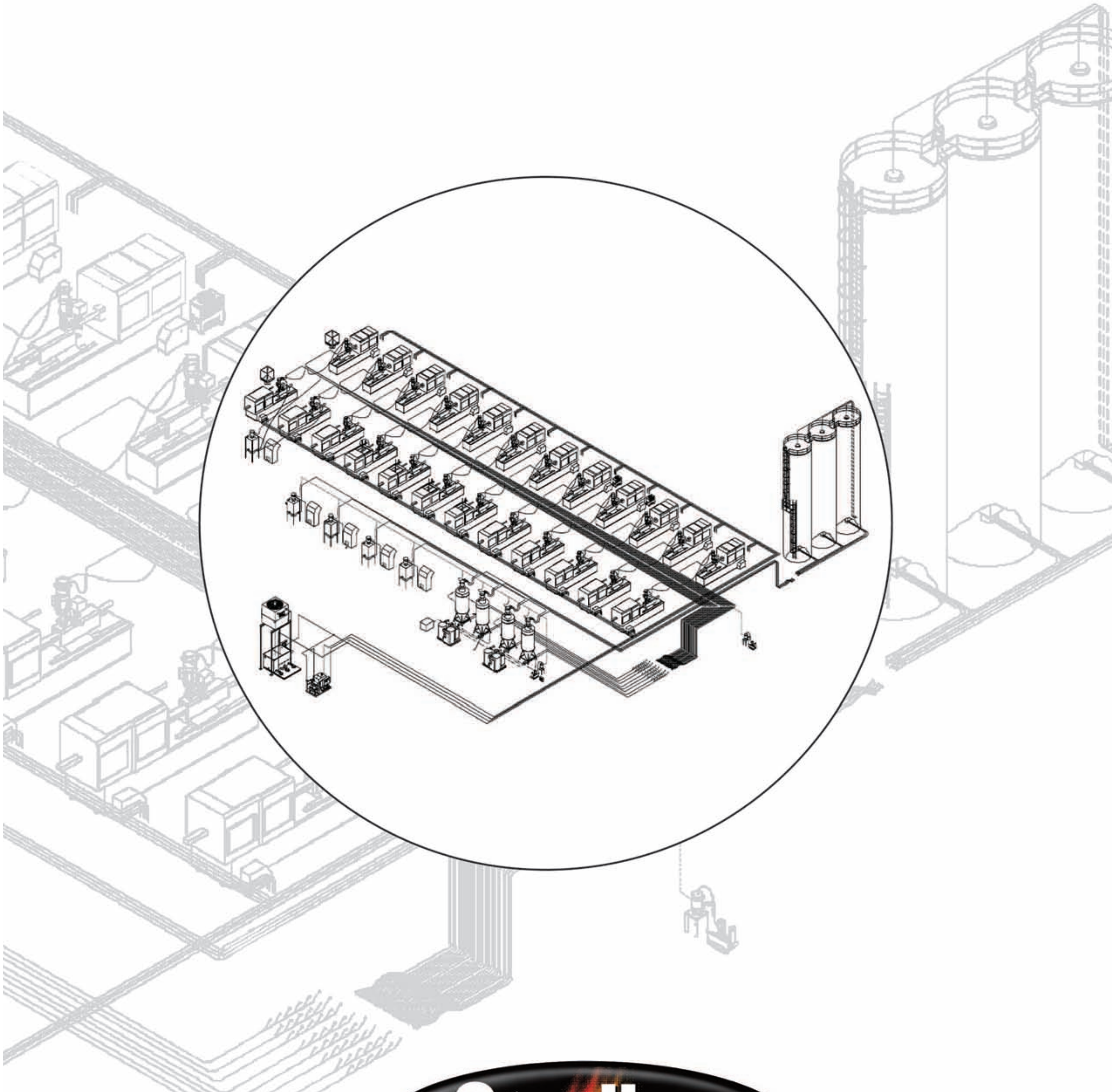

COMPLETE AUXILIARY INTEGRATION

Understanding Equipment and Systems

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Published by: Sterling, Inc.

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TRENDS IN AUXILIARY EQUIPMENT

Auxiliary Equipment is a broad topic that touches all types of processes. It plays a more important role in the overall production process than ever before. There has been much advancement in tooling, screw design, and molding machines over the past 10 years, resulting in greatly improved productivity. Today, those processors with newer machines (post-1990) have fine-tuned their machines and matched screw designs to the resin being processed. These processors are now looking at auxiliary support equipment as a critical part of optimizing operations-and, most importantly, of increasing profit margins. These leading molders are finding that matching and integrating the right auxiliaries to the process provides a good return for each dollar invested. *(See Figure 1: Complete Auxiliary Integration)*

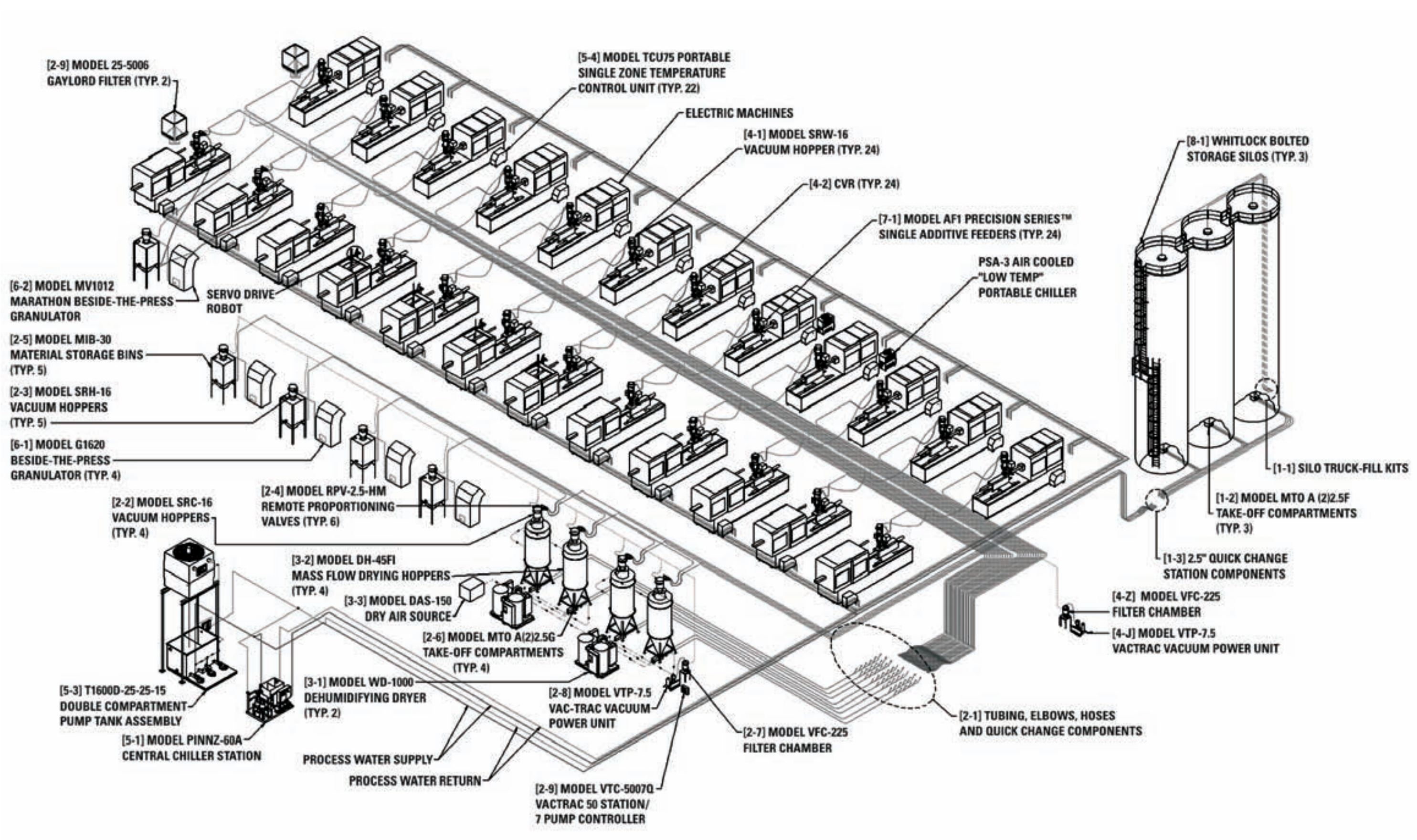

FIG.1

Today's leading processors are looking at networking and Supervisory Control and Data Acquisition (SCADA) Software for managing their process-and demonstrating control over the process to their customers. They are taking a new look at how to get material into the facility, how to monitor inventory, how to store it, how to prepare it for processing, and how to cool and control temperature in the process. They are examining post-production removal of finished product, how to handle sprues and runners, how to grind, where to grind and how to handle regrind. They are also discovering ways to be creative using auxiliary equipment.

Fig. 2

Trends in Conveying Equipment

The basic hopper loader and vacuum pumps that are the heart of most in-plant conveying systems remain in large part unchanged. Improvements in motor technology include quieter pumps, more energy efficient-motors and a trend toward providing components that are more interchangeable,easier to clean out, and maintenance free. Some suppliers offer a modular loader that can be upgraded or converted to a vacuum receiver as part of a central conveying system. Most suppliers have moved to a standard offering that allows reuse of the hopper bodies.

Another trend is certainly in the direction of smaller hopper sizes and maintaining less inventory at the machine. This results in less waste between jobs and operating shifts and reduces setup time. It also puts pressure on equipment suppliers to build in reliability-and minimize downtime. Technology and experience have led to significant improvements in designing the right conveying system for the application. Suppliers are now able to take detailed information about the physical properties of resin materials, combined with the vertical/horizontal/bend (piping) travel distances. With this information suppliers are able to design conveying solutions that minimize degradation of your resin. *(See Figure 2: Vacuum Receiver)*

Less Waste + Fewer Fines Generated = Improved Operation.

Fig. 3

Trends in Blending

Blender use has become widespread as the trend toward blending color, other ingredients,and regrind back into process continues. Extruders were the first to adopt the use of blenderson a widespread basis, and have led the evolution from volumetric blenders to gravimetric blenders. Due to varying bulk density ingredients it became very important to control weight per unit volume and then match that to machine throughput.

In the '90s a combination of more varied jobs, shorter runs, greater focus on material cost (especially colorant), and interest in reduced inventories all contributed to the"blending-in-house" trend.

Additive feeders are still important as a first step, and provide a cost-effective improvement over manual mixing.For many years volumetric blending was popular. Today, the most popular blenders sold are various types of gravimetric blenders. Gravimetric blenders now offer accuracy, consistency and materials management-forexample, inventory records, SPC data, and job cost tracking. This greater accuracy produces less resin andadditive waste and therefore more profit. Better accuracy also results in better part quality and consistency. *(See Figure 3: Batch Gravimetric Blender)*

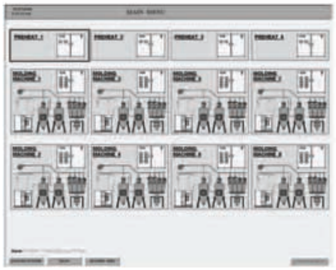

Fig. 4

Incremental mechanical and control developments in blending equipment continue.Several suppliers have introduced new super-compact microblenders. Other developments include more accurate load cells, better-designed mixing chambers, improved slidegates featuring easier cleanout, and different shapes, as well as improved process measurements and reporting. SCADA packages allow "Supervisory Control" of recipes to be done via the PC. That means you can check the recipe, change the recipe, and monitor other data from the blender. *(See Figure 4: Scada Control Package)*

Trends in Drying

Fundamental drying technology and methods have changed little. Suppliers and processors have focused their efforts on more sophisticated control and process monitoring and applying the right drying system to the application.
(See Figure 5: Central Dryer)

Fig. 5

Load-based, variable-throughput drying is becoming popular for processors with large throughputs. The constantly changing technology price curve will begin to make this viable for lower throughputs in the future. The control uses load cells to manage the volume of material in the hopper. Based on throughput and volume, the control varies airflow using variable speed drives on the blowers.

Fig. 6

Gas drying is an older trend that has not received as much focus lately. Gas can be more cost-effective in some parts of the US, Canada, and in some other countries.However, electric utility deregulation is beginning to make gas less attractive as an alternative.

Drying really happens in the drying hopper. A drying hopper with good mass flow properties allows resin residence time to be consistent for all material passing through the hopper. The steady distribution of hot, dry air within the hopper is just as important as the even flow of resin through the hopper. Many dryer manufacturers have improved their designs to assure even distribution of the air through the resin in the drying hopper. (See Figure 6: Mass Flow Drying Hopper)

Trends in Auxiliary Controls

Bridging all the developments in processing machinery and auxiliary equipment is a revolution in controls. New control technology allows us to use our machinery more efficiently and makes it easier to operate. Machines can now be networked and basic process information collected when it could never be captured before.Additional control trends include:

Additional control trends include:

- More powerful controls in smaller packages'
- A decreased use of proprietary controls with an increased use of off-the-shelf controls
- A "distributed" control approach
- More user-friendly control interfaces sometimes referred to as MMI's (Man Machine Interface)
- An "open architecture" approach for networking
- PLC's being replaced by PC's which are already being replaced by Hybrid PLC/PC's and SCADA (Supervisory Control and Data Acquisition) capabilities

Fig. 7

CONTROLS

First there were simple dials to control temperature. You would set the temperature of your dryer or temperature control unit for 200 F-but you really didn't know if it was 200 F or 210 F or 180 F. Today you have fuzzy logic and PID temperature control modules using elaborate math calculations to control the response to a closed loop measurement of actual temperature. Plus, today's control costs less than the dials and relay logic control of 15 years ago. Today's controls are using technology that cost hundreds of thousands of dollars when first developed in association with our Space Program! (See Figure 7: Fuzzy Logic Controller). Advancements in control technology play a role across all auxiliary and primary equipment. Leading processors are employing computer-integrated manufacturing technology to link auxiliary systems with their primary process, with other auxiliaries, and with their business systems.

Fig. 8

Many years ago, industrial machinery used "proprietary controls" exclusively. As recently as five years ago, proprietary controls were still considered more feature-rich, especially for the specialized industrial machinery used in the plastics industry. However, with recent developments in hardware and software allowing for more flexible features and input/output capacities, it is now increasingly evident that specialized industrial machinery is moving toward "off-the-shelf" controls. The large controls companies have taken a new approach with controls industry integrators and made their architecture "open." This is resulting in the broad development of flexible, feature-rich control options with global supply and support, assured replacement-part supply, long warranties, and common look and feel that "off-the-shelf" controls have always offered. (See Figure 8: Off-the-shelf Controller)

Major developments in controls can be broken down into the categories of hardware and software. Within both the hardware and software segments we have aggressive competition of technologies and approaches occurring. Unlike the PC operating world, where Microsoft is winning, there is no single operating system or approach. There is instead a larger focus on plug-in cross-compatibility. Interrelated with the trend toward plug-in cross-compatibility is a trend toward "distributed" control solutions. A distributed control approach results in more stand-alone equipment or devices that are network ready for one or more types of networking. These devices or stand alone pieces of equipment also can be upgraded to incorporate a new generation of standard off-the-shelf interfaces, which are variations of touch screens or touch panels. They are controlled by software, making it easy to adapt to the specialized requirements of the plastics industry-or even to certain types of processors within the plastics industry. They also more easily accommodate alternate languages and units of measure (e.g., metric). These new devices and interfaces are most often being used in SCADA environments. (See Figure9: Touch-screen Control and Figure 10: Distributed I/O Conveying Control)

Fig. 9

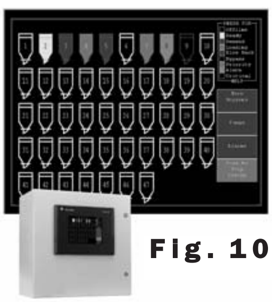

Fig. 10

Fig. 11

Programmable logic controllers have been used to control timing and sequencing in modern injection molding machines. Some industrial machinery has moved from being PLC-controlled to the PC. These are not the type of PC's you might be used to seeing in the office or your home. These are industrially hardened electronics that use the hardware and chip architecture of a PC, and the software of a PC. Often they are "rack" mounted with a touchscreen monitor or conventional keyboard.(See Figure 11: Teach-programmable Pendant Controller)

Sensors

RTD's, or resistance temperature detectors, contain sensor elements made from high-purity wire. Temperature controllers receive a digital signal from the sensor, compare this signal with the setpoint temperature, and then generate an output to the heater or cooler to return the temperature to the desired level. Digital signals are converted to a number and mathematically manipulated to produce the output signal. A pressure sensor machined into the mold can be used to monitor the time it takes to fill the mold cavity and use that information to reduce boost time and total cycle time.SensorsRTD's, or resistance temperature detectors, contain sensor elements made from high-purity wire. Temperature controllers receive a digital signal from the sensor, compare this signal with the setpoint temperature, and then generate an output to the heater or cooler to return the temperature to the desired level. Digital signals are converted to a number and mathematically manipulated to produce the output signal. A pressure sensor machined into the mold can be used to monitor the time it takes to fill the mold cavity and use that information to reduce boost time and total cycle time.

CONVEYING

Before the processing of resin can begin, materials must be conveyed to the processing equipment. This is accomplished by either hand filling the machine hopper, or with the use of beside-the-press loaders or central loading systems that use vacuum pumps (or venturis) to move the resin into the hoppers. Material characteristics determine the type of equipment needed to properly convey the material.

Railcar Unloading

Bulk materials received by truck or railcar are stored in silos, usually outside the plant, eliminating the need for warehouse space for raw material storage. While trucks are self-unloading, bulk railcars require a method of transferring the materials from the railcar compartments into the silo storage. A vacuum/pressure system facilitates conveying over long distances or at high transfer rates. Railcar unloading systems are sized based on the layout of the piping system and the material transfer rate that is required. The higher the transfer rate, the larger the equipment and piping will be. Vacuum unloading pumps that transfer materials directly from the railcar into a vacuum receiver on top of the silo are another method of unloading a railcar. These systems require manual switching of the material and vacuum lines to direct the material flow to several different silos (filling one at a time). (*See Figure 12: Railcar Unloading)*

An important addition to the equipment features now available are vacuum unloading systems which weigh and record what is unloaded, giving the receiver an instant check on what was shipped and a printed, computermonitored inventory figure. The vacuum hopper is mounted on, or suspended from, a weigh beam wired to computer controls and recorders. Central Vacuum Conveying Systems Central vacuum conveying systems create vacuum for conveying pelletized or granular material in a central material handling system. A typical use is as an in-plant distribution system for plastic processing plants. One central vacuum pump can provide the loading power for a number of loading stations. These systems are as varied as the applications that they service. Tubing and equipment in a typical system convey the material(s) at specified rates and distances. Most manufacturers can advise customers on system capabilities based on system makeup, distance, material, and conveying rate requirements.

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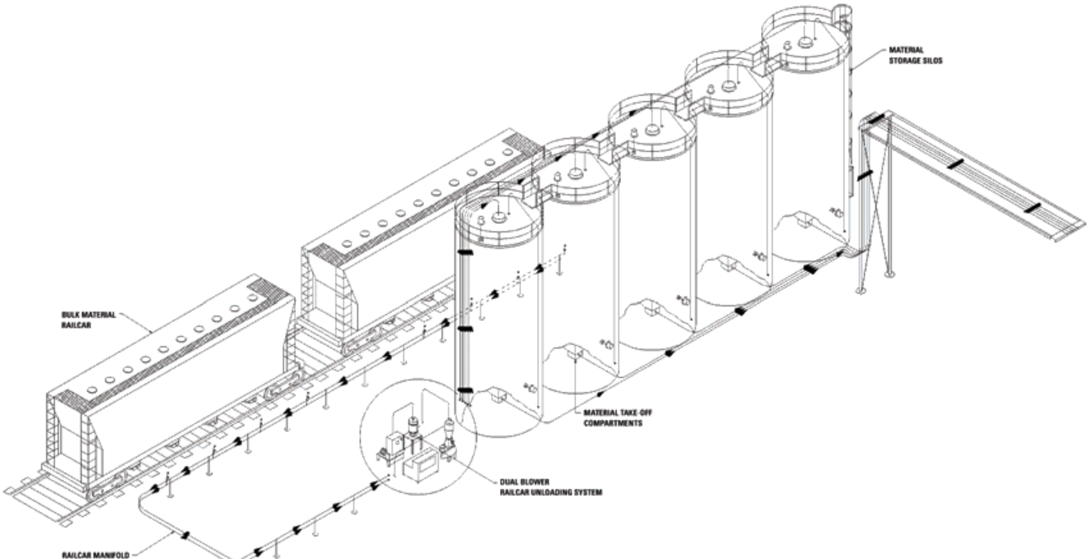


Fig. 12

Central Vacuum Conveying Systems

Central vacuum conveying systems create vacuum for conveying pelletized or granular material in a central material handling system. A typical use is as an in-plant distribution system for plastic processing plants. One central vacuum pump can provide the loading power for a number of loading stations.These systems are as varied as the applications that they service. Tubing and equipment in a typical system convey the material(s) at specified rates and distances. Most manufacturers can advise customers on system capabilities based on system makeup, distance, material, and conveying rate requirements.

A weigh loading vacuum system can deliver preset amounts of material into processing hoppers. The weight of each hopper-loader can be recorded and reorder levels signaled automatically. This way every pound of material flowing through the plant can be accounted for. The design of any material handling system focuses on the customer's performance expectations and the amount of money that is available to invest in the system.

A typical central vacuum conveying system contains the following components:

- Vacuum hopper (s)
- Sequence or atmospheric values
- Material pickup tubes/wands
- Vacuum pump
- Sequencing controller
- Vacuum and material tubing
- Filter chamber
- Material take-off compartments

Time-fill vs. Volume-fill Systems

A time-fill system conveys material to an on-line vacuum hopper for a pre-set time period. When this interval elapses, the controller conveys material to the next on-line vacuum hopper.

A volume-fill system conveys material to an on-line vacuum hopper until the material level activates the proximity switch in the vacuum hopper, or a preset time elapses. When either of these conditions occurs, the controller conveys material to the next on-line vacuum hopper. This is a more efficient and energy-saving method for central conveying systems.

Basic Operation

When the operator activates the controller, the system energizes and initiates the conveying cycle. The following components energize:

- The vacuum pump motor starter.
- The vacuum pump vent valve.
- The atmospheric valve above the first on-line vacuum hopper that requires material.

The vacuum pump draws vacuum to the first hopper. When that hopper is full or the time interval elapses, the controller then signals the atmospheric valve above the next on-line hopper requiring material to energize,allowing material to convey to that hopper. The conveying sequence continues to the last on-line vacuum hopper requiring material. *(See Figure 13: Central Vacuum Conveying Systems)*

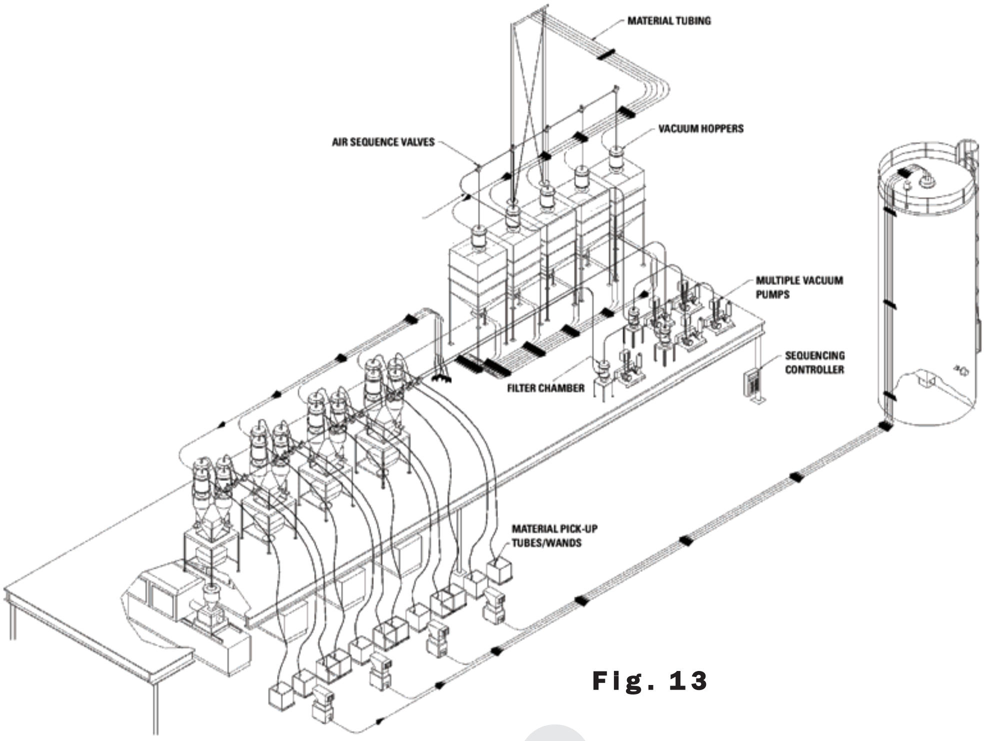


Fig. 13

When the time interval for the last hopper elapses, or the hopper is full, a new conveying cycle begins at the first onlinevacuum hopper requiring material. The cycle continues until all the material demand is satisfied in the system.

Pressure drops in the overall system can directly affect system capacity, such as number of material line bends, footage of pipe, Y-tubes, T-tubes, etc. **For maximum efficiency, plant operators should be concerned with reducing distance and using minimal lengths of flexible hose and bends on material lines, as well as keeping material lines as straight as possible.**

One important note: The occurrence of vacuum leaks anywhere in a central vacuum conveying system reduces conveying capacity.

Loaders Beside-The-Press

Many processing machines are still loaded by beside-the-press vacuum loaders that lift materials from bags, drums and boxes placed in the processing area. Machine hopper loaders are economical and efficient conveyers of free flowing pelletized or granular materials from supply containers into machine bins or other receivers. Some models feature a modular, component design resulting in significant operational advantages, while other designs may use stainless steel construction. Engineered construction permits easier cleaning and maintenance, and such devices can be quickly and easily reconfigured to accommodate future production requirements. Simple electrical and compressed-air connections are all that are needed for operation; central vacuum systems are not necessary. Some hopper loaders use an integral-mount motor with a quick-disconnect plug power cord. Other types feature a high-flow blowback valve to enhance filter cleaning, providing excellent filtration of conveying air. Some types of machine side loaders employ compressed air venturis to transport resin into the hopper.


Fig. 14

Fig. 15

Sight glass-style hopper loaders have the features of standard hopper loaders, but add a sight glass for easy monitoring of material load/discharge cycles. A typical sight glass assembly uses an adjustable proximity sensor to ensure full material discharge on each cycle. Operators can customize system operation by adjusting operating parameters with the unit controller. *(See Figure 14: Hopper Loader)*

The ratio or proportional loading function allows two feed lines to be directed to one vacuum hopper. Internal or external valving arrangements, divert vacuum power to one line at a time, providing a controlled mix of materials. This is an ideal method for returning regrind to the processing hopper in non-critical applications. *(See Figure 15 - Remote Proportioning Valve)*

Filtering

An often overlooked aspect of processing is the filtering technology built into the method of conveying. Technological developments in filtering media and methods provide more filtering choices, better efficiency, improved ability to handleregrind and easier maintenance.

More filtering choices allow you to match filtering requirements to your resin and process for greater efficiency. For example, if you are working with pelletized material, you would most likely use a stainless steel mesh screen with 10 to 16 mesh designed to keep pellets in the receiver or hopper, yet allow fines to pass and be removed by a central filter collector. For granular or powder materials, you would select a cartridge or bag filter to capture material in the process. The nature of these new filtering materials is such that they have better "release" properties, resulting in decreased pressure drop and less frequent maintenance and cleaning.

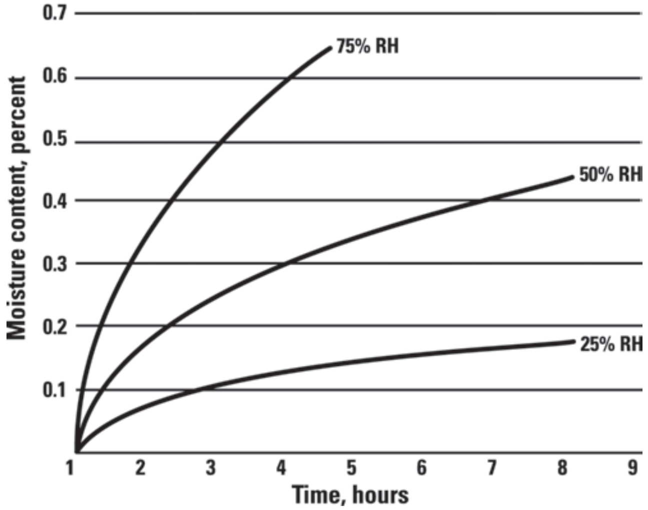
Technological improvements have also led to filterless receivers. Key to these models is efficient design of the hopper body: the higher the efficiency, the less pass-through of material to the central filter chamber. In some cases the central filter is screening more than ever, due to the high efficiency of the filtering system inside the vacuum receiver.

Dry Air Conveying

A point that has been debated among suppliers is the appropriate use and benefits of conveying with dry air. Processors of hygroscopic resins like ABS, PET, PBT, nylon, and most engineering resins must dry the material before processing. Some will recommend dry-air conveying whenever a material handling system is installed. However, another view is that the decision to convey with dry air depends on your process and is only necessary in limited situations. The only real justification is to prevent material from absorbing moisture from the conveying air. However, just as it takes hours to dry materials, it can typically take at least an hour or more for material to reabsorb moisture from the air. Since material moves at approximately 3,000 ft/min in the conveying lines, it only takes a few seconds to transfer material from the remote drying hopper to a machine's vacuum receiver-not enough time for most materials to regain moisture.

There are also other strategies to ensure that material stays dry after conveying.

- Use a portable quick-change dryer-some have an integrated pump-to dry the material on the processing machine after it has been conveyed.
- Purge material from the conveying line with dry or ambient air to reduce the amount of material sitting in conveying lines between loading cycles.
- Keep the material hot after conveying.
- Keep minimal inventory of material on the processing machine.



This diagram shows the moisture pick up on initially dry nylon 6/6 at room temperature while exposed for up to 4 hours at 75% relative humidity, and up to 8 hours at 25% and 50% relative humidity.

In damp weather (relative humidity of 75%) the moisture level of the nylon 6/6 will rise by 0.35% in 1 hour. This additional moisture by itself is enough to cause part brittleness, irrespective of how little moisture was present in the nylon originally.

On the other hand, when it is very cold and dry outside and the relative humidity inside the plant is 25% or less, the time required to pick up 0.35% moisture would be about 40 hours.

Fig. 16

DRYING SYSTEMS

Dryers are designed to generate heated air at carefully controlled temperatures for drying plastic pellets and regrind in the manufacture of high-quality plastic products. Many variables are considered in the selection of a drying system,including type of materials, residence time, throughput of the injection molding machine, ambient air moisture and temperature, and the altitude at the processing site.

Desiccant vs. Hot-air Dryers

The choice of a desiccant, or dehumidifying dryer rather than a hot-air dryer, is based on the resin being processed. Hot-air dryers are mostly used for non-hygroscopic (non-moisture-absorbing) materials such as polypropylene, polyethylene, and polystyrene. For these plastics, only surface moisture removal is necessary. Because the resin does not absorb moisture, only residual moisture which sits on the surface of the resin must be removed. Hot-air dryers blow heated ambient air over the surface of the pellets or granules to evaporate the moisture condensation and carry it out of the hopper. If the process or end product can tolerate some moisture, non-hygroscopic materials may not need to be dried prior to processing.

Hygroscopic plastics like ABS, PET, PBT, nylon and most engineering resins absorb moisture within the pellets or granules. Heating hygroscopic resins to processing temperatures with the moisture still inside the resin can destroy the polymer-or lead to bubbles and splay in the molded part. The very low-dewpoint air generated by the dehumidifying dryer acts as a sponge to remove this moisture more quickly and effectively than hot ambient air. *(See Figure 17: Dehumidifying Dryer)*

While a desiccant dryer may be safely used to dry both hygroscopic and non-hygroscopic materials, a hot-air dryer is likely to use less energy than a dehumidifying dryer and to cost much less to purchasefor the same air-flow capacity, making it more cost-effective for drying non-hygroscopic materials.

Fig. 17

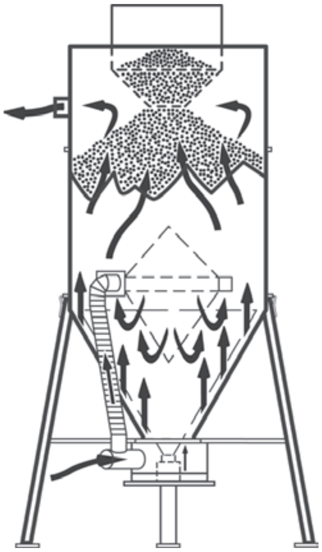


Fig. 18

The Desiccant Process/Regeneration Cycle

A chemical desiccant is used to dry air to a low dewpoint level, typically between -20ºF and -40ºF, to maintain a low moisture level under all climatic conditions. Dry, heated air enters the drying hopper at the bottom, where it is distributed through a perforated conical device, which is surrounded by the material to be dried. As the material is heated, the dry air drives out the moisture and carries it away. The moisture laden air is passed through the desiccant bed where the moisture in the air is removed. The dry air is then reheated and reintroduced through the drying hopper where the cycle repeats. *(See Figure 18: Air-Flow Cycle)*

When a desiccant bed is on-line, it absorbs moisture from the process air. In time, the bed becomes saturated with moisture and needs to be regenerated. Most dehumidifying dryers have two desiccant beds. While one bed is on-line in the process air loop, the other is offline, being regenerated. The dryer automatically redirects the process airflow to the second bed, and starts the regeneration cycle on the first bed. Also popular are carousel-type dryers that feature more than two desiccant beds or a continuous desiccant-treated wheel or disk that rotates between being heated and absorbing moisture from process air. In a semi-open system about 10% of the air is vented and a proportional amount of fresh air is added. During regeneration, the dryer system heats air and forces it through the desiccant bed. The moisture driven off the bed bleeds to the atmosphere. If you measure the temperature of the air bled to the atmosphere (bleed temperature), you should observe a rise after a period of time. This condition, called bed breakthrough, indicates that the bed is dry. At bed breakthrough, the bleed air temperature peaks anywhere between 175ºF and 400°F (79ºC and 204ºC), depending on initial moisture content in the regenerating bed and the dryer model used. In a closed system the desiccant is dried separately from the drying process using hot fresh air. No outside air is taken into the drying system.

Most drying equipment manufacturers are now offering a choice of desiccant types. This is an issue that primarily affects PET processors. A more expensive, premium desiccant type called 13x has proven to be very effective for PET processors. Desiccant type 13x has larger pore openings and increased surface area for drying applications. Pound for pound, 13x desiccant will adsorb more moisture and more water by weight than 4a, making 13x the almost universal choice now for PET drying. Type 13x's ability to adsorb Acetaldehyde, AA, which produces the bitter "plastic" aftertaste in bottles, is considered another benefit of using this desiccant.

Dryer Configurations

There are three basic dryer configurations from which to choose: machine-mounted, portable cart-mounted, and central drying systems.

Central Dryers

When large quantities of similar materials are processed in multiple machines, central drying systems may be the most economical alternative to install and operate. Since they can be installed away from the central production area, they can also conserve limited floor space.

There are three different central drying configurations. One consists of a centrally located dryer and drying hopper that convey material to several processing machines. This type is ideal for long process runs when all machines are running a single material. A second version is appropriate for processing several different types of materials. Its centrally located, high-capacity dryer provides dehumidified air to multiple machines with individual machine-mounted drying hoppers. A third configuration consists of a central drying station that delivers dehumidified air to individual drying hoppers mounted on a common stand in a central location. This allows a variety of materials to be predried simultaneously and then conveyed to multiple process machines. *(See Figure 19: Central Dryer Configurations)*

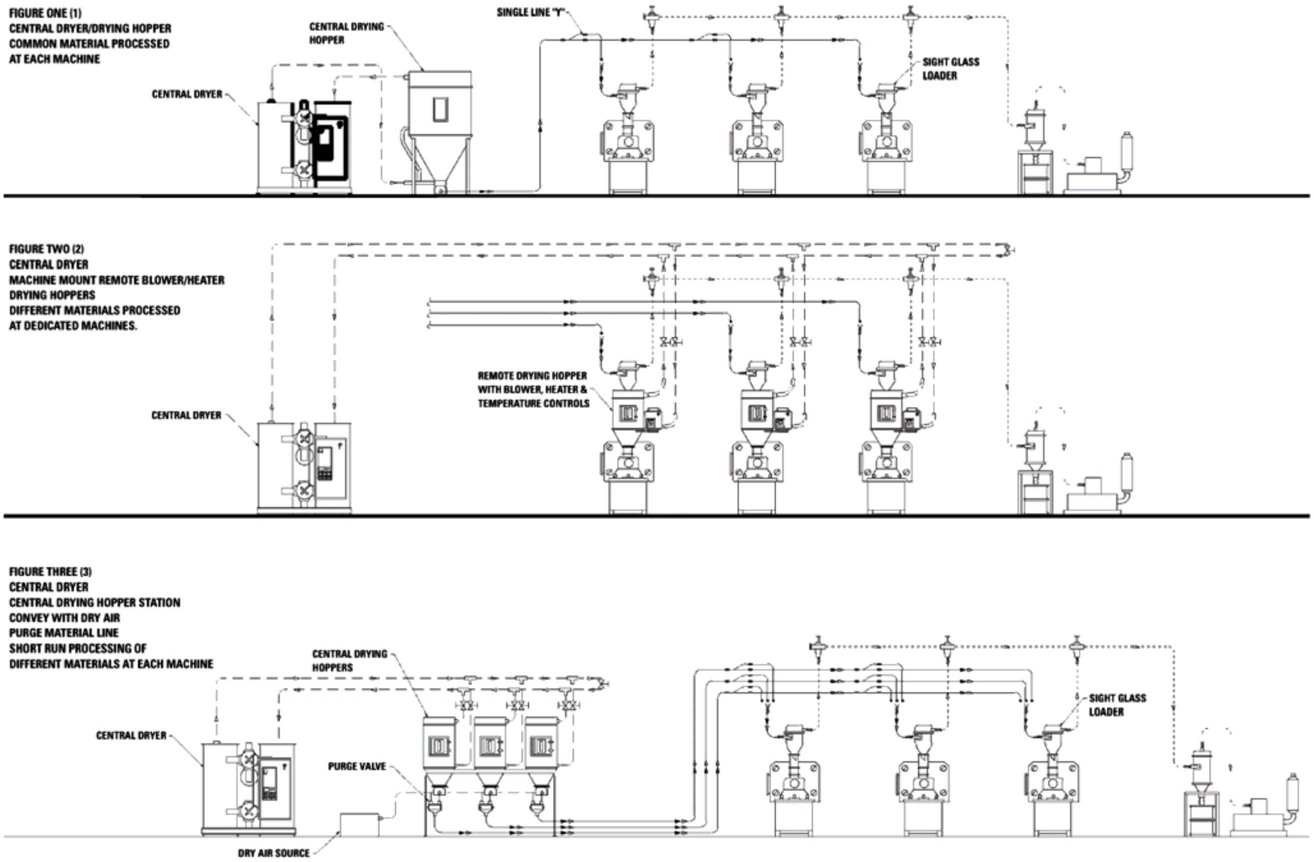


Fig. 19

Machine Mount Dryers

Machine-mounted dryers come in two configurations. The dryer and dryer hopper are both mounted directly on the machine in one configuration. In the other, the drying hopper is mounted on the machine and the dryer stands on the floor next to it. With large process machinery the dryer may be located on a mezzanine above it. *(See Figure 20: Machine-mount Dryer)* Machine mounting has certain limitations. The possible instability caused by rapid cycling and vibration of the molding press may prevent the machine mounting of larger dryers. Also, servicing machine-mounted dryers can cause additional machine downtime and safety concerns for the service workers.


Fig. 20


Fig. 21

Portable Dryers

Portable dryers, which put the dryer and drying hopper on a wheeled cart, have become the most popular dryer configuration because of their flexibility and mobility. They may be used to pre-dry material away from the processing machine or be moved from location to location to serve multiple process machines. They also they lend themselves to off-line servicing and cleanup.*(See Figure 21: Portable Dryer)*

Sizing a Dryer and Hopper

The optimum dryer size is a function of the machine's production rate, or how many pounds of material are used in one hour. The two most important parameters to consider in sizing a dryer are dehumidified air flow (cubic ft/min or cfm) and process-air temperature. However, cost, anticipated future needs, and the types of materials being processed are also important considerations. The rule of thumb for air flow is to use 1 cfm of air per pound of material being processed in one hour. Although some sources use a range of values from 0.5 to 1 cfm/lb/hr, 1 cfm is a conservative number that will allow for future versatility of the equipment with different resins. Once you have determined the required cfm, specify the next largest standard size dryer. To avoid undersizing the dryer, check the air flow specifications: dryer model number designations don't always reflect their true cfm rating. Required drying temperatures are typically specified by the materials supplier. Most dryer manufacturers offer standard and high-temperature options on their equipment. Generally, standard temperature ranges are 150ºF - 300ºF, while high-temperature models offer 150ºF - 400ºF.

Hopper size is a function of the machine's production rate, material residence time, and material bulk density. Recommended residence time at a specified drying temperature is found on the material supplier's data sheets. Most non-hygroscopic materials have a minimum residence time of 1.5 hr. Some hygroscopic materials take longer than others to release moisture and thus require more time in the drying hopper. Material bulk density, measured in weight per cubic foot, is the other key parameter when sizing a drying hopper. A critical consideration is whether regrind will be dried together with virgin material. The bulk density of virgin material is generally higher than for regrind of that same material, so you may need a larger hopper if regrind is to be used. Most equipment suppliers state drying-hopper capacity specifications in cubic feet.

Hopper size can be determined with this formula:

[Production rate (pounds / hour) ? Bulk density (pounds / cubic foot)] x (residence time required in drying hopper) = drying-hopper size (cubic feet) required to use for the process

As with the dryer, specify the next larger standard size hopper to avoid undersizing.

Dryer Features and Options

After-cooler: Mounted in the return line between the drying hopper and the dryer, an after-cooler reduces return-air temperature, enhancing the efficiency of the desiccant beds in dehumidifying dryers. Return-air temperatures entering the dryer beds should be at or below 150 F to allow the air to release its moisture more efficiently. This option is recommended when drying at temperatures greater than 250 F and is required at 300 F and above.

Pre-cooler: Mounted in the air delivery line between the drying hopper and the dryer, a pre-cooler requires a thermocouple at the inlet to the drying hopper to control the temperature to process. This option is recommended to achieve temperatures below 180 F and is required for drying at 160 F or below.

Insulated process-air hose: This option minimizes heat loss between a floor-mounted dryer and a machine mounted drying hopper.

Dewpoint monitor: This feature will monitor and provide an indication of air dewpoint prior to entering the drying hopper. This circuit can also be used to control regeneration cycles on a dryer, conserving energy and ensuring optimum regeneration cycle to maintain a process dewpoint setpoint.

Redundant high-temperature safety: A back-up temperature control system shuts down delivery of process air to the hopper if the temperature rises uncontrolled. This minimizes the chances of having melted resin inside the drying hopper due to runaway temperature controls.

Closed-loop regeneration: Closed-loop regeneration saves energy by accelerating the regeneration process while maximizing the desiccant bed's moisture-holding capacity and extending the time it can stay on-line. *(See Figure 22: After-cooler and Pre-cooler)*

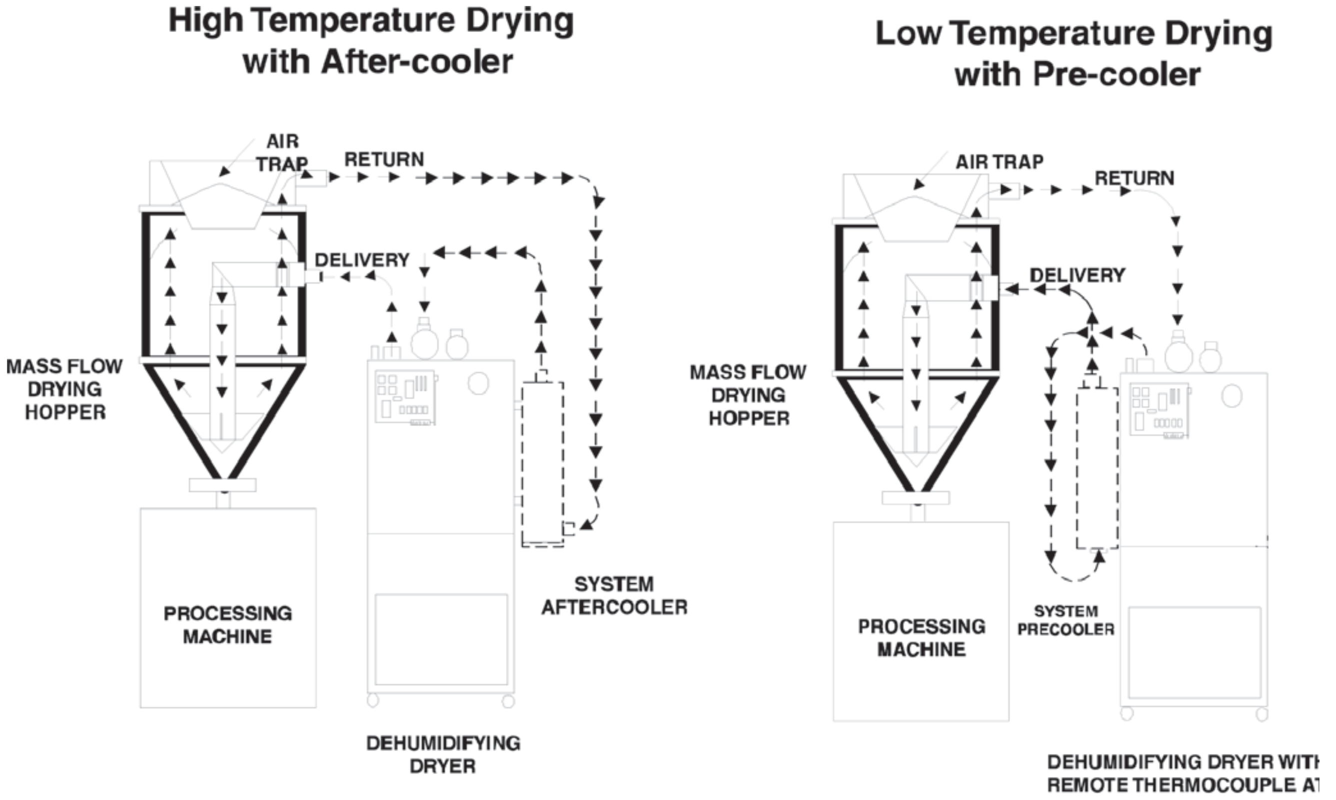


Fig. 22

BLENDERS AND ADDITIVE FEEDERS

The first blenders arrived on the scene in the '60s, so blending itself is not a new development. However, their use has become more widespread as the trend toward blending color, other ingredients, and regrind back into processcontinues. Extruders were the first to adopt the use of blenders on a widespread basis. They also evolved from volumetric blenders to gravimetric blenders earlier as well. Due to varying bulk density of ingredients, it became very important to control weight per unit volume while matching that to machine throughput. In the '90s a combination of more varied jobs, shorter runs, greater focus on material cost, especially colorant, plus interest in reduced inventories contributed to the "blending-in-house" trend. There are two types of blending systems: volumetric systems which meter ingredients by volume, and gravimetric systems which meter ingredients by weight. For many years volumetric blending was popular. Today, the most popular blenders sold are various types of gravimetric blenders.

Gravimetric Blending

Gravimetric feeders and blenders are used in compounding and primary processing operations. They accurately proportion resin and additives by weight, according to a recipe. Volumetric lenders fail to take into account the bulk density variations in materials. Gravimetric blending offers improved blend accuracy and homogeneity, reduced scrap/regrind and quicker start-ups. This greater accuracy produces less resin and additive waste and results in better part quality and consistency. Gravimetric equipment also makes available weight-based material-use data or accurate inventory control and job cost tracking. *(See Figure 23: Batch Gravimetric Blender)*

Fig. 23

Sizing and Selection Guidelines

Blender components include a weigh hopper, slide gate, auger and mixing sections. A slide gate offers adjustable metering for dispensing free flowing materials at varying rates of speed. An auger provides precision metering of small-percentage ingredients and is used for non-free flowing materials. Batch vs. Continuous Weigh Batch weigh blenders are commonly being used for injection molding applications. Continuous weigh blenders (sometimes called loss-in-weight) are used in high-throughput extrusion processes. Batch weigh blenders meter ingredients one at a time into a single common weigh hopper, whereas continuous blenders meter ingredients simultaneously. Batch weigh blending will complement most injection molding process applications and provide real process data that can be evaluated and used to maximize job profits. In most cases, weighed batch interval equipment allows for higher blending output rates when needed. *(See Figure 24: Continuous Gravimetric Blender)*

Fig. 24

Additive Feeders

Additive feeders are still important as a low-cost method of introducing additive into the injection molding process. They provide a cost-effective improvement over manual mixing. *(See Figure 25: Additive Feeder)*

Fig. 25

Fig. 26

Incremental mechanical and control developments continue in blending equipment. While several suppliers have introduced new super-compact microblenders, more accurate load cells, better-designed mixing chambers, improved slidegates featuring easier cleanout, and different metering devices are now available. Improved process measurements, reporting, and controls, such as SCADA packages (Supervisory Control and Data Acquisition) are also available. "Supervisory Control" of recipes via the PC means you can check the recipe, change the recipe, and monitor other data from the blender remotely. This ability makes it possible to eliminate paperwork on the floor and allow processors to introduce more consistency in the process through programmed recipe input. It will also allow faster, more reliable set-up (by using stored recipes) for different parts processed. *(See Figure 26: Co-extrusion Control System)*

PROCESS HEATING AND COOLING

Heat transfer is a basic element of plastics processing. Materials must be heated during processing. Molded parts must be cooled to be converted from a liquid to a solid state. Additional heat generated by hydraulic machinery and other process operations must also be dissipated. Temperature control units can be used for both heating and cooling. A temperature control unit accomplishes "controlled" cooling to an elevated setpoint. Chillers and cooling towers are used exclusively for cooling. *(See Figure 27: Temperature Control)*

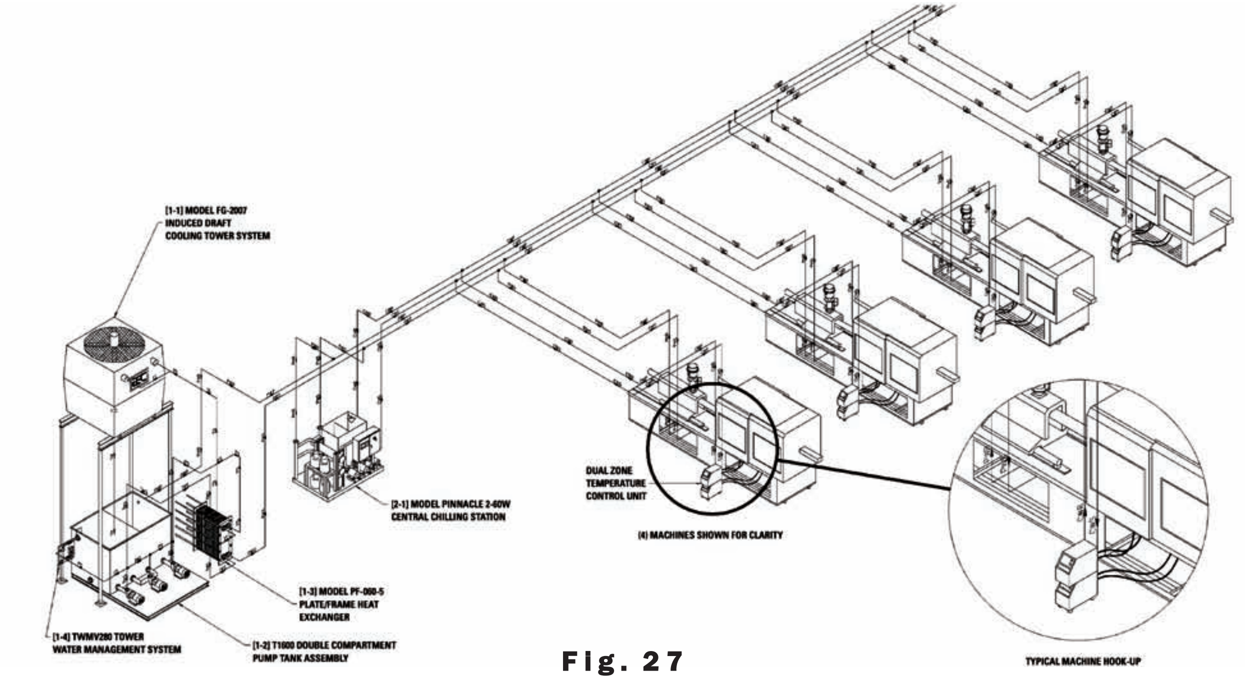


Fig. 27

Cooling Equipment Sizing and Selection

Four factors determine cooling equipment sizing and selection: the starting temperature of the material, its finish temperature, the rate at which the plastic is processed, and the physical characteristic of the material (specific heat). This can be expressed in the following equation:

(Starting temperature - Final temperature) x (Processing rate) x (Specific heat) x (Safety factor) = Heat transfer rate

Example:

Material: Polystyrene
Final Temperature in mold: 125° F
Specific Heat of Polystyrene: 0.60 Btu / lb / F

Starting Temperature in mold: 450° F
Processing rate: 225 pounds per hour
Safety Factor to account for line losses and fouling factors in the process piping and mold: 25%

(450° F - 125° F) x 1 lb / hr x 0.60 Btu / lb / F x 1.25

Heat content = 243.75 Btu / lb = Heat transfer rate per pound of material processed

Rule of thumb = lb / hr / cooling ton = 12,000 Btuh / ton / heat content in Btu / lb

12,000 / 243.75 = 49.23 lb / hr / ton for Polystyrene

Chiller standard design temperature: 50° F to process

Approximately one ton of cooling is required for every 50 pounds of Polystyrene processed

If you are processing 225 pounds per hour of Polystyrene

225/50 = 4.5 tons of cooling would be required for the heat removal in this process

Temperature Control Units (TCUs)

Liquid-circulating temperature control systems provide accurate and consistent processing temperatures in the preheat, operating, and cool-down stages of injection molding. The most common application for a liquid-circulating temperature control system is to control the temperature of a mold in an injection molding machine. Accurate temperature control maintains product uniformity, dimensional integrity, and surface finish, while providing faster cycle times and reduced scrap. A properly operating unit configured correctly also allows for faster start-up.

These temperature control systems use liquids-either water, a water-glycol solution, or heat transfer fluidbecause they are easy to circulate in tight areas, easy to pump, and transfer heat efficiently. While water systems operate at a maximum capacity of 250° F - 300° F, oil systems, which circulate heat transfer fluid, have maximum operating capacities of 600° F and above.

The system operates by circulating fluid through cored passages of a mold, drilled holes in a platen, walls of a vessel, or built-in flow patterns of rolls. Turbulent flow, determined by the speed at which the fluid travels through the passages, creates the highest rate of heat transfer. The appropriate flow rate is based on the coring layout of the mold and the pumping pressure of the system.

Typically, temperature control systems are installed beside the injection molding machine and hooked up to a manifold or directly to the mold. Most systems can be stacked, with each zone functioning independently, for flexible and multiple-zone temperature control.

Water Systems

Water or water-glycol systems are the most common. They consist of a pump, motor, heaters, temperature controllers, and a cooling medium. Most systems use centrifugal pumps to circulatea small amount of fluid through the mold at a preset temperature. When selecting a new system. It is important to take into account the pressure restrictions of the process, which are directly related to the mold's coring sizes, its number of corings, and their length and layout. *(See Figure 28: Water TCU)*

Fig. 28

Water systems can be either open or closed loop. Open systems are exposed to the atmosphere at some point in the circulation loop and are common to most injection molding applications. Closed loop systems utilize a heat exchanger or sealed and pressurized expansion chamber, which does not expose the circulating process cooling fluid to the atmosphere.

A typical process cooling system utilizes positive pressure to circulate through the process. There are limited applications that utilize negative pressure to "pull" the water through the process. The negative pressure system is used when processing is performed using damaged molds to minimize process fluid leaks from the mold.

Controllers connected to temperature sensors are used to adjust the circulating liquid's temperature. Previously, solid-state analog dials were the standard controls. Now microprocessor-based controllers provide dual-display digital readouts of setpoint and operating temperatures. These new controllers can be linked to computers and networked systems or directly to the molding machines.

Temperature sensors are located in the fluid flow path, or sometimes in the mold itself, to provide constant temperature readings to the controller. When the fluid temperature is lower than the setpoint, the controller activates the electrical heaters within the flow path to increase fluid temperature. When the fluid temperature is higher than the setpoint, the controller activates a solenoid valve that introduces a cold supply water into the system while draining overheated water through a second valve. An alternative cooling method uses either a water-cooled or air-cooled heat exchanger, thereby leaving the processing loop water intact.

Water systems are made of both carbon steel and non-ferrous materials. Non-ferrous systems are becoming popular due to their non-corrosive nature when in contact with water.

Fig. 29

Oil Systems

Oil systems are designed for higher operating temperatures than water-type units. They usually operate between 200°F and 600°F (or more) and differ in size, components used, and construction from water units. The "oil," or heat transfer fluids, which they circulate can be mineral-based, petroleum-based, or synthetic. Not all systems offer cooling as a standard feature. *(See Figure29: High-temp Oil TCU)*

Because heat transfer fluids are non-corrosive by nature, carbon steel construction is standard. To ensure fluid flow to the process with changing viscosities, it is common to use positive displacement-type pumps. Packed seals are usually used to ensure shaft protection and prevent leakage, but mechanical seals and fluid-cooled seals are also available.

Oil systems utilize one of two cooling methods. One design employs the inline orientation of a water-cooled, shelland-tube heat exchanger. The other utilizes a cool oil reservoir in conjunction with a heat exchanger or immersed cooling coils with cool oil introduced into the processing loop upon demand. While either method is effective, eliminating the inline heat exchanger reduces the potential for thermal shock.

Mechanical Chillers: Overview

Mechanical chillers are effective when water temperatures of 65°F and lower is required for the process. Due to the mechanical and physical limitations of the refrigeration circuit, process cooling above 65°F is typically accomplished in a more practical and cost-effective way with a cooling tower system. Basic components in a mechanical chiller refrigeration circuit are an evaporator, compressor, condenser, pump/tank, and controls. These chillers typically are configured as portable chillers, central chillers and outdoor central chillers and are available as water-cooled, air-cooled or remote air-cooled units. You must fundamentally choose a cooling strategy to fit your business and facility. Identifying all the heat loads in your facility and reviewing them with experienced equipment suppliers and installers is highly recommended. Refrigerants used in the refrigeration circuit include R-22. This refrigerant is preferred for its outstanding heat transfer properties but is HCFC-based and may be phased out after 2010. R-134A is an alternative refrigerant, which is environmentally safer, but is also less energy-efficient.

Mechanical Chiller Compressor Types

Chillers use one of three types of compressors: scroll, reciprocating, or screw. Scroll compressors are used on 2-50 ton machines and contain half the moving parts of the other types due to their rotary design. The largest commercial scroll compressor available today is 20 hp. To achieve the desired chiller circuit tonnage, scroll compressors are commonly used in tandem. They can handle liquid refrigerants without failure and consume 15% less energy than the standard reciprocating type. Reciprocating, serviceable hermetic compressors, are still being used in refrigeration circuits when the application makes them the value engineered choice. Screw compressors are used on large (100-350 ton) machines. Screw compressors have the advantage of handling large capacity ranges and have very few moving parts to achieve refrigerant compression. Screw compressors also have variable staging capability by design and can adjust the loading of the cooling tonnage through the circuit. This staging allows the compressor to be energy-efficient. The type of compressor used in a refrigeration circuit is driven by its ability to provide the proper cooling capacity, commercial availability of the compressor and cost per ton of cooling provided.

The general industry design standard for chillers is to provide water at 50 F to process. Water is the typical and most efficient heat transfer fluid for this application. At temperatures below 42°F, a water/glycol mixture is required (Ethylene or Propylene). Ethylene Glycol is more efficient to use but Propylene glycol is more environmentally friendly. Chiller capacity is reduced when operating temperatures fall below 50°F due to the additional work required by the compressors and the loss in efficiency of the water/glycol mixture. The sizing rule is a 2% reduction in chiller capacity per degree below 50°F. There is an additional loss of 2%-5% in efficiency due to the water/glycol mixture's heat transfer capacity. At temperatures above 50°F, there is a 2% gain in chiller capacity (for the first ten degrees). Above 60°F consult the factory for proper application requirements.

Portable Chillers

Portable chillers use either air or liquid to cool refrigerant and usually utilize water or other heat transfer fluids to remove heat from the process.

At the chiller, heat is extracted from the water that has circulated through the process and transferred to the chiller's internal refrigerant circuit. Chillers use air-cooled or water-cooled condensers to transfer heat from their internal refrigerant circuit to the environment. Water-cooled condensers typically use a cooling tower to dissipate the unwanted heat. Chillers have either an integral or remote pump/tank assembly that circulates fluid through the chiller to lower the temperature before going into the process. Once cooled, the water flows to process for heat removal and then back to the pump/tank assembly where the circulation cycle starts again.

Fig. 30

Cooling Towers: Induced Draft vs. Forced Draft

Evaporative cooling towers are the most energy-efficient method to cool processes that require a water temperature of about 85 F. Water is distributed or sprayed over the large surface area of a divided, usually corrugated, tower fill. Air-flow is either forced using squirrel cage blowers, or induced using axial fans, across the fill. Induced draft is the most energyefficient alternative. *(See Figure 30: Cooling Tower)*

During the cooling process in a cooling a tower, a combination of air-flow, large surface area, and environmental conditions allows for a small percentage of water to evaporate as the heated air is exhausted outside. The water is collected either in the basin of the cooling tower or in a remote reservoir and is recirculated to process and then back to the cooling tower.

Treatment of cooling tower water is critical to control the growth of algae and bacteria that occurs in recirculating water systems, especially those operating at warm temperatures. The levels of suspended and dissolved solids created by evaporation can also lead to scale and corrosion problems if untreated.

Fig. 31

Central Pumping System

A critical part of a central chilling solution and any system incorporating cooling towers is a central pumping system and its network of piping. Pump reservoirs themselves can be single- vs. dual-well with multiple pumps and standby pumps. Large systems can have additional reservoirs, pumps with variable speed drives and even thermal storage capability. *(See Figure 31: Central Chilling System)*

AUTOMATED PART REMOVAL, SEPARATION AND SECONDARY PROCESS AUTOMATION

There are four levels of automation generally used in injection molding: sprue removal, part removal, part removal with limited secondary operations, and a fully automated molding system. There are five major types of automation used in injection molding applications: 3-axis traverse robots, 2 and 3 axis sprue pickers, 6-axis articulated robots, side-entry robots, and other secondary process equipment including shuttles, conveyors, sprue separators, insert equipment, coating equipment and more.

Traverse Robots

Traverse robots move on three main axes, the X or strip stroke, the Y or vertical stroke, and the Z or traverse stroke. There are three basic drive types used in traverse robots: pneumatic, electric and electric linear drive.

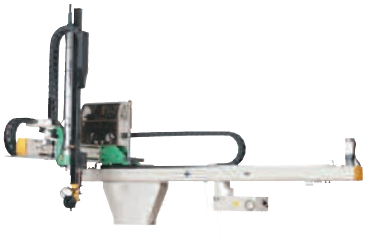


Fig. 32

Pneumatic Drive Traverse Robots

Pneumatic robots are the least expensive, simplest in design and easiest to use. They provide a low-cost solution to simple part insertion applications. A typical application would be to traverse to the mold area and, after the press opens and ejects the finished part, to place the insert in the mold, exit the mold area and traverse back to the insert pickup area to pick up another insert and repeat the cycle. Pneumatic cylinders are employed for drive on the strip, vertical and traverse axes, with limit or proximity switches used for position verification. Some pneumatic traverse robots use a simple electric drive for the traverse motion, allowing for multiple stops on the traverse axis. *(See Figure 32: Pneumatic Drive Traverse Robot)*

Pneumatic robots normally have a programmable logic controller (PLC) to initiate and monitor the programmed sequence. This type of control is very common and the language is easily understood. The control sequence can be reprogrammed by using selector switches to select options in the program or by programming the PLC.

Electric Drive Traverse Robots

As the name suggests, the other basic type of robot uses an electric motor for drive power. Most often the three main axes are motor-driven, although some units are available with motorized wrist motions. The simplest of the electric drive units uses an AC induction motor with a frequency inverter for speed control. The frequency inverter allows control over the acceleration and deceleration of the axes, providing smooth operation. A friction brake is used to stop the unit and hold it in position. *(See Figure 33: Pneumatic Drive Traverse Robot)*

Fig. 33

The easiest control system for a frequency inverter relies on limit or proximity switches to signal where to stop, accelerate and decelerate. Position accuracy of this control depends on how the switch is actuated; how long it takes the processor to scan the program, realize the switch is made, and actuate the brake; and finally, the brake reaction time. Because there is no true position feedback, the control system cannot react to changes in load, leaving open the possibility that this type of system can overshoot or undershoot the intended stopping position.

Another, more precise method of control involves the use of an encoder, or resolver, along with the frequency inverter. The encoder, or resolver, acts as a programmable positioning device, allowing the user to easily change the acceleration, deceleration and stopping points. This control method is more precise and user-friendly than the limit switch method. The ultimate robot drive design, however, is the servo-based system. Servo control systems use specially designed high performance AC or DC motors with a control system that monitors feedback from the positioning devices, usually encoders or resolvers. Servo systems allow position, velocity, and torque to be constantly monitored. As the robot travels through its intended path, the control is checking to see if the robot is where it is supposed to be at any point in time and automatically corrects by increasing or decreasing the torque.

The construction of servo motors is also significantly different from that of standard AC motors. The use of premium components such as permanent rare-earth magnets enables the system to maintain full torque at zero rpm, allowing it to achieve and sustain close positioning at slow speeds.

Servo drive units typically are offered with sophisticated control systems that allow the user to teach a program simply by taking the robot step by step through the intended motion path. This makes it very easy to change sequence for multiple molds, adding to the unit's flexibility. *(See Figure 34: Programming for Robot Sequences)*

Fig. 34

Fig. 35

Six-Axis Traverse Robots

Six-axis traverse robots are utilized for more complex and specialized molding applications. They may be used in conjunction with a traverse robot or on a stand-alone basis for applications such as assembly, degating, deflashing, and others. (See Figure 36: Six-axis Traverse Robot)

Sprue Pickers

These light-duty machines are mounted to the top of the stationary platen and used primarily to extract sprues on two- or three-plate molds. Runner sensors verify sprue removal, there by protecting the mold. The sprue is released directly into a bin or grinder ready for reprocessing. While the sprue picker is ideal for small to medium-sized presses needing to separate sprues from subgated parts, it has limited reach and flexibility. *(See Figure 37: Sprue Pickers)*

Fig. 36

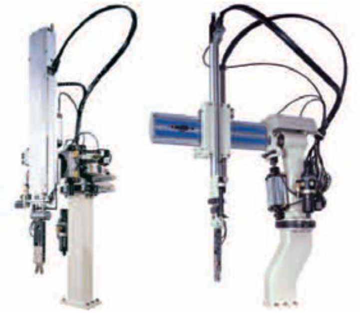


Fig. 37

Benefits of Automating

Parts removal robots provide injection molders with uniform cycle times, increased safety, cavity separation, and consistent part orientation, resulting in greater productivity. Removing the operator from the potentially hazardous molding area reduces injury and eliminates cycle delays from human error.

Robots can be top-entry or side-entry. Side-entry robots are appropriate for faster cycles as they have a shorter travel distance and are useful for shallow products needing little or no force to remove.

Level Three Limited Secondary Operations

These robots offer degating, parts stacking and palletizing, as well as parts removal capacity. Many of today's injection molded parts are attached to a gate/runner system that makes a second operation necessary to separate the two. Generally, there are two categories of degators that can be used with robotic systems: robotmounted or floor-mounted. There are also two configurations of parts collectors: linear and rotary.

At the final level of parts removal automation, a completely automated work cell allows the molding machine to operate at an optimum rate with little or no labor involved. Automated work cells for injection molders have been successfully used in applications such as compact disk jewel boxes, computer disk drive housings, magnetic tape drive hubs and computer printers.

Fig. 38

End-of-arm-tooling (EOAT)

End-of-arm-tooling allows the robot to function with one specific part or a range of parts. Sometimes the tool is made custom to the application, while in other cases a modular end-of-arm tooling solution is chosen. The modular solution approach allows various pieces of extruded aluminum to be integrated with standard grippers, suction cups, pneumatic cylinders and more.

(See Figure 38: End-of-arm Tooling and Components)

GRANULATION EQUIPMENT

Size reduction is usually the last thing thought about when starting up a new operation or operating an existing one. No one plans to make scrap, and processors try to design-in a minimum amount of sprue or runner waste. However, almost every molder generates scrap. Depending on the resin, if you use regrind in your process, selection of an efficient granulator designed for the material and product being produced can improve finished part product quality up to 40%. This can be accomplished by understanding:

- The material to be ground
- The material composition (hard, soft, heat sensitive or stable)
- The physical form of the part (parts, runners, flash, rolls or “haystacks” of film)
- Size, wall thickness and temperature of the part to be ground
- How the part will be fed into the granulator
- How the regrind will be removed from the granulator and reintroduced into the process

All of these factors help determine the most appropriate machine size, feed-throat and cutting chamber design, rotor and knife configuration, rotor speed, drive horsepower, screen size and granulate take-away system for the best granulator configuration.

Ideally, a granulator should be specified to process a specific feedstock under specific conditions. It is unrealistic to expect efficient size reduction from a general-purpose machine, which has not been designed to process all feedstocks under all operating conditions. Some degree of versatility should be obtained and built into the specifications provided, but this may result in compromises in performance efficiency.

Importance of Uniform Granulate

The first goal in granulation is to produce a uniform granulate close to the virgin resin in size and with a minimum of fines. Granule size affects bulk density. The closer the bulk density of regrind is to that of the virgin resin, the less trouble will result when feeding the two in a consistent ratio. Another benefit is that cleaner recyclate with fewer fines will keep hopper-loader screens cleaner and prevent the regrind from bridging in vacuum receivers.

Batch feeding can improve granulate quality because material is ground under a "head" of pressure. Having a head of material in the cutting chamber also dampens noise by keeping scrap from bouncing around and reducing initial impact to the knives.

Granulator Types

There are three basic types of granulators: central, below-the-press, and beside-the-press. A central granulator is typically an off-line device located away from the process. As a do-everything size reducer it can handle large, bulky parts as well as large quantities of smaller ones for a number of machines. It also allows noise to be isolated to a specific area. Its disadvantages include the need for transportation and storage space for the incoming scrap and the regrind produced. It also requires frequent and thorough cleaning to prevent material contamination. *(See Figure 38: Central Granulator)*

Fig. 39

Fig. 40

Because they can be dedicated to a specific machine/material, below-the-press and beside-the-press granulators have the advantages of minimizing scrap handling, eliminating the need for extra storage, and reducing material contamination. Generally, they are smaller and easier to clean as well. They also allow the grinding of brittle materials while they are still warm, making the scrap easier to cut and less likely to shatter into fines.

Typical below-the-press granulators feature a scissor-cut cutting chamber design, reverse flight auger screw, heavy-duty roller chain drive and easy access for cleanout. Since scrap is gravity-fed directly from the processing machine, it requires no conveying or manual handling. *(See Figure 40: Beside-thepress Granulator)*

Beside-the-press granulators for robotic, conveyor or hand feeding are by far the preferred configuration. Since they are portable, they can be moved from machine to machine, allowing greater versatility. The disadvantage is that this machine can bring more noise to the plant floor if not properly sound-dampened.

Sizing

Choosing a granulator depends upon the material to be cut as well as its size, shape and thickness. The amount of material that needs to be granulated and how the regrind will be processed are also key considerations. The feed hopper must be evaluated for operator safety. It should be sized to receive the largest part being granulated without requiring labor-intensive and potentially dangerous precutting. Most safety devices in today's granulators involve electrical interlocks that prevent access to the cutting chamber until the rotor has stopped turning. Older granulators may not have these built-in safeguards.

Cutting Chamber Design

There are three basic cutting-chamber designs: tangential, conventional and straight-drop, plus a hybrid model.

The popular tangential design positions the rotor at an offset from the feed opening so that the feedstock is directed into the downward cut of the rotating knives at a tangent to the cutting circle. This cutting chamber provides a large "bite" radius, which is the most efficient way to achieve high throughput and clean regrind with bulky, thin-walled parts.

A straight-drop design feeds material perpendicular to the cutting circle and is recommended for thick-walled parts. Its "nibbling" bites are less likely to take too much material and perhaps stall the rotor.

The hybrid model presents material to the knives at an angle somewhere between the first two and allows custom molders with a wide range of part sizes and shapes to process both thick- and thin-walled materials in the same machine.

ROTORS

The four main types of rotors are open, closed or solid, staggered and staggered/segmented.

Fig. 41

Open rotors provide unrestricted air-flow through the cutting chamber, so they are more often used for granulating heat-sensitive resins or feedstocks that are still warm from processing. *(See Figure 41: Open Rotor)*

Fig. 42

Closed or solid rotors have no open spaces between the rotating knives and the center of the shaft, providing a much stronger knife mounting arrangement and adding inertia to cut through the thickest feedstocks, such as large cold purgings. *(See Figure 42: Solid Rotor)*

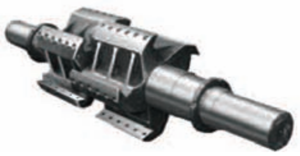


Fig. 43

Staggered rotors are offered in closed or semi-closed configurations and are excellent for cutting most heavy, thick-walled parts. In heavy-duty applications, flywheel-type pulleys increase rotor inertia and are often a more practical, cost-effective means to achieve greater cutting force without adding horsepower. *(See Photo 43: Staggered Rotor)*

Staggered/segmented rotors are usually offered in a helical pattern, which provides more cuts per revolution than traditional rotor designs. The cutting circle stays constant after sharpening, minimizing screen plugging, heat build-up and fines. This configuration is excellent for cutting most heavy, thick-walled parts.

Knives

The number of knife blades, their arrangement, tip angle, speed, and sharpness all have an important impact on granulate quality and granulator efficiency. Knives may be mounted on a stationary bed or on the rotor. The clearance between rotating and bed knives is crucial to size reduction performance. Smaller clearances produce cleaner, more efficient cuts and are important when grinding softer, more ductile polymers. Many granulator designs offer only two stationary or bed knives. Check with the granulator manufacturer for proper knife clearance recommendations based on materials being granulated. Increasing the number of knife blades on the bed, or the rotor, can significantly increase throughput by increasing the number of cuts per revolution.

A "slant-knife" arrangement that produces a scissors cutting action provides higher throughputs with less horsepower, less noise, and reduced fines and dust than the traditional straight-cut knife.

Low knife angles have blunter tips and are suited for more brittle materials. High knife angles with sharp knife edges are used to cut softer, energy-absorbing materials.

Lower knife tip speeds can increase output of uniform granulate, reduce noise and lessen knife and cutting chamber wear. With a high-speed rotor, the particles are more susceptible to being carried around the machine or frayed into fines by repeated cuts. A slower rotor speed prevents this by giving each granule a greater chance to pass through the screen.

Frequency of knife sharpening will depend on the abrasiveness of the material (glass-filled and reinforced compounds are the worst on knives), and on the steel alloy composition of the blades. Knife steels are generally designed for either toughness or wear resistance. For soft, non-abrasive materials, knives made of chrome-vanadium steel (CVS) are tough and resistant to chipping, but wear faster than other tool steels. D2 steel, the most common choice for granulator knives, is harder and provides more wear resistance, but may be more susceptible to chipping, which can be a problem if tramp metal is present. A regular periodic maintenance program should be established to check knife wear and sharpness. **Sharpened blades are important to produce quality regrind with minimal fines.**

Screen

Screen hole size is heavily dependent on material composition and machine size. When running at slower rotor speeds, smaller screen holes and a thinner screen will produce more uniform particle sizes and highest throughput. On the other hand, at higher speeds, larger screen holes are needed to achieve throughput and reduce fines, although they may increase the range of particle sizes, particularly with brittle materials. Reversible screens have a longer useful life.

Summary

The goal in a process environment is to produce the highest quality part 100% of the time with a 0% scrap rate and 0% waste in the process. This goal should be accomplished using the fastest possible machine cycle time and a minimum amount of human contact. To maximize profitability, this should all be performed at the least cost to the processor. Unfortunately, not all processors are able to achieve this goal.

Technology and experience has led to significant improvements in the design and proper implementation of the correct auxiliary equipment to match the process. **Selection of the proper auxiliary process equipment is critical to successful processing.** By taking the time to properly select the right equipment to match the process, you will be able to maximize the efficiency of the process and help to obtain the goal and expectations of your business.

Do not always look at the initial cost of the equipment. Besides fit, form, function and compatibility with your other equipment; look at the "value" that the equipment can add to your process. Evaluate the productivity gains that can be achieved (short and long term) through proper implementation of this equipment in your process. Utilizing the latest in today's technology allows you the opportunity to match and integrate the right auxiliaries into your process. This match will optimize your operations and most importantly will increase your bottom line.

All photos and illustrations contained in this article courtesy of the ACS Group

ABOUT THE AUTHOR

Joe Dziedzic, Manager of Product and Systems Development for Sterling, Inc. of New Berlin, Wisconsin, is responsible for product development and marketing activities for Sterling's material handling and process cooling product lines. Sterling provides the world's broadest line of integrated auxiliary equipment and systems for injection, extrusion and blow molders and other processors worldwide.

Joe has over 20 years of experience designing equipment and systems for plastics processors. After receiving a BSME from University of Illinois-Chicago, he began his career as a systems engineer in Sterlings's System Design and Contracting Group. Here he supported and later managed large material handling and cooling system projects. Joe then moved to a product engineering position, where he worked closely with customers and sales representatives applying standard and custom equipment for a variety of plastics industry applications. He eventually moved into new product development, where he designed conveying, drying and blending equipment including: conveying system controls, filter chambers, hoppers, drying hoppers, additive feeders and blenders. Joe holds several patents including a special pneumatic pick-up wand commonly used with hopper loaders for transporting resin from gaylords.

From 1995 to 1996 Joe served as Project Manager and Engineering Consultant for Globetrotters Engineering-Chicago. He was assigned to major projects at O'Hare and Midway Airports and served as the primary liaison to the Chicago Department of Aviation.

In 1996 Joe returned to Sterling where he managed process cooling activities and assisted with marketing the product development for material handling. In 1997 he was named Manager, Product and System Development for both heating and cooling and material handling and continues this capacity today. Joe recently stated, "I am part of creating a new Sterling, a company whose structure and products are designed around customers and their operations. More than ever we are responsible for working closely together to design processes that leverage today's ever-changing technology."

Joe is a proud father of two boys and resides in Addison, Illinois.

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