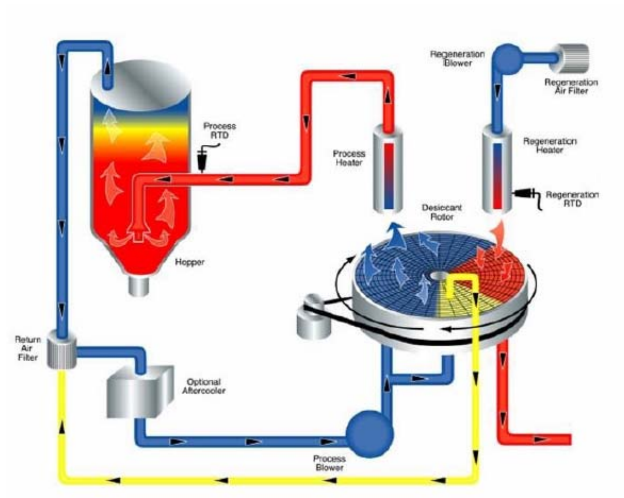
Evaluation of Desiccant Wheel Dryer for Plastic Resins

ET 07.18 Final Report



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Acknowledgements

Southern California Edison's Design & Engineering Services (D&ES) group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technology program under internal project number ET 07.18. D&ES project manager Babu Joseph conducted this technology evaluation with overall guidance and management from Gregg Ander. Controlled laboratory tests conducted for this project were carried out at the Novatec Technical Center in Baltimore, Maryland under the supervision of Babu Joseph. This project received technical support from Mark Haynie of Novatec and from the Matsui Corporation of America. For more information on this project, contact *Marekat.Joeseph*@sce.com.

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 Society of Plastics Industries (SPI) and Society of Plastics Engineers (SPE). These industries are heavy electricity users. 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; PET, 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 usual dryer utilized by the majority of customers is a Twin Bed Dryer, which has two desiccant beds in operation. Recently, some dryer manufacturers have introduced a new dryer with several attractive features aimed at this market segment. This dryer is generically called a Desiccant Wheel dryer. There are claims that the new dryers are more energy efficient, and also faster in operation. At present there are no reliable quantified data to support this, only the manufacturer's claims. To make matters more complicated, there are also no energy efficiency standards for the present Baseline Twin Bed Dryer, making any comparison impossible. But general observations lead one to believe that there may be real energy savings. So this project was initiated to evaluate the new dryer against the Baseline Twin Bed Dryer and to quantify the savings.

This project was conducted by SCE in cooperation with Accent Plastics in Corona, California. Accent is a customer of SCE, and operates several injection molding lines. They were particularly interested in the resin drying operations, and the efficiency associated with the process. The initial SCE plan was to conduct a comparative study between the Desiccant Wheel dryer and Twin Bed dryer (baseline), each rated at 400 pounds per hour at the Accent Plastics molding facility. The study was to be conducted for polycarbonate resin with a target of 200 parts per million (PPM) final moisture level. During the tests, it was observed that steady states were not achievable for the drying process for both dryers, due to rapid fluctuations of production rates. So the study plan was changed to a "controlled test" between the two dryers at a laboratory in a technical center operated by Novatec under the supervision of the SCE Project Manager and an SCE consultant.

The tests showed 47.2% energy savings for the Desiccant Wheel dryer over the Baseline Twin Bed dryer. The Baseline dryer recorded an average kW power level of 7.88 during the test cycle, while the Desiccant Wheel dryer recorded 4.16 kW. Both tests were carried out at a drying rate of 100 pounds per hour. 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 9.16 kWh/100 kg of resin dried.

There were several additional important benefits for the Desiccant Wheel dryer over the Baseline dryer. First of all, the final resin moisture level conditions were very stable with the new dryer which is a very important quality control issue for the customer. Throughout the four hours of testing the final moisture level was controlled within a very small range. When the final resin moisture level increases, the molding or extrusion could result in defective parts, which is a major concern for the customer. The Twin Bed 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 dryer is the very short "warm up" time. Warm up time is the duration when the dryer reaches the final set resin moisture level after plug-in. This period ranges from about two hours to about six hours for Twin Bed dryer under production conditions. During this time molding operations cannot start. It is considered wasted time for the operators. This is especially costly to the customer when they operate under job-shop mode because of the frequent product changes on the line. The Desiccant Wheel dryer had a "warm up" time of less than 30 minutes, which was a major benefit to the customer.

Third, the Desiccant Wheel dryer is much more compact than a Twin Bed dryer, with a footprint about 25-35% of comparable Twin Bed dryers.

For new purchases the Desiccant Wheel dryer is little more expensive in the 100lbs/hr size than the Baseline unit, but the increased price vanishes and reverses for larger sizes. In addition to the operating savings from reduced electrical energy use, the Desiccant Wheel dryer offers a significant maintenance cost advantage due to its much longer desiccant life. The Twin Bed dryer needs service once every two years. During this service, the desiccant in both chambers needs to be replaced. For the 100 lb/hour size, the service cost-estimate is $2,000, which includes resin cost and labor. The desiccant typically costs $7.00 / lb. On the average the 100 pounds per hour rated Twin Bed dryer has an expected maintenance cost of $1,000.00 per year.

In general, the Desiccant Wheel dryer should be the choice for customers using polycarbonate, ABS, and PET resins.

INTRODUCTION

BACKGROUND

California has over 1200 plastic fabrication processes. The majority of them 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 have 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 these are further supported by utilities for lighting, 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 extrusion machines. 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 to be 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 pointed 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 dryer. The new technology selected for this study is the Desiccant Wheel dryer. It is also expected that the dryers that serve this group of resins will number about 1,000 in the SCE territory.

TECHNOLOGY TESTED

TWIN BED DRYER

Dehumidifying desiccant bed drying technology was introduced some 50 years ago. This type of desiccant dryers (Twin Bed 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 typically last a very long time.

Twin Bed 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 use. 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 but 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 for Twin Bed dryers is in the region of 4 – 6 hours depending on the material and the initial moisture content. This type of dryer, however, tends to consume a lot of energy.

FIGURE 1 TWIN BED DESICCANT DRYER

DESICCANT WHEEL DRYER

Desiccant Wheel type dryers differ from desiccant bed type dryers in terms of size and operation. The dryer is based on a wheel which has desiccant crystals impregnated and grown on a fiberglass substrate. This lightweight wheel has a high desiccant surface area to air flow volume and has a much smaller thermal mass than the conventional canister. The structure also produces a lower pressure drop to both the process and regeneration blowers, allowing use of smaller, energy efficient blowers. The low thermal mass of the wheel allows the use of lower regeneration temperatures than conventional desiccant drying systems while still achieving the required overall temperature for effective regeneration. In addition since the desiccant wheel is in continuous rotating mode, the moisture adsorbed by the desiccant is mostly concentrated on the outer edge of the porous structure of the desiccant crystals, thus making it easy to regenerate.

The Desiccant Wheel dryer has a very short "warm up" time. Warm up time is the duration when the dryer reaches the final set resin moisture level after plug-in. The Desiccant Wheel dryer has a "warm up" time of less than 30 minutes compared to 4 to 6 hours for the Twin Bed dryer.

The Desiccant Wheel dryer is much more compact than a twin bed dryer, with a footprint about 25-35% of comparable twin bed dryers.

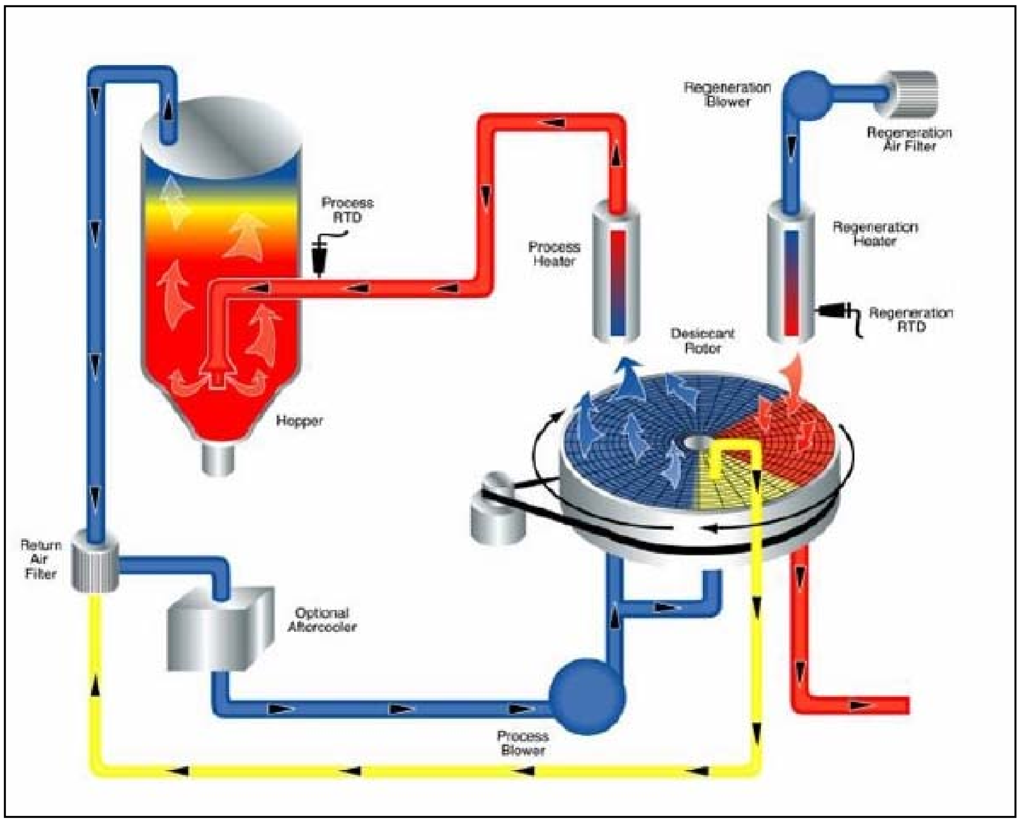

FIGURE 2 DESICCANT WHEEL DRYER

TESTING APPROACH

TEST BACKGROUND

The initial plan was to conduct energy efficiency evaluations on both dryers at the Accent Plastics facility in Corona. 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, the important factors that needed to be controlled were:

- Type of resin
- Initial and final moisture level of the resin
- Constant drying rate, almost at the top of the rating 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 Desiccant wheel 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 amble 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 dryer. Model # NDB 150
- The Desiccant Wheel dryer was a Novatec Model # NW 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) Set-up

Each dryer was set up and run on a trial basis one day before actual testing in accordance with the test plan. These set up 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 followed the trial test the next day.
- The Baseline dryer test and the Desiccant Wheel dryer test followed one after the other, with the Baseline test being the first.
- Instrumentation and data gathering were as described in the Test Measurement Devices Section above.
- Each test was four hours long.
- Each test data was tagged by "B" for Baseline and "H" for Desiccant wheel.
- 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 DESICCANT WHEEL DRYER

RUN NUMBER	SCHEDULE	DRYER TESTED	RUN TIME
1	**Day 1, First Run - trial**	**Twin Bed**	**1 hour**
2	**Day 1, Second Run - trial**	**Desiccant Wheel**	**1 hour**
3	**Day 2, First Run**	**Twin Bed Dryer**	**4 hours**
4	**Day 2, Second Run**	**Desiccant Wheel**	**4 hours**

RESULTS

DATA ANALYSIS

The data collected was analyzed to determine the electrical energy usage for both the Twin Bed dryer and the Desiccant Wheel dryer under equivalent operating conditions.

TWIN BED DRYER

The kW power demand of the Twin Bed 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 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 following equation.

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 pound to lkg conversion factor: 2.2 lbs = kg

Test results for the Twin Bed 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 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**.

DESICCANT WHEEL DRYER

The kW power demand of the Desiccant Wheel dryer was recorded over a four hour test period to obtain operating data comparable to the Twin Bed dryer test data. The kW power demand measurements were then averaged over the four hour cycle to obtain the average power demand (kW) for the Desiccant Wheel dryer for a 100lbs/hr process rate. Using measured average power demand (kW) data of **4.16 kW** from the Desiccant dryer test at a process rate of 100lbs/hr and Equation 1, an energy consumption of **9.16 kWh** to dry 100kg of resin was calculated.

DISCUSSION OF RESULTS

Comparison of the energy consumption of 17.34 kWh needed to dry 100kg of resin for the Twin Bed dryer to the energy consumption of 9.16 kWh needed to dry 100kg of resin for the Desiccant Dryer showed a 47.2% savings in energy using the Desiccant dryer over the Baseline Twin Bed dryer.

TABLE 2 SAVINGS COMPARISON OF THE TWO DRYERS

DRYER TYPE	KW	KWH/100 LBS	KWH/100 KG
Twin Bed	7.88	7.88	17.34
Desiccant Wheel	4.16	4.16	9.16
Savings	3.72	3.72	9.18

There were additional important benefits for the Desiccant Wheel dryer over the Baseline dryer that were verified by the tests. First of all, the final resin moisture level conditions were essentially constant 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 four hours of the Desiccant Wheel dryer test the final moisture level stayed below 200 PPM and was controlled within a very small range. The Twin Bed dryer on the other hand showed more variability, even though the final resin moisture level was always below the 200 PPM target level.

TABLE 4 FINAL MOISTURE LEVEL COMPARISON OF THE TWO DRYERS

DRYER TYPE	INITIAL MOISTURE (PPM)	AVERAGE FINAL MOISTURE LEVEL (PPM)	RANGE OF FINAL MOISTURE LEVEL (PPM)
Twin Bed	1,591	24.8	59
Desiccant Wheel	1,563	36.2	35

A second benefit for the new Desiccant Wheel dryer, mentioned earlier, is the very short "warm up" time of less than 30 minutes. Warm up time is the duration when the dryer reaches the final set resin moisture level after plug-in. This period ranges from about two hours to about six hours for Twin Bed dryers under production conditions. During this time molding operations cannot be started. It is considered wasted time for the operators. This is especially costly to the customer when they operate under job-shop mode because of the frequent product changes on the line. The Desiccant Wheel dryer had a "warm up" time of less than 30 minutes.

TECHNOLOGY COSTS

CAPITAL COSTS

A comparison of initial capital costs of the Baseline Twin Bed dryer and the Desiccant Wheel dryer are presented in Table 2.

TABLE 5 SUMMARY OF CAPITAL COSTS FOR BASELINE TWIN BED DRYER AND DESICCANT WHEEL DRYER

PROCESS RESIGN FLOW RATE (LBS/HR)	BASELINE TWIN BED DRYER COST	DESICCANT WHEEL DRYER COST
100	$10,500	$12,700
200	$18,300	$16,050

For new equipment purchases the Desiccant Wheel dryer is a little more expensive in the 100lbs/hr size, but the increased price vanishes and reverses for larger sizes. It is also to be noted that these are plug-in equipment moveable on wheels, so installation costs are not applicable.

OPERATING AND MAINTENANCE COSTS

Compared to the Baseline Twin Bed dryer, the Desiccant Wheel dryer provides a previously discussed 47.2% savings in electrical energy usage.

The Desiccant Wheel dryer also offers an ongoing desiccant-related maintenance cost advantage. The Baseline Twin Bed dryer utilizes 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.

The Desiccant Wheel dryer uses a desiccant permanently bonded onto the woven desiccant substrate offering a much longer lifetime. The Desiccant Wheel has a projected life of 15 years, substantially reducing desiccant-related maintenance costs.

CONCLUSION

The tests showed 47.2% energy savings for the Desiccant Wheel dryer over the baseline Twin Bed dryer. The Twin Bed dryer recorded an average kW power level of 7.88 Kw during the test cycle, while the Desiccant Wheel recorded 4.16 kW. Both tests were carried out at a drying rate of 100 pounds an hour. Both dryers used the same polycarbonate resin from one single batch with the same initial conditions. For a molder or extruder, this equates to 17.34 kWh/100 kg versus 9.16 kWh/100 kg of resin dried.

The confidence level of this data will depend on the accuracies of the metering devices utilized in testing. The instrumentation accuracies are discussed in the attached Test Plan. Based on these accuracies the maximum error estimate is 0.5 kW or less, which is far less than the recorded savings of 3.72 kW.

There were several additional important benefits for the Desiccant Wheel dryer over the Baseline dryer. First of all, the final resin moisture level conditions were essentially constant with the new dryer which is a very important quality control issue for the customer. Throughout the four hours of the Desiccant Wheel dryer test the final moisture level stayed below 200 PPM and was controlled within a very small range. The Twin Bed 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 dryer is the very short “warm up” time. Warm up time is the duration when the dryer reaches the final set resin moisture level after plug-in. This period ranges from about two hours to about six hours for Twin Bed dryer under production conditions. During this time molding operations cannot be started. It is considered wasted time for the operators. This is especially costly to the customer when they operate under job-shop mode, because of the frequent product changes on the line. Desiccant Wheel dryer had a “warm up” time of less than 30 minutes.

Third, the Desiccant Wheel dryer is much smaller than a Twin Bed dryer, with a footprint about 25-35% smaller than the twin bed dryers.

For new purchases the Desiccant Wheel dryer is a little more expensive in the 100lbs/hr size than the Baseline unit, but the increased price vanishes and reverses for larger sizes. In addition to the operating savings from reduced electrical energy use, the Desiccant Wheel dryer offers a significant maintenance cost advantage due to its much longer desiccant life.

In general, the Desiccant Wheel dryer should be the choice for customers using polycarbonate, ABS, and PET resins.

APPENDIX – TEST PLAN

Description:

This testing is designed to establish the electric energy consumption and drying energy efficiency in *kWh per 100 pounds* and drying efficiency in *kWh/100 pounds* of two new resin dryers currently available for plastic fabrication processes. Desiccant and vacuum dryers offer potential energy savings compared to the base case existing technology. The D&ES project recommendation (ET 04.11) provides the justification, rationale and background information for performing these tests.

Basic test assumptions:

1. All dryers in this test are capable of drying a variety of plastic resins. For purposes of this test, only polycarbonate resin will be used.
2. The base case resin drying equipment is the Twin Bed Desiccant Dryer (NBD150). This dryer is the current standard for drying resins by the side of the press, and so is taken as the *Baseline Dryer.*
3. Dryers offering potential energy savings are
   - Desiccant Dryer (NW100)
   - Vacuum Dryer (VRD100)
4. The moisture content of the supplied resin is expected to be 0.14-0.16%
5. The target moisture content after drying is 0.002%.
6. Novatec laboratory personnel have experience in testing resin for moisture content, establishing necessary drying rate for proper processing, and measuring energy consumption of the drying process.

Test instrumentation:

1. Laboratory scale – AND Model HP 30, accuracy: 1 gram or .5 % accuracy of full scale.
2. Computrac Humidity meter, model MAX2000XL, accuracy: 0.0005% or .5% moisture of full scale.
3. Fluke kW meter, 0-50 kW, accuracy: 0.5% of full scale, and/or, Hawkeye kW meter, 0-36.03 kW range, accuracy: 0.5% of full scale.
4. Stop watch or similar time keeping device.

Test procedure:

Pre-test:

Even though each dryer has certain maximum drying rate claimed by the manufacturer, it may not be accurate for polycarbonate resins. It is important to conduct the testing at the same drying rate for all three dryers, and also achieve the same end points for moisture level. A pre-test will be conducted to establish that rate.

- Moisture content of the polycarbonate material will be measured as supplied. Novatec personnel will ensure that plastic remains unexposed to the environment during testing so that supply media does not change moisture content during pre-testing.
- b. Feed rate for each dryer will be established based on moisture samples taken after the dryer and by weight change of the supply material. The target moisture content after each dryer is 0.002%. The target feed rate is 100 pounds per hour. If 100 lbs/hr is not achievable by all of the dryers, then the highest mutually achievable production rate will be used for testing and comparison purposes.

Test procedure:

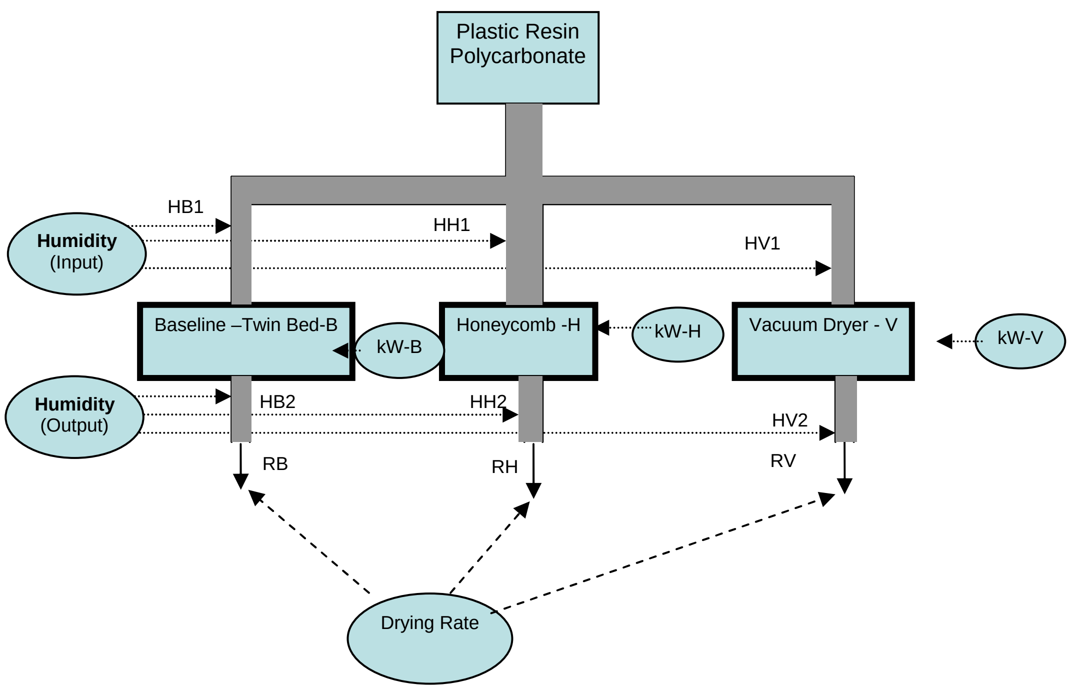

FIGURE 3. TEST SCHEMATIC FOR PLASTIC DRYER TEST

The above test schematic explains the procedure for testing the three dryers. The test will be conducted at the drying rate determined in the Pre-Test explained earlier.

- Fluke and Hawkeye meters will be connected and set up to measure kW values of the dryer at 15 second intervals, averaging and logging these values every 60 seconds.
- Moisture content of the polycarbonate material before the dryer(s) will be measured. Novatec personnel will ensure that plastic remains unexposed to the environment during testing so that supply media does not change moisture content during testing.
- Feed rate for the Twin Bed dryer (NBD150) will be set as established in pre-testing.
- Test run is started using stop watch or similar, initial readings/measurements are taken for moisture content and weight of supply material. Fluke and Hawkeye meters begin measuring and logging electrical data.
- Every 30 minutes, material weight and polycarbonate moisture content after the dryer is measured and recorded. If feed rate or moisture content of the material is not correct, adjustments will be made to the feed rate and the test will be re-started.
- The desired test duration for each dryer is approximately 3 hours. At the end of the test run, the moisture content of the supply material will be measured again to verify that the supply material moisture content did not change significantly. If it varies sufficiently, material handling procedures will be examined and modified as necessary to minimize the variation in supply material moisture and the test will be run again.
- At the end of the test run, weight, moisture and kW data will be reviewed, and the kWh per 100 pounds of material dried calculated. The following data will be summarized for each dryer:
    - Initial and ending moisture levels for the supply polycarbonate material (it is important that these numbers are about the same, otherwise testing will have to be performed again)
    - Weight measurements of material at 30 minute intervals to confirm consistent and desired feed rate.
    - Average and peak (one minute average peak) kW (these numbers should be about the same) for each dryer recorded.
    - kWh per 100 pounds of material (this value will be used to determine energy consumption for each dryer and energy savings for the Honeycomb and Vacuum dryers)

Test Notes:

- The Edison Program Manager will determine allowable levels of variance between tests for feed rate, weight, and moisture measurements to result in defensible energy consumption and energy savings data.
- After the test equipment, instrumentation and materials are set-up for the pre-testing, Novatec and the Edison Program Manager will determine if it is possible to test more than one dryer at the same time. The desired test configuration is presented in Figure 1.

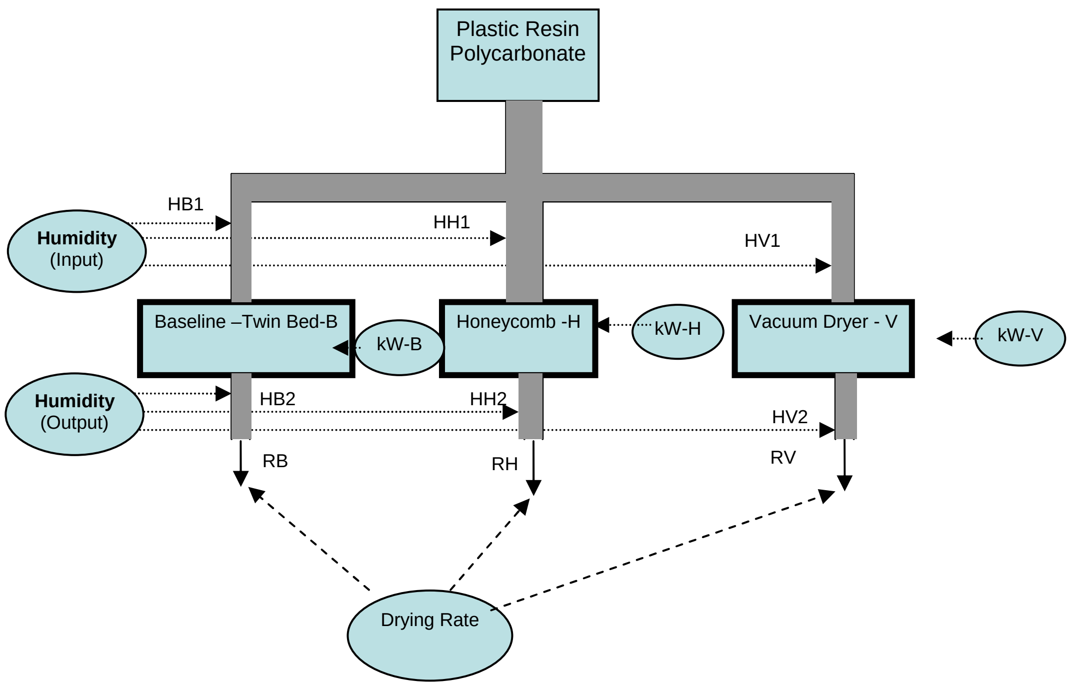

FIGURE 4. TEST SCHEMATIC FOR PLASTIC DRYER TEST