HOW TO SOLVE
BLOWN FILM PROBLEMS

lyondellbasell

How to Solve Blown Film Problems

This technical brochure covers some of the most common blown film problems and their probable solutions. It is hoped that the information contained here will be of assistance to you in your film operations.

Table of Contents

Blown Film Basics

The goal of this brochure is to describe specific defects that can appear in tubular blown film and to suggest probable causes and solutions. However, a review of the process of blown film extrusion is worthwhile.

An operator can become so familiar with a given film line that problems are solved intuitively, but training new personnel or bringing a new line on stream may raise difficulties. Some inherent and half forgotten quirk of the process (and there are many) may be of no consequence under familiar conditions, but can become the unrecognized cause of defects when conditions are changed to accommodate new products or processing requirements. Reviewing the blown film extrusion process can prepare you to handle these problems.

Blown Film Process Basics

The process of producing film by extruding molten resin into a continuous tube is, at first glance, extremely simple. The elements of the process **(Figure 1)** include the resin pellets which are fed through a hopper into an extruder. Here, heat and friction convert the pellets to a melt which is forced through an annular or ring-shaped die to form a tube.

The tube is inflated to increase its diameter and decrease the film gauge. At the same time, the tube is drawn away from the die, also to decrease its gauge. The tube, also called a "bubble," is then flattened by collapsing frames and drawn through nip rolls and over idler rolls to a winder which produces the finished rolls of film.

However, anyone familiar with blown film extrusion knows this simplified explanation is less than half the story.The blown film extrusion system is, in fact, one of the most complex and sensitive of all plastics processing technologies. The tubular blown film process is efficient and economical, and can produce a magnificent array of products — from a light gauge, clear converter film to heavy gauge construction film, which when slit and opened, may measure 40 feet or more in width.

Basic Blown Film Line

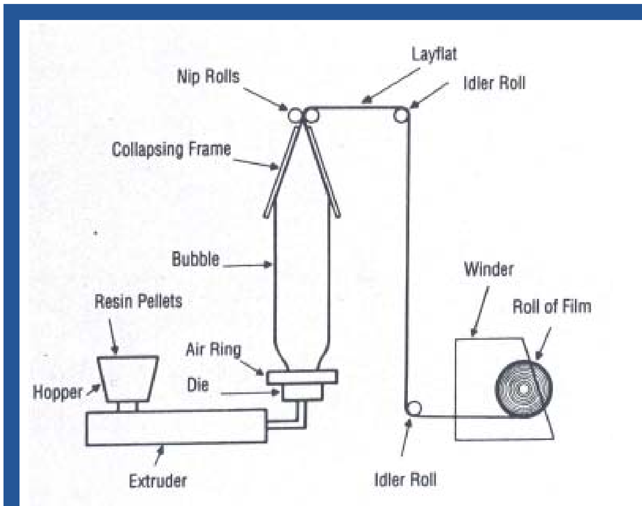

Figure 1

Elements of Blown Film

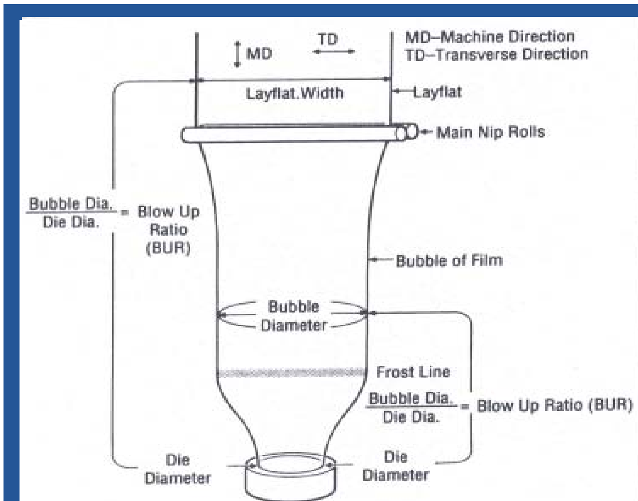

Figure 2

Main Arena of Action

More of the problems in blown film extrusion take place in the section of the tube illustrated in **Figure 2** — from within the die to the far side of the nip rolls — than in any other portion of the line. Elements in this section are labeled and are referred to again in this booklet.

Even though practice does not always follow theory, theory can help explain many of the problems encountered in extruding polyethylene into blown film. For example, blow-up ratio (BUR) used alone as a film-making parameter is meaningless. BUR must be related to draw-down ratio and die gap. In **Figure 3,** all three of these parameters are used to illustrate a theory of melt orientation, an important factor in extruding the high quality film required by customers.

Melt Orientation Theory

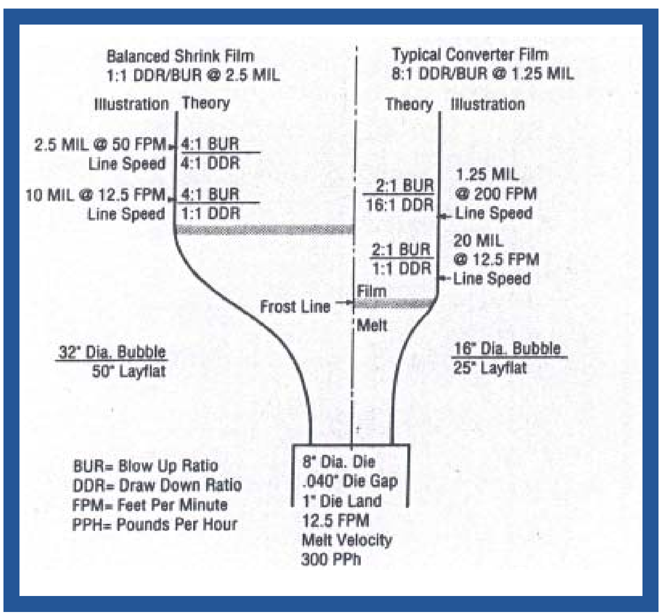

Figure 3

To illustrate melt orientation, it is necessary to separate the blow-up and drawdown functions. In reality, however, these take place simultaneously in the melt below the frost line. In this area almost all of the important characteristics of the film are fixed-orientation, shrink properties, clarity, gloss, strength, etc.

The formula to obtain the BUR and drawdown ratios and their meanings are as follows:

$$\text{Blow Up Ratio (BUR)} = \frac{\text{Bubble Diameter}}{\text{Die Diameter}}$$

BUR indicates the increase in the bubble diameter over the die diameter. The die gap divided by the BUR indicates the theoretical thickness of the melt after reduction by blowing. Since it is difficult to use calipers on the bubble to measure its thickness unless you knock it down, a more practical formula is:

$$\text{BUR} = \frac{0.637 \times \text{Layflat Width}}{\text{Die Diameter}}$$

The final thickness reduction in the melt after blowing is indicated by a drawdown ratio.

$$\text{Drawdown Ratio (DDR)} = \frac{\text{Width of Die Gap}}{\text{Film Thickness} \times \text{BUR}}$$

A third ratio, called the blow ratio (BR), is the increase of layflat width over die diameter. BR is used less frequently, but can easily be confused in conversation with the more common BUR.

A blow-up ratio greater than 1 indicates the bubble has been blown to a diameter greater than that of the die orifice. The film has been thinned and possesses an orientation in the transverse direction (TD).

A drawdown ratio greater than 1 indicates that the melt has been pulled away from the die faster than it issued from the die. The film has been thinned and possesses an orientation in the machine direction (MD).

In practice these numbers are only approximate because the melt swells as it leaves the die gap. The above calculations are made using the die gap dimension because the degree of swell varies with the resin used and processing conditions.

Collapsing the Bubble

Although these ratios provide general parameters, some incompatibility exists between the configuration of the bubble and that of the film after it has been collapsed over the various rolls. After film is wound, its size is called the layflat width. Brief study of **Figure 4** shows the reason for this incompatibility. The sketches show front and side views of a bubble 16 inches in diameter collapsed to a layflat width of 25 inches (some numbers here are rounded off for ease of comparison).

Theory Geometry of the Collapsing Bubble

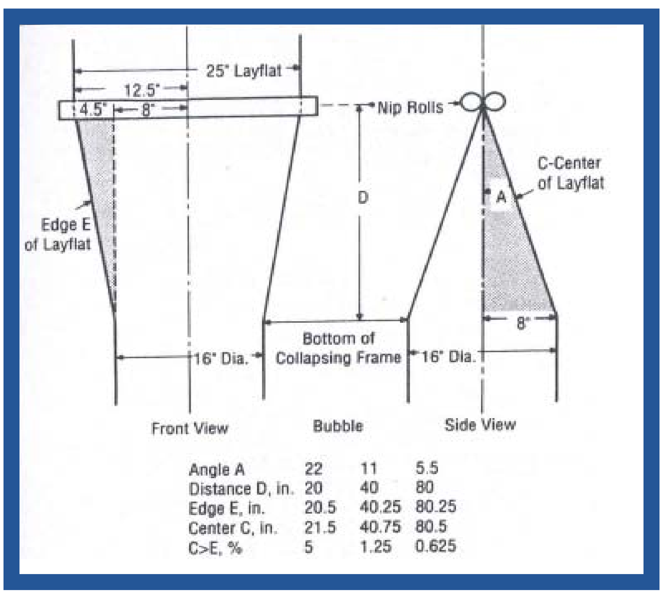

Figure 4

In **Figure 4,** on the front, a right triangle is formed (shaded area) with the length of the vertical side equal to D, the distance between the nip rolls and the bottom of collapsing frame; the length of the base side is equal to half the layflat width minus the radius of the bubble, or 4½ inches.

On the side view, a right triangle is formed (shaded area) with the vertical side equal to D as before, but the base side is equal to the radius of the bubble, or 8 inches (½ of the diameter).

Since the two triangles have vertical sides of equal length, D, but different base lengths, 4½ inches vs 8 inches, the third sides of the two triangles (E vs C) must also have different lengths. In other words, the length of film that forms the edge of the layflat (E) is not equal to the length that forms the center of the layflat (C). Yet these unequal lengths must travel from the plane of their point of contact with the collapsing frame to the nip rolls in the same amount of time.

Tabulated data at the bottom of **Figure 4** show the magnitude of this discrepancy in length. If the angle A, formed by the center line of the bubble and the edge of the collapsing frame is 22°, then distance D must be 20 inches for a collapsing frame long enough to accommodate the full bubble width. By calculation, the edge E is found to be 20½ inches long, while the center C is 21½ inches. The center of this section of film is one inch, or about 5%, longer than the edge.

To bring a layflat out of the nips that actually lays flat, the edge of the film should theoretically travel faster than the center. In other words, the velocity of the film should gradually increase from the center until, at the edge, it is 5% greater than that of the center. With a line speed of 120 feet per minute (fpm) at the center, the edge must travel at about 126 fpm.

Fortunately, film made from low density polyethylene can stretch. The edge must stretch to permit the center to remain taut as it goes through the nips. If the edge does not speed up (stretch), the center will be baggy and broad “smile” wrinkles will appear across the web.

Less extensible film — stiff overwrap from resin with a density of 0.935 g/cm^3, or a high density, paper-like film — does not have the ability to stretch. The broad “smile” wrinkles appear if no attempt is made to increase the edge velocity. However, if the edge velocity is too great, edge wrinkles occur.

Normal procedure at this point is to close down the collapsing frame. This procedure decreases the angle A (see **Figure 4**) and reduces the difference between the lengths of the center and edge. Decreasing the angle from 22° to 11° narrows the difference in length between the center and edge to 1¼ %. At a 5½° angle, the difference is a mere 5/8%, essentially solving the problem, although not completely.

Closing down the collapsing frame however, doubles and quadruples the surface area of the frame in contact with the film. Unfortunately, films with a high surface coefficient of friction drag between the collapsing frames. As the center area of this warm film in contact with the collapsing frames increases, the additional drag distorts the flatness of the film, making it baggy at the center and difficult to print and convert.

The perfect theoretical solution to the bubble-to-layflat problem is a collapsing frame 200 feet long with a zero coefficient of friction. In this frame, the length of the edge and center of the film would not differ by so much as a hair’s breadth. However, like many theoretical solutions, this one is just not practical.

Rotation of Die

Rotating the die and/or air ring as shown in **Figure 5** can help mask errors built into the melt by process faults which cause variations in the film thickness, called gauge bands.

By rotating the die and air ring, the gauge bands can be moved around the surface of the film as the bubble is extruded. The bubble itself does not rotate. The gauge bands are thus distributed across the face of the roll, level wound as fish line on a reel, and the result is a cylindrical roll of film of perfect symmetry.

Rotation

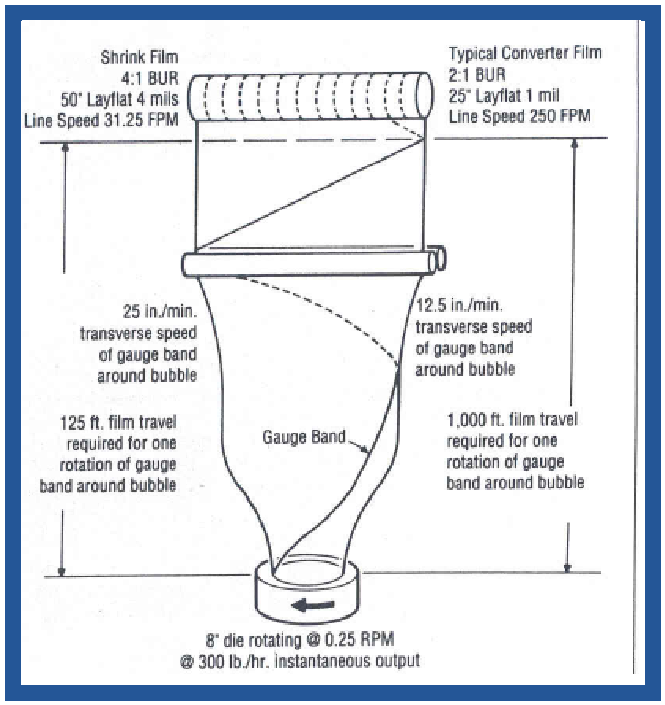

Figure 5

Without rotation, these faults build up in one place on the roll of film, as fish line on a reel without a level wind. The result is a roll of film with a surface looking like a wood turning for a short thick balustrade.

Unfortunately, rotation can introduce problems of its own in that the gauge bands now gradually move across the face of the collapsing frames. Such action causes the web to move back and forth between the frames and the layflat to wander back and forth in the line down-stream from the main nips. A web guide is required to finally track the layflat in a straight line so the film winds up as a good roll.

Generally, broad gauge bands caused by a draft of air or a heat rise off the front end of the extruder against the melt cannot be rotated because the melt itself is not rotating through this fault. As a consequence, the roll of film may be tapered or have convex or concave faces as the different thicknesses of film build up upon themselves.

Again, as the bubble or die diameter is increased, so is the transverse speed of gauge bands across the faces of the collapsing frames increased for a given rotational speed. This can cause bubble instability, intermittent wrinkling in the nips and web wander downstream. These three problems can be corrected by reducing rotational speed.

However, one rotation should never take less than the time it takes to build a roll of film. Otherwise, the gauge bands will not have had time enough to be uniformly distributed across the entire face of the roll of film.

Conclusion

Many problems occur in blown film extrusion in the hot melt between the die and the frost line and where the tube is collapsed at the main nip. Other sections in this booklet deal more specifically with problems such as uneven rolls, gauge bands, wrinkles, maintainng output, physical and optical problems and solutions.

Prevention Checklist

To prevent problems in extruding blown film, purchase the proper equipment to do the job. Then, make sure the equipment is installed properly, checked and maintained regularly and scheduled efficiently so that high quality film can be produced at high output rates with minimum scrap.

Checklists are excellent memory joggers for both production and maintenance personnel. An operator should check each film line against a checklist at least one time per shift. Lines should also be checked when there is an order change, and at start-up or at shutdown, since some equipment can be inspected only at those times.

All or part of the following checklist usually is incorporated in plant process descriptions, plant operating standards or the plant maintenance department's sched-ule. The checklist cannot include everything because each blown film extrusion shop is different. However, regular use of the checklist should minimize many potential problems.

Resin, Additives and Regrind

1. Are the polyolefin resin and additives the right grades for the film being extruded?
2. Are the quantities sufficient to com-plete the run?
3. Are the resin loading system filters clean or have they recently been replaced?
4. Were the additive feeders emptied and cleaned when out of service to prevent dribble from contaminating the next resin to be run?

5. Were the recycle/regrind systems for salvaging edge trim and roll scrap recently checked to make sure that the proportion of scrap to virgin resin is accurate?
6. Are the scrap rolls of film compatible with the virgin pelletized resin being used?
7. Are all rolls of scrap clean and labeled by resin type?
8. Was the equipment cleaned between resin changes to prevent contamination?
9. Are all hoppers and boxes of resin covered, not only to prevent contamination of the resin, but also to prevent possible damage to the extruder by tramp metal or other materials?

Extruder Drives

1. Most extruders are equipped with some type of variable speed drive for consistent output control. Are all fluctuations in revolutions per minute or power consumption, as indicated by the screw tachometer or drive ammeter, checked along with other causes for extruder surging?
2. Are all dirty air filters replaced? Otherwise, sensitive solid-state drive components can overheat and burn out.
3. Are the extruder transmissions and thrust bearings properly lubricated?

Extruder Heaters and Controls

1. Are temperature controllers for each extruder zone checked for excessive temperature override or insufficient heating?
2. Are the melt temperature and pressure indicators and the screw tachometer and drive ammeter — which all indicate extruder operation stability — frequently monitored and maintained?
3. Are all heater bands and thermocouples around the extruder head, adapter and die checked for loose wires? Be sure the power is off when a check is made.
4. Is the wiring for the heater bands correctly connected, e.g., not “in series” if “in parallel” is required or vice versa.
5. Are thermocouple leads correctly connected to their corresponding extruder zones? For example, the thermocouple lead for zone 3 should not be connected to the temperature controller for zone 2.
6. Are all the heater bands for a specific extruder zone of the same size and watt density? Mixing different bands in the same zones can cause cool areas or hot spots depending upon thermocouple location.
7. Are the die heater band terminals not aligned in a row? If they are aligned in a row, the resulting cool spot can create a gauge band in the film.
8. Is the extruder regularly checked for loose thermocouples, burned-out heater sections and loose or broken wires? Most of the time, these problems are not readily visible and finding them requires specific maintenance.

Extruder Cooling

1. Is there a specific instrument that checks for overheating in the extruder drives?
2. If the extruder is water-cooled, are the feed throats cool to the touch? Inefficient plumbing that does not force all of the air out of the water-cooled chambers of the feed throat can cause poor circulation and hot spots on the surface of the feed throat.

Resin can melt and stick to these hot surfaces, bridge and interrupt the resin feed to the extruder. The result is a reduction in output, surging, or in time, the complete loss of feed and shutdown of the extruder.

3. Has the automatic barrel water cooling system been checked recently? This can be done by lowering the set point of the barrel zone temperature controller for a moment, listening for the pumps to start and observing a temperature drop on the instrument.
4. If air is used in automatic barrel cooling, has the blower exhaust been checked for hot air output?
5. If water cooling is used on the screw, are both the incoming and outgoing water flows at the correct temperatures? Cooling water is normally fed through a siphon tube to the end of the screw. The outgoing water modifies the temperature of incoming water before it reaches the end of the screw. Otherwise, if the incoming water were too cold, it could freeze the melt.
6. Is the water flow in both feed throat and screw cooling areas controlled on the output side only? Control on the input side can lead to cyclic heating and cooling, caused by the periodic displacement of water with steam (water hammering effect), leading to surging.
7. Are all the extruder water systems filtered and are all the filters checked regularly?

Rotator, Die and Air Ring

1. Is a record kept of screens used and date installed?
2. Is the pressure gauge at the end of the barrel checked often? A high pressure indicates a filled screen. A low pressure indicates a blow-out.
3. Are the die and air ring level and parallel to each other, with the air ring concentric with the die orifice?
4. If the air ring is raised above the die face, is there any dirt between the die face and the bottom of the ring? Dirt in this area can interrupt the air flow of melt and cause gauge bands in the film.
5. Is there any dirt or contamination on the lips and venturi tube of the air ring? Die lips should be regularly cleaned with brass shim stock or knitted copper cleaner pads.
6. If die and/or air ring rotator drives are in use, are the commutator rings and brushes required for full rotation regularly cleaned?
7. Are the power and thermocouple wiring checked for freedom of movement and any scuffing, if rotating systems are in use?
8. Is the air hose used to inflate the bubble removed before die rotation begins?

Tower and Line

1. Is the bubble symmetrical around a plumb line dropped from the center of the main nips to the center of the die? This symmetry is essential for wrinkle-free film.
2. Are the collapsing frames symmetrical with each other and the tops aligned with the main nip rolls? If not, the collapsing film can be distorted as it enters the nip rolls, resulting in continuous or intermittent wrinkles on one or both edges, depending upon the misalignment. Also, too large a gap between the top of the collapsing frame and the bottom of the nip rolls allows the collapsed bubble to partially reinflate and cause edge and/or full “smile” wrinkles across the width of the film.

3. Is gussetting equipment easily adjustable? Does it have a locking lave a matte finish to provide a relatively friction-free surface for the film to slide upon? Film tends to cling to a brightly finished metal surface.
4. Do the metal surfaces of equipment have a matte finish to provide a relatively friction-free surface for the film to slide upon? Film tends to cling to a brightly finished metal surface.
5. Are the collapsing frames clean and smooth with no sticky coating, dirt or dust? If the nip rolls are steel and rubber, it is preferable to part the film from the smooth dry surface of the steel roll rather than from the rougher rubber surface which can become tacky and induce MD wrinkles. All rolls should be clean and dry (not sticky) and all idler rolls should turn freely.
6. Are nip roll and other line drives checked for speed adjustment?
7. Are the variable speed nip and line drives individually controlled? This situation is difficult for an operator to synchronize and can cause excessive scrap when the downstream nip is permitted to overdrive the primary nip.
8. On lines equipped with drives that depend on the main nip roll drive as a master speed reference for all downstream nip roll (and equipment) drives, is the main nip roll overdriven by excessive web tension (trim pots turned up to high on downstream drives)? This excessive tension can result in the loss of line speed control, excessive speed hunting in the line and a large amount of off-size scrap film.
9. Is the blown film tower stable with no vibration or sway?
10. Is the tower isolated from drafts?
11. Are any slightly diagonal MD wrinkles or web wander visible? Although it is usually beyond the ability of an operator to tram (align) rolls in a tower, these defects can result in misaligned rolls.
12. Are treater bars properly gapped and parallel with the treater rolls? The dielectric covering of the roll must be free of punctures and the roll grounded back to the treater through a carbon brush to the shaft.
13. Are in-line embossing, slip-sealing, reinflating and postgusseting, printing and bag making equipment checked regularly according to prescribed procedures?
14. Are winder drive and tension controls checked and the winder set to accommodate the core sizes and widths for the product to be run?
15. Finally, are roll doffing equipment, cores and packaging supplies readily available?

Tools and Adjustments

1. Does the operator have the tools necessary to operate and adjust a line?
2. Is the film thickness gauge calibrated regularly to maintain quality film standards?

For the Operator

When you go on shift or take over another line, do you “stop, look, listen and feel?”

LOOK —

- Are the resin, additive and recycle systems correctly adjusted and functioning properly?
- Are the melt temperature pressure gauges and temperature controllers functioning?
- Are there any temperature over- or under-rides?
- Are bubble shape and frost line normal?
- Are there any wrinkles in the web?
- Is the trim too narrow or too wide?
- How does the roll look on the winder?

LISTEN —

- How do the extruder drive system, resin feed system, barrel cooling pumps, relays and treater sound? Any variations in sound can be an indication of trouble. If you become familiar with sounds of the line in operation, many times you can stop a problem from becoming a larger one, if not prevent it altogether.

FEEL —

- Is there excessive heat or vibration in the extruder transmission and drive bearings?
- Is the air chiller functioning in the air ring?
- Are water cooling lines cool, warm or hot?
- Is the web tension too tight or too loose?
- How hard is the roll across the face?

Many elements of a properly designed, installed and adjusted blown film line remain trouble-free for a long time. Other parts may need repair often. Most malfunctions show up quickly in the form of some defect in the film. Other sections of this booklet help pinpoint the causes of film problems and explain how to correct them with a minimum loss of time and product.

Dies and Air Rings

Setting Up the Die and Air Ring:

1. A die should always be centered beneath the main nip roll assembly. A plumb line dropped from the center of the nips should be no further out of plumb than the edge of a dime placed on the center of the die face.

   Obtaining a true plumb line can be a problem if you use a die from another line or a new die which has an incorrect adapter length. The further the die is off-center, the more the film is distorted by the uneven distances it must be drawn to the nip rolls. This cause of both wrinkles and poor gauge cannot be corrected by the operator.

2. The top of the die should be leveled only after the die and extruder are up to operating temperature, the barrel clamps tightened to the die adapter and all casters on the die cart in firm contact with the floor. The die cannot be leveled separately from the extruder for several reasons:

   A. Most floors are not level, which means the die must be leveled in place.

   B. The distances from the floor to the center-lines of the die adapter and the extruder barrel increase at different rates as they are brought up to operating temperatures.

C. If any of the die stand casters are not down tightly on the floor, there is a good chance the die is not level. There is also a chance that the die and air ring will vibrate because the extruder barrel is supporting part of the weight of the die and air ring assembly. This vibration can manifest itself as air ring chatter.

3. Only after the die is properly leveled can the air ring be leveled and centered. Because the air ring is not usually fastened to the top of the die, but is dependent upon its own weight to hold it in position, a good operator always checks the air ring for center and level when the bubble is down. With a bubble up, it is not possible to see whether the die or the air ring needs adjustment.

4. Finally, some air rings are set on a flame retardant pad on top of the die. Other air rings are not on such a pad, but are raised above the top of the die with the air gap providing insulation.

5. If an air gap exists between the air ring and the top of the die, the air ring is usually less sensitive (more forgiving) to blower and top opening adjustment. However, this air gap means there is an air flow between the bottom of the air ring and the top of the die that impinges upon the hot melt as it extrudes from the die. Any dirt, pieces of purge or silicone grease in this open space can disturb the air flow and lead to gauge bands in the film.

Die and Air Ring Adjustment

1. Most dies currently in use are adjustable. **Figure 6** illustrates the two basic designs of adjustable dies and how they are identified:

   A. In the most common configuration (upper diagram), the adjusting bolts are in the die ring above the die body.

   B. In the older configuration (lower diagram), the adjusting bolts are in the die body below the die ring.

   On design A, the adjusting bolt is turned in to ***open*** the die gap, while on design B, the adjusting bolt is turned in to ***close*** the die gap.

2. When adjusting a die,

   A. You are only going to open or close the die gap by one or two thousandths of an inch and maybe a quarter turn of the bolt at the most.

   B. Except for a few very special dies, you cannot open and close the die gap in one place. Try it, and you strip the bolt threads first. What you are trying to do is center the die ring around the

Film Die Gap Adjustment

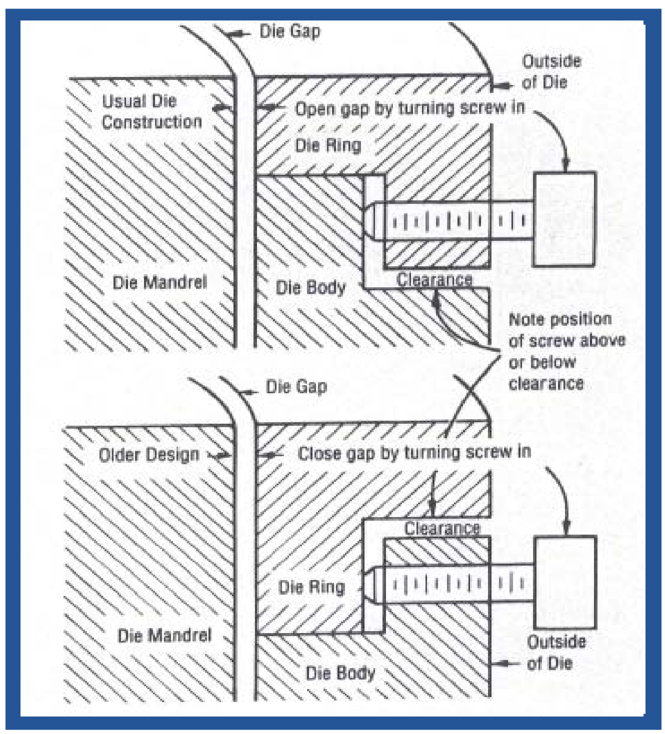

Figure 6

die mandrel so the die gap is symmetrical all the way around to extrude a film of constant thickness.

C. The die ring can only be adjusted by pushing on it, because there are no pull bolts. After choosing the bolt or bolts to push, loosen all other bolts until each is about one-eighth of a turn back. This prevents the die ring from moving too far if it is suddenly released.

D. Do not try to make major adjustments as they may result in the bubble coming down.

E. When the adjustment is complete, bottom but don't tighten the remainder of the bolts to hold the ring in place.

3. In explanation of an apparent anomaly, thick film comes from a narrow die gap and thin film from a wide die gap. The thick, hot melt from a wide die gap holds its heat longer and draws down to thinner film than the hot, but thin, melt from the narrow die gap which cools and freezes faster into a thicker film.

4. As shown by **Figure 7**, the air ring must be clean. The air ring in **Figure 7** was dropped on its edge one time. Since then, this air ring's internal perforated metal baffles have had a tendency to clog in two areas 180° apart. One baffle section is shown in **Figure 18.**

In an experiment, a hot die was leveled and centered to a uniform 0.038 inch hot die gap. The air ring described above was then leveled and centered on the die. The two gauge profiles taken from film blown with this set-up illustrate the difference cleaning an air ring can make.

The first film profile sample in **Figure 7** with the two high and two low film gauge variations opposite each other also illustrates the type of defect that can occur when an air ring is off-center or tipped and not level. The operator, not knowing his air ring was askew, tried to adjust the die. **Figure 8** illustrates film from a die that is out of adjustment. Note the 1.3 mil film from the wide 0.041 inch die gap at point C and 1.65 mil film from the narrow 0.035 inch die gap at point A. A similar gauge variation can be caused by an off-center air ring on a centered die.

Figure 9 illustrates the gauge variation that occurs in a film from a centered die and a tipped air ring. This also could just as well be from an off-center air ring.

5. Finally, in the last three figures, note how the bubble shape and frost line appear in the areas of thick and thin film. Variations in bubble shape and frost line are usually the first and best indicators of changes in the quality of the film being extruded.

Film Gauge Variation Caused by Dirty Air Ring

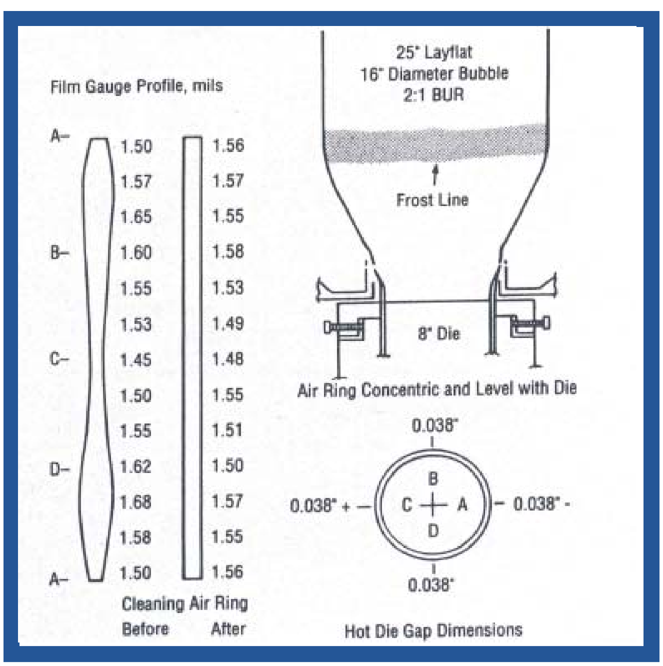

Figure 7

Film Gauge Variation Caused by Poor Die Adjustment

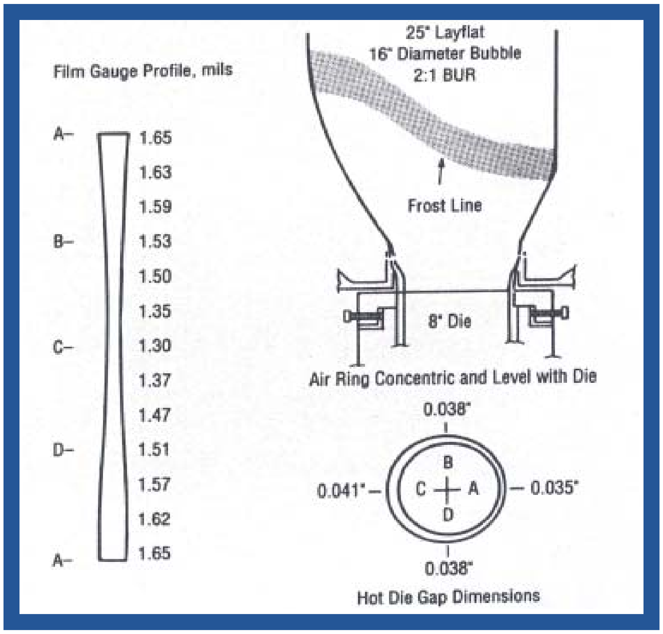

Figure 8

Film Gauge Variation Caused by Tipped Air Ring

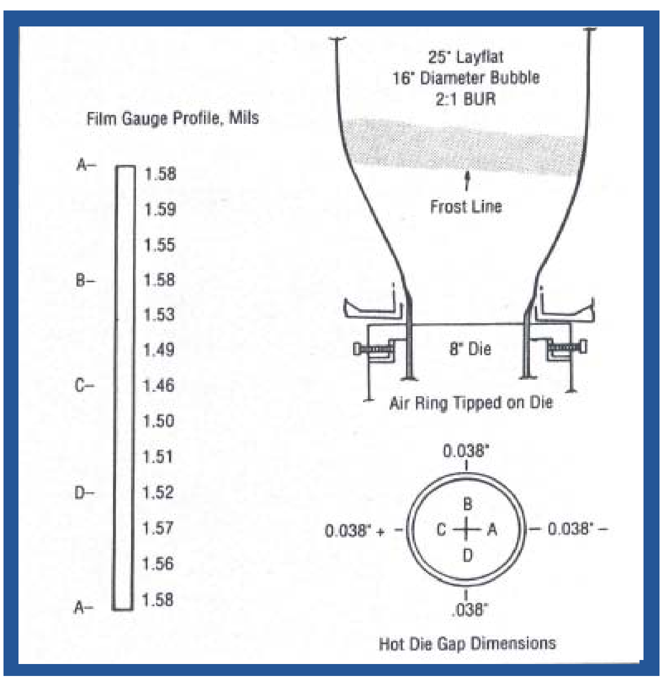

Figure 9

Figures 7, 8, and 9 illustrate data developed from film extruded with an eight inch die and air ring on a 3½ inch extruder.

Maintaining and Improving Film Output

Causes of decreased output rates should be corrected immediately to prevent schedule and quality problems from escalating. Several factors can cause short-term reductions in output, and in some cases, eventually result in other, more serious problems.

Productivity can be viewed in three ways:

- Maintaining Satisfactory Output
- Improving on that Output
- Reducing Scrap

What is Satisfactory Output?

Determining whether your production line is performing at top efficiency is difficult. To simplify the calculation, lines can be divided into two types:

- Those dedicated to a specific resin and product
- Those used to run several different resins and produce a broad range of products

Resins include LDPE, HMW-LDPE, LLDPE, MLLDPE, HDPE, HMW-HDPE and blends, plus additives and reground film, such as edge strip and scrap. Products include clarity sheeting, multi-wall bag liner, merchandise bags, grocery sacks and garbage bags.

Output is probably best defined as the pounds per hour (PPH) of a resin that can be extruded through one circumferential inch of die gap (DG) or PPH/inch DG.

Example:

- If a 16 inch die has a 50 inch circumference and operates at 12 PPH/inch DG on high clarity sheeting, the instantaneous die output is 600 PPH.
- If the sheeting is 48 inch wide and requires a 1 inch trim from each edge of a 50 inch layflat, 4% of the instantaneous output is being recycled and there is a net output of 576 PPH of sheeting off the winder.

To obtain the average PPH, divide the number of premium pounds made by the number of machine hours required to make them. The closer the average PPH is to the instantaneous die output in PPH, the higher the efficiency of the line.

Dedicated lines usually operate from 10 to 25 PPH/inch DG and up with refrigerated air cooling the bubble. Higher output rates are obtained with internal bubble cooling and external cages to size and stabilize the bubble. At higher output rates, the line versatility usually is limited to variations of a single product extruded from one type of resin.

More versatile film lines may include the capability to wind tubing flat or gussetted, make centerfold or "j" film, produce single or double wound sheeting and, with a bag machine ahead of the winder, generate single bags or bags in a roll.

Instantaneous output for LDPE or blends with LLDPE, plus additives and regrind, ranges from 8 to 25 PPH/inch DG. The output is largely governed by the product requirements of size, gauge, BUR and whether the end product is wound film or bags.

Remember, a die can act as a valve on the output of an extruder when you review the following table of output ranges expected from six different sizes of 24:1 L/D (length/diameter) extruders. The range is necessarily broad to allow for age, wear, screw-design, drive, power level and resin to be extruded.

Extruder Size (inches)	Drive, hp	Output, PPH
1½	5 - 15	20 - 60
1¾	7½ - 25	30 - 100
2	10 - 40	40 - 150
2½	25 - 60	100 - 250
3½	40 -125	120 - 500
4½	60 - 250	240 - 1000

By comparison, on dedicated lines with high horsepower extruders with 28 to 32:1 L/D, the output rates can be 20 – 30% higher than those in the table.

Maintaining Output

Both slow and rapid reductions in normal output rates can occur for many reasons. The true cause needs to be quickly identified and appropriate measures taken to correct the problem. If incorrect solutions are applied, the problem can be compounded.

Some causes of reduced output are resin-related.

Fines and Fluff in the Feed Stream

Fines are bits of pellets that adhere to the walls of transfer system piping and other equipment through which resin passes, propelled by forced air. Resin fines contain a disproportionately large amount of slip additive, as much as 8 to 12%. This is because slip is intentionally incompatible with the film resin so that it blooms to the surface as the film is extruded and performs its function of preventing blocking. Slip also blooms to the surface of the pellets. Thus, because the surface of the pellets is the usual portion in contact with equipment walls, fines contain higher levels of slip than the resin from which they come.

Fines that coat the upper, inner surfaces of the hopper and then fall into the extruder cause a sudden increased concentration of slip, which greases the extruder screw. Melt throughput and bubble gauge both decrease for a time until the extra slip clears through the extruder. Any overreaction to this problem, such as increasing extruder speed, quickly results in a film with an unwanted increased gauge when the slip has cleared.

Fluff, when recycled and added to the feed stream, leads to an unpredictable decrease in the bulk density in the hopper. The feed section of the screw — which is only a conveyor — senses only bulk, not weight. The feed section does not speed up to maintain delivery of pounds of melt to the die. Thus, output and gauge go down when significant amounts of fluff go through the extruder. Similarly, if fluff feed decreases, more virgin resin is fed to maintain the bulk through the extruder, and output and gauge go up. If supplies of scrap or fluff are small and intermittent, they can be saved and run for utility grade film. But if large amounts of scrap are generated regularly, then improved recycle systems — proportional feeders, hopper stuffers, etc. — may be worth purchasing.

Blending of LLDPE and LDPE

On older machines with lower HP drives, the addition of 15% to 20% or more of LLDPE to LDPE can reduce the output. Raising barrel temperatures, particularly Zone 2 at the transition portion of the screw on some extruders, can sometimes eliminate the problem.

Some output problems are machine-related.

Sudden Machine Shut-Down

When an extruder restarts after an unforeseen shut down, it may deliver little or no melt or it may surge. Heat from the screw transition section has travelled back to the feed section, which in a neutral screw, is normally cooled by the resin pellets fed to it. The feed section, now hotter than usual, partially melts the pellets which stick to the screw, bridging and partially or completely blocking the section. The bridged screw, of course, does not deliver the expected melt output.

If the screw is not badly bridged, the adhering pellets can be cleared by inserting a flinch rod made from the resin into the feed throat while the screw is turning over slowly. The screw flight will cut sections from the rod, and these will break away partially melted pellets sticking to the screw. If bridging is severe, the screw may have to be removed and cleaned. In any case, all safety procedures must be carefully followed.

For other than emergency shut-downs, the extruder and die temperatures should be reduced to the point where the die drools at a lowscrew rpm, while the mass of the equipment cools before shutdown. Do not reduce the temperature to the point where the melt can solidify and blow the drive fuses or rupture a gate or die. Special heat-stabilized purge compounds are excellent for shut-down because they flush the system and do not decompose in the equipment as it cools.

Fluff Recycling Lines

Bridging is a particular problem with lines that recycle fluff from ground trim and scrap film. Plug the front end of the bore of the screw and water-cool the first three to five feed flights to partially solve this problem and keep output at required levels.

Improper Water Cooling

Improper water cooling in the extruder can result in reduced output. For a discussion of water cooling, see the Prevention Checklist discussed earlier in this booklet.

Screen Pack Plugging

As screen packs gradually get plugged, output just as gradually decreases. In response, the operator often increases screw speed which increases melt pressure and temperature and raises the frost line. The hotter melt and subsequent higher frost line can lead to an unstable bubble.

The operator's solution works for only a short time. The best way to prevent this problem is to keep good records of when screen packs were changed and have operators frequently refer to them. A melt pressure gauge at the end of the barrel also provides a warning that screens are plugging.

Improving Output

Barring the installation of newer more sophisticated blown film lines in their entirety, the output of older lines can be increased by several means, assuming the lines are well designed and have been maintained. With increased output however, additional tower height for cooling and increased corona surface treatment capacity may be necessary.

Melt Separation Screws

New, more efficient melt separation screws with a barrier flight and mixing head can be retrofitted for the extrusion of LDPE, HMW-LDPE, LLDPE, HDPE, HMW-HDPE and blends, plus additives and reground material. These screws do not help an extruder that is under-powered but should improve both film quality and output of any extruder with an adequate drive matched to the transmission, thrust bearing and extruder size. The addition of a new low pressure die with a second mandrel extension to provide a wider die gap to extrude LLDPE and a dual lip air ring will improve output rates with both LDPE and LLDPE.

Tower Modifications

To run HDPE, the tower must be modified so the height of the main nip roll and collapsing frame assembly can be changed. Furthermore, an adjustable height iris must be added above the die for bubble stabilization. Also, a new, smaller die and air ring may be necessary to accommodate the 4:1 BUR required to obtain a high strength HMW-HDPE film.

Bubble Cooling

Refrigerated air can stabilize and cool a bubble produced by the hotter melt generated by increased output from an old screw or the additional melt output from a new mixing screw. Improved and more consistent cooling also results in better gauge and less scrap. If refrigerated air is used, the air ring must be corrosion-resistant or given a protective, moisture-resistant coating, and the outside of the ring should be insulated to eliminate condensation. Condensation droplets which fall into the air stream strike the bubble and cause it to snap off. When the line starts up, this chilled air must be turned on to bring the ring to operating temperature and blow out any condensed water droplets before the bubble is pulled up.

If all equipment operates smoothly, film is now going through the main nips at rates fast enough to require a line speed increase. Many lines never operate at speeds more than one-half to two-thirds of their maximums. With the commonly used DC and eddy current variable speed drives, the slower line speeds can result in a loss of control and additional scrap.

To illustrate, a line with a maximum speed of 150 fpm, driven through a reducing transmission by a drive with ± 1% speed control, can vary ± 1.5 fpm. If the line is run at a slow speed of 15 fpm, this same 1.5 fpm translates to a ± 10% variation in line speed.

Four-speed transmissions that enable the line drives to operate in the top third of their speed ranges with acceptable speed control, regardless of line speed, are an excellent investment for the multipurpose line. The amount of scrap produced in stopping and starting the line to shift gears should be relatively low; actually, the amount of scrap should decrease and the film quality improve.

Decreasing Scrap

One way to increase output is simply to reduce scrap. A line producing scrap is more costly than a line sitting idle. A line producing scrap is not productive; it costs money to operate; and it is turning out material that requires further handling to salvage.

Scrap can result from simple human error: wrong resin for the job, misinterpretation of specs for size and gauge, etc. Scrap can also be the result of not scheduling production orders in a sequence that minimizes changeover from size to size, gauge to gauge, or resin to resin. These problems cannot be solved in any specific way; individual shop conditions must be considered.

Two other common sources of scrap can, on the other hand, be easily eliminated. Adding simple roll doffing equipment gives the operator greater control in removing the roll of film from the winder and placing it intact on a pallet or in a carton.

Having operators exchange information about current operations at shift change is another way of preventing problems that might lead to increased scrap. It is only human for operators to feel they know best. When the shift changes, the first move an operator may make is to readjust certain controls. The effects of these moves may not be apparent for several hours. By this time the operator has forgotten the specific changes he or she has made — so the results are problematic. The solution to such occurrences is to have some overlapping time at shift change so operators can exchange information.

Roll and Film Defects

All film defects ought to be detected by the film extrusion shop manager or foreman before the roll gets out the door. But in practice, through oversight, inattention to detail or unexplainable circumstances, defective film can go undetected until examined by the customer.

Overall film appearance is most important. A good-looking, “machined cylinder” roll of film is what the customer should receive. A superficially dirty or impaired roll, which may actually convert like a charm, can have the customer examining the entire order for real or imaginary defects.

A machined-cylinder roll has no scuff marks, damaged edges, fuzzy ends, protruding or buried core ends or crushed cores. Other, less obvious defects can be buried in the roll, but these apparent defects should have been caught and eliminated by the operator.

Wetting test kits are available, and instructions should be followed closely if consistent results are to be obtained. Ink can be applied from an aerosol can or by by an anilox roll. The film must be completely dry before tape is applied to check adhesion.

To assist the customer, wind a one-side-treated film with the treated surface inside or outside, as specified, and so label the box. Causes of poor treatment include:

1. Under-powered treaters

   The treater must be matched to line output rates and web speeds.

2. Improper grounding

   The treater roll should be grounded through a carbon brush assembly. This can improve its efficiency. Grounding through the treater roll bearing is inefficient because the bearing lubricant acts as an insulator.

3. Film too cold

   Warm film is easier to treat. The top of the tower, just after the main nips, is the best location for the treater station.

4. Wrinkled film

   Film must lie smooth on the roll, and the treater bars must be positioned parallel with the roll.

5. Improper levels of slip additive

   For example, if a film resin with slip levels designed for 1-mil film is used to produce a 4-mil film, four times as much slip additive blooms to the surface, resulting in a white coating on the printing plates or a powdery build-up on the working and sealing surfaces of bag-making machinery.

6. Excess silicone grease on the die and air ring surfaces

   Both ink adhesion and heat sealability of the film can be adversely affected if this grease gets on the film. Excess grease can also contaminate the surfaces of the collapsing frames, nip rolls and idler rolls.

Visible Roll Defects

Visible roll defects can usually be classified as those caused by defective film or poor web or roll handling. In some cases, the same defect can result from either cause.

1. Rolls with corrugated (uneven) ends can be caused by:
   - Poor tracking (web wander) in the line ahead of the winding station.
   - Variable width film resulting from an unstable bubble. A web guide located before the winder magnifies the condition by positioning the film on the core so that the guided edge of the roll winds evenly; as a result, the the depth of the corrugations at the opposite end doubles.
   - Variable tension in the edge trimming or slitting station. At low tension, the sheet is widely slit and at high tension the sheet is narrowly slit. Again, web guiding into the winder can magnify the condition by placing the defect at only one end of the roll.
2. Fuzzy roll ends can be caused by:
   - Dull cutting blades
   - Poorly aligned blades
   - Edge slit sheeting because the film cannot be perfectly guided in order to maintain the blade exactly in the center of the edge fold.
3. Symmetrically deformed rolls can be caused by:

Blocking

Blocking, or film layers sticking to one another, can result from:

1. Too much winding tension

   Tension levels can easily be overlooked unless they are so great the core is crushed, making it impossible for the operator to remove the roll from the winder shaft. If the core is crushed only slightly, the operator may be able to remove the core from the shaft, but the customer may then find it impossible to remount it on a let-off stand. Just as bad a problem can arise if the winding tension is too low, blocking will not occur, but the film may telescope out from one end of the roll, making the film impossible to convert.

2. Hot weather

   The inner surfaces of insufficiently cooled film block as they pass through the nips. To correct:

   - Reduce output
   - Raise the main nip rolls
   - Use refrigerated air or other means of increasing cooling efficiency
   - Reduce nip roll pressure

3. Inefficient air ring
4. Incorrect additive levels in resin

   If the additive levels are designed for a 4-mil film and you are producing a 1-mil film, not enough slip and antiblock additives are present to prevent blocking from occurring.

5. Over treatment and/or high gloss

Tendency to Split

Film with splitty tendencies can also be overlooked unless samples are examined. The conditions below can occur singly or in concert, leading to an increase in the film's orientation in the machine direction. This makes the film easy to split.

1. Insufficient cooling
2. A high frost line
3. Too low a blow-up ratio
4. Nips set too tightly, particularly with an old and hardened rubber nip roll, leading to film deformation in the edge crease
5. Die lines or bad weld lines from the die
6. Scratches from splinters in the collapsing frame or other sharp objects
7. Very fine weld lines caused by degraded particles of resin or dirt lodged under or in the die lips **(see Figure 10).**

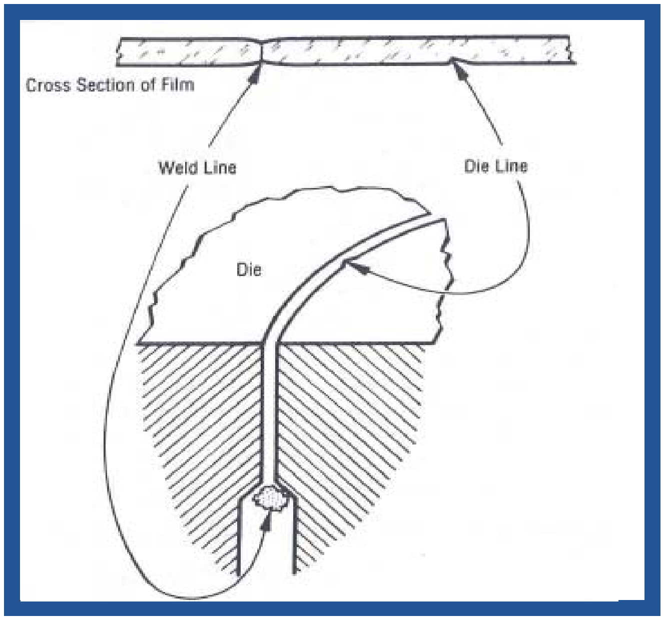

Figure 10 **The weld line in the film resulted from dirt hung up below die lands. The die line resulted from a damaged die mandrel.**

Printing Problems —Treatment

In-line treatment (or mistreatment) to enable printing is the key to many problems the customer is often the first to discover.

The two most common methods used to check film for treatment are by a surface wetting test and by ink adhesion.

- Uniform gauge variations across the width of the film. They may or may not be immediately visible to the customer, or to the operator who made them. However, if you measure the roll circumferences at each end, you will find this defect.

Cross Section of Film

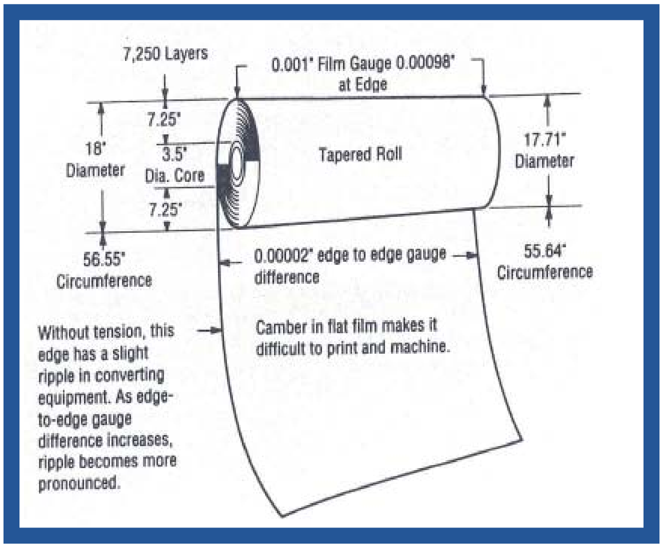

Figure 11

Figure 11 illustrates a symmetrically deformed or tapered roll of film. The calculations show that only a very slight gauge variation was required to cause this defect. Measuring 0.00002 inch is beyond the capability of any in-plant micrometer, and measuring ten thicknesses of the film to determine a 0.0002-inch variation is also difficult with most available equipment.

Furthermore, the tapered roll has an almost uniform surface hardness, although the large end may be slightly harder than the small end. The customer finds the defect quickly, particularly in a high speed printing operation, because the one rippled edge, caused by the camber in the film, tracks in a straight line through the converting operation.

Figures 12 and 13 illustrate the same type of roll defect. However, because the film is supported in the roll, either at the center or at both ends, by the thicker film, there is usually a noticeable difference in surface hardness across the roll face. This causes baggy film or rippled edges.

Convex Roll

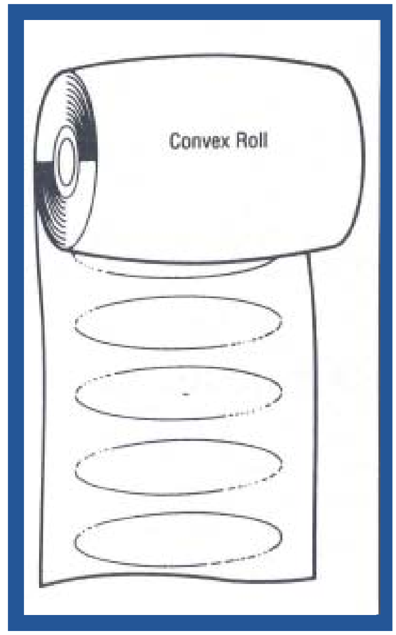

Figure 12

Concave Roll

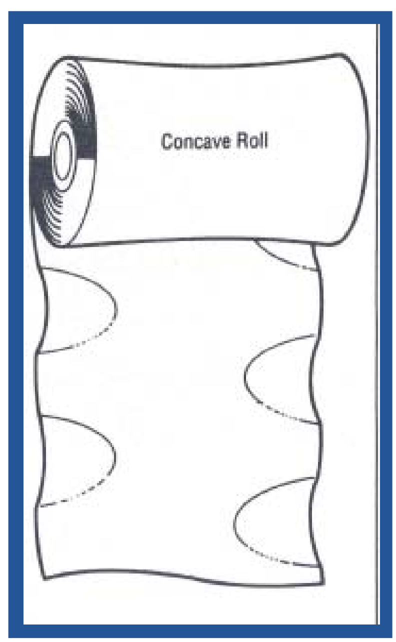

Figure 13

This defect manifests itself on a large sheeting line where two or more rolls are cut from the web and wound on a single shaft. As soon as the thin film at the small diameter end of the roll is cut free from the thicker film at the other end of the roll, the thin film end winds with little or no tension. Then, either while winding or doffing off the shaft, the roll will telescope, resulting in a good deal of scrap.

Often this film defect is uniform over a period of time, indicating a continuous problem in production. A rise in the temperature or warm air cooling the barrel off the front end of an extruder, parallel with the line and winder, can cause a roll of tubing, or the roll of sheeting from the back of the bubble above the extruder, to have a concave face. If the extruder is at a right angle to the line, the rolls can taper. A flame retardant cover will usually solve the problem by providing some insulation. Frequently, the intake of an air ring blower can create enough draft to cause the problem. Hot air heaters or floor fans are other sources. If the problem occurs only during the day, the cause may be an open door that usually is closed at night.

Tapered rolls can also result if the die and/or air ring are tipped. In this case, the film from the lower side of the die or air ring has to travel further. Die and air ring rotation cannot correct tapered, convex or concave rolls **(Figures 11, 12** & **13)** because the bubble does not rotate (see **Blown Film Basics**).

These defects occur in the bubble in its most sensitive area, between the die and frost line. The finished film is formed between the die and frost line by the simultaneous blowing and drawing of the tube of hot melt extruded from the die. It takes only small outside forces (light air currents, heat, stretching) to deform the bubble and cause these defects.

The same defects can be caused by something as simple as an uneven closure across the nip rolls. In this case, the film is not pulled through the nips with equal force at both ends. The film may actually slip at the less tightly closed end.

These roll defects generally do not occur on lines with overhead rotation. In general liners with fewer layers will have die rotation, while lines with three layers or more will have overhead rotation. The reason for this is that the seals in a multi-layer die are too complex to allow die rotation.

Early versions of overhead rotation are very complex in nature, while newer versions are quite reliable and cause few problems. Older versions frequently do not rotate concentrically, which causes non-uniformity that is directly proportional to the time for one cycle of the overhead equipment.

4. Defects found more frequently on large lines

   With the exception of fuzzy roll ends, the roll defects discussed in this section occur more frequently, and produce much more scrap, on large blown film lines, particularly those producing sheet. It is easier to notice — and correct — an unstable bubble 16 inches in diameter making a 25-inch layflat than it is with a bubble 48 inches in diameter making a 75-inch layflat.

   The sheer size of a 48-inch diameter bubble makes it more susceptible to vagrant breezes and drafts in the area than the 16-inch diameter bubble. Similarly, roll alignment for a 75-inch layflat requires more attention to prevent wandering.

Problems are further compounded when the film extruded is high clarity packaging to be printed and converted at high speeds.

To minimize some of the defects that occur more often on larger lines, non-contact gauges for the precise measurement and control of film thickness may be economically justified.

Larger lines offer increased output and reduced labor needs, but operators handling thee lines need greater skill and training — and they command higher wages.

Gauge Variations

Gauge variations occur both in the length of the web in the machine direction (MD) and across the width of the web in the transverse direction (ID).

MD Gauge Variation

Gauge variation in the machine direction is generally associated with extruder or line take-up problems, rather than with die and air ring problems. Cyclic surging of the extruder causes MD gauge to run on the plus side as output increases, and on the minus side as output decreases. In severe cases, MD gauge variations can be accompanied by a change in layflat web width as the frost line rises and falls with variable output, causing the bubble diameter to change.

Each surge cycle may last from five minutes up to several hours. Therefore, changes in frost line height or bubble instability may not be immediately apparent — even less so on large lines because of the size of the bubble involved (see previous section).

Extruder Surging

Extruder surging can be caused by common maintenance problems such as loose thermocouples, defective temperature controllers, burned out barrel heaters, variable water supply for screw and/or feed throat cooling, etc. Other causes include:

1. Overheated extruder drives

   The speed of these drives should be regulated at 2% or less of base motor speed with a 95% load change. Solid-state DC power cabinets should be located where temperatures do not exceed 100°F or they should be fitted with a filter and cooling blower.

2. Running high speed extruders at half speed

   A variation of 2% of 1,800 rpm base speed is 36 rpm; but at 900 rpm, 36 rpm is a 4% variation. It is better to change drive belt sheaves or gears if a range of screw speeds is desired. It is more efficient to operate in the upper third of the drive speed range.

3. Automatic on/off barrel cooling

   Surging can result, particularly when two or three zones are cooled simultaneously. Proportional control is needed to eliminate shock cooling.

4. The wrong screw and/or barrel temperature profile

5. Adding fluff or scrap at variable rates

   These additions alter the bulk density of material in the extruder feed hopper.

6. Partial or intermittent bridging of material in extruder hopper, feed throat or on the screw.

Cyclic Surging

Cyclic surging of the line speed can duplicate and be indistinguishable from effects of extruder surging. Causes include:

1. Too much tension in the web

   Winder or secondary nip rolls that overdrive the main nip rolls can cause speed to vary and an increase in web tension.
2. Poor regulation of electronic drive speed

   Particularly when the line is run at low speeds, a means of maintaining drive speed in the high range is needed. Quick-change gear boxes, sprockets or pulley changers can all be used between the drive and the nips to keep the drive speed high.
3. Mechanical and electrical faults

   Partially seized bearings, loose drive sprockets or chains, loose wiring, etc., can all contribute to variable line speed.

   For all extruder line drives, a drive ammeter can immediately indicate the area of trouble but not whether it is mechanical or electrical. The actual cause of the surging can be complicated, such as the combination of an overheated DC power source with the motor operating in mid-speed range. The problem is intermittent because the DC power source cools down at night and warms up during the day, resulting in the system alternately in and out of an acceptable speed control range.

   Another mechanical cause of surging can be a loose drive chain tensioner with a sprocket loose and slipping on the shaft. The guard can be removed and the loose drive chain fixed, but the loose and slipping sprocket can remain unnoticed.

   If MD gauge variation is suspected, the die and air ring rotation should be stopped, a stub roll of film made and then cut open. At one point, the gauge should then be checked down through the layers of film. Layflat web width can be checked at the same time. Non-contact thickness gauges will indicate MD gauge variation as cyclic average changes.

TD Gauge Bands

Gauge bands in a roll of film are caused by variable film thickness in the transverse direction (TD), or across, the web. As the film is rolled up and the roll increases in diameter, a build-up of thicker areas of the film occurs. At the same time, the thinner areas of the film stretch down into the valleys between the thicker bands. The greater the winding tension, the more pronounced the bands become and the more distorted (not flat) the film is when

Maximum Distortion

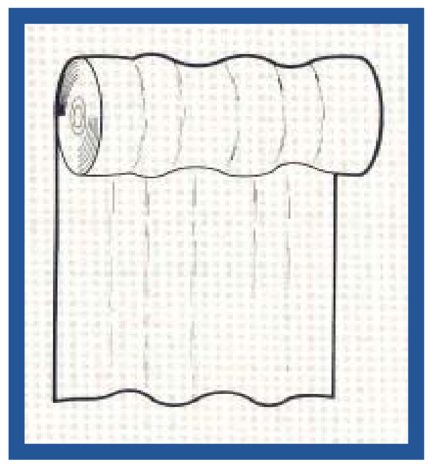

Figure 14

Minimum Distortion

Figure 15

unwound from the roll **(Figure 14).** Rotating the die and air ring can minimize but not eliminate this distortion in the film by distributing the gauge bands evenly across the roll face **(Figure 15).**

Bubble shape is a fair indication of film thickness. A symmetrically shaped bubble indicates that there are no gross gauge defects in the film. An unevenly shaped bubble suggests several problems. First, the die is not centered and needs adjustment, but only if the operator has set up the film line well. If the set-up is not good, the air ring may not be concentric with the die or, if not firmly mounted, may be cocked and not parallel with the top of the die.

For unpigmented films that are not too cloudy, the evenness of the frost line is another excellent indication of film thickness **(Figure 16).** In a misshapen bubble, the frost line is cocked and not parallel with the top of the die and air ring. The high and low areas in the frost line indicate areas of poor gauge and the location of problems in the equipment beneath the bubble. If these areas of uneven film gauge do not rotate when the die and air ring rotate, then the problem may be due to drafts striking the hot melt below the frost line, or some defect in the non-rotating body of the air ring.

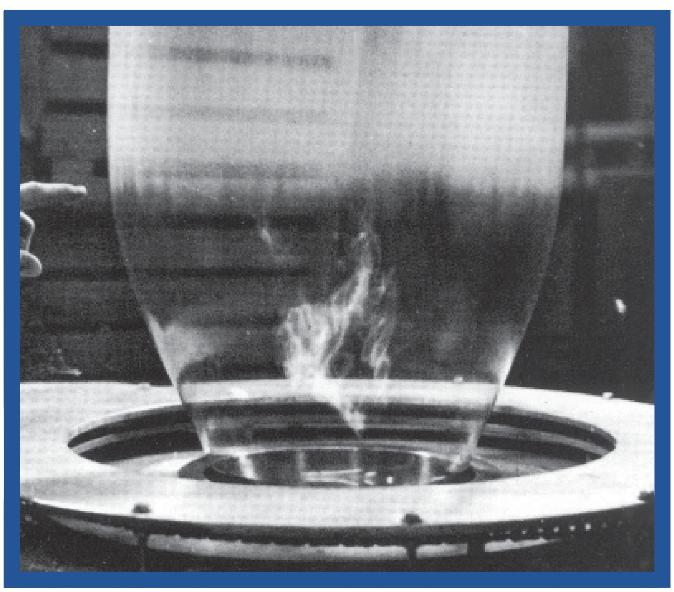

Figure 16: A well-shaped bubble with horizontal frost line visually indicates good gauge control.

The installation of 500-watt floodlights in the film line area helps make the frost line fully visible to the operator. The lights should be mounted just above the usual frost line height, at least 30 inches from the largest bubble blown and aimed down through the frost line area towards the center of the bubble. The lights should be turned on during start-up for die and air ring adjustment or frost line check during production. The lights must be mounted carefully; if they are too close to the frost line and bubble, their heat can result in gauge bands.

Some other causes of gauge bands include:

1. Drafts of air on the bubble

   Gauge bands caused by drafts are immediately visible on a roll of film extruded from a rotating die and air ring. When stationary equipment is used, the cause is not so obvious. Often a curtain, shroud or enclosure is placed around the bubble to eliminate drafts. However, if there is a hole in the enclosure, air hits the bubble. Other causes can be a leak in a non-rotating air ring body, a leak in a near-by air line or a piece of metal deflecting air upon a portion of the melt. The resulting gauge bands can be from less than an inch to several feet wide.

2. Defective or poorly adjusted dies

   Older design, stationary side-fed dies with tapered mandrels, which have been sprung by a cold start, usually produce films with two high and two low areas of gauge opposite each other.

The same defect can occur when a die has been adjusted eccentrically and the air ring moved off-center to the die to align it **(Figure 7)**. Off-center adjustment usually occurs if dies have not been cleaned for a long time or if they have been improperly assembled after cleaning. Degraded and carbonized melt that has leaked inside the die has made the die impossible to adjust. This defect is seldom caused by an out-of-round die ring because, except for special flex-lip dies, it is practically impossible to deform a die ring. The threads of the adjusting bolts would strip first.

A die that has been damaged, repaired by welding, polished and replated can still cause a gauge band in the film from the welded area. Unfortunately, the weld metal never has the same heat transfer rate as the original metal, thus affecting melt flow in the area and causing the gauge band **(Figure 17).**

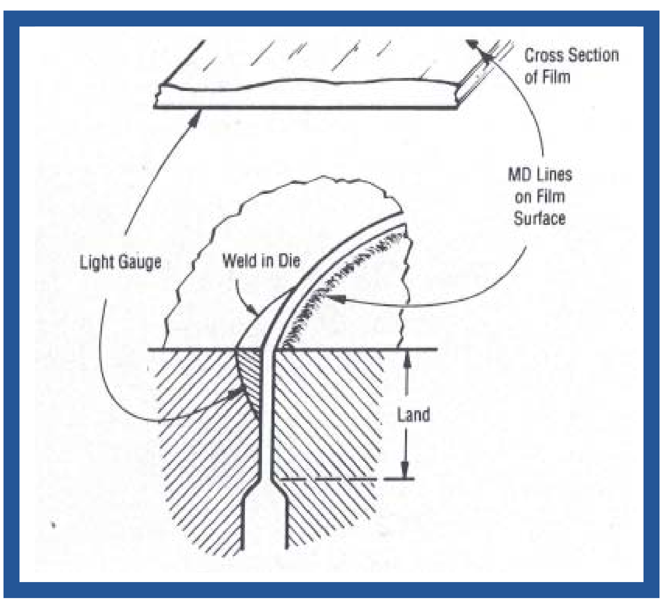

Figure 17: A gauge band results from the weld in the die lip. The build-up on the die lip drags and marks the film surface.

3. Degraded material on the die lips

   Even more noticeable than gauge bands are the lines and coarse surface of film extruded from a die with a build-up of degraded and carbonized material on the die lips or in the die lands just beneath them. Usually these deposits indicate excessive melt and die temperatures. These deposits should be cleaned from the top of the die with a brass shim stock inserted between the die lands **(Figure 17).**

   Other causes of die lip build-up are offset die lips or die lips with wire edges, too large a radius or very fine nicks. These defects cause the melt to momentarily drag across the face of the higher die land as the melt leaves the die.

4. Other die defects

   Causes include:

   - Poorly designed internal flow passages
   - Segments of a heater band burned out
   - Loose heater bands
   - Die heater band terminals aligned on one side of the die

   The last three problems cause the die to be heated unevenly, affecting the melt flow in the die ahead of the die lands and resulting in gauge bands.

5. Defective or poorly adjusted air rings

   An air ring's first function is to stabilize the bubble; the cooling from the air used is a bonus. An air ring should be machined as precisely as the die and securely mounted parallel and concentric to the top if the die. When a die is cleaned, the air ring should also be cleaned of dirt carried in the cooling air. Blockage of the air ring **(Figure 18)** causes gauge bands.

Some air rings are mounted slightly above the die face with an air gap between the ring and the die, while others are placed on a flame retardant gasket directly on top of the die with no air gap. A common cause of gauge bands when the air ring is mounted above the die is an accumulation of silicon grease between the top of the die and the bottom of the air ring. This grease partially blocks the uniform flow of air through this passage, resulting in gauge bands where the hot melt extruding from the die is not cooled.

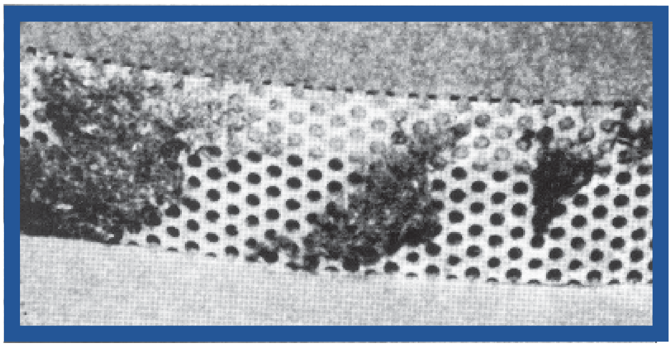

Figure 18: Dirt in screen caused 5" gauge band.

However, despite this problem, not all air rings should be mounted on a gasket. Some types of air rings are difficult to adjust if there is no air passage between the top of the die and the bottom of the air ring.

Essentially, gauge bands caused by defective or poorly maintained equipment cannot be corrected simply by adjusting the die gap or centering the air ring. Such problems are eliminated only by proper set-up and maintenance of the equipment. Rotation merely implants gauge bands deeper into the roll of film.

6. Excess silicone grease

Often used to keep hot melt from sticking to the top of the die on start up, silicone grease, when used in excess, is a very common cause of gauge bands. Grease on the inner lip or in the throat of the venturi disrupts the ring's air flow. The gauge band's width is usually equal to about how far the grease has been rubbed around the air ring surfaces multiplied by the blow-up ratio.

Bubble Trouble and Blemishes

The best film made from a die and air ring can be rendered useless by inattention to the design, maintenance and set-up of the downstream bubble-collapsing and web handling equipment, including the tower and the winder. Operating conditions governing the take-off equipment all affect the film's properties and appearance and adjustments to one piece of equipment can lead to problems elsewhere. For example, opening the collapsing frames to reduce drag and obtain flatter film results in more space at the top of the bubble. If air is not added, the bubble diameter and the layflat width are reduced. In other words, an attempt to improve the film's appearance can result in decreased productivity. All the equipment in the film production system is interconnected, a fact that must be recognized in adjusting operating conditions.

Collapsing the Bubble

Conditions to check:

1. The main nips must be centered over the die. The center of the die, bubble and main nip rolls must be in alignment with one another. If this equipment is not aligned, film from one section of the die must travel further than film from another section to reach the nips. The greater the

misalignment, the more the film is distorted and the more difficult the process of collapsing the bubble and processing the web downstream becomes.

2. Bubble stabilizer bars must be centered. Bubble stabilizer bars should be mounted so they can be adjusted symmetrically about the center line of the bubble. Off-center stabilizer bars can lead to pulled and stretched film. The bars' contact with the bubble should be vibration free and minimal. Vibration and excessive drag on warm, freshly-formed film can only lead to chatter marks, bagginess and wrinkles **(Figure 19).**

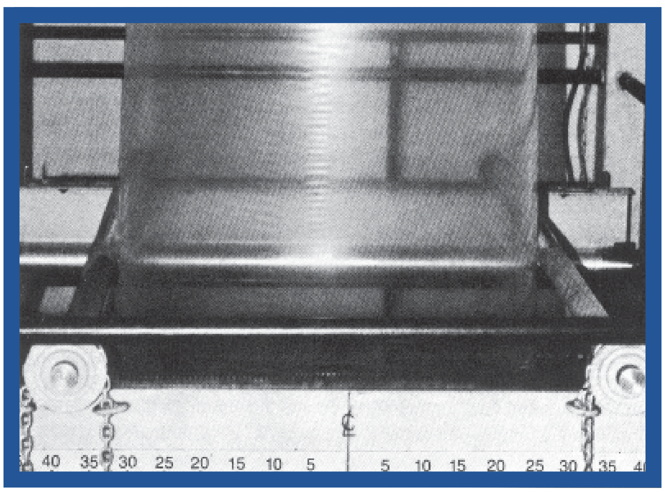

Figure 19: Graduation on beam aid adjustment of bubble stabilizer bars. Drag causes wrinkles.

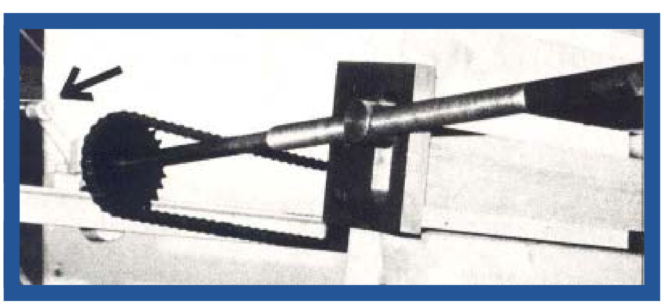

Figure 20: Collapsing frame with single point adjustment. Arrow indicates crank handle.

3. Collapsing frames must be aligned. The best collapsing frame is free of vibration and symmetrically mounted so it can be opened or closed about the center line of the bubble by a single control **(Figure 20).** Aligning the four lower corners of the frames individually is time consuming and difficult to do without racking them, which would worsen rather than solve a problem.

There are two additional mounting faults that commonly occur, either singly or combined, with collapsing frames:

A. If the frames are mounted too far below the nip rolls, the film can partially reinflate above the frames, usually causing wrinkles into and out of nip rolls across the center of the web.

B. Off-set or misaligned with the nip of the rolls, collapsing frames can cause continuous or intermittent wrinkling of the film edges out of the main nips.

Of course, collapsing frames that have not been regularly cleaned, repaired or maintained, or roller frames with rollers that turn unevenly or not at all, can also contribute to film wrinkling. Wrinkles are also a common occurrence after a transition to a wider layflat film following a long run of narrow tubing. Dirt collects on the surfaces of the collapsing frames during the narrow tubing run. The edges of the wider tubing rub against these surfaces as the bubble collapses. The result is wrinkles in the film as it moves out of the nip rolls.

However, despite perfect equipment alignment, determining the proper collapsing frame opening to achieve the flattest film is still, to some extent, trial and error. **Figure 4** on page 4 suggests the closer the frames, the better the film. Unfortunately, the closer the frames, the more film in contact with the frame's wooden slats and the greater the drag to distort the film and make it baggy in the center of the web.

The final frame opening is a compromise. The size of the bubble (contact area), line speed (drag across the contact area), thickness of the film (remembering the amount of slip not only varies from resin to resin but also depending on the thickness of the film) and the resin used (degree of stiffness) must all be considered.

4. Gusset blades must be aligned.
5. All other equipment must be in aligned or trammed. Not only must the tower be plumb and all the rolls trammed, but the film die must be vertical and aligned with the air ring and main nip rolls. Winders and other equipment must be properly aligned and trammed with the tower if the web of film is to track through them smoothly.

Handling the Web Through the Tower

As the web of film moves from the main nips to the winder, the film can be visualized as a long rubber band experiencing constantly changing tension. To prevent the film from stretching as it moves through the tower, this tension should be kept to a minimum. Excessive tension results in MD wrinkles that are then folded into the film as it passes over each roll. The folds make the end product defective and unacceptable. However wrinkles will always appear in film on the line. Only on occasion do these wrinkles indicate a problem.

Air can carry over in the layflat from the bubble before the main nip rolls are closed at start-up. This air can reinflate the tube just before it passes over an idler and cause excessive MD wrinkles. The air can also collect just ahead of a treater roll, resulting in poor treatment or treatment of the wrong side of the film where it has folded.

To prevent air collection, during set-up the web should always be diagonally slit in a number of places across its width right after the main nips to bleed off any trapped air. If air does appear, the nips should be checked for tightness and the film for size.

Wrinkles, slightly diagonal to the MD of the web, can indicate a roll that is either galloping or constricted. Again, because of the changing tension in the web (particularly on older lines), film should be cut to width only between two pairs of nips that isolate this station from web tension changes. If not isolated, film width can vary excessively with web tension changes upstream. The web can drop right out of the cutting station knives during the momentary loss of tension downstream when film is cut over to a new core on the winder.

Film Appearance

Film appearance should first be defined before being discussed. The term includes haze (clarity), gloss (reflectance) and general appearance (no imperfections in or on the surface). Good film appearance is the result of the right combination of resin, equipment and process.

Resin quality is initially controlled by the resin supplier. The resin must meet the customer's requirements for physical properties, additive levels, etc. However, even though prime resin is shipped to the customer, every time the resin is handled, there are additional opportunities for it to be contaminated, first by residual material in the transfer system, and second, by residual material in the container itself **(Figure 21).** Stones and dirt from transfer hoses left lying on the ground alongside railroad sidings are often removed from the screen packs of many extruders.

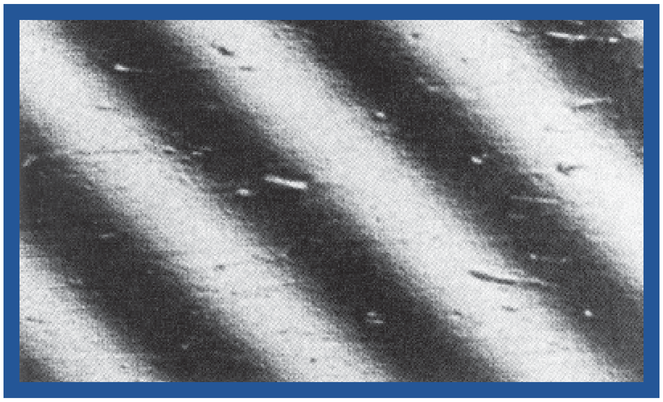

Figure 21: Gels were caused by moisture getting into resin when delivery truck was unloaded in the rain.

Resin stored in fiber drums or boxes without lines can pick up cellulose fibers that can result in gels which can knock down a 1-mil bubble faster than it can be reblown. Additional, sources of contamination are dirty, unchanged filters in resin transport systems and the upper inner surfaces of extruder hoppers coated with layers of dust from many different resins previously used. This material can intermittently fall into the extruder and contaminate resin in the system.

Contamination also can come from inside the extruder by a new resin gradually purging an old, degraded resin from stagnant areas in the system. A die that has been overheated or that has not been cleaned often can cause gels in the film, particularly when a new resin is introduced to the system. In both cases, the gels are usually random throughout the film and can be clear to amber to black in color and look like tapioca and/or arrowheads **(Figure 22).**

Gels from a hole in a screen pack, from a burn in the die web or from a point inside a side fed die where two melt flows join, appear only in one area of the film. Again, one or more flood lights mounted to illuminate the frost line and the melt below it can also help operators identify and determine the type or origin of the gels.

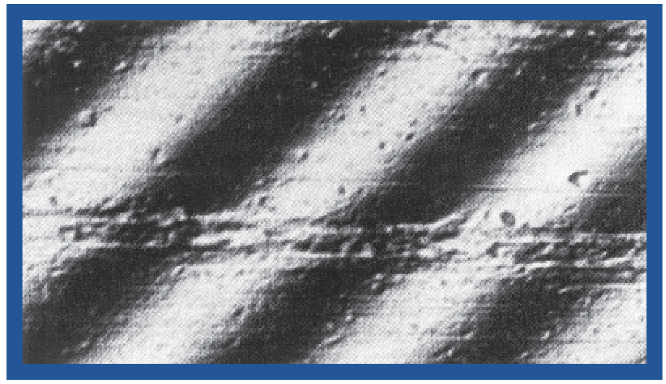

Figure 22: Severe die lines indicate that a dirty die is the probable source of gels in the film.

Air ring chatter marks appear as close, uniformly spaced lines around the bubble in the TD of the film. High frequency vibration of the hot melt just above the die caused by improper air movement or excessive air velocity from the ring are the usual causes. Normally, this vibration can be eliminated by adjusting the air ring and/or the blower.

Film can be scratched by being dragged over any sharp or abrasive surface. The source can be a splinter in the collapsing frames, a sharp edge on a gusset blade, dirt on the face of a “frozen” roll, etc. Scratch lines are usually coarse and white in color. On occasion, these lines are intermittent and are always parallel to the MD of the film. In contrast, die and weld lines have a melted-in appearance, and with die rotation, are slightly diagonal to the MD of the film.

“Applesauce” or “orange peel” surfaces in film can be a resin-related defect. These defective surfaces appear as faint to heavy aberrations in the film, distorting its clarity. Orange peel also can be caused by blending resins that are not fully compatible.The extruder, die, air ring and processing conditions can have a significant effect upon the final haze and gloss of a film from a given resin. Additives, and the proportion of scrap recycled to production all have an additional effect.

If colorants are used, the appearance of the film is dependent on a thorough dispersion via a good mixing screw, assuming there is good master-batch color uniformly mixed with the resin prior to extrusion. Poor color dispersion shows as clouds of color in the film and can result in heat seals with variable strength as the amount of color and film density varies in the seal area.

Roll Defects — Whose Fault?

Roll and film defects discussed in this booklet are summarized in **Table 1.** A common converter complaint is wrinkled film near the core of the roll. This problem can be due to operator error. How much skill does the operator have in cutting the film from the finished roll to a new core? Was there a fixed reference mark to locate the core or was it "eye-balled" for position on the winder shaft with the resultant buried and protruding core ends? Or, was the damaged roll just too heavy for the operator to handle?

Other, non-operator, conditions can contribute to roll and film defects, including the location and/or the accessibility of winder nips, slitting, and trimming stations, treating stations, gusseting equipment, etc.

Telescoping or crushed cores, with possible blocking, are the result of too little or too much winding tension. Again, defective cores could be the result of inattention to tension control as the roll builds or a need for maintenance work on the drive.

Color in the roll ends of natural film results from three unrelated problems. Blue/gray coring in the first inch (or less) of film around the core is caused by too much initial winding tension and can indicate crushed cores if severe enough. If blue/gray coring occurs, some cores may collapse at a later time, as the film ages, shrinks and increases the stress on the core.

Making a roll change too soon after changing resins can also cause a color change in the roll end from the core to the finished diameter. There is nothing inherently wrong with the film, but such transition rolls should be scheduled to meet orders where such a roll is acceptable. For instance, such a roll of film might be quite acceptable as the last roll of a general purpose clarity order rather than the first roll of a high clarity order.

Finally, on some equipment it is very difficult to purge color, particularly white. Liner, rather than clarity orders, should be scheduled following orders for colored film. A clarity film scheduled after a white film appears clear in single thickness, but on the roll the residual color, still purging from the extruder and die, whitens the end of one or several rolls of otherwise clear film.

Care should always be taken to know and not exceed the number of splices allowed in a roll and the number of spliced rolls acceptable to the customer in an order. Splices are costly in the time they take to check and thread through converting equipment. Uniform roll diameters, consistent weights and good appearance are important customer requirements.

Table 1

Roll Defects	Film Defects
Gauge Bands	Low Yield
Non-Uniform Surface Hardness	Gauge Bands, TD
Convex Face	Variable MD Gauge
Concave Face	Flatness
Tapered Through Length	Camber
Wrinkles	Wrinkles
Corrugated Ends	Variable Width
Fuzzy Ends	Uneven Gussets
Telescoping	Fuzzy Ends
Blocking, wound with too much tension	Blocking
Crushed Cores	Treatment Level
Roll End Color	Splittiness
Damaged Edges	MD Film Strength
Scuff Marks	Edge Creases
Core Ends	Die & Weld Lines
Protruding	Scratches
Buried	Appearance
Splices	Gloss
Weight	Clarity
Diameter	Color
Roll-to Roll-Uniformity	Imperfections
Identification—missing roll labels	Applesauce
Treated Surface	Gels
Wound Wrong Side Out	Arrowheads
Incorrectly Identified	Air Ring Chatter
Not Identified	Blocking
Incorrect Additive Levels	Very High Gloss
	Incorrect Additive Levels

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