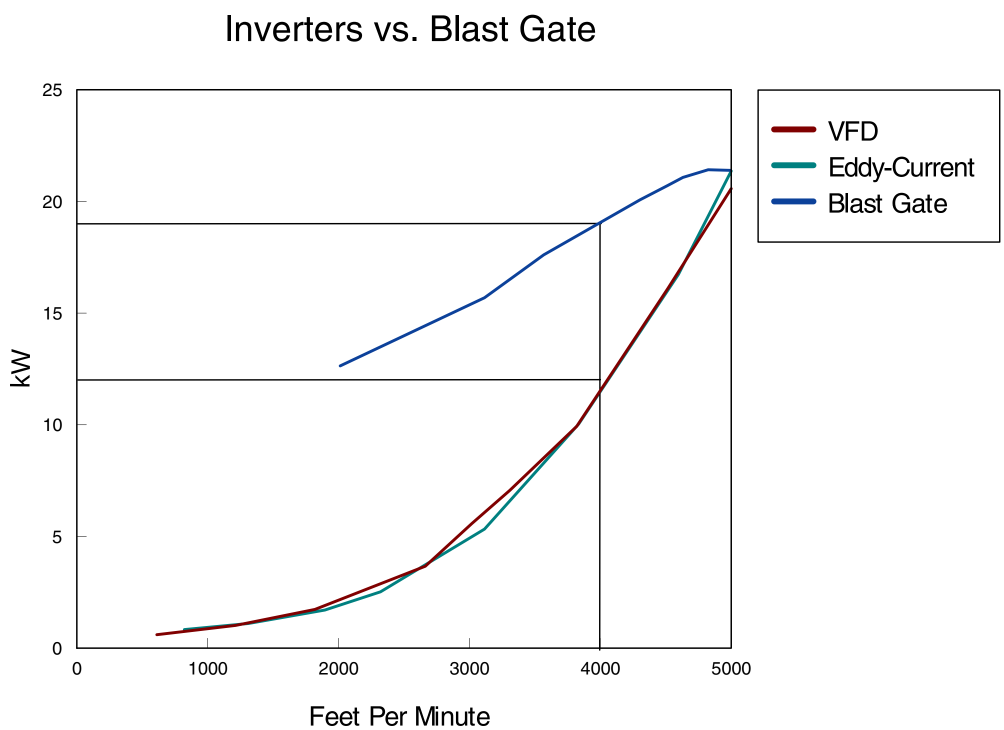
* Note: Equivalent to modutrol position for 14 degrees

The uniformity of the air flow in the separating chamber is important for the following reason: the "break point" between lifting desirable free lamina and dropping whole leaves and stem is a vertical velocity of around 450 feet per minute (FPM). If a portion of the chamber has 650 FPM and another portion 250 FPM, whole leaves will be lifted in the first and good free lamina dropped in the second. Thus, in order to control stem content, the air flow on the whole machine will need to be reduced, resulting in many pieces of free lamina being lost.

The lift in the chamber is dependent upon the amount of air flowing in the system, or cubic feet per minute (CFM) and the density of the air. The CFM is controlled either by restricting the flow from the fan by mechanical dampers or by varying the speed of the fan. The density is dependent upon the static pressure in the chamber and the temperature of the air. With variable frequency drives available now to withstand the environment in threshing lines, varying the speed of the fan by this means gives both better control of lift and when running less than full speed, a considerable energy saving.

Most separators today are of the closed-loop type, i.e., the same air is recirculated through the chamber continuously. As with the transport systems, in order to maintain the system as slightly negative and to skim off fine dust entrained in the air stream, a bleed-off of air from the fan is required. This is normally set at about 5% of the volume of circulating air and helps to cool the machine down by inducing fresh air to the system. The venturi in the transport system removes additional air from the separator circuit, so the net removal is about 7½%. If no means of fresh air intake is provided and the bleed-off causes excessive negative pressure, this will lower the density of the air and adversely affect separation.

Inverters vs. Blast Gate



Bleed-off air and air from dust hoods is induced by fans drawing through bag filters. These filters are normally cleaned by reverse jet-compressed air pulses and should operate at a differential pressure of 2–3" water gauge. If these bags become contaminated because of insufficient pulsing or moisture or simply old age, this differential pressure will rise. This will place more load on the fan and cause a reduction in air flow in the bleed-off and hood systems. While this will not have a catastrophic effect on the operation, it will adversely affect it and should be addressed.

Line Configuration

Threshing lines are normally designed to handle an average throughput based on seasonal requirements and available working hours. Average throughput is real, attainable throughput over a period of time taking into account breakdowns and grade changes. Actual instantaneous throughput will always be higher than this. The average design throughput for a first-stage thresher is typically 50 LB/HR.INCH and for a first-stage separator, 100–150 LB/HR.INCH. Separators are less load-sensitive than threshers and although efficiency decreases with load, no size is lost if there are additional separators in series to recover the lost particles.

Thus a typical threshing line will have two or three first-stage threshers in parallel feeding three or four separators in series. The efficiency of each separator is affected by the load, the particle size, the amount of free lamina available and the target stem content of the separated product. Typically the first separator after each thresher is the most efficient as it recovers all the small particles and the lamina to stem/leaf ratio is high. Each successive separator has a more delicate job and although the load is less, the available free lamina is less and the efficiency drops. Separator efficiency is defined as follows:

$$\text{Separator Efficiency} = \frac{\text{Free Lamina Separated x 100}}{\text{Total Available Free Lamina Introduced}}$$

The first-stage is the most critical, with 50–70% of the total lamina typically being removed and the largest particles. Three or four machines are usually used in series, with the first about 75% efficient and the last about 10%. As our tests show that passing free lamina through a thresher does not reduce its size significantly, we believe that three Counterflow or four Multisep separators are sufficient with two or three threshers in the first-stage. If more threshers are used, loads will go up, individual separator efficiencies will drop and more will be required. Our strategy is to go to multiple lines rather than heavy single lines.

To show the effect of each separator, consider 100 LB of lamina going into the first-stage separators.

Separator	1	2	3	4	Remaining
Input (lb)	100.00	25.00	15.00	12.50	11.25
Efficiency	75%	40%	15%	10%	
Removal (lb)	75.00	10.00	2.25	1.25	88.50

This shows a stage efficiency of 88.5% with four separators and 87.25% with three separators.

Separator Types

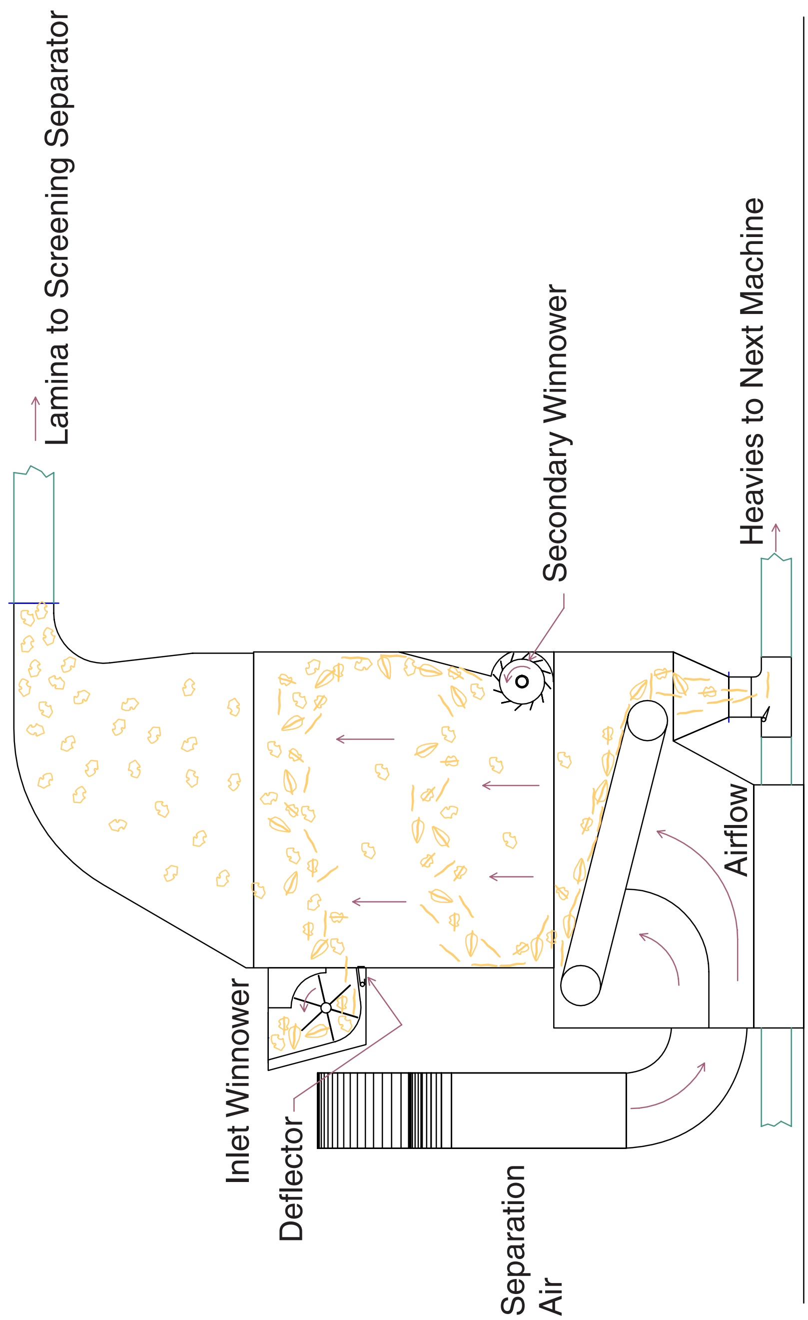
There are several popular types of separator in use today. Probably 70% of the world's tobacco is now processed by Universal's Counterflow separators. These separators employ the same flotation principles but the triple-pass system makes each chamber very efficient. The double-pass VLS and RPL separators are about 5–10% less efficient under comparable conditions and the single-pass Multiseparator, Swan and PAL separators are very similar.

Recent improvements to the Counterflow have increased its efficiency to some extent, but as can be seen from the table on preceding page, small differences in efficiencies of machines do not affect the total stage efficiency by much.

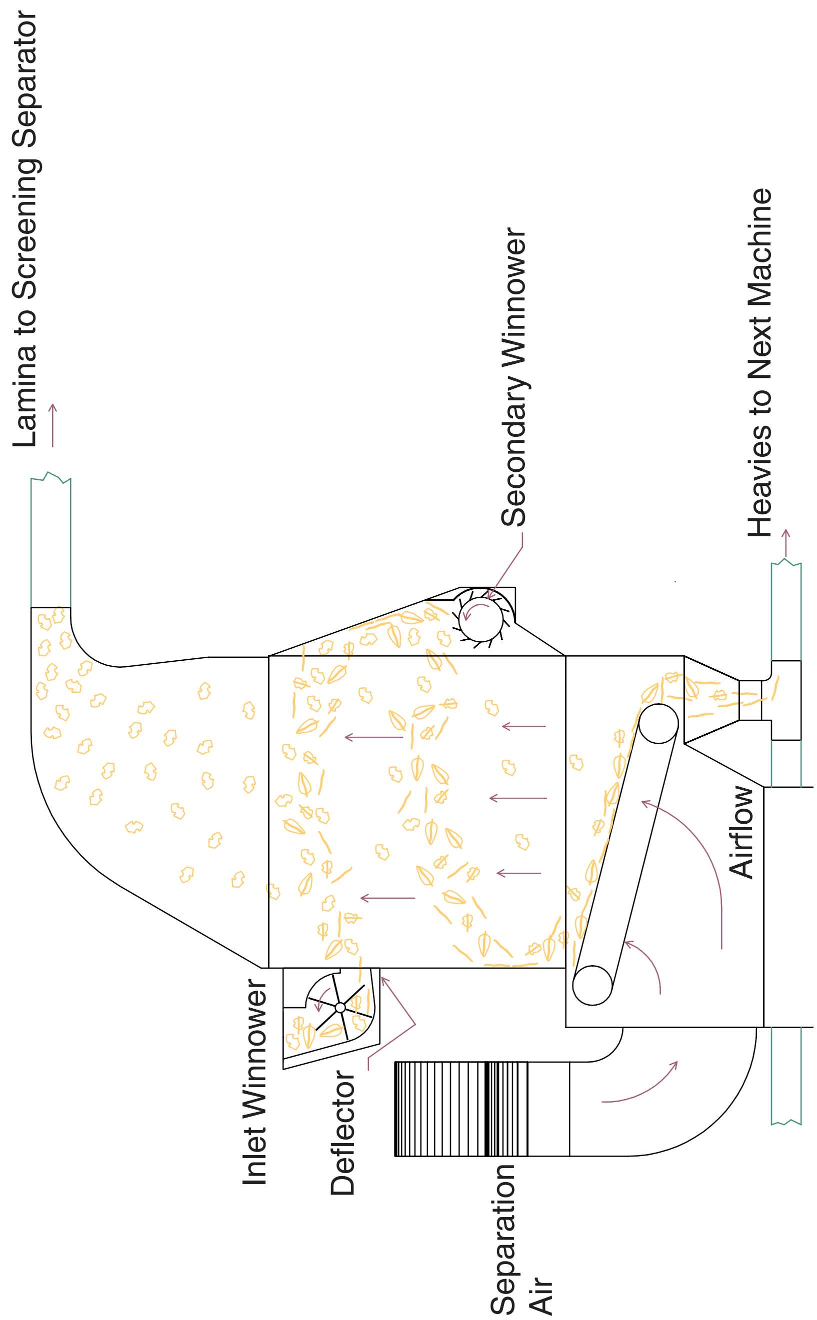
ULT's Multiseparator system uses eleven separators as opposed to a standard ten in a Counterflow system to give equal or better results with a 30% space saving and 40% energy saving.

Griffin's Modswan separator is similar in principle to the Multiseparator but does not reproject any heavies which fall to the apron.

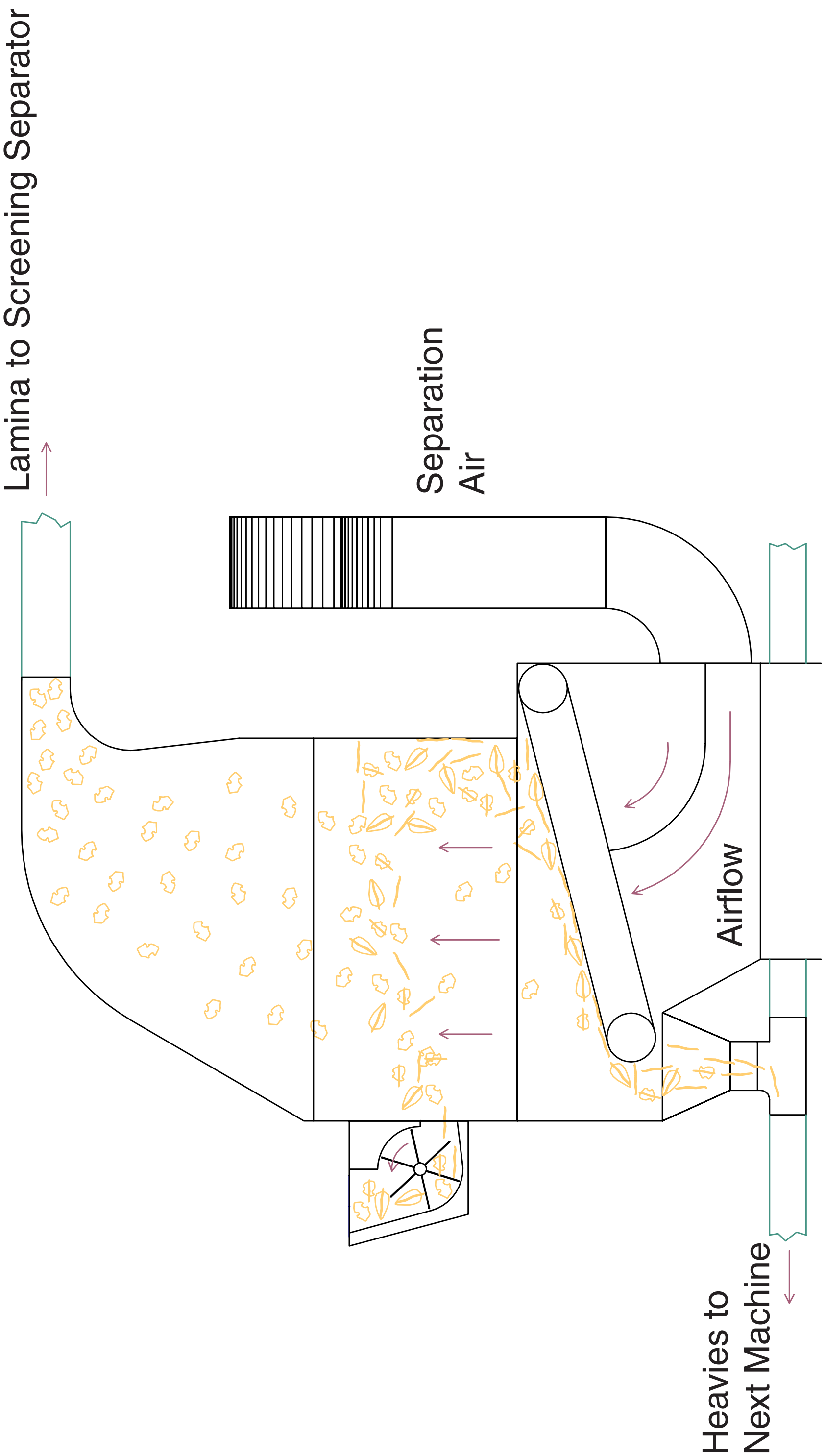
Counterflow (Old Style)



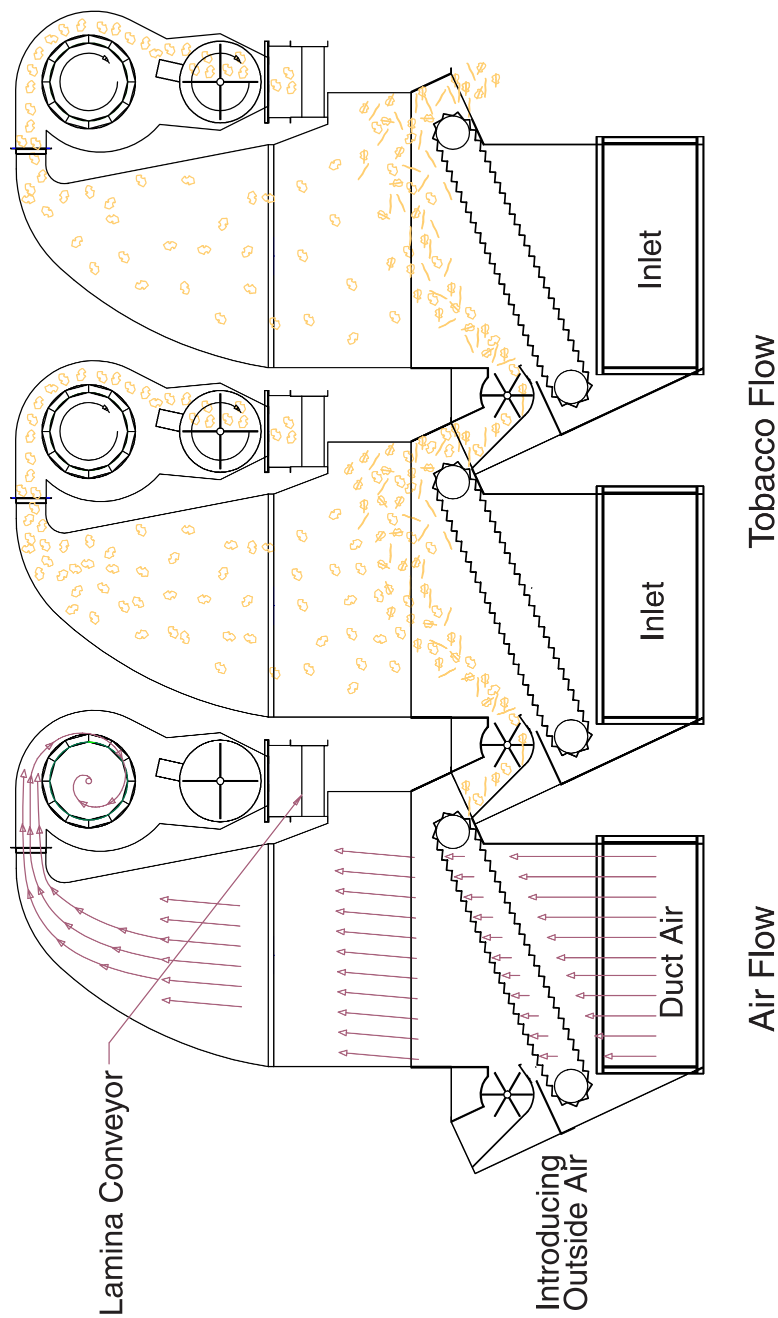
Counterflow (New Style)



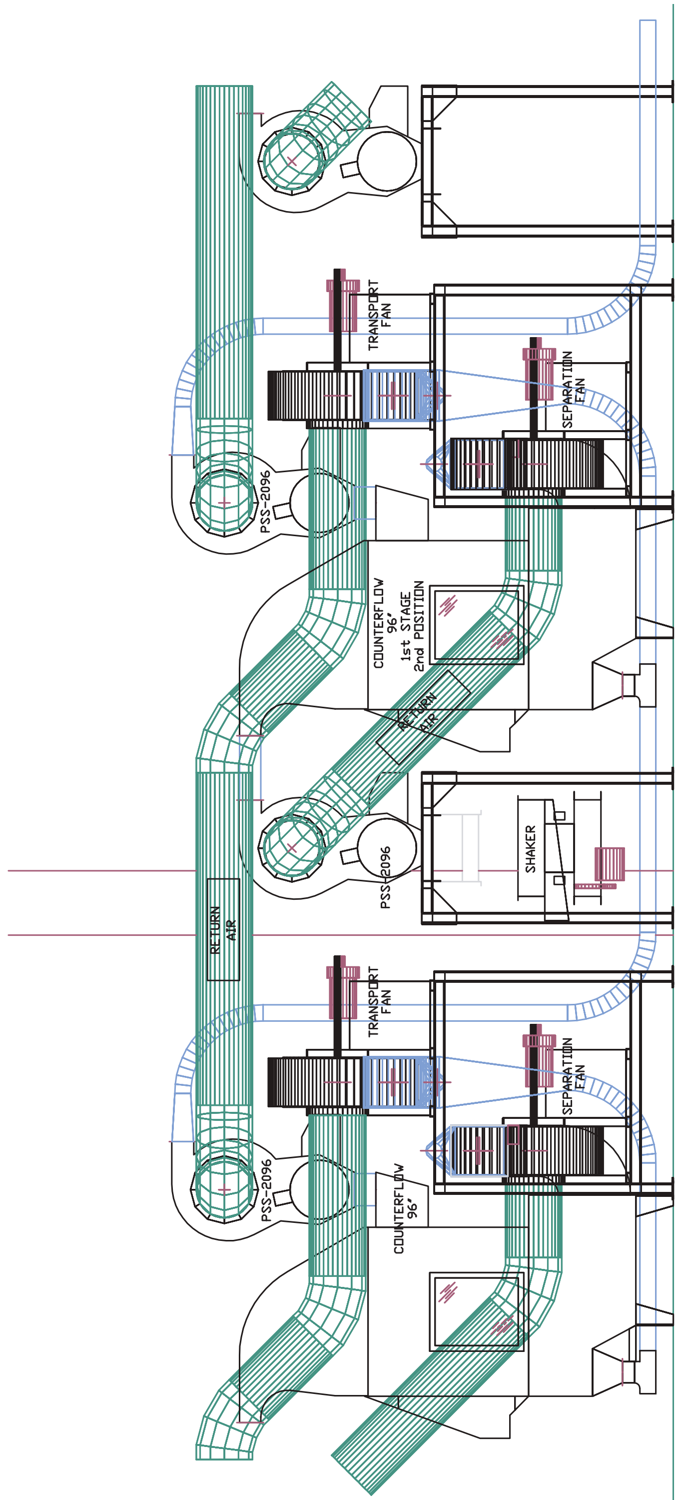
Vertical Lift Separator



Multiseparator

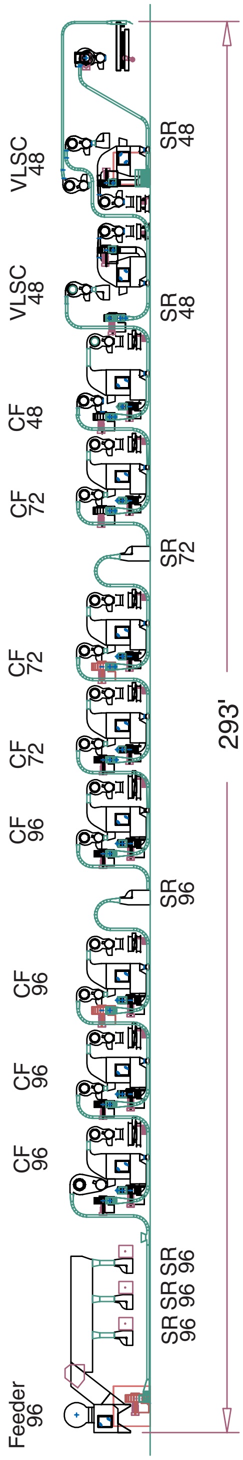


Typical Counterflow Position

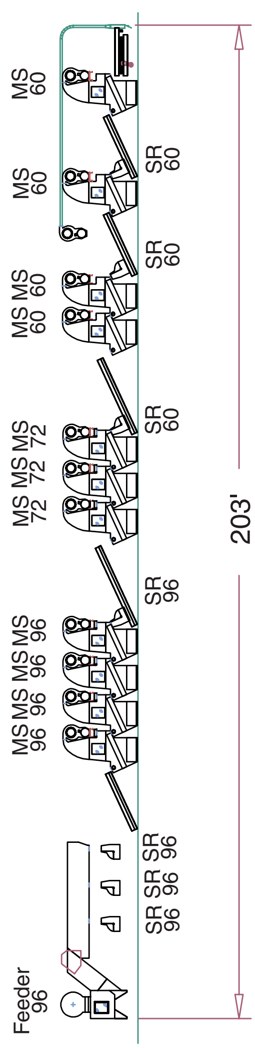


Threshing Lines

Typical Counterflow Threshing Line



Typical Multi-Sep Threshing Line



41% Power Savings

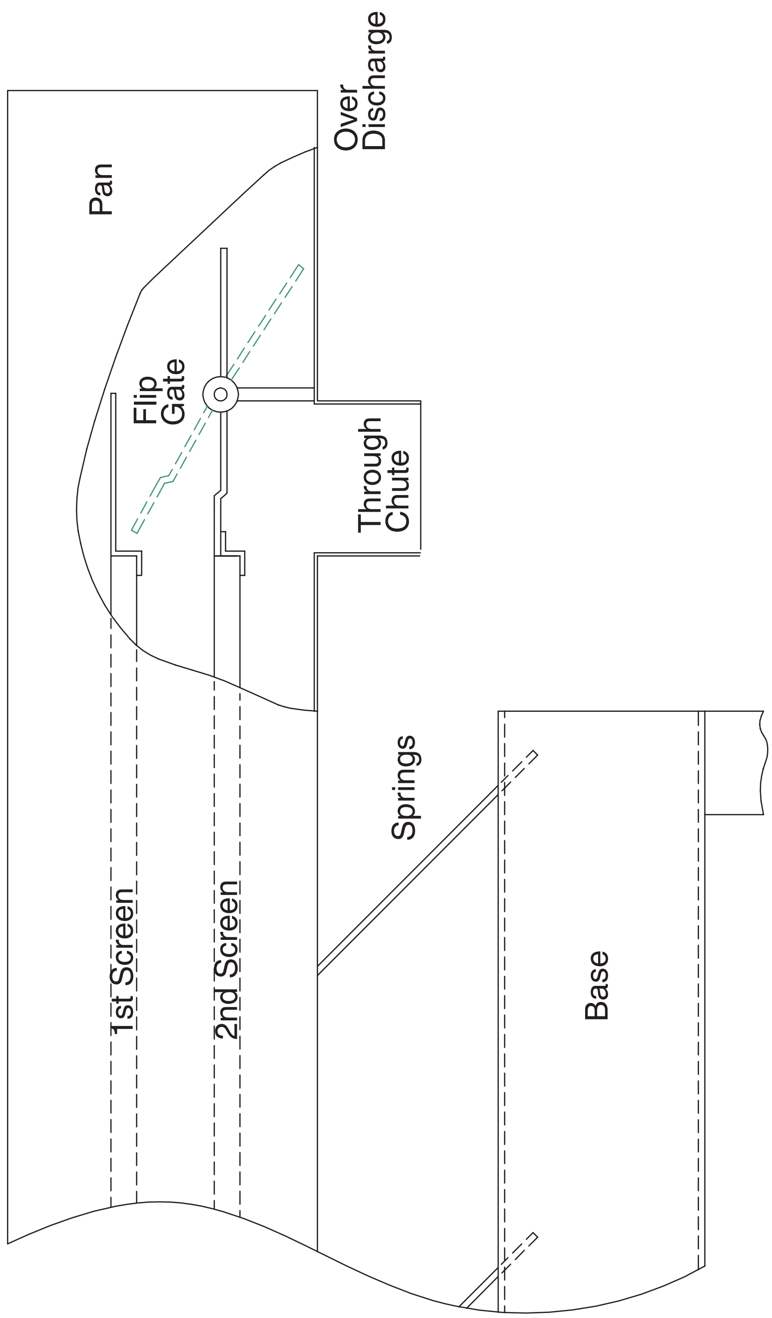
Scrap Removal

The threshing process inevitably produces small particles at each stage and some small particles are generated on the farm and during handling of the bales or sheets. These small particles are not desirable material for the cutters in cigarette plants and must be removed and handled separately. Conventional methods of screening are vibrating shakers and rotating reels. Both systems are dependent upon a very shallow carpet of tobacco to remove scrap efficiently. The reel offers a large area of screen in a small space, but the lifting and dropping action on the product has been found to create more scrap, so this method is not favored. Also, the reel tends to create rolls of tobacco where the outside is exposed but the center remains unscreened.

Vibrating shakers are the machines of choice, and the main point to focus on is to spread the tobacco lightly and uniformly to give a good exposure. In this application where 97% of the product is not going to pass through the screen, width is more important than length. A short, wide shaker will be more efficient than a long, narrow one of equal area simply because carpet depth is dependent on width and unaffected by length unless a large proportion of the product is going to pass through the screen.

Woven mesh screens generally have more open area than perforated plates and the square aperture allows a wider range of removal than the round hole of equal size. However, tobacco moves more slowly on the woven mesh and the mesh must be cleaned more frequently. Scalping screens of larger size can be used to thin the load to the sizing screen when heavy loads are encountered. Correct conditioning, efficient routing and well maintained threshers all help to reduce the generation of scrap in the system. The Multiseparator and Modswan systems with no pneumatic conveying and conveyor belts between stages offer good opportunities to reduce scrap generation.

Shaker Flip Gate



ULT Standard Wire Meshes/Punched Plates/Slotted Plates

The following specifications are considered standard for product size classification systems in ULT plants. Always refer to customer instructions for specific requirements.

I. Wire Meshes

Wire Type	Mesh/Inch	Wire Dia.	Clear Opening	% Open Area
Plain Weave				
SS	2	.080”	.420”	70.6
	4	.047”	.203”	65.9
	4	.080”	.170”	46.2 (Gallaher)
	6	.035”	.1317”	62.7 (PME)
	8	.032”	.093”	55.4
	8	.025”	.100”	64.0 (RJR)
	16	.016”	.0465”	55.4
	20	.015”	.035”	49.0
	32	.009”	.0223”	50.9

II. Punched Plates

1/2” Dia. Punched Holes, Staggered, 11/16” Centers	48% Open
1/2” Dia. Punched Holes, Staggered, 11/16” Centers	48% Open
1/2” Dia. Punched Holes, Staggered, 11/16” Centers	48% Open
1/2” Dia. Punched Holes, Staggered, 11/16” Centers	48% Open
1/2” Dia. Punched Holes, Staggered, 11/16” Centers	48% Open

III. Slotted Plates

1/4” x 15/16” Slots, Staggered, 7/16” Centers	40% Open
3/16” x 13/16” Slots, Staggered, 5/16’ Centers	60% Open

Drying

The objectives in the drying process are as follows:

1. To dry tobacco strips to a uniform moisture, usually twelve to thirteen percent
2. To maintain a minimum standard deviation
3. To cause minimum curling of strip

The steps necessary in accomplishing these are to:

1. Deliver a uniform flow of tobacco to the dryer
2. Spread the tobacco uniformly on the apron at a uniform density
3. Circulate a stream of heated air through the bed of tobacco from each direction, first up and then down
4. Remove a percentage of the moisture-laden air via exhausts to atmosphere
5. Bleed in an equivalent amount of fresh air to blend with the heated air
6. Cool the tobacco down to 100ºF (37.6º C)º with ambient air
7. Re-condition the tobacco with steam and water.

Theory

The drying of any cellular organic matter relies on moisture migration from within the cells to the surface, and the continuous removal of the surface moisture.

The migration can be caused by two different phenomena:

Heat When a cell is heated, the pressure in the cells rises due to expansion of the water/vapor mixture contained in the cell. This increased pressure forces moisture out through the pores in the leaf surface.

Air Current Removal of the vapor layer on the leaf surface by a current of air. This causes a drop in vapor pressure at the surface, and moisture from within the cell moves to the low pressure area.

Our dryers use a combination of heat and air circulation. By removing moisture laden air continuously, the relative humidity of the circulating air is maintained at about 30%. This means that this air can accept more moisture before it becomes saturated. Thus the air takes up moisture from the leaves, and this is exhausted to atmosphere.

For a given flow of tobacco, the rate of drying is dependent on four conditions:

1. The temperature of the air stream.
2. The time the tobacco is exposed to the air stream.
3. The relative humidity of the air stream.
4. The amount of air circulating.

Using the analogy of a conventional oven cooking a loaf of bread, it is apparent that by using different combinations of temperature, time, humidity and airflow, very different results can be achieved.

If the bread is exposed to a temperature of 1000°F for 15 minutes it may have the same average moisture as a loaf cooked at 350°F for two hours. However, in the first case the loaf will have a charred crust and moist interior; in the second it will be uniformly cooked.

Tobacco behaves in much the same way. It is important that the correct combination of the four variables be employed so that uniform drying occurs. Just like the bread, this is a matter of subjective evaluation and there is no magic formula. However, certain effects are obvious.

1. Low temperature for long exposure times give better uniformity than high temperatures for short times.
2. Low RH can only generally be accomplished with higher temperatures.
3. The greater the quantity of air circulating, the more exposure each leaf gets and the quicker the vapor layer is removed. Thus high air circulation can allow lower temperatures to be used
4. The carpet depth is a function of flow and apron speed. For good circulation a depth of 2½ to 3" is recommended. Less than this causes holes, more causes wet centers.

The Heating System

As a matter of choice, our dryers are steam heated. Electric and gas dryers are common in other industries. We have run experiments using microwaves, but these proved to be dangerous and gave little advantage.

Steam

Steam is a loose term to denote a mixture of water and water vapor or pure water vapor. A vapor is physically identical to a gas, the term vapor being generally applied to the gaseous phase of fluids that exist as liquids at ambient temperatures.

Our boilers generate dry, saturated steam at about 125 PSIG, which means the temperature of the vapor is 353°F. As the steam travels down the lines to the dryer, some steam condenses due to heat losses through the pipes. This is removed by steam traps at various points.

The pressure of the steam does not affect the heating value very much. The greatest amount of heat is derived from the latent heat given up when dry steam condenses to water.

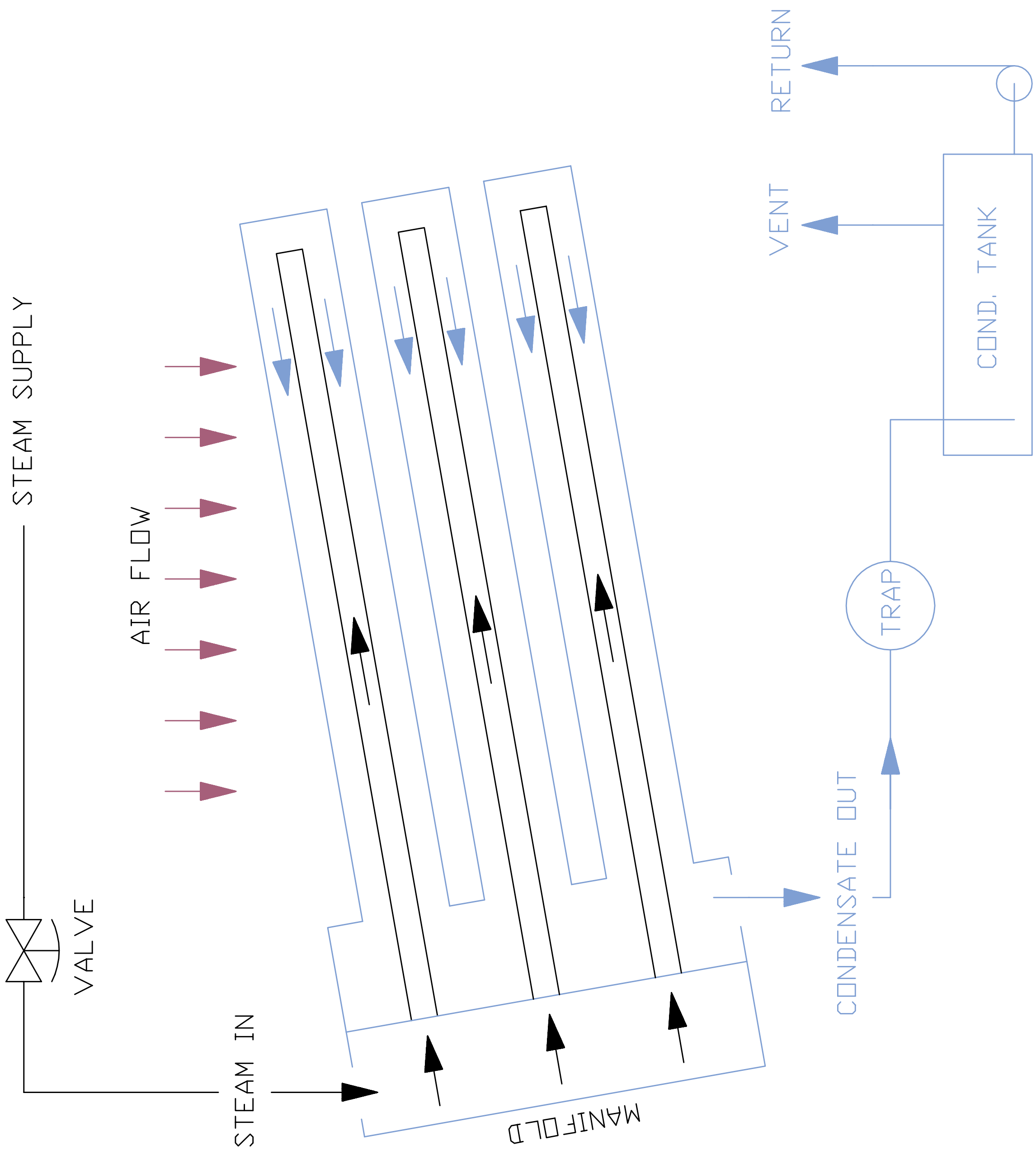
At 125 PSIG, latent heat = 869 BTU/LB
At 80 PSIG, latent heat = 892 BTU/LB
At 60 PSIG, latent heat = 905 BTU/LB

Thus, it can be seen that at 60 PSIG, more latent heat is available than at 125 PSIG. However, the temperature of steam at 60 PSIG is 308°F as compared with 353°F for 125 PSIG steam. Therefore, although more heat can be gained from the lower pressure steam, the maximum temperature possible will be less.

The Heat Exchanger

Proctor heat exchangers are unique in their construction (see Figure 1). For a heat exchanger to be efficient, it must be made of a material which conducts heat well, must have smooth internal and external surfaces, thin walls and the maximum surface area. Proctor accomplishes this by using steel with copper fins and a system of concentric tubes so that the inner tube serves to give additional heating surface and direct the steam flow down the full length of the fincoil. The fin spacing is sufficient to allow small particles of dust to pass through, but any accumulation of scrap between the fins will impede airflow and lower efficiency. The coils are tilted slightly to facilitate the draining of condensate. Any accumulation of water in the coils will reduce efficiency as even hot water will not release the heat that the condensation process does.

Figure 1. Heat Exchanger



Controls

The temperature of the air in any section is measured by a thermocouple *before* the air comes into contact with the tobacco but after the heat exchanger. This is the hottest point in the system.

This temperature is compared with a set-point in the controller for that section. The controller will modulate the control valve to supply the correct steam flow to the coil to maintain the desired temperature. Note that although the supply pressure may be 125 PSIG, pressure in the coil may be very low (± 20 PSIG) because the steam is condensing as fast as it is being supplied. In order for the control system to function smoothly, all the condensate must be continuously removed from the coil with no back-pressure. This is accomplished by means of correctly sized steam traps and a condensate tank which is below the lowest point of the coils.

Airflow

Air is circulated through the tobacco and over the heat exchanger by means of one or more centrifugal fans per section. Ideally, the air is distributed evenly across the width of the apron by means of perforated diffuser plates, but in practice more air is directed to the side furthest from the fans due to the fact that the air is reluctant to make the tight turn to flow up next to the fans. This causes overdrying on one side and underdrying on the other. There have been various attempts to improve this, and a perforated plate diffuser with graduated open area across the width of the machine has been most successful so far. A typical air-up section is shown in Figure 2. Air-down is shown in Figure 3.

Figure 2. Air-Up Drying Section

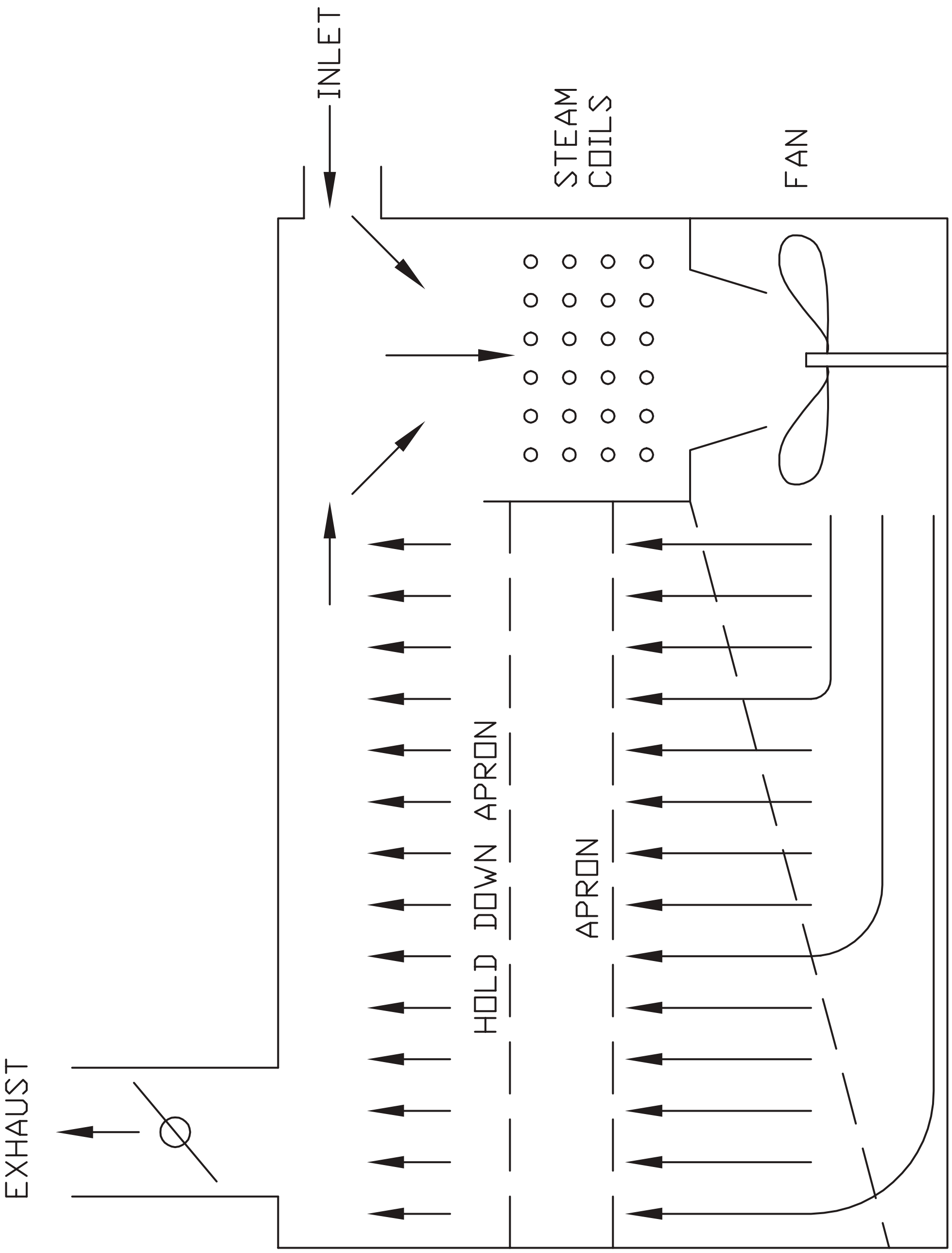
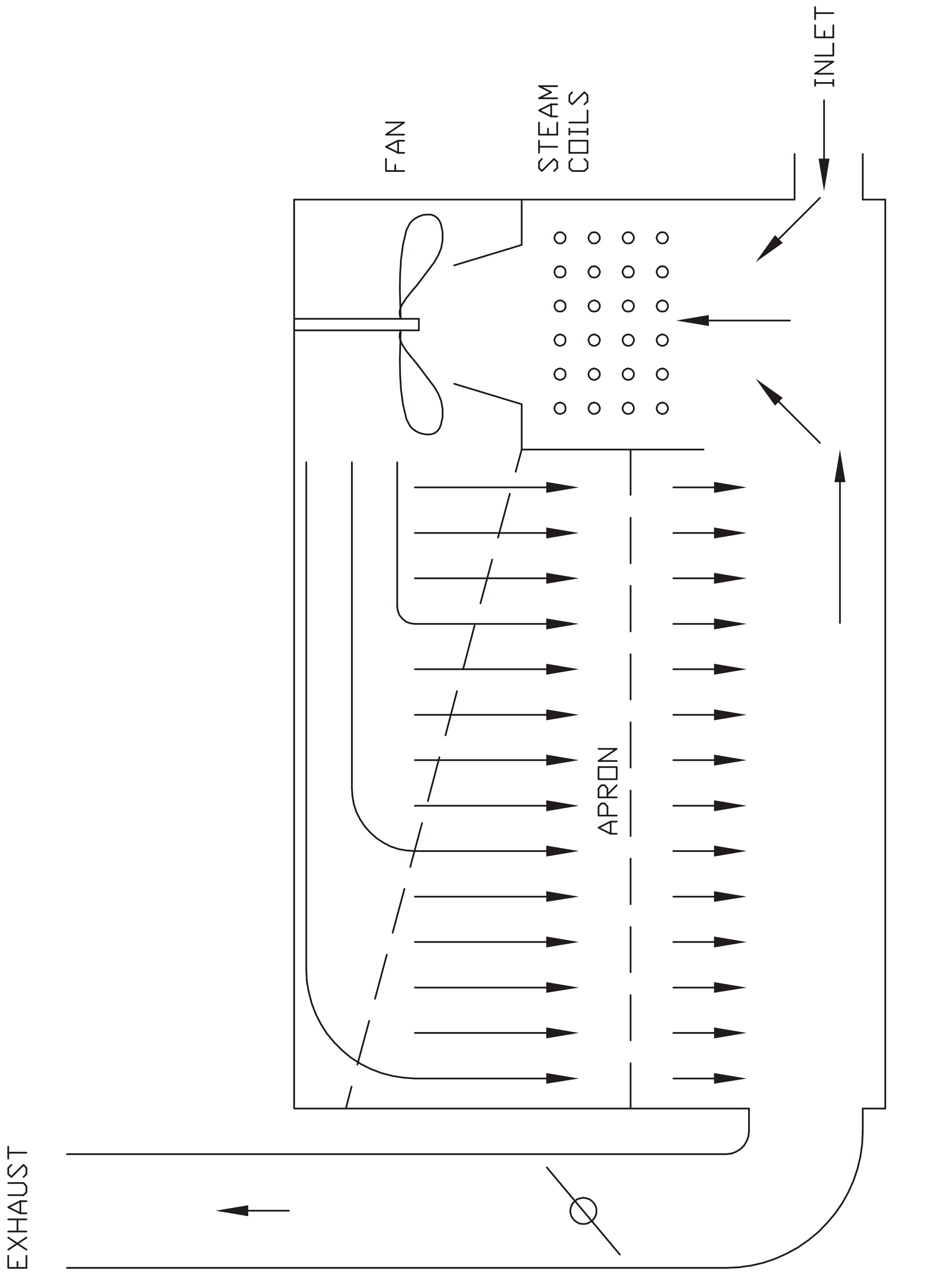


Figure 3. Air-Down Section



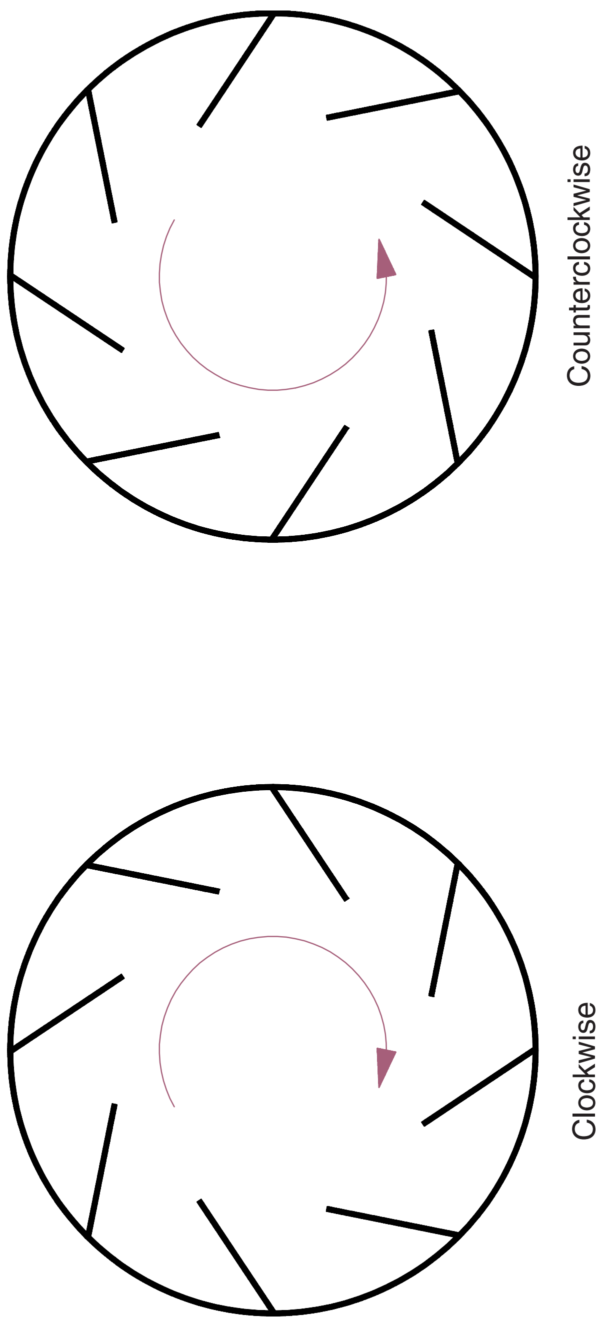
Exhaust air can be set by using the dampers on each exhaust duct. The most common way to set these is to measure the RH in each exhaust and set the damper to give about 30% under normal drying conditions. The amount of exhaust has a profound effect on drying characteristics and this adjustment should be made carefully. The fresh-air intakes are normally left wide open.

The amount of circulating air is controlled by varying the fan speed using an inverter variable frequency controller or by adjusting volume control discs in each fan. The volume control disc has the effect of blanking off part of the depth of the fan. The Sargent dryers have adjustable louvres to control airflow.

Airflow in air-up sections is typically 160–180 FPM and in air-down and cooler sections about 200 FPM. In air-up the flow is limited to the amount that will pass through the tobacco without blowing holes in the carpet.

The rotation of the fans is important. All Proctor fans are of the backward inclined blade design which give a fairly constant airflow over a broad range of pressures. For those fitted with variable speed drives, the amount of airflow is directly proportional to the percent of full speed at which the fan is set. In order to get maximum circulation, the fan must be rotating in the right direction, the aprons and perforated plate diffusers must be clean and the fincoils must be unobstructed by lint or scrap. For correct fan rotation please refer to Figure 4. Note, there are clockwise and counterclockwise constructions of fans. It is not good practice to reverse fans to reduce airflow except as a very temporary solution. The best drying is obtained by using the maximum possible airflow.

Figure 4. Fan Rotation



In the air-up section there is a possibility of lifting small particles of tobacco into the air stream. In order to protect all fincoils from contamination, a hold-down apron is necessary. This is normally mounted with the lower flight 8–10" above the main apron to sandwich the tobacco in the air-up section. As very little product comes into contact with it, it is necessary to move it only fast enough to allow it to remain clean, normally 1–5 fpm. A jet of air from the first air-down section normally blows the hold-down apron clean as it passes through the drive jog. This is controlled by a small slide gate taking air from the first air-down fan.

The Cooling Section

The cooling section serves two purposes:

1. To cool the tobacco after drying.
2. To further dry the tobacco by removing the layer of vapor around each leaf.

The cooling section is an air-down section because large volumes of air are moved and because it is sandwiched between the dryer air-down and the ordering air-down.

In order to dry tobacco of varying incoming moistures down to a final consistent moisture, it is necessary to over-dry it to some extent to reduce the variation in moisture. If this is done, it is necessary to add a controlled amount of moisture to achieve the final desired target. If this moisture is added in the form of steam, the steam must condense on the tobacco to raise the moisture. However, in condensing it will also give up heat, which will raise the tobacco temperature.

The cooler is inserted to reduce the temperature of the tobacco so that steam will condense on it in sufficient quantities to raise the moisture to the final target, without raising the temperature to the point that the packing temperatures are dangerous.

Modern coolers are designed as shown in Figure 5, but many of the older machines have been modified. The principle remains the same. Air is blown in above the bed of tobacco by two fans and sucked from below the bed by two fans, giving a "balanced" cooler. The temperature in the cooler is controlled by recirculating a portion of the air from exhaust to intake via motorized dampers (1).

The air above the tobacco is normally set at about 100°F (± 40°C), a figure that has been arrived at by experience.

The pressure in the cooler can be varied by adjusting blast gates in the inlet and exhausts ducts (2). This is normally set to give maximum circulation and a slightly negative pressure.

In recent years there has been a great deal of thought concerning the necessity for the cooler. As the high pressure misting systems are able to add moisture to the tobacco without staining it, steam is only required to maintain a temperature sufficient for packing, usually about 105°F in the container. It is also thought that the majority of the curling of the particles occurs because of thermal shock in going from the last drying section to the cooler. Some tests have been done raising the cooler temperature to as high as 130°F and also turning the cooling fans off. The packed temperature was affected very little. It is possible that in the future the coolers will be converted to additional drying sections.

Conversely, some plants have tried evaporative or refrigerated cooling on the cooler intakes in hot weather. Whereas this does lower cooler temperatures, again it does not affect packed temperatures by more than 5°F.

Figure 5. Cooler

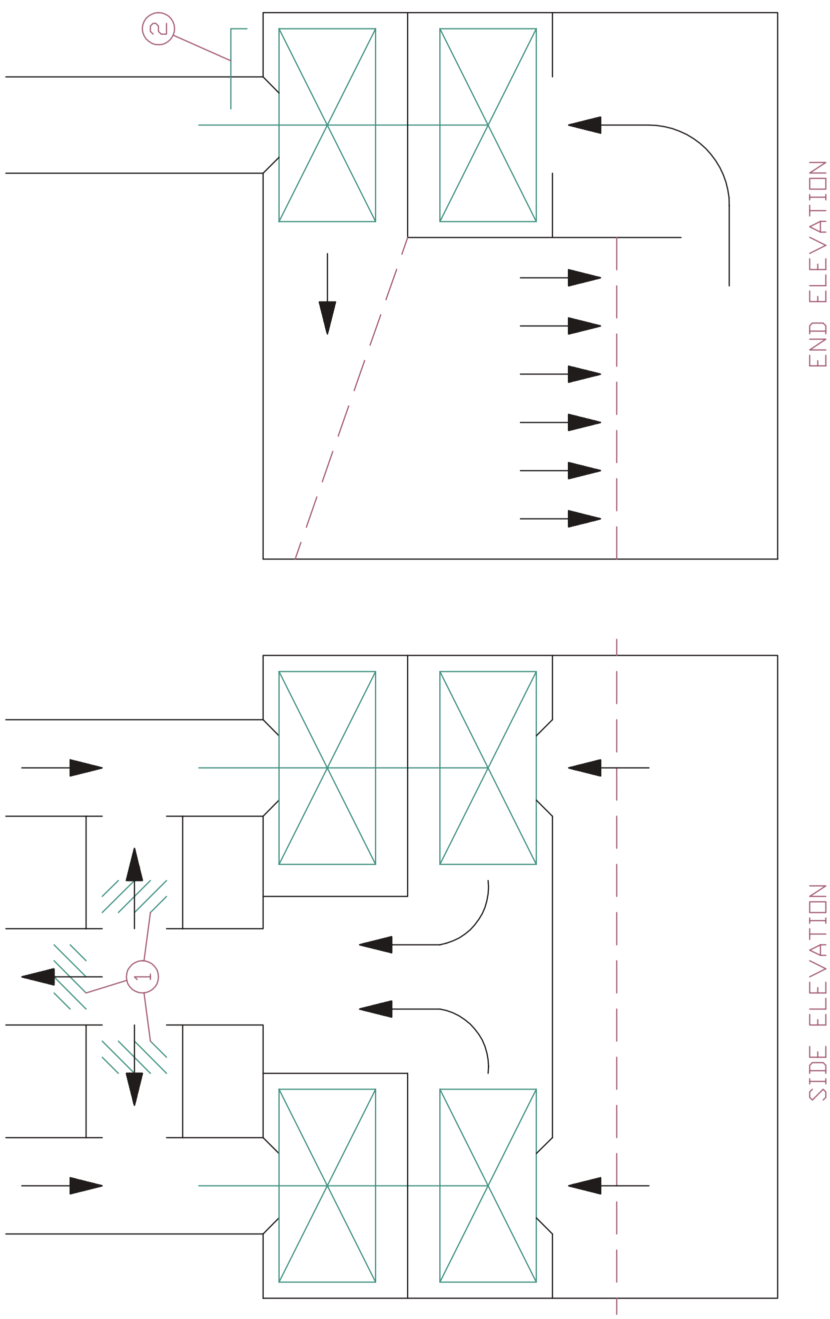
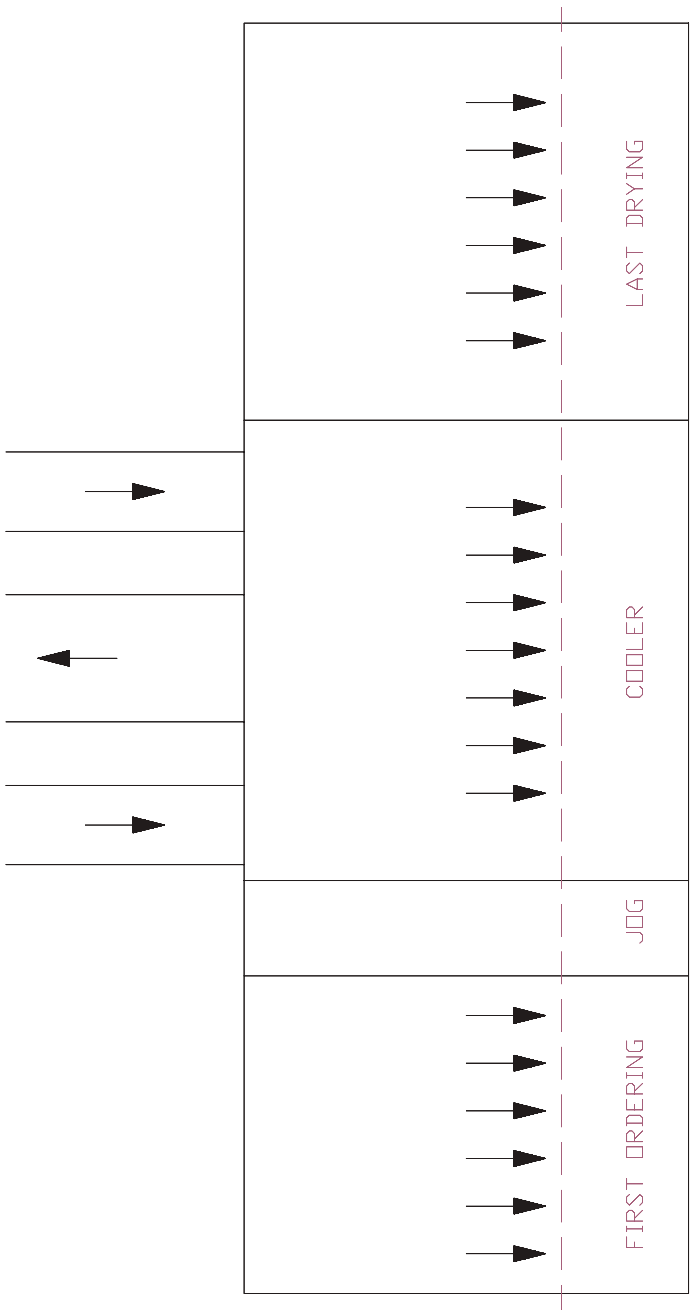


Figure 6. Cooler Position



The Ordering Section

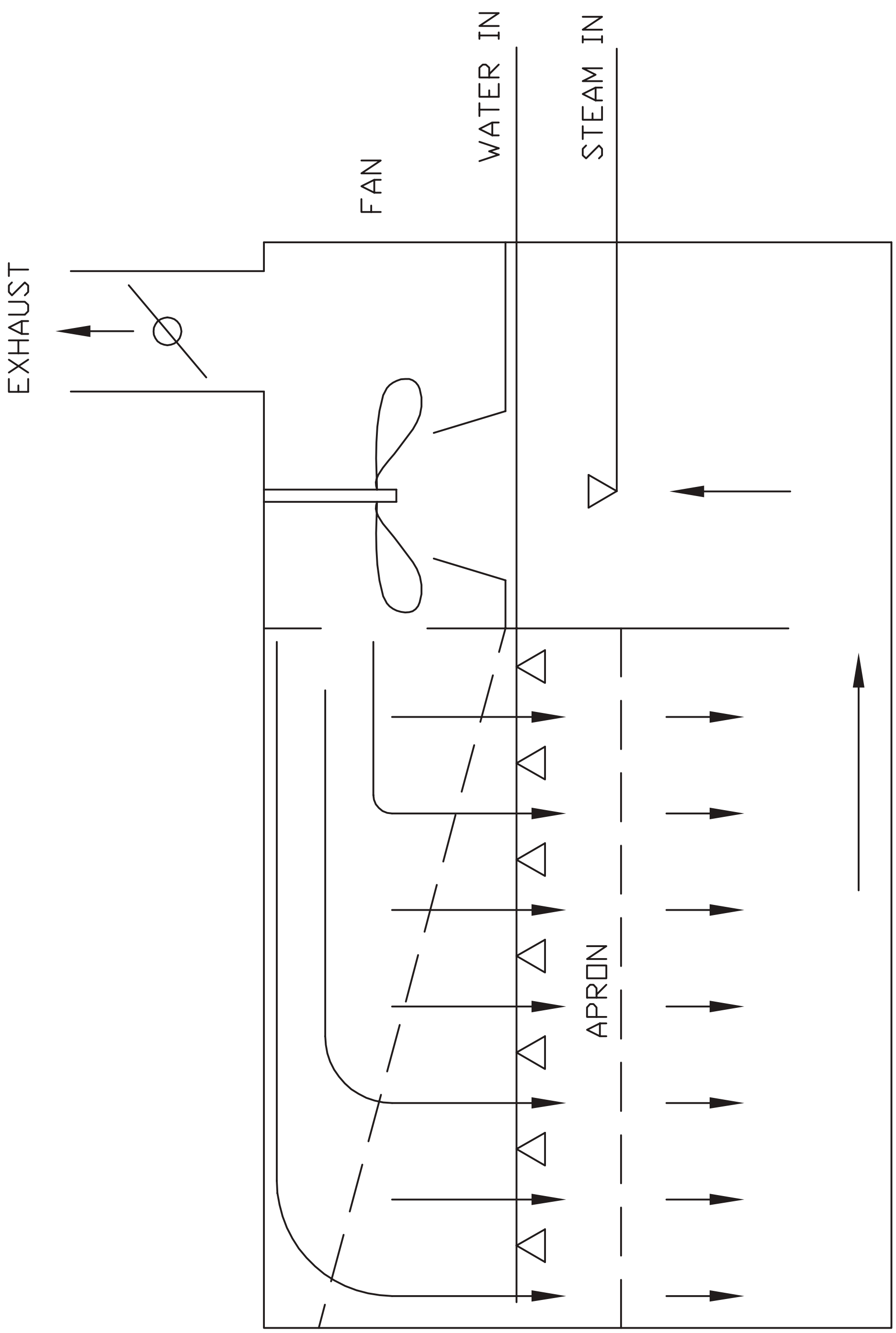
This is the area where moisture is added to the tobacco in controlled quantities to attain the desired final moisture. It involves circulating humid air and steam through the tobacco, first from the top down and then from the bottom up. As the air penetrates better in the air-up direction, the ratio of down-to-up is about 1:2, as in the drying section.

The fans in the ordering section are normally of the axial type (propeller) as not a great deal of airflow is required. These fans cannot work against high back pressures, so the air path must be kept clean.

The moisture is added by means of direct steam and water injection. The original machines used steam powered atomizers to break up the water into fine particles mixed with steam. The atomizers were positioned outside the dryer and directed the steam through slots in the sides of the chamber. In doing so, the venturi effect also entrained air with the steam. The combination of steam and air being forced into the chambers caused a pressure build-up in each section, so provision had to be made to exhaust some humid air (see Figure 7).

With the advent of the high pressure misting systems, it made sense to only use sufficient steam to maintain desired temperatures and it made no sense to bleed in cool air and exhaust expensive energy. Most machines have now been converted to internal steam injection and limited fresh air is introduced. If pressure builds up because of high steam usage some exhaust air may be removed. This is accomplished by adjusting dampers on the exhaust ducts (see Figure 7) or varying the speed of the exhaust fan. Note that in machines with wooden ordering sections, some fresh air is always required to dilute the amonia fumes given off the tobacco. If these build up on the machine, rapid carbonization of the wood occurs.

Figure 7. Ordering Section—Air Down



Ordering Steam

The quality of the steam reaching the ordering section is important. The first requirement is that it is dry and saturated. Dry, saturated steam is an invisible gas, so if the steam is white it definitely contains water droplets. Once this condition exists, it is difficult to control the amount of water in the steam which may lead to inconsistent ordering.

The steam normally is supplied at 125 PSIG which has a saturated temperature of 353°F (i.e. water boils at 353°F under a pressure of 125 PSIG). The control valve reduces this pressure but not the heat content.

Thus, directly downstream from the control valve the steam is in a superheated condition, which is when a gas is heated beyond its evaporation point. If this steam were introduced directly into the dryer in this condition, much of it would not condense on the leaves and would go out the exhausts, therefore wasting energy. To remove the superheat, a section of non-insulated pipe is installed between the control valve and the ordering section. This is known as the cooling loop, and cools the steam to saturation temperature. At 20 PSI, this would be 260°F. This is a crude solution to the problem and wastes considerable energy. More recent thinking leads us to believe that it is better to eliminate this cooling loop and allow the steam to enter the chamber through large diameter pipes at low velocity, thus conserving all the available energy.

By utilizing the water-mist system, the superheated steam can be cooled and condensed on the leaves and the exhausts can remain closed.

In order to control the packed temperature at ± 105°F, the tobacco must leave the dryer at 125–135°F, depending on the weather. As it travels to the packer, some moisture flashes off due to the air currents caused by conveying which cause evaporative cooling and moisture loss. A good rule of thumb is 20°F loss in temperature for each 1% loss in moisture, or conversely in the ordering box, a 20°F gain in temperature for each 1% gain in moisture if no water is being used.

Controls

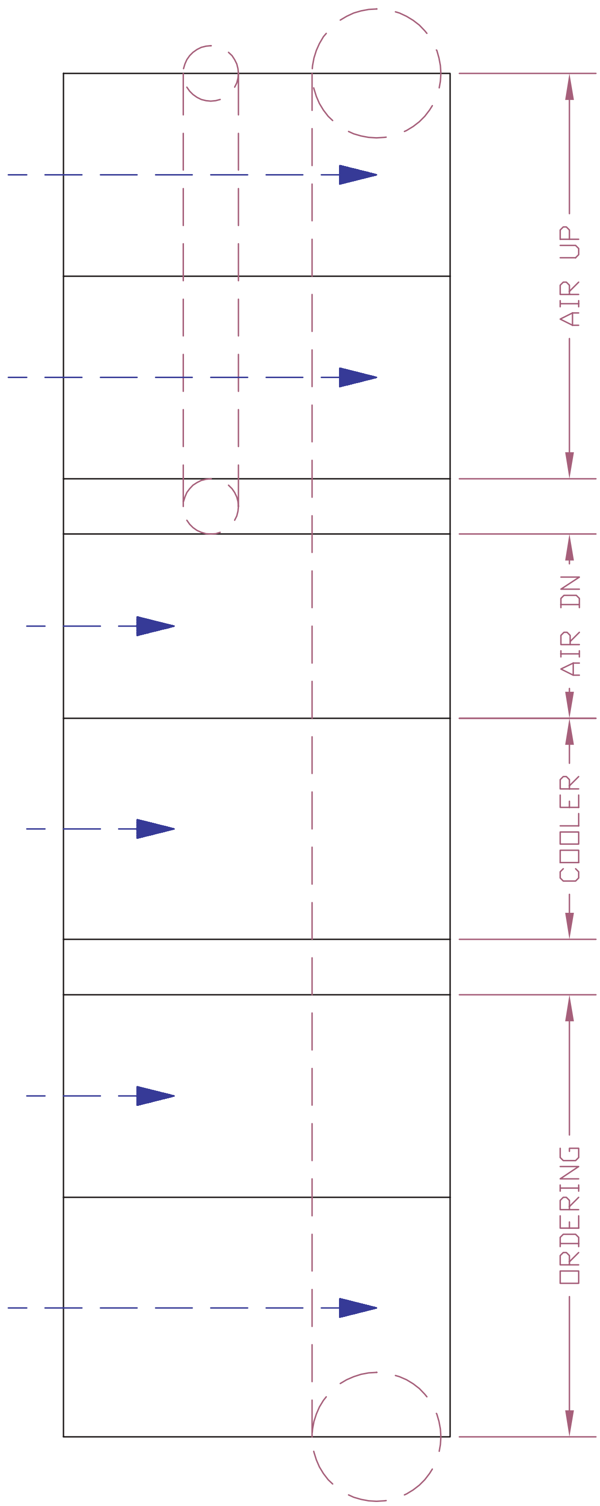
Most of our machines are now equipped with solid state controllers which accept temperature and pressure readings from sensors on the machine. The location of the sensors is shown in Figure 8. These controllers can be tuned to give precise control as long as incoming conditions do not change rapidly.

If flow or moisture are fluctuating, controllers will have difficulty in responding, as they are all feedback systems. It is therefore important to intervene manually if large, sudden changes occur. For best control and optimum results a uniform flow and uniform incoming moisture are important.

To date no one has developed an on-line moisture meter which can consistently read actual moisture on varying products. This is partly because of varying colors, textures and densities and partly because our oven standard is measuring all volatiles, not only moisture. However, moisture meters are reasonably accurate indicators of change, and should be used with this in mind.

Traditionally we have controlled ordering steam by pressure, but with the new enclosed ordering boxes and large open area pipes these pressures are now quite low, which adversely affects the accuracy of the controller. On modern installations, we control via a steam flow measuring device which will be at a constant pressure upstream of the control valve.

Figure 8. Temperature Sensor Locations



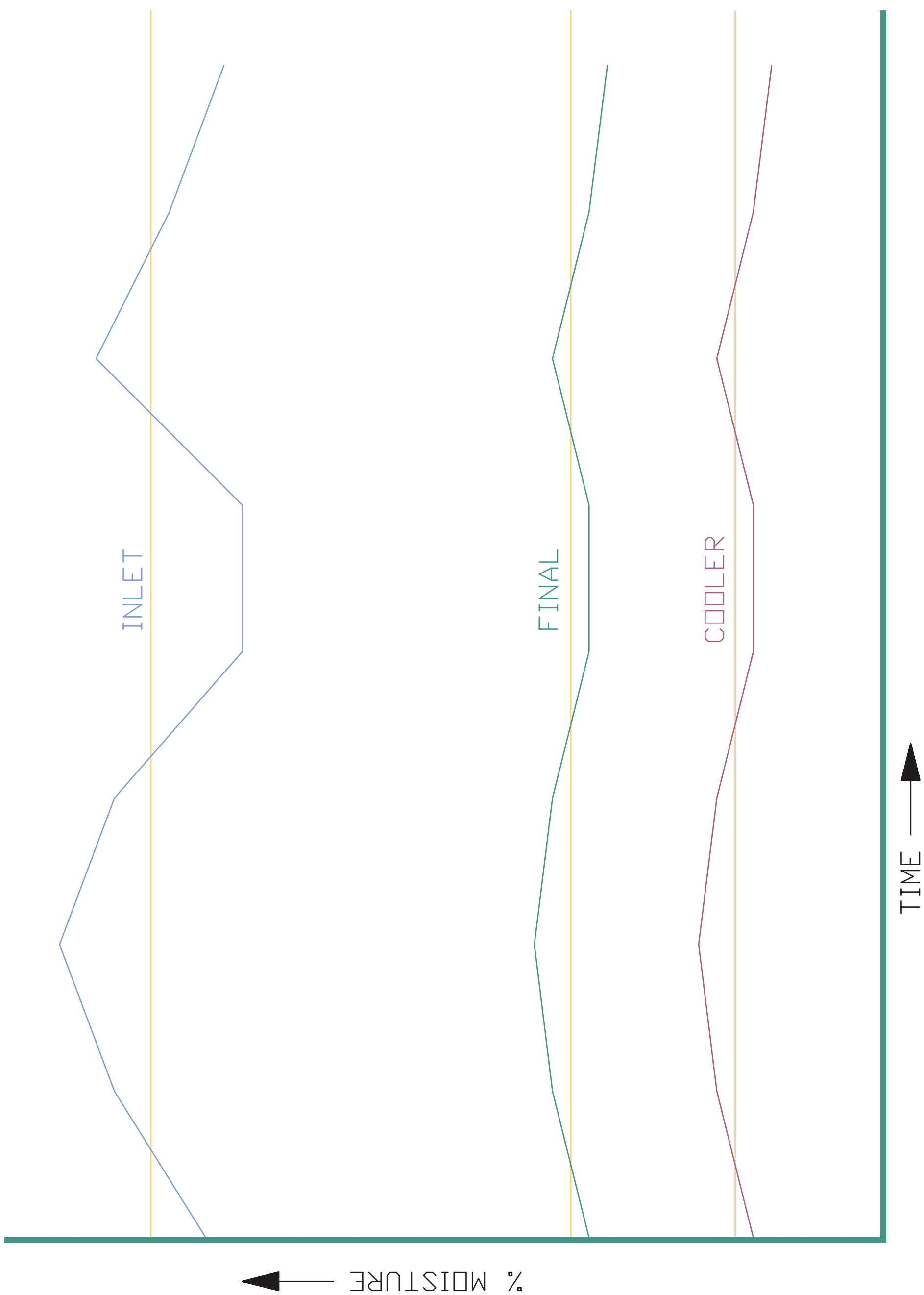
Other Factors

1. Uniform flow and uniform incoming moisture are important.
2. A uniform carpet of tobacco on the apron is important.
3. A clean machine gives better results.
4. Travel guards and brake lining must be tight.
5. Curtains must be lightweight and free to move.
6. Valves and traps must be sized correctly and be in good shape.
7. Control dampers on exhausts and cooler must be clearly marked and free to operate.
8. Lack of attention to exhaust settings and damper adjustments can lead to poor results and undesirable emissions from the dryer.

Common Rules of Thumb

1. For minimum curl, a dryer loading of 15–20 LB/HR-FT^2 of drying is desirable.
2. Carpet depth should be 2½"–3 ½".
3. Ratio of air-up to air-down drying should be 2:1–3:1.
4. Ratio of ordering air-up to air-down should be 2:1–3:1.
5. It takes about 0.5 LB of steam to dry and order 1 LB of tobacco when using the misting system.
6. It takes about 0.7 LB of steam per 1 LB of tobacco when using steam only.

Figure 9. Drying Curves



Packing

Once tobacco has been dried to a suitable moisture in the dryer, it must be packaged in a form appropriate for transportation and storage. This is done by means of a hydraulic press.

Package Types

Packages are designed for several criteria:

a) Cost of packaging material
b) Size of package for efficient containerization
c) Size of package for man-handling
d) Size of package to minimize handling
e) Size of package for blend recipes
f) Size of package for existing material handling systems

The cheapest form of packing is the burlap-wrapped bale, as in most countries burlap is readily available and inexpensive. Used burlap wrappings can be recycled or discarded. Sewing can be done manually or mechanically. This form of packing is popular in countries where labor is cheap and the package will not be hauled too far. The disadvantages are that burlap-wrapped bales are labor intensive to produce and are limited in size to about 100 KG, meaning that the packer has to do twice as many cycles as when packing 200 *KG* cases. This severely limits packer capacity.

The most popular package is the cardboard case. This comes in a number of sizes and styles but is generally ± 30" x 30" x 42" and of two-piece construction. It is made from fluted cardboard to give stacking strength and is normally strapped with three or four plastic straps. Usually 200KG/450LB is packed in these boxes, but for very low-density tobaccos this figure may be down to 180KG. When tobacco is to be shipped by container, these cases are the most practical and efficient. Volume of package is 21 ft^3 and density of package is 21 lb/ft3.

The hogshead is a holdover from the days when barrels were rolled to market, and is a very expensive and inefficient package in terms of space utilization. It is normally comprised of 4' wooden staves banded together with steel straps and measures 48" in diameter by 48" high. Normal packing weight is 950 lb. At this weight, presses have a high capacity and the number of packages to be handled is half that with cases or four times that with bales. Volume of package is 50 ft^3 and density of package is 19 lb/ft3.

The Tersa, or extruded bale, is a 1000 lb cube, normally 40" x 46" x 46" with ¾" plywood boards on top and bottom with three steel straps. This is an excellent package in terms of cost and efficiency and the packing operation can be fully automated. A cardboard or plastic outer wrap is used to prevent spillage of tobacco from the exposed sides. Volume of package is 49 ft^3 and density is 20 lb/ft3.

Conveying Tobacco to the Press

Conveying the tobacco from the dryer to the press has various effects on the quality of the product. Depending on the layout of the plant, the conveyor system may be simple or multiple. The simpler the system, the less trauma there is on the tobacco, as at each drop and direction change the tobacco is subjected to friction and agitation as it decelerates and accelerates again.

Although time is a factor because of cooling effects, generally the slower the conveyors the less the trauma. Also, a deep carpet of tobacco retains its heat and moisture better than a shallow one. Tobacco normally leaves the dryer at 13–14% moisture and 125–135° F. Depending on ambient temperature and humidity and how well the conveyors are covered, it will lose 1–1½% moisture and 20-30° temperature between the dryer and the container. Note that any hole or gap in conveyor covers will cause undesirable cooling and drying. The exception to this is in very hot weather, when covers may need to be opened to avoid excessive packed temperatures (over 108°F).

In very cold weather, penthouses need to be heated and humidified in order to prevent the tobacco from cooling off too much. For good flexibility the temperature in the container should not fall below 100° F. Cold tobacco is difficult to compress, takes up more charger height and tends to break under compression. This gives bad audits when checked against dryer exit size.

The limit of incline for transporting dry tobacco by rough top conveyor is about 25° F. At this angle, for every one foot measured horizontally, a vertical rise of 0.46 foot is gained. Thus for a press with a fill height of 36 feet, a horizontal distance of 77 feet would be required. As this is difficult to accomplish in one span without wasting space, normally three conveyors forming a "U" are used. In the case of two-floor plants, if the dryer is on the second floor and the press on the first floor, a much shorter conveyor can be used.

Weighing the Charge

A precise amount of tobacco must be loaded into each charger on the press in order to obtain packages of uniform weight. This is accomplished by means of scales under each charger on the press or by means of a weighbelt in the conveying system to the press. Both systems have their pros and cons, but with modern low-profile weigh cells and conveyors through the press, the direct weighing system is generally more precise. A well calibrated and clean weighbelt can do an excellent job, but vibration, dirt and belt inconsistencies usually are a factor and detract from the weighbelt accuracy. In the case of the direct weighing scales, dirt accumulation, friction and vibration can also be problems and the amount of the tobacco "in the air" when setpoint is achieved can be a factor, as this is unknown and varies with flow rate.

Distributing the Flow

Uniform density in a package is important for the following reasons.

1. If pockets of high density exist, there will have been excessive pressure and heat and this will create dangerous conditions for carbonization with certain tobaccos and moistures.
2. Our customers slice the finished packages when making their blends and different densities give different weight slices.
3. High density pockets form pads which cause problems in the primaries.
4. Unbalanced filling causes misshapen packages which are difficult to close and cause problems in filling containers efficiently.
5. High and low ends on cases make stacking dangerous, as the low ends collapse under pressure from the boxes above.

The perfect distributing system has not been invented. With different container sizes, different tobacco types and different flow rates it is impossible to devise a system which works for all. In general, there are three types of distributor in common use.

1. The rotary distributor with extending paddle, designed for hogsheads.
2. The rectangular distributor with two or three reciprocating flaps, designed for cases and bales.
3. The "Quad Fill" by Fishburne, which has one vertical reciprocating blade and two pivoting blades.

Uniformity of flow, spread across feed-belts and air exhaust from the charger all assist distribution, but good results are still really dependent upon the operator's judgment in setting the system correctly and monitoring results frequently.

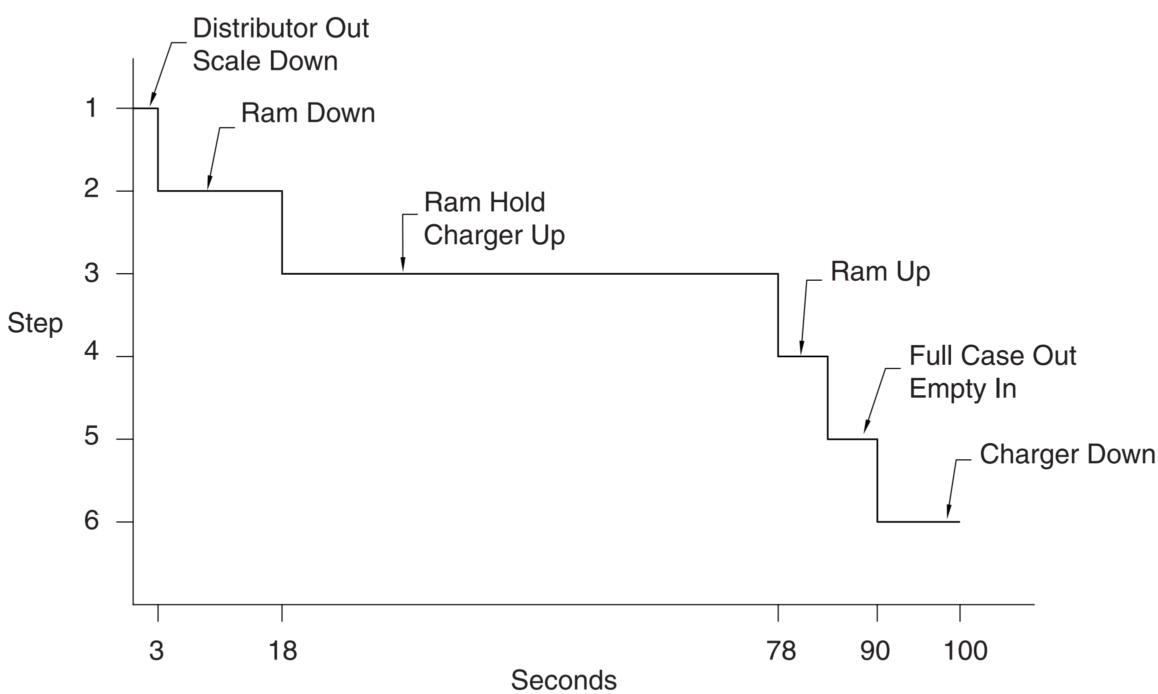
The Press

Many different designs of press have been tried over the years. However, experience has shown that to obtain the most uniform package with a uniform grain and high capacity, the single- stroke down packer is the best. In this design, the full weight of tobacco required for one package is filled into a vertical column inside a charger. The bottom of this charger is the case or other container. A hydraulic ram with a head conforming to the dimensions of the charger compresses the column of tobacco until it is all inside the container.

To handle all types of tobacco at high speed, a charger height of about 30 feet is required. If the charger is too short, the required weight of tobacco cannot be fitted into a single charge, and an intermediate press cycle is required. This gives a split in tobacco density and slows down the cycle time.

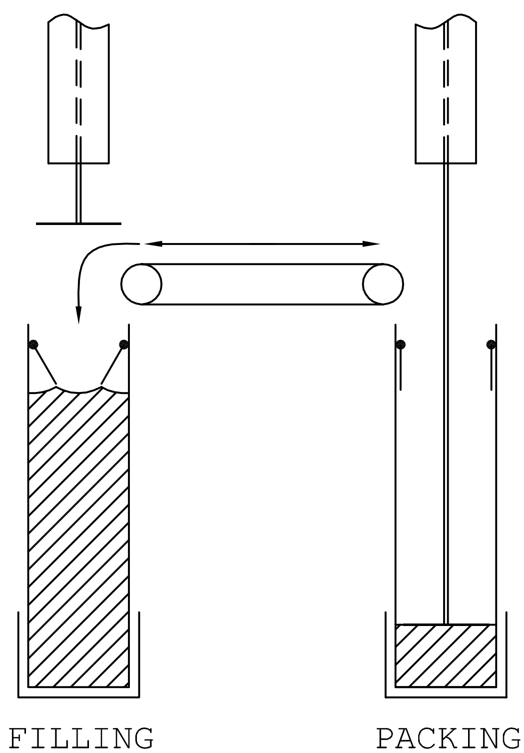
Cycle Time

The cycle time of a press is very important from the production standpoint. Cycle time is defined as the time required from the moment the press starts packing until it is ready to receive another fill. This usually includes a holding period, when the ram maintains pressure on the charge until it loses its rebound pressure. A typical cycle is as shown below:

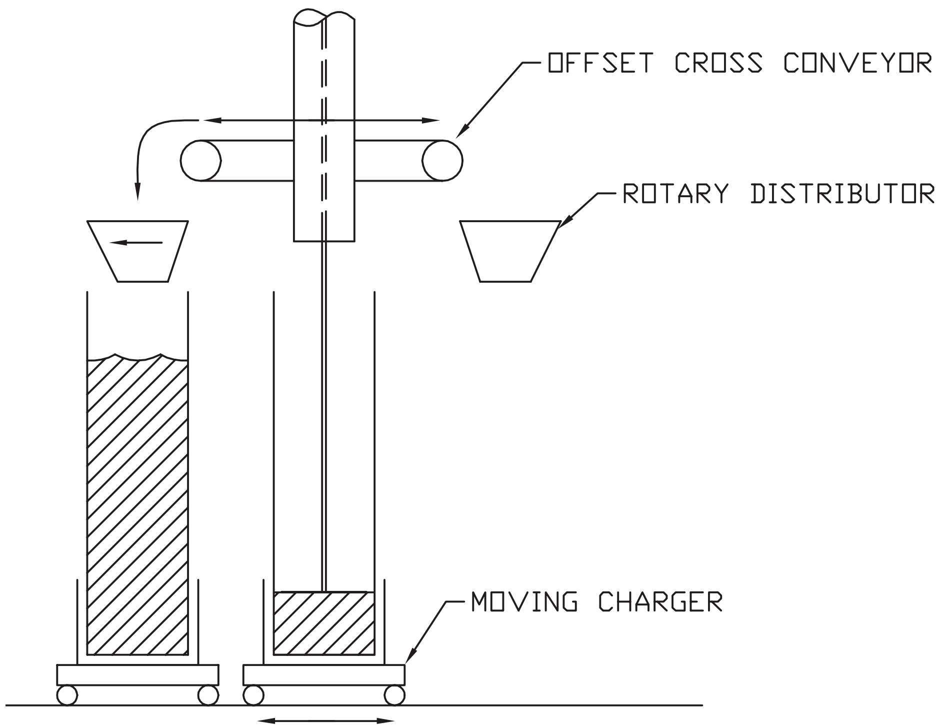


Presses can be installed in pairs with one packing while the other is filling, or as single- ram systems with chargers which move in and out, or single-ram systems with accumulator conveyors. The most desirable system is the twin-ram press, as there is no transfer time involved and tobacco does not accumulate and cool off. Also, accumulator systems tend to give a less consistent distribution in the container.

Twin Ram



Single Ram Double Charger (Godioli)

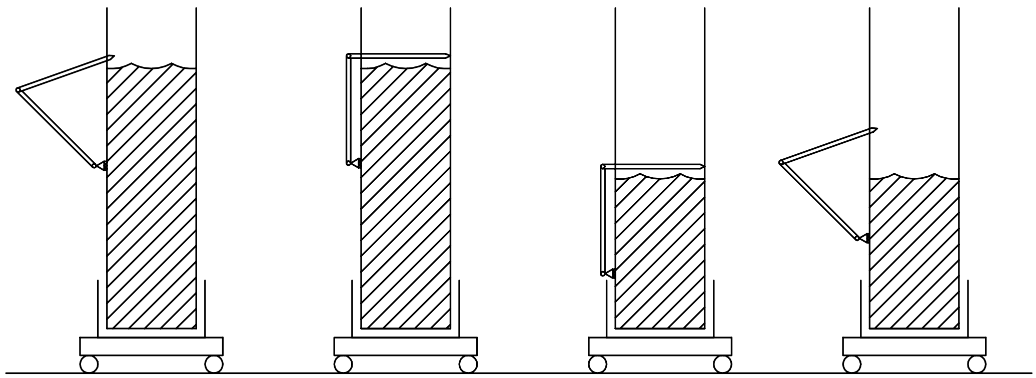


In this setup, the charger is filled off to one side of the ram, and when full, is moved under the ram. The drawbacks to this system are:

1. Cycle time is increased by the time it takes the charger to move under the ram and back again, which can be as much as 20 seconds.
2. The charger height is limited by the practicality of moving back and forth without instability.

Godioli has overcome the second problem by installing continuous compacting fingers on the chargers. These insert across the charger high up above the tobacco, move downwards to compact the tobacco and retract to repeat the cycle. This means a much shorter charger is required, with a corresponding savings in ram length. This offsets the charger-moving addition in cycle time to some extent, as the ram up and ram down times are less.

Godioli Compactor Sequence



Single-Ram and Accumulator

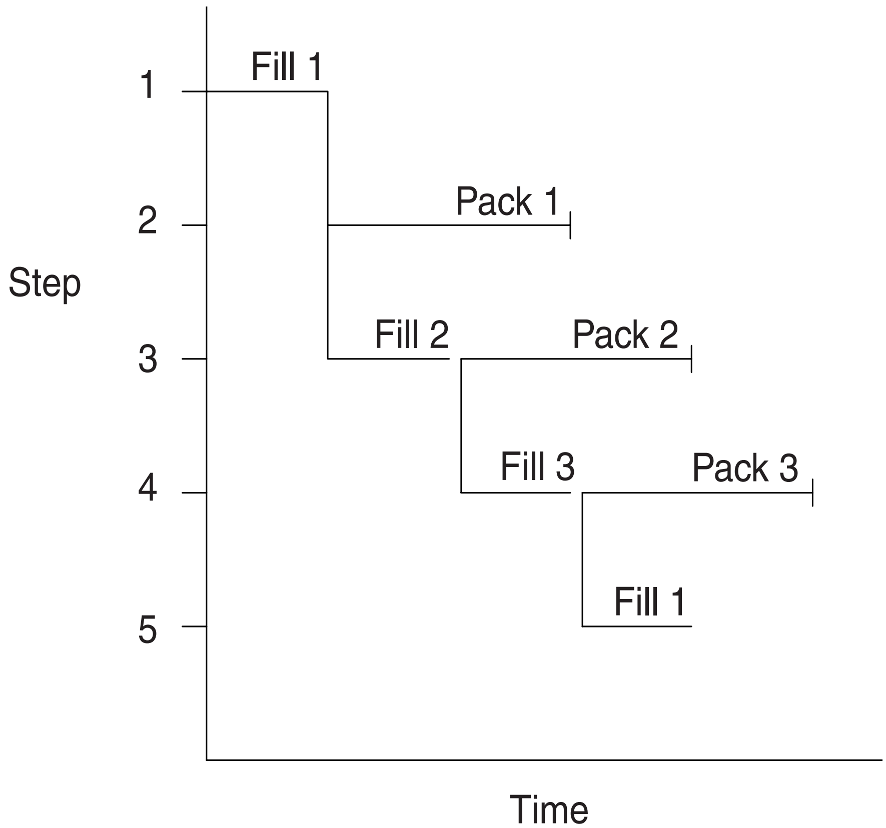
For reasons of space and economy, another alternative is to use a single-ram with an accumulator conveyor. In this setup, while the press is packing, the feed conveyor reverses slowly, accumulating the flow of tobacco from the dryer. As soon as the press is ready, the feed belt reverts to fast forward and delivers the accumulated tobacco plus the flow from the dryer until the weight is reached. This system is not quite as fast as the twin-ram system, as the fill time must be added to the total cycle time. Typically, this would require a minimum of ten seconds, which, using the previous example, would give a capacity as follows:

$$\text{Max Capacity} = \frac{200 \times 3600}{110} = 6{,}545 \text{ kg/hr}$$

Note that these capacity figures are for comparison only. Actual cycle time will be determined by stroke length, pump capacity, hold-time and conveyor speed.

3-Ram Packer

For very high production rates, a 3-ram packer is commonly used. This has double the capacity of the twin-ram, as two chargers can be filled while the third is packing.

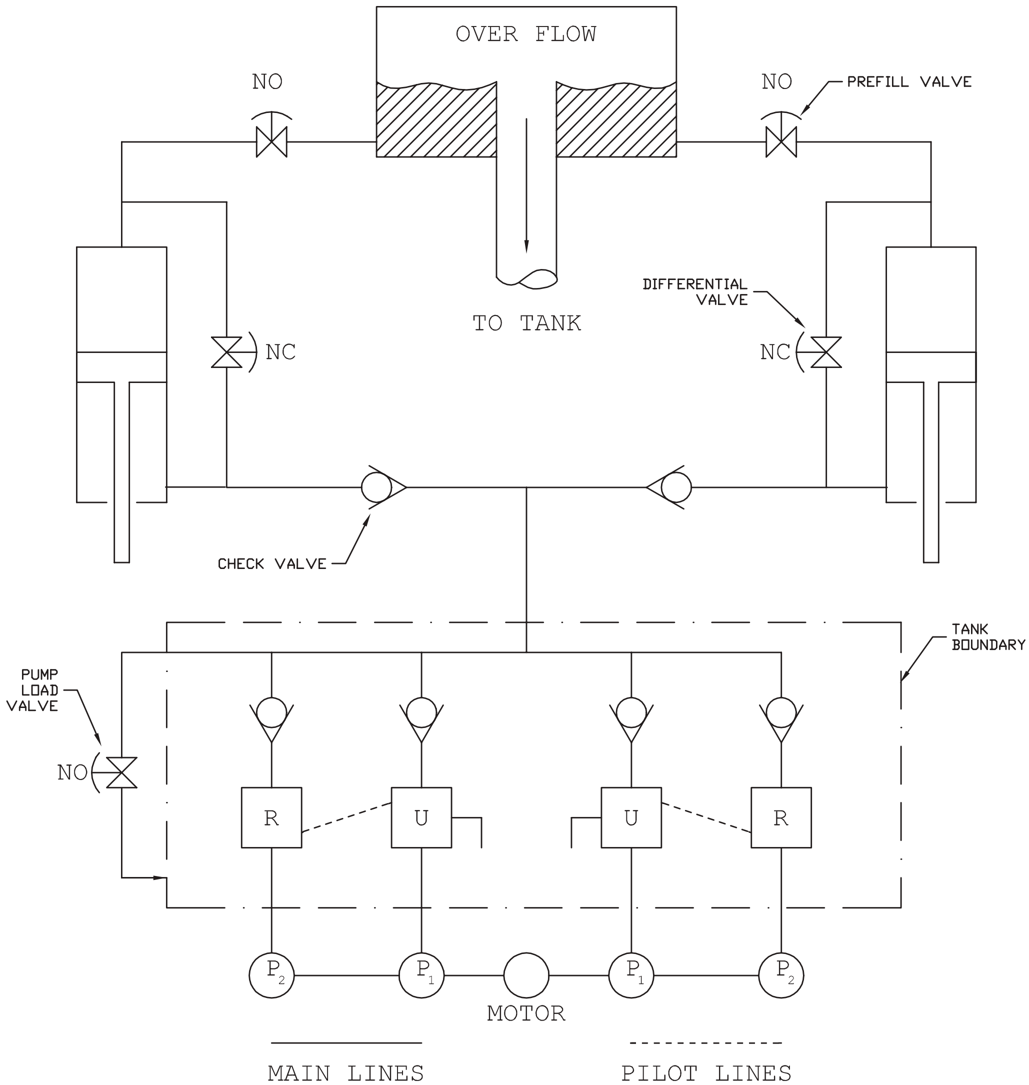


Hydraulics

The most popular hydraulic circuit is the prefill/differential circuit developed by Fishburne. This takes advantage of the area difference between the top and bottom of the piston head to give a force using equal pressures in both ends of the cylinder. The main benefit to this is no forces are applied to the piston head packings, with the additional benefit that on the downstroke, oil from the bottom of the cylinder is forced to the top. The prefill tank takes advantage of the considerable weight of the ram, which can free-fall about half its travel. Oil from the prefill tank supplements the pump oil and oil from the bottom of the cylinder to rapidly fill the large volume at the top of the cylinder. The prefill valve closes when the free-fall loses momentum (controlled by a timer) and the pumps drive the ram down.

On the upstroke, the prefill valve opens and allows an unrestricted flow of oil from the top of the cylinder, thus allowing the ram to ascend rapidly. The following schematic shows a typical hydraulic circuit.

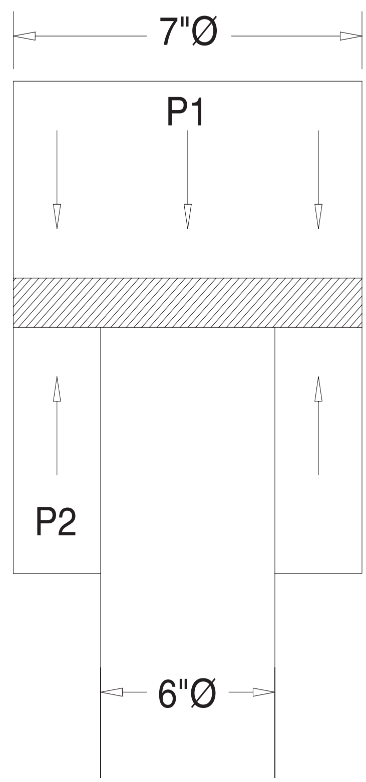
Typical Hydraulic Circuit for Main Rams



	SINCLAIR COLLINS OR CARTRIDGE VALVE
NO	*NORMALLY OPEN*
NC	*NORMALLY CLOSED*
R	*RELIEF VALVE*
U	*UNLOADER VALVE*
P_1	*LOW PRESSURE / HIGH VOLUME PUMP*
P_2	*HIGH PRESSURE / LOW VOLUME PUMP*

This is very much simplified and does not show circuits for chargers or cushion lines, but serves to demonstrate the advantages of the prefill/differential system. The typical ram has a 7" bore with a 6" rod. The areas are as follows:

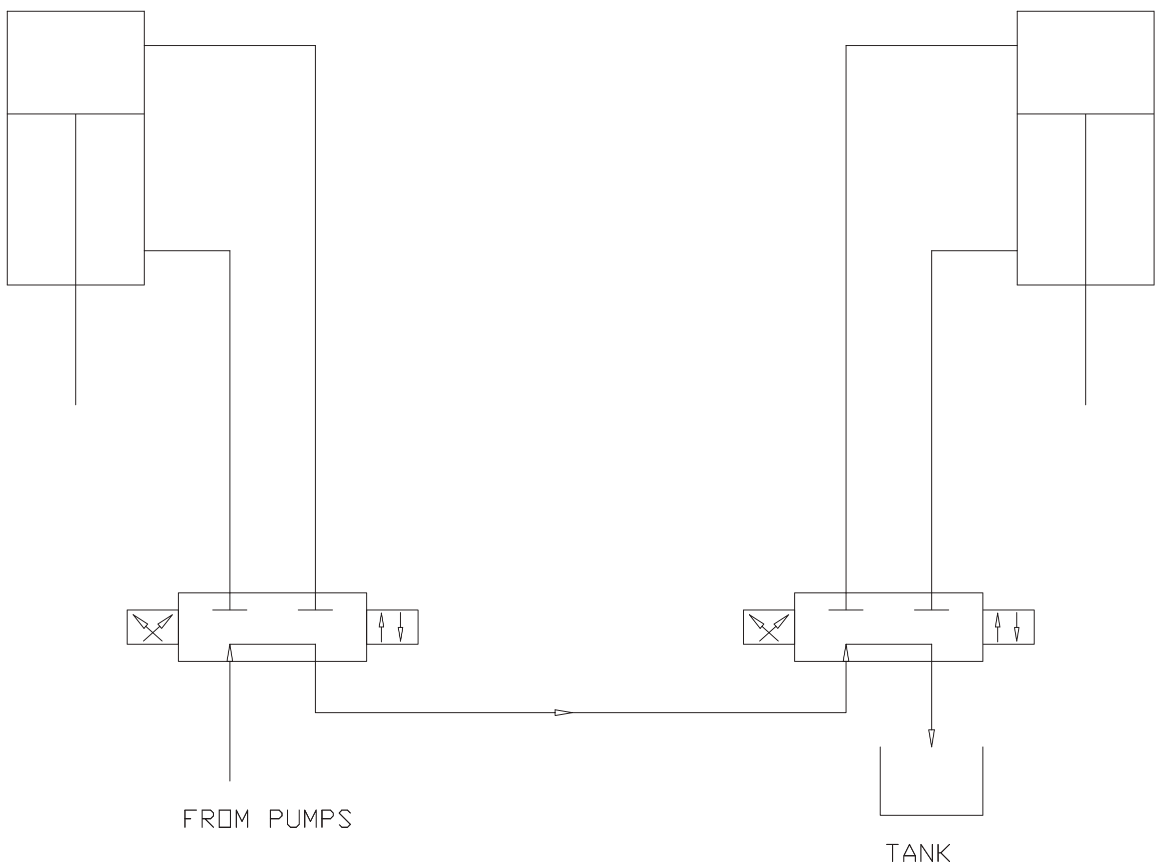
Area on top of piston head	=	4	=	38.48 IN ^{2}
Area on bottom of piston head	=	4	=	10.21 IN ^{2}
Thus, effective area if $P_1 = P_2$	=	38.48–10.21		
	=	28.27 IN ^{2}		



Force down	=	P x 28.27 + weight of ram
If P = 1500 PSI	=	1500 x 28.27 + weight of ram
	=	42,405 lb + weight of ram

As can be seen from the above equations, the differential system causes a loss of about 26% of the potential power of the system. However, for most applications this is not a problem. For packages packed to high densities (Brazilian bales, stems) the differential circuit is not used. In these cases, the standard 4-way valve gives full power to the ram at the expense of putting full pressure on the piston head packing.

Standard 4-Way Valve System



In this case, Force F	=	1500 x 38.48 + weight of ram
	=	57,720 lb plus weight of ram

Sleeves and Corsets

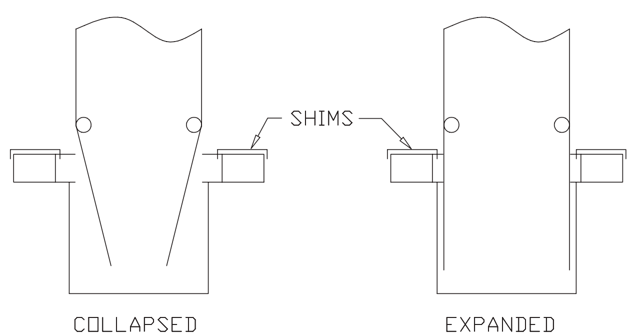
In order to protect the container during the pressing process, a metal sleeve or corset is used. The sleeve fits snugly inside the case or hogshead and takes the lateral forces caused by the vertical forces from the ram. If there were no support, the container would be split. There are two types of internal sleeves used:

1. The Fishburne collapsible sleeve (patented) which normally consists of 4 x 8' long sides hinged at the top and supported by a tubular steel rectangle just above the box. Air cylinders draw the paddles inward as the sleeve is inserted into the box to provide a wedge to align the box. Once the sleeve is down, the air cylinders cause the paddles to expand against the tubular steel frame. By fitting different shims inside the frame, different case sizes can be accommodated.

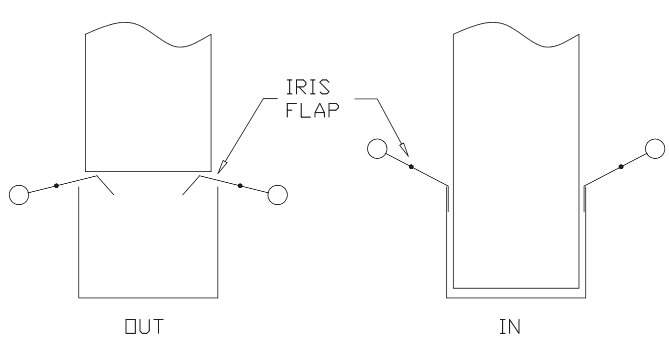
2. The rest of the industry uses the fixed sleeve with iris to align the box. The iris has four flaps which are hinged and counterweighted which the sleeve must pass through on its way down. The iris works on the shoehorn principle, but if fixed in place can drag the tobacco if it expands out of the box as the box leaves the press. Also, fixed sleeves are generally only useful for one size of box.

External corsets are generally used only on hogsheads, and in this case two semi-circular shells of steel are hinged at one side and open and close by air cylinders on the other. Thus the open corset is lowered over the hogshead and then tightened up using the air cylinders.

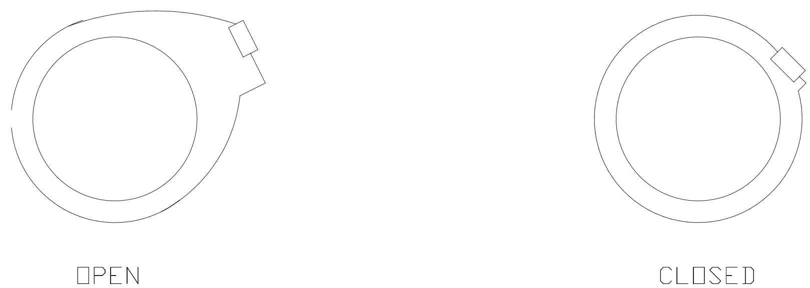
Fishburne Sleeve



Fixed Sleeve



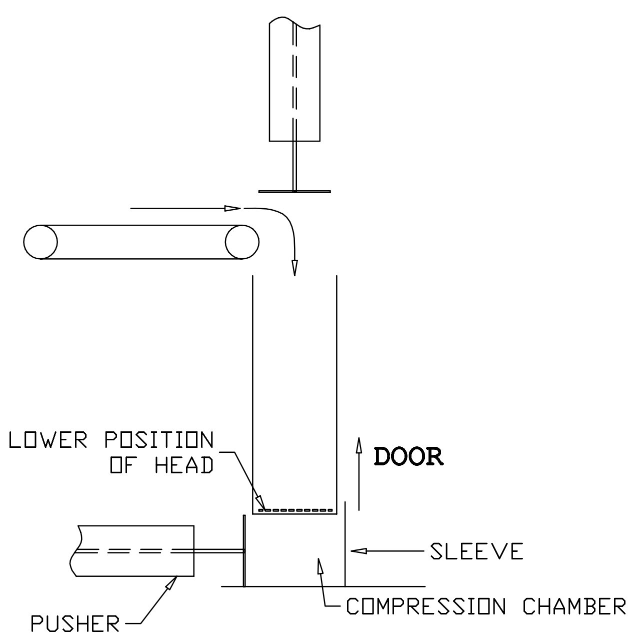
Hogshead Corset



Good support for the containers is essential. However, the sleeve or corset must fit snugly in order to avoid any stresses on the container and to leave minimum clearance between the side of the container and the tobacco when the sleeve is withdrawn.

In the case of an Extruder press, the package is first compressed in the vertical direction by the main ram. The compression chamber is formed on two sides by the side walls of the charger, on the back by the pusher head and in the front by the door. When compression is complete, the ram locks down, the door opens and the pusher forces the cube into a sleeve, where it can be strapped or pushed into a burlap bag to form a bale. The Extruder press is a very fast machine which has the minimum of manual operators and is well suited for bales and Tersa bales. As there is no hold time in the compression chamber and no container to get in and out, Extruder cycle time can be as low as thirty seconds, depending on the horsepower supplied.

Extruder Press



Rules of Thumb

1. For standard vane pumps, 1 GPM at 1500 *PSI* takes about 1 *HP*.
2. For a standard 7" bore x 6" rod main ram,
   volume/FT above the piston head = 2 *GAL/FT*.
   volume/ft below the piston head = 0.53 *GAL/FT*.
3. 1 gallon = 231 IN^3
4. *WORK* = *PRESSURE* x *VOLUME* *(FT-LB)*
5. *HORSEPOWER* = *WORK/TIME* *(FT-LB/MINUTE)*
   e.g., to move ram 6' down @ 1500 *PSI* in 5 secs, = 126 *HP* + FRICTION LOSSES

Container Dimensions

The following are inside dimensions of corrugated boxes used in the US to pack strips:

Inside Dimensions

Style	Length	Width	Height
C48	43 5/16"	26 3/8"	28 15/16"
C99	43 5/16"	26"	28 15/16"
JTI	42 1/8"	26 3/4"	27 1/4"
T21*	42"	28 7/8"	27 1/4"
T6B **	45"	27 3/4"	26 1/2"

* Used only by JTI for Burley
** Used only by TTWMB

Inside Dimensions

Style	Length	Width	Height
C48	1100 MM	670 MM	735 MM
C99	1100 MM	660 MM	735 MM
JTI	1070 MM	679 MM	692 MM
T21 *	1067 MM	733 MM	692 MM
T6B **	1143 MM	705 MM	673 MM

Containers used for other products include:

	Length	Width	Height
PM-80 (PM By-products)	42 ¾"	40 ½"	42 7/8"
J67 (American Tersa Wrap)	46 ¾"	39 5/8"	48"
J68 (American By-products)	47 1/8"	37 1/8"	43 ½"
Tersa Bales: American	46 ¾"	39 ½"	46"
Tersa Bales: RJR	46 ¾"	39 ½"	44"
Gallaher Bag	43 11/16"	26 9/16"	28 15/16"

PM Hogsheads: 48" diameter x 48" height

Hold-Down Presses

After the package leaves the main press, the weight might need to be adjusted slightly by adding or removing tobacco. (This is not possible for Extruder packages.) After this step, the package is pressed once more in a hold-down or headout press, where the tobacco is pushed down into the container again and moisture sample taken. In the case of the hogsheads, the cap is put on at this time using a shoehorn-type iris. For cases, outside the hold-down press, the flaps are folded closed and the package is strapped.

Automatic Strapping

Most plants use automatic strappers, where the closed box is indexed through a rectangular track containing the strap and at each strap position the strap is tensioned, sealed and cut by the automatic strapper. Sealing is normally accomplished by means of heat or friction. Standard strappers are the Signode MCD series and the Landen type. Both use polypropylene or polyester strapping 7/16" wide.

Marking

The finished packages are identified by printed tags which are stapled or glued on according to the customers requirements. Most tags now contain bar codes which uniquely identify the package. In some cases, ink jet printers are used to mark the sides of the box directly.