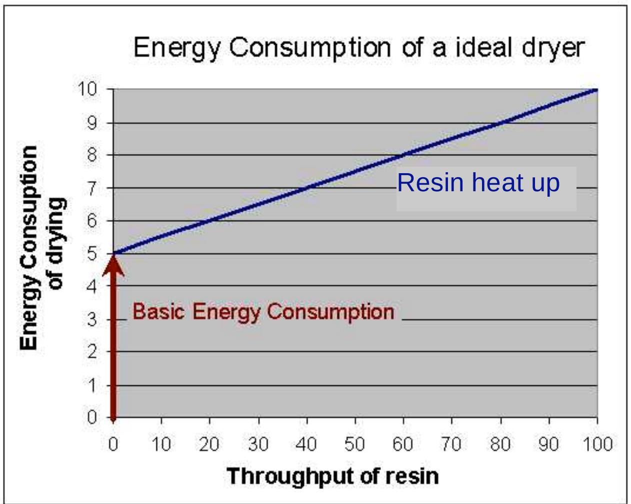
Standard for Energy Rating with Resin Dryers and classification of dry air quality

Resin at room temperature	Drying heat per 1000kg 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 $\frac{kWh}{1{,}000\,kg}$

1 Introduction

With this standard we define a rating value to compare different dry air dryers in energy consumption. The rating value is the basic energy consumption normalized at 1000 kg air.

In a real production the throughput is between zero and maximum of the dryer capacity. It is possible to calculate the total consumption within a production if we know the basic energy consumption. The total energy consumption is the basic consumption add with the heat energy of the resin.



The heat energy is a material property and independent of the type of dryer. The next table gives a rough overview of some main materials:

2 Ambient Condition

The rating measurement are taken within a range of ambient condition.

The room temperature is 27°C (80°F) up to 38°C (100°F)

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

3 Measurements for Energy Rating

The energy rating is taken from a dryer with a filled hopper. The hopper size is typical to a given maximum throughput (residence time about 3 hours).

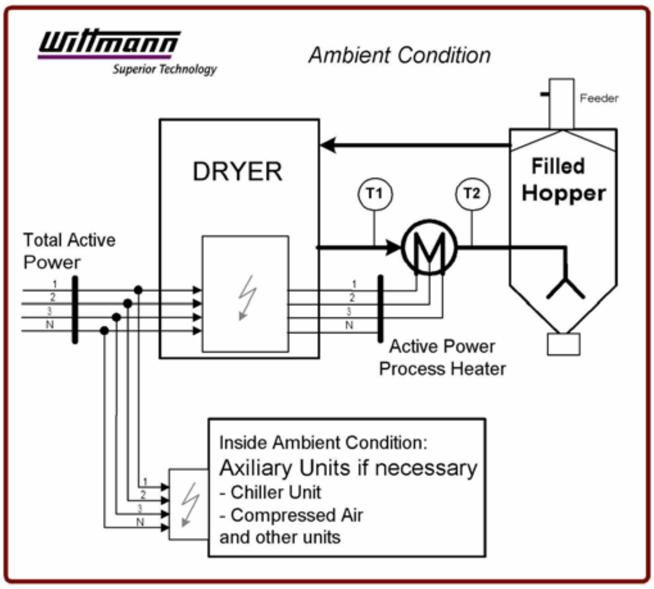
Set the drying temperature at 80°C (176°F).

If the dryer equip with a dew point sensor the set dew point is –40°C.

If the dryer equip with a chiller connect to the water and switch on.

3.1 Electrical Power

We measure the total active power P_{total} and separate the active power of the process heater P_{heater} and build a average over 30 seconds. Both power data we save for later calculation. The measurement is taken with 50 Hz and 60 Hz power supply and calculate separate.



Principle of Energy Measurement

3.2 Temperatures at Process Heater

The difference of temperatures T2 – T1 is taken every 2 seconds (or faster). Over 30 seconds we build a average of each difference temperature ΔT and save the average for later calculation.

4 Calculate the Rating Value

4.1 Basic Energy Consumption

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

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

4.2 Calculate Dry Air Massflow

The mass flow is calculate from the power equation

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

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

Mass flow of air

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

4.3 Rating Value

The rating value is the energy consumption per 1000 kg dry air and calculate with value (1) and (2):

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

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

The energy rating we define give only answer of energy consumption. Resin drying requires a low dew point and the drying speed depends on the drying temperature and the vapor pressure. The difference of the vapor pressure inside the resin and surround creates the force the water coming out of the resin.

The vapor pressure corresponds with the dew point:

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	0.150
-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

We see a not linear behavior between dew point and vapor pressure. Especially with a wide range of dew point variations we find a difference calculating the average directly with the dew point and calculating the average with vapor pressure and convert back to dew point.

The dry air classification use the average over time with vapor pressure of the dry air.

Classification of dry air	
Dry Air Class	Average of Vapor Pressure
A	< 0.17 mbar (–37°C or below) (–35°F or below)
B	0.17 mbar … 1.03 mbar (–37°C … –20°C) (–35°F … – 4°F)
C	1.03 mbar … 6.11 mbar (–20°C … 0°C) (– 4°F …+ 32°F)
D	> 6.11 mbar (0°C or above) (+32°F or above)

During measurement of the rating values we take the dew point of process air with a chilled mirror dew point meter.

For calculation the average of vapor pressure we use the approximation to convert dew point below 0°C (32 °F) to vapor pressure:

$$vapor\ pressure\ [mbar] = 6.103 \cdot 10^{10} \cdot e^{\frac{-6{,}282}{dew\ point\ [Kelvin]}}$$

6 Energy Sticker

The energy sticker contains 3 values, the Basic Energy Consumption; the Dry Air Massflow and the Rating Value.

Example of the Energy Sticker SI Units

With the rating data it is possible

- to calculate the energy consumption within a producton
- to calculate the maximum drying capacity of a selected material
- to compare directly dryers with dryers in energy efficiency