Evaluation of Low Pressure Dryer for Plastic Resins

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Disclaimer

ABBREVIATIONS AND ACRONYMS

ABS	Acrylonitrile Butadiene Styrene
IOU	Investor Owned Utilities
PC	Polycarbonate
PET	Polyethylene Terephthalate (PETE or PET™)
PPM	Parts per Million
SPE	Society of Plastics Engineers
SPI	Society of Plastics Industries

FIGURES

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EXECUTIVE SUMMARY

California has over 1,200 plastic fabrication industries in operation according to industry sources like the Society of Plastics Industries (SPI) and the Society of Plastics Engineers (SPE). These industries are heavy consumers of electricity. In the past SCE, and other Investor Owned Utilities (IOUs) in California, conducted several Emerging Technology (ET) projects to assist these customers in improving energy efficiency in various plastic fabrication processes. These projects varied in scope from Injection Molding Machine efficiencies to auxiliary equipment energy consumption. This project evaluates the energy efficiency of resin dryers used prior to the plastic material being supplied to the Injection Molding and other extrusion processes.

Plastic resin falls into several categories; Polyethylene Terephthalate (PET), Acrylonitrile Butadiene Styrene (ABS), polycarbonate (PC), nylon, and others. Each type of resin, in conjunction with the fabrication process, determines the moisture level allowed in the resin prior to extrusion. Based on this target moisture level, different types of resin dryers are used. For polycarbonate and ABS, the dryer used by the majority of customers is a Twin Bed Desiccant (baseline) dryer. Recently, some dryer manufacturers have introduced a new dryer with several attractive features aimed at this market segment. This dryer is generically called a Low Pressure dryer. There are claims that this new dryer is more energy efficient, and faster in operation. At present there are no reliable quantified data to support this, only claims. To make matters more complicated, there are also no energy efficiency standards for the present baseline dryer, making any comparison impossible. However, general observations lead one to believe that there may be real energy savings using the new Low Pressure dryer. So this project was initiated to evaluate the new dryer against the baseline dryer and to quantify any potential savings.

A test was devised and conducted to evaluate the comparative energy efficiency performance of the two dryers under controlled conditions. The units were tested at a testing facility operated by the Novatec Company in Baltimore, MD.

The tests showed 49.3% energy savings for the Low Pressure dryer over the Baseline Twin Bed dryer. The Twin Bed dryer recorded an average kW power level of 7.88 during the test cycle, while the Low Pressure dryer recorded 4.00 kW. Both tests were normalized to a drying rate of 100 lbs/hr. Both dryers had the same polycarbonate resin from one single batch with the same initial conditions to make the results obtained from the two dryers comparable to each other. For a molder or extruder who prefers the metric system, these results equate to 17.34 kWh/100 kg versus 8.80 kWh/100 kg of resin dried using the baseline drier and the new drier respectively.

There were some additional benefits for the Low Pressure dryer over the baseline dryer that were verified by the tests. First of all, the final resin moisture level conditions were more consistent with the new dryer which is a very important quality control issue for the customer. As the final resin moisture level increases, the molding or extrusion may produce defective parts, which is a major concern. Throughout the Low Pressure dryer test the final moisture level was maintained at or below the 200 parts per million (PPM) area, and was controlled within a very small range. The baseline dryer, on the other hand, showed more variability, even though the final resin moisture level was always below the 200 PPM target level.

A second benefit for the new Low Pressure dryer is the very short “warm-up” time of less than one hour, which is a major benefit to the plastics manufacturer. Warm-up time is the duration from initial plug-in until the dryer reaches the final set resin moisture level. For

the baseline dryer this period ranges from about two hours to about six hours under production conditions. During this time molding operations cannot start and is considered wasted time for the operators. This is especially costly to the manufacturers when they operate under job-shop mode because of the frequent product changes on the line.

Third, the Low Pressure dryer is much more compact than the baseline dryer, with a footprint about 50% of comparable Twin Bed dryers.

For new purchases the Low Pressure dryer is a little more expensive in the 100lbs/hr size than the Baseline unit, but the increased price reverses for larger sizes. In addition to the operating savings from reduced electrical energy use, the Low Pressure dryer offers a potential maintenance cost advantage because there are no desiccant towers or regeneration heaters to maintain and no desiccant replacement costs as would be the case with the Twin Bed dryer. The baseline dryer needs service once every two years. During this service, the desiccant in both chambers needs to be replaced. For the 100 lb/hr size, the service cost-estimate is $2,000, which includes desiccant cost and labor. The desiccant typically costs $7/lb. On average, the 100 lbs/hr rated baseline dryer has an expected maintenance cost of $1,000 per year.

The primary maintenance areas for the Low Pressure dryer involve occasional replacement of the blower filters and canister gasket seals. The durability of the canister vacuum seals is currently unknown and a possible area of concern. Effects on product quality and maintenance costs could become an issue if the canister vacuum seals are not durable enough to maintain adequate vacuum levels during dryer operation without the need for frequent replacement. Further operating experience is needed to clarify this issue.

Based on this evaluation, the Low Pressure dryer is the better choice for customers using polycarbonate, ABS, and PET resins.

INTRODUCTION

BACKGROUND

California has over 1200 plastic fabrication industries in operation. The majority of their processes fall into one of the following categories;

- Injection Molding
- Blow Molding
- Tube Extrusion
- Sheet Extrusion
- Miscellaneous processes like: Presses, Thermoforming, etc.

All of these are electric energy-intensive operations. Extrusion processes typically surround themselves with one or more auxiliary systems which also are significant energy users. For example, an injection molding operation will use resin dryers prior to the extrusion, granulators to recover the unused parts, mold heaters, and coolers. All of these use electricity in their function. All are further supported by utilities for lighting, Heating, Ventilation and Air Conditioning (HVAC) and may be clean rooms, compressed air, cooling towers, chillers, etc. SCE observed early on that the auxiliary systems were contributing to about 50% or more of the electrical load.

To address this situation SCE started investigating new and advanced auxiliary equipment in the area of granulators and plastic resin dryers. This report documents this emerging technology study on resin dryers.

Plastic resin dryers are needed for most types of extrusion processes. In the SCE territory, around 1500 plus dryers are estimated to be in operation. They can be central dryers that serve multiple extrusion machines, or can be dedicated to a single extrusion machine. Also, depending on the type of resin processed and the specifications of the extrusion, different levels of dryness are required. Based on these criteria different types of dryers are used. However, due to a lack of clear understanding of the technical issues, many customers select dryers by trial and error. The general technology investigations in this area point to the need to quantify the energy efficiency of alternative dryers. Based on simple observations, SCE saw an opportunity for an energy efficiency improvement for drying polycarbonate, PET and ABS resins. The baseline dryer in use at this time for these resins is a Twin Bed Desiccant dryer. The new technology selected for this study is the Low Pressure dryer. It is also expected that the dryers that serve this group of resins will number about 800 in the SCE territory.

TECHNOLOGY TESTED

TWIN BED DESICCANT DRYER

Dehumidifying desiccant bed drying technology was introduced some 50 years ago. Desiccant dryers typically use large electric heaters and oversized blowers to obtain the temperature and humidity-free air that is required to dry plastics. These dryers have large beds of desiccant that create substantial airflow resistance to drying air, which is why they require oversized blowers. The scale of these units requires large heaters to maintain a constant temperature. These units function well and, with proper maintenance, typically last a very long time.

Desiccant dryers work by passing moisture-laden air through a canister containing desiccant beads. The strongly hygroscopic desiccant adsorbs moisture from the air to produce dry air, which is then heated and passed through the drying hopper containing the plastic granules. The warm dry air then removes moisture from the granules and the wet cooler air is recycled back to the dryer through a closed loop system for further drying and reuse. The desiccant canister is regularly removed from the drying stream for high-heat regeneration to remove the moisture that it has adsorbed. The typical dryer uses either indexing desiccant canisters or valve arrangements to regularly cycle the desiccant through the drying and regeneration stages to avoid overloading the desiccant. The cycle can be determined either through a simple timer (which is energy inefficient), or when the dry air dew point reaches a set point (to indicate the need for regenerated desiccant). However, the most efficient method is to measure the moisture content of the material to determine the regeneration cycle time.

The regeneration stage is completely separate from the drying stage. It is common for the heat used during regeneration to be recycled into heating the process air before it is sent to the drying hopper. The typical process cycle time for desiccant drying is in the region of four to six hours depending on the material and the initial moisture content. Desiccant dryers, however, tend to consume a lot of energy.

FIGURE 1: TWIN BED DESICCANT DRYER

LOW PRESSURE DRYER

Low pressure type dryers differ from desiccant bed type dryers in terms of size and operation. The Low Pressure dryer is based on the use of a reduced pressure (partial vacuum) in a chamber containing preheated resin pellets. The low pressure reduces the boiling point of the moisture in the resin pellets resulting in the moisture being pulled from the pellets as vapor.

FIGURE 2: LOW PRESSURE DRYER – EXTERIOR VIEW AND CANISTER CONFIGURATION

A three step carousel process is used in which three stainless steel canisters are indexed through the process. In the first stage a canister is filled with resin pellets and heated to the appropriate temperature for the resin type (about 250°F for polycarbonate resin). The heating stage takes 20-30 minutes. The canister is then indexed to the second position within the dryer where custom-designed gaskets seal off the ends of the canister and a vacuum of approximately 25 inches of mercury is applied. This reduces the boiling point of the moisture in the resin to about 133°F, which results in the moisture in the resin being quickly "boiled off" and then evacuated from the canister. The vacuum-drying stage takes about 20-30 minutes. The canister is next indexed to the third position where the dry resin is unloaded and transferred to the process machine. During the dryer operation canisters are continuously moving through the indexing sequence to provide an uninterrupted supply of dried resin.

The primary maintenance areas for the Low Pressure dryer involve occasional replacement of the blower filters and canister gasket seals. The durability of the canister vacuum seals is a possible area of concern due to limited availability of information. Effects on product quality and maintenance costs could become an issue if the canister vacuum seals are not durable enough to maintain adequate vacuum levels during dryer operation without the need for frequent replacement. Further information on vacuum seal reliability based on additional operating experience is needed to clarify this issue. There are no desiccant towers or regeneration heaters to maintain and no desiccant replacement costs as would be the case with the Twin Bed dryer.

The Low Pressure dryer offers a significant energy savings due to the efficiency of the vacuum drying process and the elimination of the energy required for regenerating desiccant.

Warm-up time is the duration when the dryer reaches the final set resin moisture level after plug-in. The Low Pressure dryer has a warm-up time of less than an hour compared to two to six hours for the baseline dryer.

The Low Pressure dryer is much more compact than a twin bed dryer, because there are no desiccant towers and no large resin hopper required. The footprint is about 50% of a comparable twin bed dryer.

TESTING APPROACH

TEST BACKGROUND

The initial plan was to conduct energy efficiency evaluations on both dryers at a molding shop located in SCE territory. However, it was found that such evaluations are almost impossible at production-level operations due to the ever changing nature of the drying rate caused by changes in molding rate. So a second plan was devised to test the units under controlled conditions at a testing facility operated by the Novatec Company in Baltimore, Maryland. For controlled tests, several important factors needed to be considered:

- Type of resin
- Initial and final moisture level of the resin
- Constant drying rate, almost at the top of the design drying rate for the equipment

The following Test Procedure was developed to meet these conditions.

TEST DESCRIPTION AND METHODOLOGY

TEST PURPOSE

This test was conducted to evaluate the energy efficiency performance under controlled conditions of the following:

A. A Twin Bed plastic resin dryer (baseline), and

B. A Low Pressure plastic resin dryer

VARIABLES

a) Controlled Variables

- Plastic Resin - All tests were carried out using the same batch of polycarbonate resin.
- Drying Rate – All tests were conducted at 100 pounds per hour drying rate, as close as possible. Since the drying performance was normalized as kWh per 100 pounds, minor differences in resin flow did not result in significant errors in the final outcome.
- Moisture Levels - All tests used the same batch of resin. The actual initial resin moisture level was determined and recorded.

- Personnel -Novatec provided trained laboratory personnel for this test. They have ample experience performing these tests routinely for their customers at their request.
- Novatec provided meters to read the humidity level in the laboratory.

b) Measured Data

- Electrical demand and energy consumption by the dryer in kW and kWh, respectively
- Amount of resin dried per hour during the test. This was initially adjusted to 100 pounds per hour, as stipulated in the Test Plan.
- Initial resin moisture level
- Final resin moisture level

EQUIPMENT TESTED

- The baseline dryer was a Novatec Twin Bed Desiccant dryer, Model # NDB 150
- The Low Pressure dryer was a Novatec Model # VRD 100

MATERIALS

All tests used polycarbonate resin: Bayer MAKROLON Type 3100 MAS 318.
Batch: 03PM6B1730 ART 03789652

TEST MEASUREMENT DEVICES

- Power meter: Ohio Semitronics Model No. FC5-063D, used to measure kW data at an interval of one reading per second
- Weigh Scale: Ohaus Model CKW, Maximum Capacity 60 pounds, used to determine process drying rate in pounds per hour
- Moisture Analyzer Meter: Aboni FMX Hydrotracer, used to determine water content of solid samples; results include only water, no other volatiles

PROCEDURE/TEST SEQUENCE

a) Setup

Each dryer was set up and run on a trial basis prior to actual testing in accordance with the test plan. These setup tests used polycarbonate resin, but not the virgin batch as required in the actual test. All instrumentation was tested for proper operation during this trial test.

b) Actual tests

- The actual tests were similar to the trial test, and conducted after the trial test was completed.
- The baseline test and the Low Pressure dryer test followed one after the other, with the baseline tested first.
- Instrumentation and data gathering were as described in the Test Measurement Devices Section above.
- Tests ranged from 50 minutes up to a maximum of four hours in length depending on test conditions and the cycle length of the dryer.

- Each test data was tagged with "B" for Baseline and "L" for Low Pressure dryer.
- Each data set was also identified with time and date.

c) Test schedule

The test was run according to the following schedule:

TABLE 1: TEST SCHEDULE FOR BASELINE TWIN BED DRYER AND LOW PRESSURE DRYER

RUN NUMBER	SCHEDULE	DRYER TESTED	RUN TIME
1	Day 1, First Run - trial	Baseline Twin Bed Dryer	1 hour
2	Day 1, Second Run	Baseline Twin Bed Dryer	4 hours
3	Day 2, First Run - trial	Low Pressure Dryer	2 hours
4	Day 2, Second Run	Low Pressure Dryer	50 minutes

RESULTS

DATA ANALYSIS

The data collected was analyzed to determine the electrical energy usage for both the baseline dryer and the Low Pressure dryer under equivalent operating conditions.

BASELINE DRYER

The kW power demand of the baseline dryer was recorded every second over a four hour test period that included both the drying and regeneration portions of the operating cycle. The measurements were averaged over the four-hour cycle to obtain the average power demand (kW) for the 100lbs/hr process flow rate used during the test.

The power demand and process flow rate information was then used to obtain the dryer energy usage normalized to a kWh/100kg value (kWh needed to dry 100 kg of resin). This was done using the formula in equation 1.

EQUATION 1

Dryer Energy Consumption in kWh/100kg = P • 2.2

Where:

- P is the average power measured during the test cycle at 100lbs/hr (kW)
- 2.2 is the lb to kg conversion factor: lbs = kg • 2.2

Test results for the Twin Bed Desiccant dryer indicated an average power demand value of 7.88 kW for a 100lbs/hr process rate. This means that operating at an average power of 7.88 kW the dryer consumed 7.88 kWh of electrical energy while drying 100 lbs of resin.

Then from Equation 1:

Dryer energy consumption in kWh/100kg = 7.88 kW/ (100lbs/hr) • 2.2 lbs/kg = 17.34 kWh/100kg.

LOW PRESSURE DRYER

The kW power demand of the Low Pressure dryer was recorded over a 50-minute test period (one complete cycle) to obtain operating data for comparison to the baseline dryer test data. The trial test was initially attempted at the full 100lbs/hr process rate, but the dryer was not able to dry the resin to the target moisture content of 200 PPM at this process rate. After the rate was reduced to 95lbs/hr, the dryer was able to dry the resin below the 200 PPM target level on an average basis.

The original intent was to meter the dryer for three complete cycles (about 180 minutes). Each cycle refers to a 360˚ turn of the carousal going through first canister to the third, and coming back to the first again. However, the first two cycles of the test run turned out to be not acceptable. The final moisture content was consistently about the target of less than 200 PPM. This was discovered only after two hours because the moisture analysis on each sample takes about 40 minutes. After the problem was detected, the drying rate was adjusted from 100 lbs/hr to 95 lbs/hr, and then the dryer was able to meet the moisture target. When all three canisters met the moisture target, the test was considered an acceptable test run. The 50 minutes of data corresponds to this part of the test run.

Detailed results of the 100lbs/hr trial test and the 95 lbs/hr actual test are shown in Table 2. In the 100lbs/hr test, final resin moisture content was above the 200 PPM target in batches from all three canisters. In the 95 lbs/hr test, final resin moisture content was below 200 PPM in batches from canisters 2 and 3, and essentially met the 200 PPM target for the batch from canister 1 (202 PPM). Overall the performance at 95 lbs/hr averaged 186 PPM, comfortably below the 200 PPM target. The 202 PPM reading for canister 1 was possibly due to the dryer not being fully stabilized at the start of testing, as the subsequent batches from both canisters 2 and 3 achieved a consistently lower level of resin moisture content. Results from the 95lbs/hr test were normalized to a 100 lbs/hr rate for performance comparisons.

TABLE 2: TEST RESULTS FOR THE LOW PRESSURE DRYER TESTS

TEST RUN NUMBER	PROCESS RATE	INITIAL RESIN MOISTURE CONTENT	FINAL RESIN MOISTURE CONTENT CANISTER 1	FINAL RESIN MOISTURE CONTENT CANISTER 2	FINAL RESIN MOISTURE CONTENT CANISTER 3
1-Trial	100 lbs/hr	1,530 PPM	239 PPM	223 PPM	258 PPM
2-Actual	95 lbs/hr	1,530 PPM	202 PPM	181 PPM	175 PPM

Note: The Low Pressure dryer (model VRD 100) could not meet the < 100 PPM goal during these tests when operated at the top rating of 100 lbs/hr. However, the dryer is affective and could meet customer needs at a reduced capacity of 95 lbs/hr.

The kW power demand measurements were averaged over the 50-minute cycle to obtain the average power demand (3.601 kW) for the Low Pressure dryer for a 95 lbs/hr process rate used during the Low Pressure dryer test. In addition to the power demand of the dryer itself; there is an additional power demand from the operation of an air compressor. Compressed air, along with the Venturi Effect, is used to provide the reduced pressure (partial vacuum) in the canister during the drying step. The power demand of the compressor was calculated using the formula in Equation 2.

EQUATION 2

Air Compressor Power Demand in kW = SCFM / 4.45

Where:

- SCFM (Standard Cubic Feet per Minute) is the average compressor air flow as measured during the test cycle at 95 lbs/hr resin process rate.
- 4.45 is the SCFM to kW conversion factor. This factor is based on an average condition for a medium sized screw compressor system kW = SCFM/4.45

Using measured compressor average air flow data of 0.87259 SCFM from the Low Pressure dryer test at a process rate of 95 lbs/hr and Equation 2, an average vacuum pump power demand of 0.196 kW was calculated.

Combining the dryer demand (3.601 kW) and the air compressor demand (0.196 kW), results in a total average dryer system power demand of 3.797 kW for a process flow rate of 95 lbs/hr.

The average power demand obtained for the 95 lbs/hr process rate used during the test was extrapolated to normalize the power to the standard rate of 100 lbs/hr using the formula in Equation 3.

EQUATION 3

Low Pressure Dryer Power Demand in kW/ (100 lbs/hr) = P • (100/95)

Where:

- P is the average power measured during the test cycle at 95 lbs/hr (kW)

Using the total power demand value of 3.797kW from the Low Pressure dryer test at a process rate of 95lbs/hr and Equation 3, an average vacuum pump power demand of 4.0 kW was calculated for the standard 100 lbs/hr process rate.

Operating at an average power of 4.0 kW the dryer consumed 4.0 kWh of electrical energy while drying 100 lbs of resin.

Then from Equation 1 above:

Dryer energy consumption in kWh/100kg = 4.0 kW/ (100 lbs/hr) • 2.2 lbs/kg = 8.8 kWh/100kg.

DISCUSSION OF RESULTS

During initial dryer trial operation it was detected that the Low Pressure dryer was not able to dry the resin to the target moisture content of 200 PPM for the full 100 lbs/hr rated capacity of the dryer. For the test, the process rate was reduced slightly to 95 lbs/hr to meet the required 200 PPM dried resin moisture level. This indicates that the dryer's rated process flow rate might not be fully available under some conditions.

Comparison of the energy consumption of 17.34 kWh needed to dry 100kg of resin for the baseline dryer to the energy consumption of 8.8 kWh needed to dry 100kg of resin for the Low Pressure dryer showed a significant 49.3% savings in electrical energy usage using the Low Pressure dryer over the Baseline Twin Bed dryer.

There were some additional benefits for the Low Pressure dryer over the baseline dryer that were verified by the tests. First of all, the final resin moisture level conditions were more consistent with the new dryer which is a very important quality control issue for the customer. As the final resin moisture level increases, the molding or extrusion may produce defective parts, which is a major concern. Throughout the Low Pressure dryer test the final moisture level was maintained at or below the 200 PPM area and was controlled within a very small range. The baseline dryer, on the other hand, showed more variability, even though the final resin moisture level was always below the 200 PPM target level.

A second benefit for the new Low Pressure dryer, mentioned earlier, is the very short “warm-up” time of less than one hour. Warm-up time is the duration from initial plug-in until the dryer reaches the final set resin moisture level. For the Twin Bed dryer this period ranges from about two hours to about six hours under production conditions. During this time molding operations cannot start. It is considered wasted time for the operators. This is especially costly to the manufacturer when they operate under job-shop mode because of the frequent product changes on the line.

Finally, the Low Pressure dryer is much more compact than a Twin Bed dryer, because there are no desiccant towers and no large resin hopper required. The footprint is about 50% of a comparable Twin Bed dryer.

TECHNOLOGY COSTS

CAPITAL COSTS

A comparison of initial capital costs of the Baseline Twin Bed dryer and the Low Pressure dryer are presented in Table 3.

TABLE 3: SUMMARY OF CAPITAL COSTS FOR BASELINE TWIN BED DRYER AND LOW PRESSURE DRYER

Process Resin Flow Rate (lbs/hr	Baseline Twin Bed Dryer Cost	Low Pressure Dryer Cost
100	**$10,500**	**$12,600**
200	**$18,300**	**$15,700**

For new equipment purchases the Low Pressure dryer is a little more expensive in the 100 lbs/hr size, but the increased price reverses for larger sizes. It is also to be noted that the Low Pressure dryer is a portable plug-in, so installation costs are not applicable.

OPERATING AND MAINTENANCE COSTS

Compared to the baseline dryer, the Low Pressure dryer provides a previously discussed 49.3% savings in electrical energy usage and corresponding energy costs.

The baseline dryer uses a bed of desiccant beads which tend to disintegrate over time, typically requiring replacement within two years. For the Twin Bed dryer Model NDB 150 used in the test, the cost for desiccant bead replacement is about $2,000 every two years. The $2,000 total cost consists of $1,000 for the desiccant bead material at $7 per pound and an installation cost of about $1,000.

For the Low Pressure dryer there are no desiccant towers or regeneration heaters to maintain and no desiccant replacement costs as would be the case with the Twin Bed dryer. The primary maintenance areas for the Low Pressure dryer involve occasional replacement of the blower filters and canister gasket seals. The durability of the canister vacuum seals is unknown and a possible area of concern. Effects on product quality and maintenance costs could become an issue if the canister vacuum seals are not durable enough to maintain adequate vacuum levels during dryer operation without the need for frequent replacement. Further operating experience is needed to clarify this issue.

CONCLUSION

The tests showed 49.3% energy savings in electrical energy usage and corresponding energy costs for the Low Pressure dryer over the Baseline Twin Bed dryer. The Twin Bed dryer recorded an average kW power level of 7.88 during the test cycle, while the Low Pressure dryer recorded 4.00 kW. Both tests were normalized to a drying rate of 100 lbs/hr. Both dryers had the same polycarbonate resin from one single batch with the same initial conditions. For a molder or extruder, these results equate to 17.34 kWh/100 kg versus 8.80 kWh/100 kg for the baseline and the new drier respectively.

There were some additional benefits for the Low Pressure dryer over the baseline dryer that were verified by the tests as follows:

- final resin moisture levels were more consistent
- extremely short warm-up time
- more compact with a 50% smaller footprint, and
- low maintenance

In general, the Low Pressure dryer would be the recommended choice for customers using polycarbonate, ABS, and PET resins versus the baseline dryer.