Extrusion 101

A basic introduction into the world of blown film extrusion and what makes it work.

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This document will be broken into three basic parts, each part dealing with a particular aspect of the extrusion process. This document is aimed at operational staff who have limited knowledge of the technology.

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3. Operating extrusion technology.

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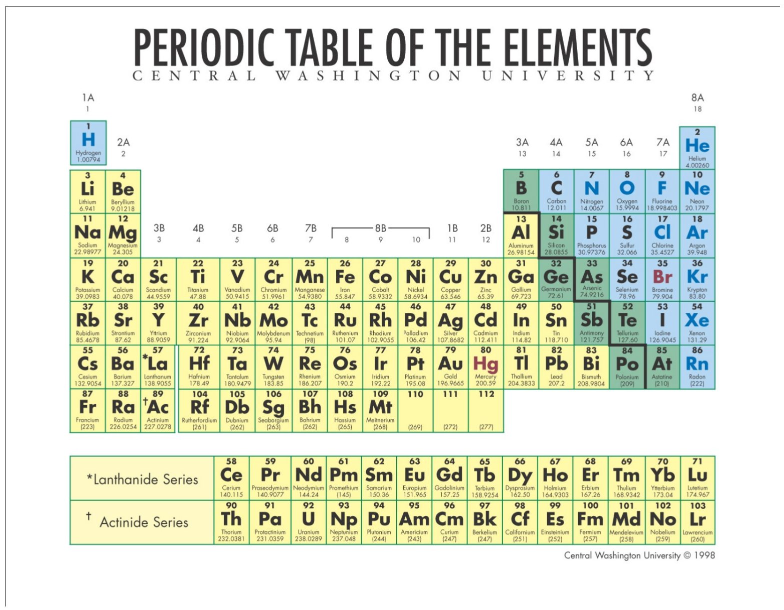
Basic Introduction – What is Extrusion?

- What is Extrusion? The formal definition of extrusion is 'To shape or form by forcing through a die'
- The process is used in a host of industries ranging from plastic sheeting and piping manufacture, to wire drawing, steel and Alumina profile forming .
- Requires that the base material be pushed or pulled through a predetermined shape or profile which is representative of the finished product.

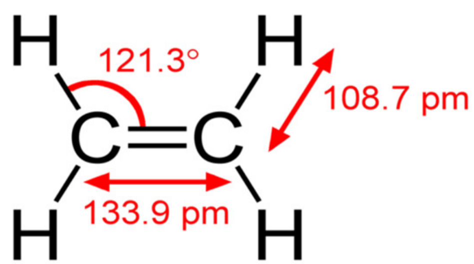
Basic Introduction – What is a Polymer?

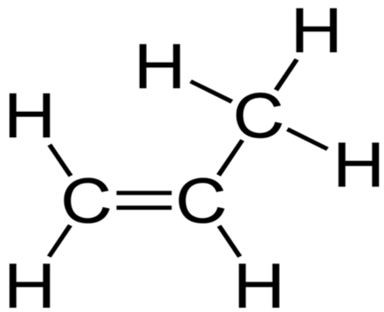
- Poly:- consisting of many. A substance formed from a number of simple molecules joined chemically to form a long chain.
- Carbon, the magical building block



The Basic Building Blocks of Polymers

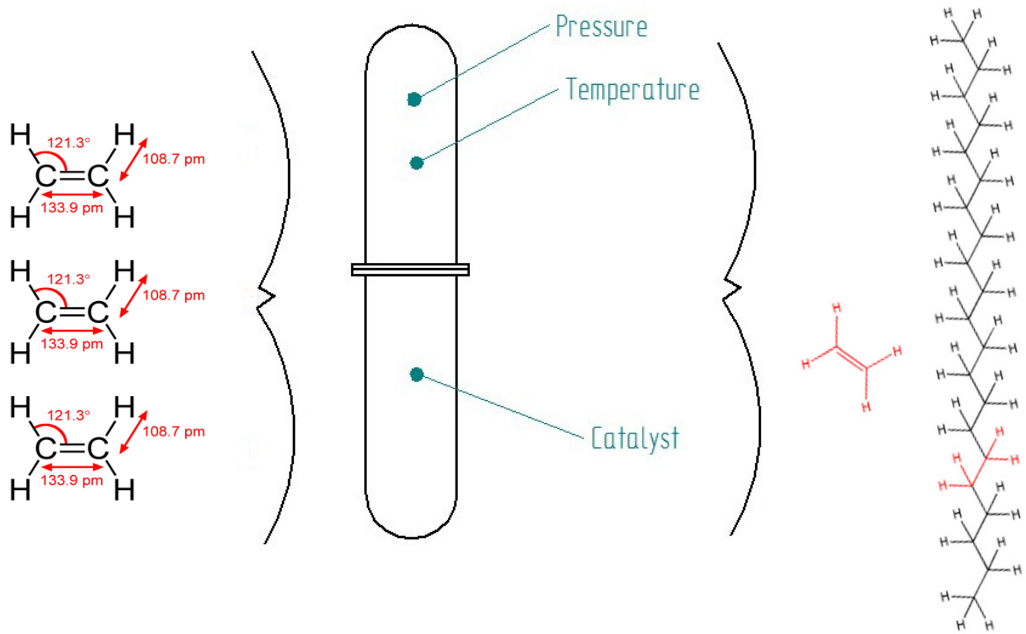
- **The pursuit of chemical perfection, all elements try to emulate a noble state, a state of absolute stability. For Carbon this is the magical number 10.**
- **Elemental Carbon lacks 4 electrons in its outer orbital's.**
- **Will form bonds with itself, as well as other elements and compounds in an attempt to try fill its outer orbital's with electrons.**
- **One of the simplest and most commonly used Carbon compounds found in polymer production is Ethylene (C_2H_4).**
- **Another example of a product we use is based on Propylene (C_3H_6)**

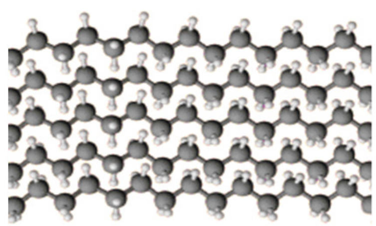


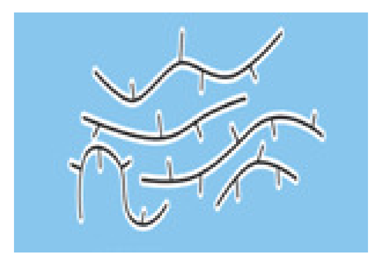


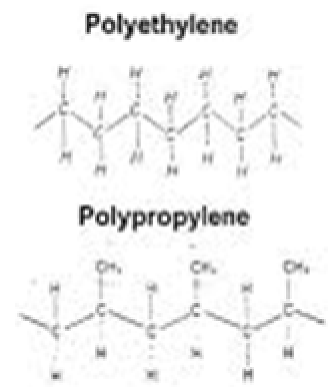
All basic building blocks are characterized by at least one primary double bond in their formation, all exist in the gaseous phase.

From Single Molecule to Chain….
(From Monomer to Polymer)







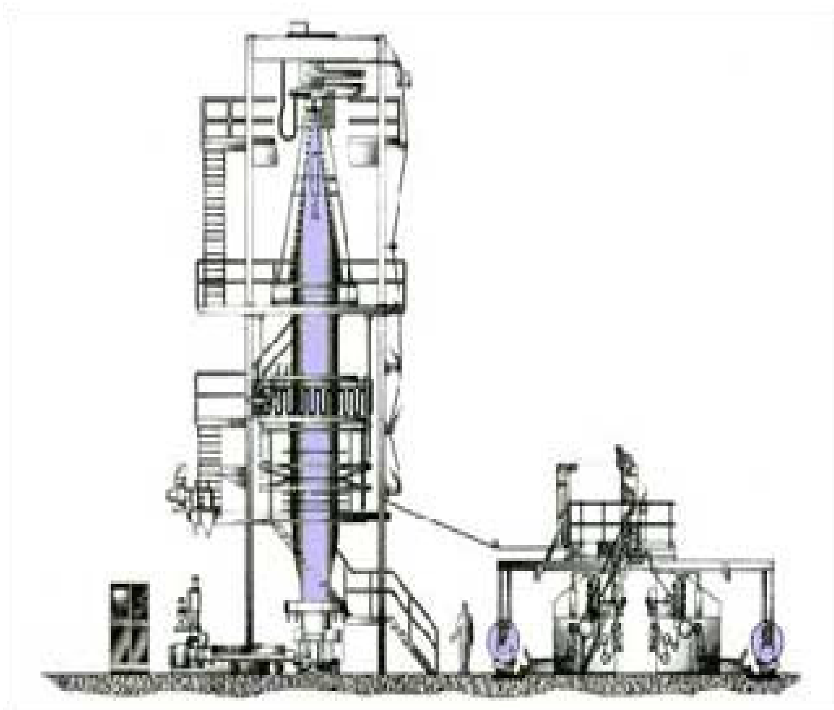


LDPE

HDPE

LLDPE

Basic Introduction – Basic Blown Film and Zip Lock Extrusion Lines



Basic Introduction - What do blown film Extruders do?

The extruder consists of several discreet components, so arranged to convert pellets of polymer into a molten resin, which is then forced through a die and inflated to form a tube of film.

This is a continuous process through the machine line, with pellets being fed in one side and tubular melt coming out of the other.

Basic Introduction - What do Extrusion lines consist of

- Extrusion lines are composite machines, usually consisting of the following components:

  The basic pump assembly, (comprises a base plate or frame, on which is mounted a motor/gearbox assembly, a barrel and screw fitted with heating elements and cooling fans, and a feed hopper or some form of material batching or mixing devise.)

  A screen pack housing

  A die assembly , which can be rotating or stationary

  An air ring which may include a gauge control system.

  An internal bubble cooling devise which may include a lay flat (material width) control system.

  Some form of bubble support system or calibration basket

  A tower assembly with various lay down rollers

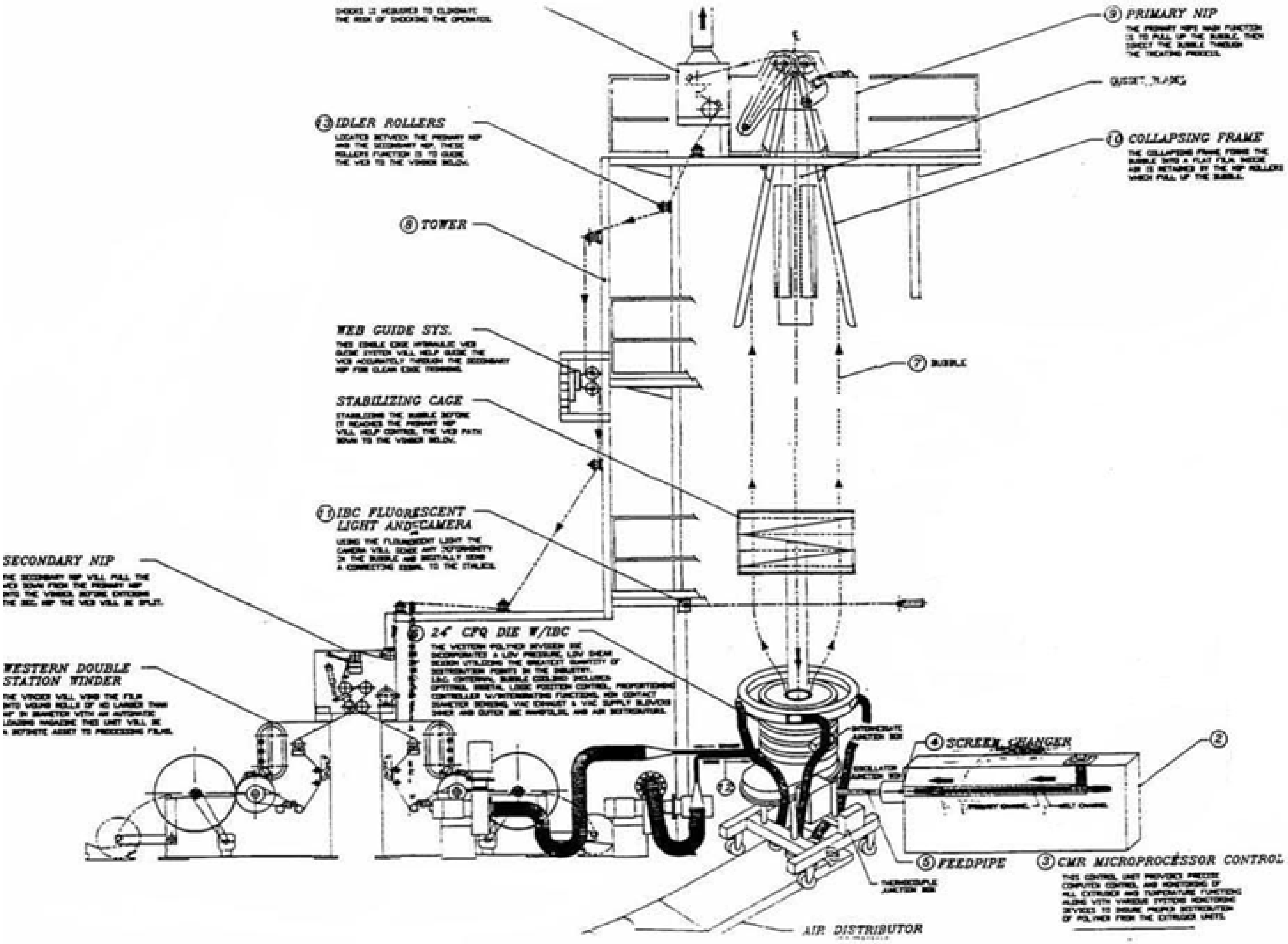
  A collapsing frame

  A haul off or nip roller assembly

  A treater unit and generator

  A winder

  An electrical cabinet that houses the technology needed to control the machine line and by which the operator interacts with the machine.



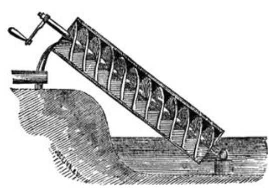
9 PRIMARY NIP
QUSSET BOARD
10 COLLAPSING FRAME
13 IDLER ROLLERS
8 TOWER
WEB GUIDE SYS.
7 BUBBLE
STABILIZING CAGE
11 IBC FLUORESCENT LIGHT AND CAMERA
SECONDARY NIP
6 24" CFQ DIE W/IBC
WESTERN DOUBLE STATION WINDER
4 SCREEN CHANGER
2
5 FEEDPIPE
3 CMR MICROPROCESSOR CONTROL
AIR DISTRIBUTOR

Zip Lock Extrusion Line

Blown Film Extrusion Line

Basic Introduction – How do extrusion Pumps work?

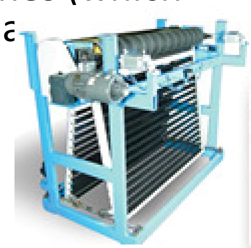
- Archimedes - designer extraordinaire lived between 287-212 B.C. Designed a screw pump for dewatering ships holds, which is the fore father of the screw and barrel design used in extrusion pumps today. Also formulated the laws of buoyancy.
- Devises such as this are considered to be positive displacement devices.



- The extrusion pump essentially consists of a barrel and screw arrangement, which has a series of heater bands strapped around the outside of the barrel to provide controlled heating via a temperature control instrument and sensing thermocouple.
- The screw is driven by an electric motor and gearbox assembly. The screw is so profiled as to perform different functions along its length. A feed hopper is attached over the feed zone of the barrel.
- The feed end of the screw lies within a grooved section of the barrel called the feed zone, which meters pellets into the barrel at the materials bulk or volumetric density. As the screw moves the material across its length it starts melting while the metered volume gets progressively smaller changing the material from its volumetric density to its absolute density.
- Once the material is melted it is mixed and plasticized before leaving the lead end of the screw, passing through the screen pack (which removes any solid impurities from the polymer) and being pushed into the die.
- Besides heating elements, the barrel is also fitted with cooling fans or water coils which act to cool the barrel down as it starts to overheat as a result of the friction between the stationary barrel ,screw and moving polymer when the machine is operational. Heating the barrel positively when the machine is stationary, while cooling it when the machine runs to prevent polymer overheating is called dual set point temperature control.

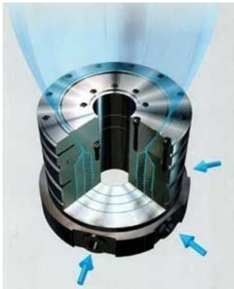
Basic Introduction – What purpose does the haul off perform

- The haul off or nip rollers act to draw the extruded molten polymer tube down to the correct gauge or thickness. The faster the nip roller of haul off rotates against any set extruder speed, the thinner the material gauge will be.
- The haul off consists of a driven set of nip rollers and may be orientated either vertically above the die (as in film extruders) or horizontally in line with the winder (as in the Zip Lock extruders).
- The driven roller of the haul off sets the speed reference for the rest of the machine line.
- The drawing down of the polymer occurs in that region of the extruded bubble below the freeze line and above the die lip.
- In film extrusion the haul off performs a second task of trapping the air within the extruder bubble needed to ensure the correct width or lay flat of the material being extruded.
- Polymer orientation is determined by the blow up ratio (diameter of the bubble / diameter of the die) of the extruded material. In Zip Lock this ratio is typically 1 or there about while in film extrusion values of between 1,5 to 4 are typical.
- Some haul offs are able to rotate (while the die remains stationary) while some are stationary and are associated with rotating die technologies. The main reasons for rotating dies and haul offs are to spread any thickness idiosyncrasies in the material across the width of the roll, resulting in a smooth cylindrical roll appearance.
- Zip Lock machines have neither rotating dies or haul off's, and unlike blown film lines (which have the haul off or nip mounted directly over the centre point of the die), have ha which locate just in front of the winder

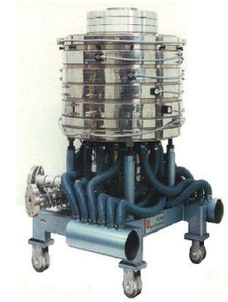


Basic Introduction – Why do Extruders need Winders?

- The prime purpose of the winder is to collate the extruder material into a roll of a set or predetermined length.
- In Film extrusion the film is coiled onto a core which fits around a winding shaft, that is driven at a speed comparable to that of the haul off speed.
- In Zip Lock the material is coiled onto a bobbin which fits onto the drive shaft of the winder.
- Two basic winder formats exist, those in which the roll is wound by contacting a winding calendar (called contact winding) or where the shaft winding the roll is physically driven by the machine (called gap winding).
- In new generation machines, the speed of the winder will change as the roll get bigger, slowing down progressively, thus preventing the core or bobbin from being crushed. This phenomena is call 'tapper control'.
- Most winders will be fitted with counters which are so calibrated as to measure the length of material wound onto the roll in meters or feet.
- Automated winders will automatically cut the material off when the desired roll length is achieved.



Basic Introduction – What is a Die?



- Dies are used to form the molten plastic into the desired shape and dimension needed in the final product. In tube extrusion the forming parts (mandrels) of the dies are concentric in shape with a small gap between the inner (male) and outer (female) parts.
- Two die formats exist, one which is side fed and one that is bottom fed. In both instances the molten plastic leaving the extruder needs to be distributed around the entire circumference of the die, while being constantly worked to maintain its plasticity, before being pushed out through the die gap
- In Zip Lock the form of the male and female parts of the zip are integral with the top forming face of the die.
- The dimensions of the die are fundamental in ensuring the final material geometries and performance properties.
- Dies, as with barrels and screws, are polymer sensitive, with different polymers requiring different die gaps and back pressures.
- The forming faces of the die lips are crucial in ensuring good product quality.
- In multi layer or co-extrusion machines more than one polymer mix is introduced as a discreet layer into the die, and is then fused to any other such layers just prior to the melt leaving the die.

Basic Introduction – What is an Air Ring and what purpose does it serve?

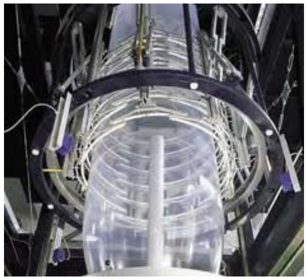
- Air rings provide the cooling needed to convert the molten polymer back into solid material. This is achieved by blowing cooled air onto the surface of the bubble in a controlled fashion
- Air ring systems consist of a speed or iris controlled blower, a heat exchanger and the air ring itself.
- The air ring consists of an annulus which has a series of venting holes or ports along its inner circumference.
- In blown film extrusion these ports take the form of slots which are lipped on either side. A dual lipped air ring is thus an air ring having two circumferential slots.
- Zip Lock air rings are typically pin holed along their inner circumferential face
- Zip Lock air rings can be stacked or pancaked to give greater cooling efficiency.
- Most high output film extrusion lines cool the bubble both externally as well as internally. This concept is called IBC or internal bubble cooling . It entails blowing cool air into and removing hot air from the inside of the bubble at such rates as to maintain the integrity of the bubble diameter.

Basic Introduction – What purpose does an Extrusion Tower serve?

- Extrusion towers serve one main purpose, and that is to provide enough cooling to the extruded bubble prior to folding it flat or collapsing it, to prevent the inner surfaces from blocking or sticking together. Thus the height of the tower is directly related to the maximum extruder output and smallest bubble diameter to be extruded at that output.
- Extrusion towers also provide a support base to the collapsing frame and haul off, and can also be used to support peripheral equipment such as treater stations, edge guides and the like.
- The material path from the top of the tower to the winder (and haul off in Zip Lock) is via a series of layoff rollers which are so positioned and spaced as to afford the material maximum support and stability.

Basic Introduction – What is a Collapsing Frame?

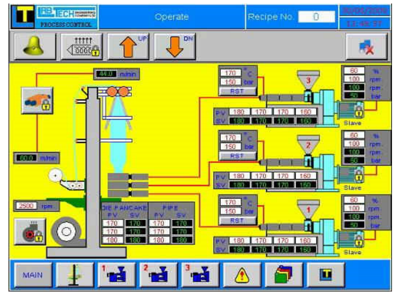
- Collapsing frames serve the purpose of folding the tubular profile of the extruded bubble into a flat sheet
- This is achieved by progressively squeezing the bubble between two boards set in an inverted V shape (which can have a solid, roller or slated surface), squashing the bubble flat in one plane while allowing it to expand into the other.
- Collapsing frames can also house gusset boards which allow for the reverse folding of the collapsing bubble to form two symmetrically opposed gussets.
- Depending on the format of the haul off, collapsing frames can either rotate with the haul off or be of a stationary nature.



Basic Introduction – Other Components

- Bubble guides or calibration baskets are so called because they provide radial support to the bubble just after it has been frozen by the air ring. (The term calibration baskets was adopted as these guides have the ability of being open or closed, and as such can be calibrated to the exact bubble diameter needed to achieve a required material width. When setting the machine up it the bubble is inflated to touch the elements of the guide). Often on older machines these guides consists of an adjustable iris, or cross rods.

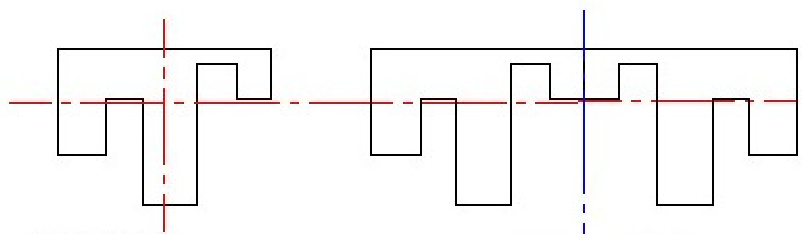
- Screen packs are used to filter out solid impurities from the molten polymer just prior to it passing into the die. Two formats of screen packs exist, one being cartridge or tubular shaped while the second is a flat disc. Screens need to be supported on substantial support plates as when they become blocked substantial pressure differences can build up across them. These devices are normally protected by pressure sensors which are placed just upstream from their location.



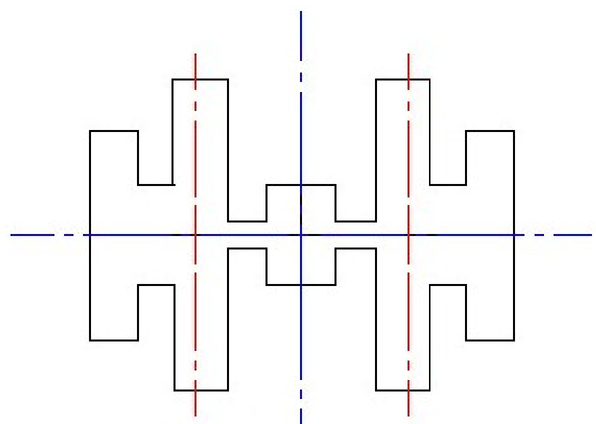
- Control panels serve two basic functions on any machine line. Firstly they house the technology needed to make the machine operate in the fashion intended, and secondly they create an interface between the machine and its human operators.
- Control panels are so designed as to best protect the technology house therein, and are normally considered to be intrinsically safe.
- Do not open electrical panels and attempt to perform work on any of the contained componentry unless you have been trained to do so and are aware of the dangers involved!

Machine Design Principals – Symmetrical shapes and Bi-Symmetry Axes of symmetry

- Shapes which are mirror imaged across a single axis are call axially symmetrical, which those mirror imaged across two axes are call bi-axially symmetrical



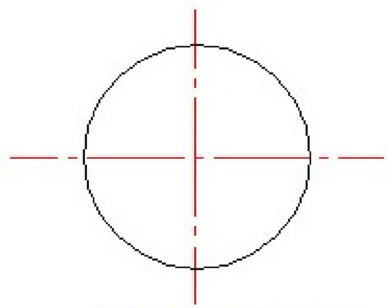
Non Symmetrical Shape   Axially Symmetrical Shape



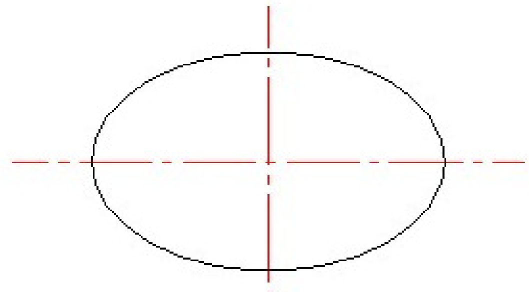
Bi-Axially Symmetrical Shape

Machine Design Principals – Symmetrical shapes and Bi-Symmetry Axes of symmetry

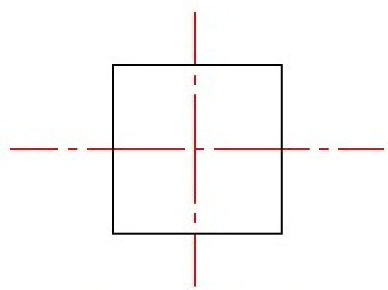
- Typical examples of shapes which are bi-axially symmetrical



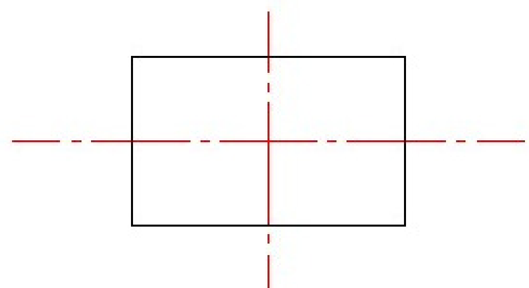
Bi-axially symmetrical Shape – Circle



Bi-axially symmetrical Shape – Elipse



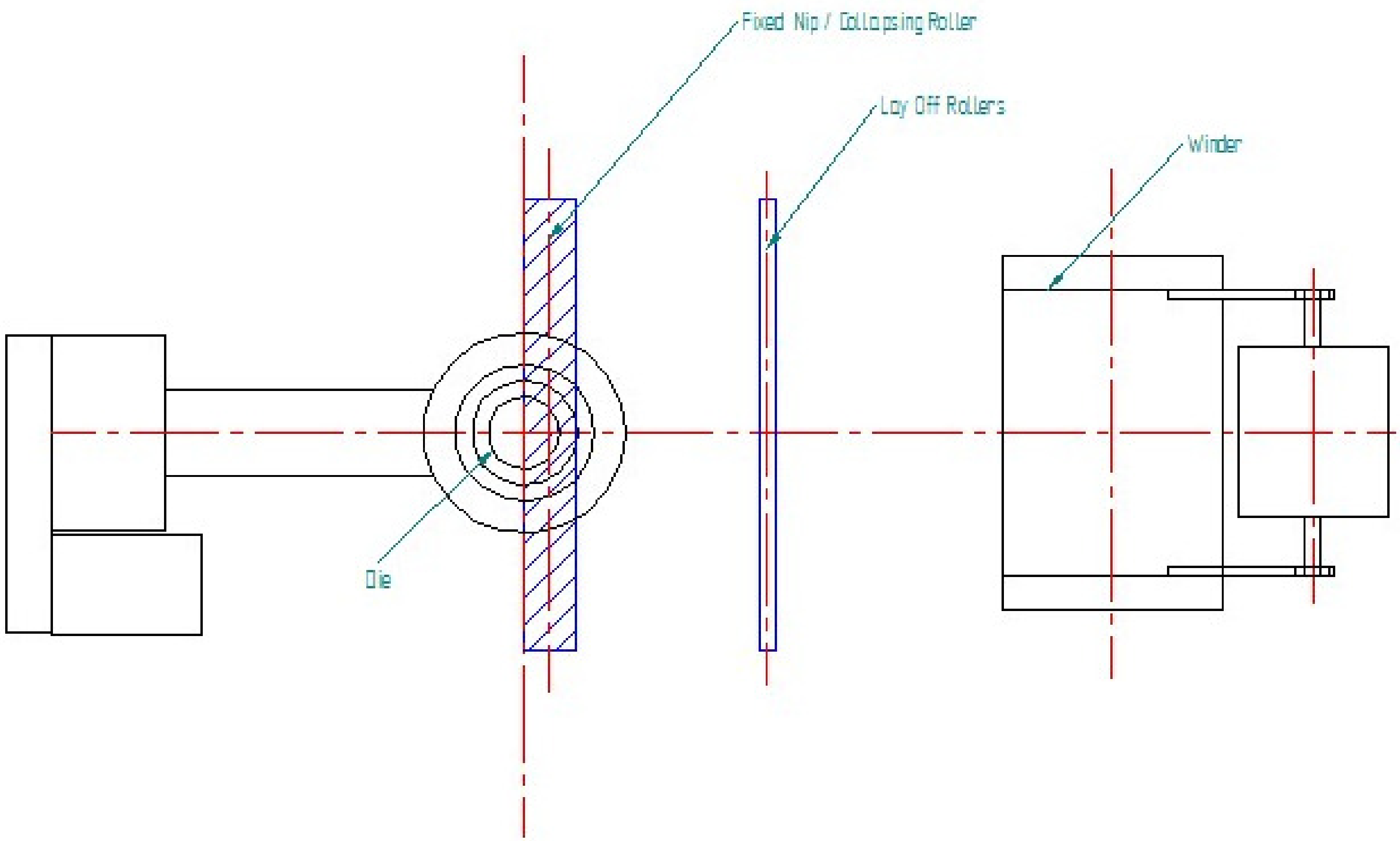
Bi-axially symmetrical Shape –Square



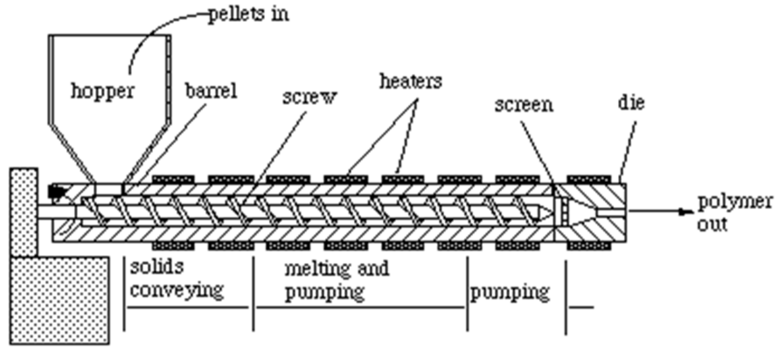
Bi-axially symmetrical Shape – Rectangle

Machine Design Principals – Centre Lines and Machine Symmetry

2 centre lines along which the machine is aligned, intersecting at the centre point of the die.

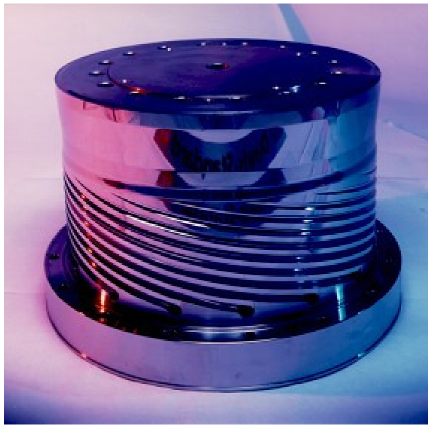


Machine Design Principals – Barrels and Screws



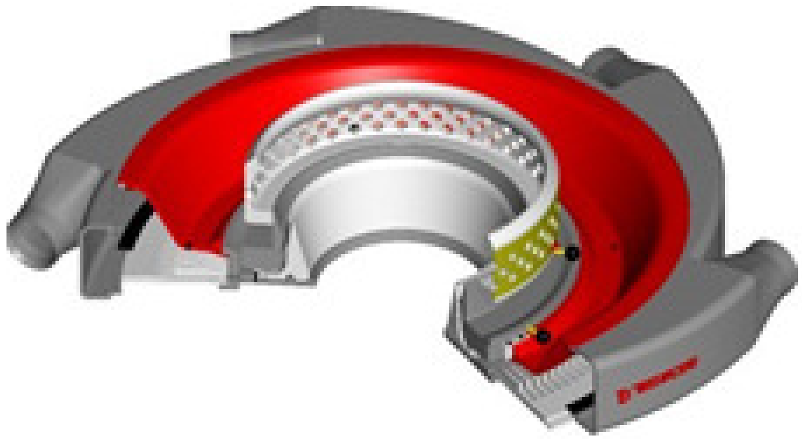
- Barrels are parallel bored high pressure vessels capable of with standing pressures of many 100's of bars. Typically their inner surfaces either consist of a tungsten sleeve or are nitrided to give a hard wear surface
- The barrel bolts onto the gearbox via a bell housing which contains a labyrinth sealing chamber. The feed zone and gearbox is heat isolated from the rest of the barrel assembly by virtue of a cooling zone which has chilled water circulated through it
- The screw fits neatly (tolerances of 0,2 to 0,3mm) into the barrel, and is spline driven from the main drive gear. When loaded this gear pushes up against the gearbox housing by virtue of a large profile thrust bearing
- The screw performs a series of functions, starting off by conveying the solid polymer pellets into the machine. As the pellets start melting the flight volume of the screw decreases, ultimately changing the pellets into an air free molten mass. (Many screws employ a second flight in this area of the screw, such screws are referred to as barrier screws). Once the polymer is molten it passes through a mixing zone which homogenizes the melt, and it is finally pumped out of the end of the barrel, through a screen pack into the die
- Screws are purpose designed to the types of polymers to be processed. Polyethylene screws differ markedly from those used specifically for processing Polypropylene or Polyamide. Screw profiles for HDPE differ from those used for LDPE, which is turn is differ to those used in processing LLDPE.
- Screws are manufactured from some of the hardest metals known to man which makes them really strong but very brittle
- Screws and barrels are wear components on extruders, their life being determined by the types of polymers and additives being processed through them
- Screws and barrels with their attachments are usually pressure protected by virtue of a sensor and control circuit which removes the electrical supply to the motor in the event of an over pressure situation arising
- It is important to ensure that the machine is preheated to the correct temperatures before starting, cold starting the machine can shatter the screw

Machine Design Principals – Dies



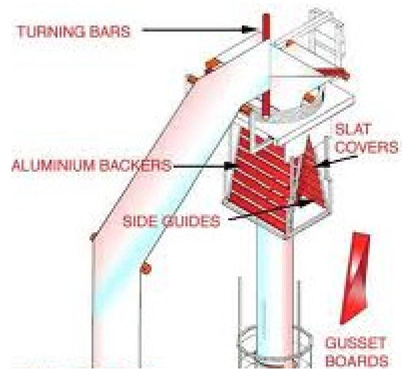
- Extrusion dies are highly precise and expensive bits of equipment and need to be handled and looked after accordingly
- Polymer contacting surfaces of dies are highly polished and accurate in their shape and format
- Dies are high pressure devices which rely on accurate surfaces to ensure their sealing integrity
- When working on dies always use soft materials like copper, aluminum or brass when contacting the die surface, never use steel or harsh abrasives which can damage the polished surfaces
- All mechanical fasteners used on dies should be tightened using a torque wrench to ensure uniform tightness and sealing integrity
- When adjusting dies always loosen opposite adjusting bolts before tightening the push bolts needed to move the adjustable mandrel
- The lips of the male and female mandrels of the die should be smooth and continuous and should not be chipped or marked. Any deformation of these lips will result in slurring or die lines in the formed polymer.

Machine Design Principals – Air Rings



- Air rings are so designed as to provide a continuous curtain of cooled air onto the surface of the extruded bubble
- Provided the die gap is perfectly uniform, any variation in material thickness or gauge can be attributed to variations in cooling or air ring performance.
- These devices need to be properly centered around the extruded bubble to provide accurate and uniform cooling
- These devices, as for the dies are highly precise and expensive bits of equipment and need to be handled and looked after accordingly
- Cooling rates of air rings are controlled by the amounts of air being allowed to pass through them, which in turn is controlled from the blowers supplying the air.
- As for dies the design of these devices are based on being axially symmetrical

Machine Design Principals – Collapsing Frames



- Collapsing frames are designed to be axi-symmetric about the two principal machine planes.(i.e. that the position of the collapsing boards are to be set at exactly the same position on the front and back as well as on the left and right hand sides of the frame).
- Any non symmetries will result in the bubble being consistently pushed across to one side of the collapsing frame, resulting in varying material lengths across the collapsed bubble. This results in rolls of material of varying circumferences which have soft edges or centers and which track badly through down stream conversion equipment.
- All fixtures and adjustment points on these frames need to be secure and rigid in the planes they are intended to operate

Machine Design Principals – Haul Offs and Winders

- Haul Offs and winders operate in unison with each other in controlling and collating the collapsed film. The haul off speed controls the rate of draw down of the extruded material, while the winder speed controls the tension in the material and the hardness of the rolls
- In most extrusion lines the speed reference of the haul off is used as part of an integrated loop control system in controlling the speed of the winder. Material tension is achieved by varying the ratio of these speeds relative to one another
- Of paramount importance is the alignment of both these units relative to the machine center line. These machine units need to be exactly aligned, parallel and level to each other to ensure uniform travel of the extruded material from the haul off onto the roll. Any misalignment between these units will result in poor roll edge profiles, material creasing or roll telescoping in extreme cases

Operating Extrusion Lines –What is important regarding temperatures and temperature profiles on extrusion lines?

- Temperature differences between any two surfaces dictate the rate at which heat (energy) will be transferred between them. The larger the temperature difference, the larger the energy transfer rate per unit of time.
- The rate at which any substance will absorb energy is a fundamental property of the substance itself.
- Polymers are Carbon Based materials which exist as solids at room temperatures. On heating these materials they will start to soften and eventually melt over a range of temperature. Typically LDPE will soften at about 70^{o}C and melt at about 110^{o}C. If these polymers are overheated they start to break down, and in the absence of oxygen start forming free Carbon.
- The process whereby heat energy is transferred into the polymer during extrusion is referred to as transient heat transfer, in that the polymer has a defined time period in which to absorb enough energy to melt while being pushed through the barrel by the screw. Thus the ambient temperature the barrel has to be heated to has to be somewhat higher than the melt temperature of the polymer. Here in lies a dilemma. If the material is stationary in the barrel for too long, or if the barrel is too hot while the polymer will start breaking down to form free Carbon. By the same token if the polymer is not adequately molten before the screw is rotated chances are that the screw will be snapped.

- Thus the values at which temperatures range across the barrel and die need to be set is very much a function of the types of polymer being processed, and the quantity of polymer being pushed through the extruder.
- These values are usually obtainable from the polymer suppliers and are specified to yield the best processing characteristics for their product. Typically the temperature profile across an extruder blowing LDPE will range from 135^{o}C at the feed zone to 185^{o}C at the exit level of the die, while for HDPE the temperature range is some 40^{o}C higher.
- Ideally one would like to keep the temperature of the feed zone as low as possible for two reasons, one it assists in metering the polymer pellets into the extruder and secondly limits the amount of heat permeating back into the gearbox assembly.
- The fundamental requirement is that the temperature of the polymer entering into and through the die needs to sufficiently high to allow for the viscous flow needed to support the bubble prior to freezing.
- Temperature directly effects the clarity, surface texture and stability of the extruded film. Too low melt temperatures are characterized by poor clarity and 'shark skinning' of the film surface, were as too high melt temperatures result in bubble instability or dancing.

Operating Extrusion Lines –Reading the Works Order and Process Document

- All information pertaining to the requirements of the product to be manufactured is communicated via the Works Order
- This document will include all information regarding to exactly what is to be made, how much of it needs making, what it is to be made from, as well as any specific instructions regarding treatment, roll orientation, slitting and format
- Before starting or setting up any job make sure that you have read and fully understand exactly what the Works Order requires you to produce.
- Make sure that you have all the materials and equipment needed to produce the required product, including spools or cores, plugs, overlays, tapes, tools, and documentation.
- If you have any doubts about any of the information contained on the Works Order, if you do not understand something or believe the information to be incomplete contact your Supervisor or Department Manager before attempting to set the job up on the machine line.
- When setting the machine up follow the specifications as laid out in the process document exactly. This will include temperature profiles, extruder, haul off and winder speeds, amounts of cooling air required and all other relevant process data.

Operating Extrusion Lines –Polymer Mixes and Mixing

- Rarely are products made from a single polymer type or grade.
- Polymers are alloyed or blended together to achieve desired properties which are not attainable in a single polymer grade: for example high density polymers are characterized by high strength but are brittle and exhibit poor heat sealing characteristics, where as low density and linear low density polymers are weaker, far less brittle and have good heat sealing characteristics. Thus by blending these polymer grades together we can achieve a reasonable strong material which exhibits some degree of puncture resistance and forms acceptably strong heat seals.
- When setting up any job make sure that the material being used is the correct blend or mix.
- When mixing materials make sure that you follow the instructions of what and how much of each polymer needs to be added into the mixing unit or blended exactly.
- If mixing materials off the machine line in a mixer, allow enough mixing time to ensure proper dispersion of the each constituent of the mix. This can be checked by taking a handful of mixed polymer and separating the various polymers and additives. The quantities of these polymers and additives should be in the same ratio as that of the desired mix.
- Poor mixing is characterized by the uneven dispersion of the polymers and additives in the extruded film. This is quite often evident when using master batches to add color to base materials.

Operating Extrusion Lines –Setting Dies and Air Rings

- Blown film extrusion dies are to a large extent of fixed shape and design, with all components being located by virtue of mechanical spigots, keys and seats. The only moving parts on any die are one of the two mandrels which form the exit annulus or die gap. (Most dies allow for the adjustment of the outer or female mandrel, although some particularly older die formats allow for the adjustment of the inner or male mandrel).
- A good reference point to start from is to loosen all the die setting bolts, and with the aid of a soft feeler or pin gauge adjust the relevant setting bolts to set the die gap to the same width around the entire circumference of the die. (Some die formats use a pull system of adjustment on the setting mandrel while others use a push system of adjustment). Always make sure that the opposing bolts to the one being adjusted are slacked off or loosened prior to attempting any adjustment.
- Once the die is properly centered, lock down the adjustment bolts to securely locate the mandrel.
- The outer mandrel should periodically be removed from the die for purposes of cleaning, particularly when continuous vertical lines (die lines) start appearing in the film.
- Die manufacturers recommend that at regular intervals of between 6 and 12 months dies should be totally stripped, cleaned and rebuilt.

- When working on dies always use soft metal scrappers and relevant cleaning utensils. Do not attempt to strip or repair a die, leave this to people who have been trained and who are technically component to do so.

- Air rings are from a gauge (thickness) consistency and control view point of paramount importance.
- For proper operation air rings, air ring blowers and heat exchangers need to be clean, with all slides, orifices and adjusting rings free and easy to operate.
- Air rings need to be exactly centered around the center point of the die, need to be machine leveled and need to deliver a consistently uniform curtain of air onto the extruded bubble. Any deviation from the above will result in variations and inconsistencies in the gauge of the extruded material
- Air rings and their associated componentry are sophisticated and sensitive bits of equipment. When working with or interacting with this technology please exercise due care.

Operating Extrusion Lines –Pulling up a bubble

- Once the job has been properly prepared for and the machine has been pre-heated and soaked to the required operating temperatures, the extruder can be started and the extrusion bubble pulled up.
- To achieve this it is necessary to web a web belt or length of film through the machine line from the top of the die, through the collapsing frame, haul off and onto the winder.
- Ensure that the bubble inflation hose is connected to the die, or that the IBC system is switched on, and that the air ring is operational.
- Wear the correct Personal Protective Equipment which should include eye protection and gloves
- Start the extruder and haul off drive. Allow some melt to push through the top of the die.
- Attach the melt onto the web belt or film described above, and start to gently pull or drive the belt or film through the machine line. (When attaching the melt onto the draw belt or film keep the attachment area as small as possible to ensure that the attachment point can pass freely through all the nip and constriction points on the machine line)
- Open the bubble inflation air or start the IBC system
- Once the attachment point has passed through the nip roller assembly of the haul off , close the nip rollers and allow the machine to pull the material through itself.
- Web the material through the winder, attach the film onto a bobbin or core and allow the winder to accumulate the material.

Operating Extrusion Lines –Setting material widths and lay flats

- Once the bubble has been pulled up and is stable the width or lay flat of the product can be set.
- This is achieved by setting up and controlling the diameter of the extruded bubble, which in turn is controlled by the amount of air inflated into the bubble through the inflation hose or IBC system.
- The lay flat or width of the material is measured after the bubble has been collapsed, and in extruded film is defined as half the circumference of the bubble, while in zip lock it is considered to be the distance from the bottom fold of the material to the bottom of the zip. This value is always specified on the Works Order.
- It may be necessary to decrease the width of the material. In hose inflated bubbles this is achieved by puncturing the material of the bubble with a series of small holes which will bleed air as they progress up the height of the bubble. In IBC operated machines this is achieved by decreasing the amount of air being pumped through the inside of the bubble.
- Some extrusion lines are fitted with automatic width control devices which will automatically inflate or deflate the bubble to achieve the desired material width.

Operating Extrusion Lines –Adjusting the Material Gauge

- The thickness or gauge of the material is controlled by the amount by which the melt is stretched between leaving the die gap and being re-frozen back into a solid. (Typically die gaps are specified in mm, while material thicknesses are specified in microns or $1/1000^{th}$ of a mm) This stretching effect is controlled by the speed of the nip roller assembly of the haul off.
- Besides the average gauge of the material having to be compliant with specifications, it is also necessary for the gauge around the profile of the lay flat to fall within required tolerances. As previously stated gauge variations are caused by poor cooling. Any marked anomaly in the gauge across an area of the lay flat can be compensated for by adjusting the die gap marginally to allow more or less melt to pass through a specific area of the die.
- Adjusting the die is a time consuming task which requires monitoring the effects of making small changes to the die gap.
- Material is considered to be thickness compliant when both the average as well as the specific points measured comply with the specification contained in the Work Order

Operating Extrusion Lines –Collapsing the bubble

- As previously described collapsing the bubble is achieved in the collapsing frame by squashing the bubble flat in one plane while allowing in to expand into the opposing one. Collapsing frames are sized to accommodate the maximum working widths of the haul off and winder.
- When setting the collapsing frame always make sure that the collapsing boards are set exactly symmetrically on opposing sided of the collapsing frame.
- In order to ensure as smooth a collapsing transition as possible always use as much of the length of the collapsing boards as practical. Allow the bubble to contact the boards about 50 to 100mm from their bottom, never allow the bubble to curl or furl around the bottom of the boards. Never open the board to the extent that the bubble necks or folds itself onto the nip or collapsing roller.
- Side boards should be set to locate the bubble at their bottom edge, and so angled to allow the bubble to fully flatten itself without being folded.
- When setting the closing pressure of the nip rollers do not over pressure or crush the material. The material is still soft in this part of the process and any marked side or gusset fold lines will be a point of weakness in the final product. Nip pressures should be adequate to draw the material and seal the expanding air within the bubble, but should not create undue deformation on any fold lines.

Operating Extrusion Lines –Setting the Winder

- Winders perform the task of collating many thousands of meters of extruded material into rolls which are subsequently unwound in other processes. Thus these devises need to perform in such a manner as to protect both the integrity of the wound material as well as the integrity of what ever it is being wound up on.
- In setting up the winding operation, the tension of the material is controlled between the haul off and the winder nip, and between winder nip and the contacting calendar or roll drive shaft. This is achieved by varying the applied torque of the various motors driving the drawing components, and manifests itself as a changing force or load on the material. (Some winders do not have an interposing or second nip station. Material tensions are then controlled between the haul off nip roller assembly and the roll drive shafts).
- Tension control in the winding operation should be such that the material does not fuse or block itself on the wound roll, collapse or compress the bobbin or core on which it is being wound, be of sufficient magnitude to prevent the material from sliding off itself when the roll is handled and should be so controlled as to provide a smooth cylindrical roll, free of creases with square sides. Ideally the tension in a roll of wound material should decrease or tapper off as the roll diameter increases.

Operating Extrusion Lines – Gussets, Zips and Aprons

- The last part of the setting operation is to fold the gussets (if required)into the material, and in zip lock to setup the zip closing station and ensure that the apron of the zip lock bag is compliant with Work Order specifications.
- Gussets are formed by reverse folding the tube of film along one or both of its side folds.
- In film manufacture gusset boards form part of the collapsing frame and side gussets are formed during the collapsing operation. These gussets are of symmetrical dimension on either side of the collapsed tube. Setting the gusset boards is subject to the same considerations as discussed previously for setting the collapsing boards.
- In zip lock extrusion a gusset is often required along the side fold of the tube opposite to the zip and apron. This is achieved by using an inner former and disc, in conjunction with a static folder. The operation is performed after the material has been collapsed and relies on a disc reverse folding the material into a slot in the former which floats inside the tube of material. The material is lead into the former by the static folder.
- The area between the male and female parts of the zip form the apron. Once the tube is folded close and the zip locked, this apron is slit and forms the open side of the zip lock bag. It also provides the purchase or grip area needed to pull the zip open. The dimensions of this apron are usually strictly toleranced and need to be closely monitored during the extrusion operation. When extruding zip lock material using dies which result in a blow up ratio greater that 1, it may be necessary to provide additional cooling to this area of the tube to prevent the apron from over forming.
- Once the geometries of the extruded material are fully compliant with the Work Order specifications, the material can be fed onto a new roll and the machine brought into production.

Operating Extrusion Lines - Measuring or setting the length of product

- In Extrusion we measure the machine performance and raw material usage as a function of mass (kg/hr and kg), but production requirements are usually specified in meters (m), the unit of measure used in all down stream processes.
- Most extrusion lines employ a pulsed sensor type length measuring system which is driven from one of the machines nip roller assemblies. This sensor communicates with a preset counter which either automatically cuts the roll when it reaches its preset length, or informs the operator that the desired roll length has been achieved.
- If the winder has no counter system, the production run can be monitored by virtue of weighing the mass of produced material or by monitoring the amount of raw materials used. The mass of raw materials or product required to complete a job can be calculated as a function of the product length.

  By definition $M = [L \times 2 \times W \times t \times \rho]$, where M is the mass of raw materials needed or product produced, L is the length of product required ,W is the width or lay flat of the produced material, t is the thickness of the material and ρ is the apparent density of the polymer. In zip lock the mass of material is calculated for the base width of the tubing, measured from the bottom of the zip to the edge fold of the material, to which is added the mass of the zip and apron per meter x the length of product required.

Operating Extrusion Lines – Manufacturing Documentation

- All extrusion operations comply with the laws of the conservation of mass, which simply state that on the completion of a job, the mass of raw materials issued must equal the mass of product produced plus the mass of scrap made.
- All extrusion material usage documentation is based on this premise. Recording of this information is computer based and forms part of the Enterprise Resource Planning (ERP) system. This information is automatically collated using an integrated scale and bar coding system.
- Other need to know information is the time taken to produce a particular order, reasons why a the production run was interrupted including the duration of these interruptions, the recording of process conditions and a cross check of the total amounts of raw materials used and production made.
- Several paper based recording systems are currently used in the company to record the above information.
- Most of these will be phased out once the accuracy and repeatability of the ERP system is proven.

Operating Extrusion Lines – QC Requirements

- Operators carry the prime responsibility for ensuring product compliance.
- Two quality compliance systems exist within the company, the first requires that all new jobs and jobs that have been interrupted need to be signed into production jointly by the production department involved and by the quality department. The second system requires that all production needs to be quality checked by the operator, who in turn will be checked by a quality representative.
- The quality checks and requirements you are responsible for will be communicated to you, by job, in the Work Order specifications
- If at any point in time you cannot set the machine up to comply with the quality requirements or Work Order specifications, please notify your supervisor immediately.
- It is preferable to rather make no production than to produce materials which will ultimately have to be scrapped.