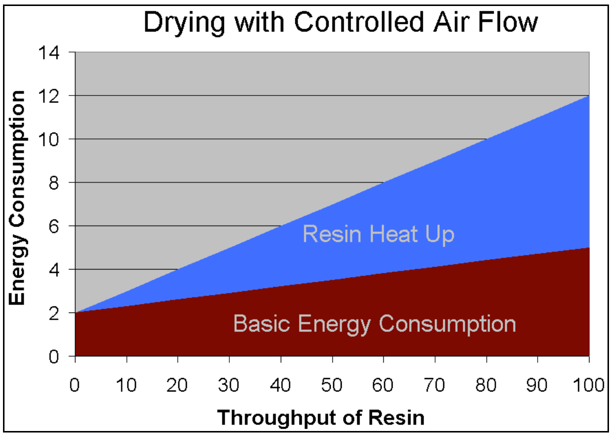
Extended Standard for Energy Rating with Resin Dryers and Classification of Dry Air Quality

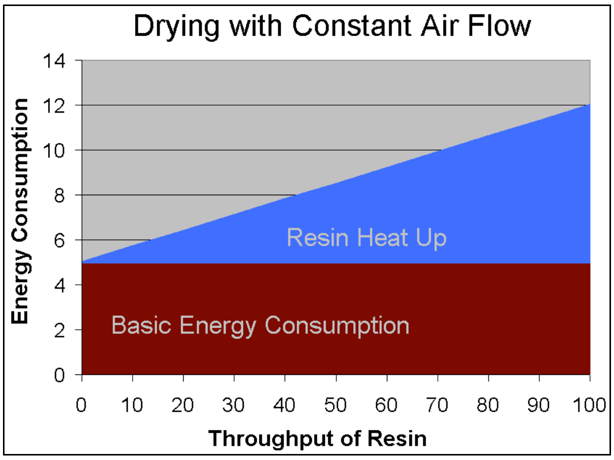
1 Introduction

This standard is defining a rating value to compare different dry air dryers in energy consumption. The rating value is the basic energy consumption normalized at 1,000 kg of dry air.

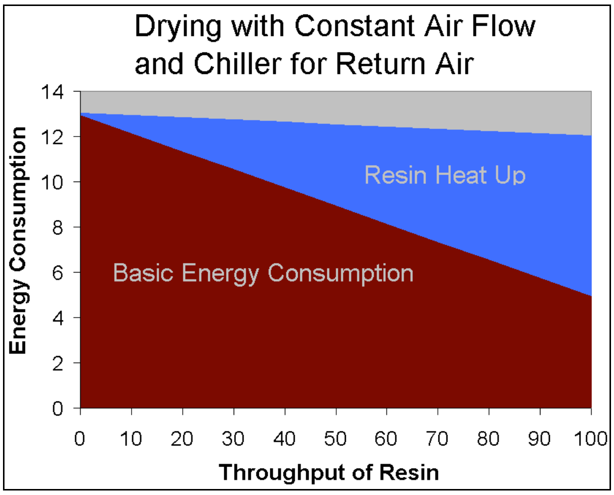
In reality the throughput lies between zero and the maximum of the dryer capacity. There are three different mathematical models to calculate the total energy consumption within a production – if the design features of the dryer are known. The total energy consumption is the basic consumption added to the heat energy of the resin.



Mathematical model 1: Dryer with controlled frequency transformer



Mathematical model 2: Standard dryer



Mathematical model 3: Standard dryer with chiller

All three models are using the maximum throughput for the calculation, and all are leading to the same energy consumption. But with partial load or machine stop we find huge differences.

The heat-up is a material property and independent from the type of dryer. The following table gives a rough overview of some main materials:

Resin at room temperature	Drying heat per 1,000 kg resin at drying temperature
ABS	19.9 $\frac{kWh}{1{,}000\,kg}$
PA6	26.0 $\frac{kWh}{1{,}000\,kg}$
PBT	39.6 $\frac{kWh}{1{,}000\,kg}$
PC	30.9 $\frac{kWh}{1{,}000\,kg}$
PEEK	81.0 $\frac{kWh}{1{,}000\,kg}$
PMMA	22.5 $\frac{kWh}{1{,}000\,kg}$

By means of Energy Rating it is possible to compare different drying systems in regard to their energy efficiency. With rating data it is also possible

- to calculate the energy consumption within a production,
- to calculate the maximum drying capacity of a selected material,
- to compare dryers directly in regard to their energy efficiency.

2 Ambient Condition

The rating measurements are done under the following ambient conditions.

The room temperature ranges from 27°C (80°F) up to 38°C (100°F).

The moisture is measured in dew point and lies between 20°C (68°F) and 24°C (75°F). The preferred measurement system is a chilled mirror.

3 Measurements for Energy Rating

The measurements are executed with a dryer that is linked to a resin filled hopper. The hopper size is typical for a given maximum throughput (residence time of about 3 hours).

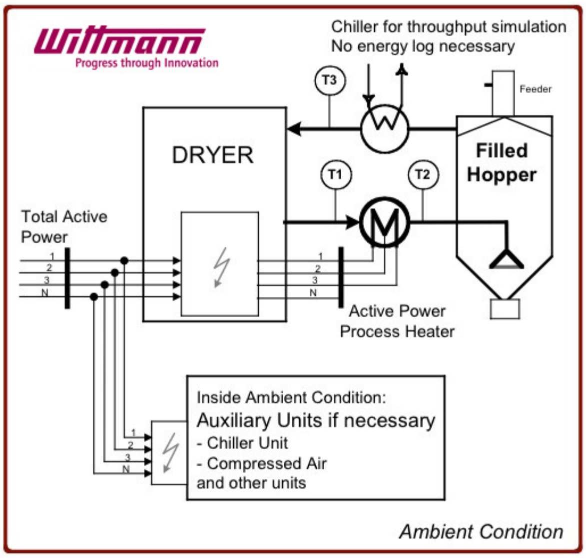
The set drying temperature is 80°C (176°F).

If the dryer is equipped with a dew point sensor, the set dew point is -40°C (-40°F).

If the dryer should need cooling water, it is connected to chillers that are situated within the conditioned area.

3.1 Electrical Power

The total active power P_{total} is measured, and separately, the active power of the process heater P_{heater} is measured. A sliding average is calculated over 5 minutes. Both power data are recorded for further analysis.



Principle of energy measurement

3.2 Temperatures at Process Heater

The difference between T2 and T1 temperatures is recorded every 2 seconds (or more often). An average of all the difference temperatures ΔT is calculated over a period of 60 seconds. This average value is recorded for further use.

3.3 Simulation of maximum throughput

A chiller is placed in the way of the return air that is coming from the hopper. Temperature T3 is set between 45°C (110°F) and 50°C (120°F). An energy log of the chilling power is not necessary. In case of a real throughput the energy also is discharged from the drying process.

A chiller turn-off stops the throughput simulation (IMM Stop).

4 The Rating Value

4.1 Basic Energy Consumption

The basic energy consumption is the average value of the total electrical power [kW], appraised over 5 hours or more.

$$P_{total}\,[kW] = \frac{1}{N}\sum_{i=1}^{N} P_i \qquad (1)$$

4.2 Dry Air Massflow

The mass flow is calculated from the power equation:

$$P_{heater} = c_P \cdot \dot{m} \cdot \Delta T$$

		Units
P_{heater} :	Electric Power from Process Heater	$kW = \frac{kJ}{s} = \frac{kJ}{s}\cdot\frac{3{,}600s}{h}$
c_P :	Specific Heat of Air	$1{,}005\frac{kJ}{kg\cdot K}$
$\dot{m}$:	Mass per Time	$\frac{kg}{h}$
ΔT :	Temp. Difference	$°C - °C = K$

Mass flow of air

$$\dot{m}[\tfrac{kg}{h}] = \frac{3600\,\tfrac{s}{h}\cdot P_{heater}[kW]}{1.005\,\tfrac{kJ}{kg\cdot K}\cdot \Delta T[K]} \qquad (2)$$

4.3 Rating Value

The rating value is the energy consumption per 1,000 kg dry air. It is calculated using value (1) and (2):

$$Rating\,[\tfrac{kWh}{1{,}000kg}] = 1{,}000\cdot\frac{P_{total}\,[kW]}{\dot{m}\,[\tfrac{1{,}000\,kg}{h}]} \qquad (3)$$

4.4 Conversion to Imperial Units

Basic Energy Consumption		
SI Unit	conversion	Imperial Unit
kWh	$1kWh = 1kWh$	kWh

Dry Air Massflow		
SI Unit	conversion	Imperial Unit
$\frac{kg}{h}$	$1\frac{kg}{h} = 2.20462\frac{\text{lb}}{\text{h}}$	$\frac{lb}{h}$

Rating Value		
SI Unit	conversion	Imperial Unit
$\frac{kWh}{1{,}000\,kg}$	$1\frac{kWh}{1{,}000\,kg} = 0.9072\frac{\text{kWh}}{2{,}000\,\text{lb}}$	$\frac{kWh}{2{,}000\,lb}$

5 Classification of dry air quality

5.1 Background

The Energy Rating value is only significant in regard to the energy consumption. Resin drying requires a suitable dew point, because the drying speed is depending on the drying temperature and the vapor pressure. The difference between the vapor pressure inside and outside of the resin is creating the force that is extracting the water from the resin.

The vapor pressure is similar to the dew point and can be converted:

Dew Point		Vapor Pressure	
°C	°F	mbar	"w.c.
-60	-76	0.009	0.0036
-50	-58	0.039	0.016
-40	-40	0.124	0.0498
-30	-22	0.373	0.15
-20	-4	1.03	0.414
-10	+14	2.6	1.04
0	+32	6.11	2.45
+10	+50	12.3	4.82
+20	+68	23.3	9.23

This is showing a not linear relation between dew point and vapor pressure. Especially when the dew point is fluctuating heavily, the data from this relation are leading to different average values.

5.2 Measurement of Dry Air Class

During the measurement of the rating values the dew point is recorded by means of a dew point meter: a chilled mirror.

For the calculation of the average value of the vapor pressure approximation formula “dew point to vapor pressure” is used. The approximation formula is valid for dew points < 0°C (32°F).

$$vapor-pressure\,[mbar] = 6.103 \cdot 10^{10} \cdot e^{\frac{-6282}{dew\,point\,[Kelvin]}}$$

5.3 Dry Air Classification

The dry air classification is using the average (over time) of the dry air vapor pressure.

Classification of Dry Air	
Dry Air Class	Average of Vapor Pressure
A+ excellent	< 0.17 mbar (-37°C or below) (-35°F or below)
A good	0.17 mbar … 1.03 mbar (-37°C … -20°C) (-35°F … -4°F)
B good enough for some resins	1.03 mbar … 6.11 mbar (-20°C … 0°C) (-4°F … +32°F)
C like a Hot Air Dryer	> 6.11 mbar (.0°C or above) (+32°F or above)

6 Measurement Data

The dryer has to be measured in four situations:

Nº	Frequency	Throughput simulation
1	@50 Hz	IMM stop
2	@50 Hz	Maximum throughput
3	@60 Hz	IMM stop
4	@60 Hz	Maximum throughput

From this a set of rating data is arising:

Nº	Basic Load	Air Capacity	Rating Value
1	applying equation (1)	applying equation (2)	applying equation (3)
2			
3			
4			

7 Energy Sticker

The main value on the Energy Sticker is the Rating Value. From the four different measurement data (see chapter 6) the average is calculated.

Beside this average rating value the sticker is also presenting the basic load as well as the air capacity values that have occurred in all four measured situations.

Energy Sticker with constant air flow, SI Units

Energy Sticker with controlled air flow, SI Units

Applying the table from chapter 4.4 makes it possible to convert the results into imperial units.