German Drying Technologies

a little seminar on Hop Drying

Joh. Barth & Sohn GmbH & Co. KG

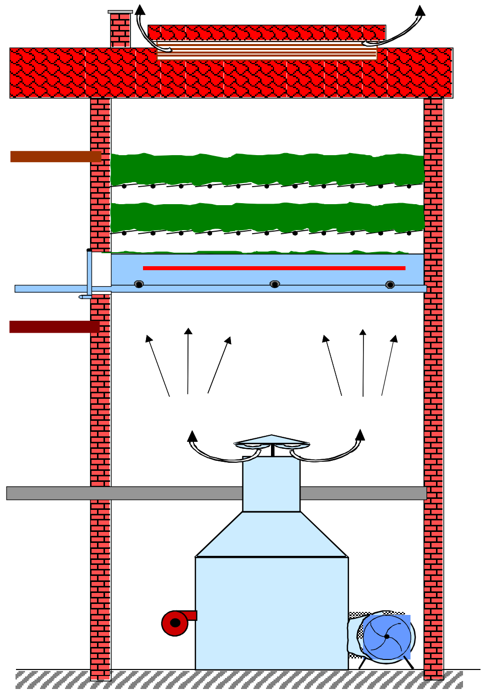
Traverse City, March 2016

Content

1. Hop Drying in Germany – traditional and new
2. Quality Assurance Hop Drying - theory
3. Parameters of Hop Drying
4. Parameters Responsible for Improvements
5. Discussion

Hop Drying in Germany

- approx. 85 % tier kilns with 3 or 4 layers, incl. one bottom drawer
- rest belt dryer with usually 3 layers
- temperatures 63 - 65° C (145- 149° F)
- kilning time 5 – 6 hours
- kilning takes place with hot air
- heated with diesel burner and heat exchanger (indirectly fired)



scheme of a hop kiln

kilning temperature: 62-65°C

dumping height: 30-35 cm (1 ft)

source: J. Münsterer, LfL Bayern

Hop Drying in Germany

• average diesel consumption per 100 kg (220 lbs) dry hops: approx. 50 liters (13.2 US Gal), which equates 12.0 US Gal/bale (200 lbs)

• average performance per m² (10.8 ft²) kiln area and hour: approx. 5 kg (11 lbs)

• 15 years of development by Bavarian Institute for Agriculture

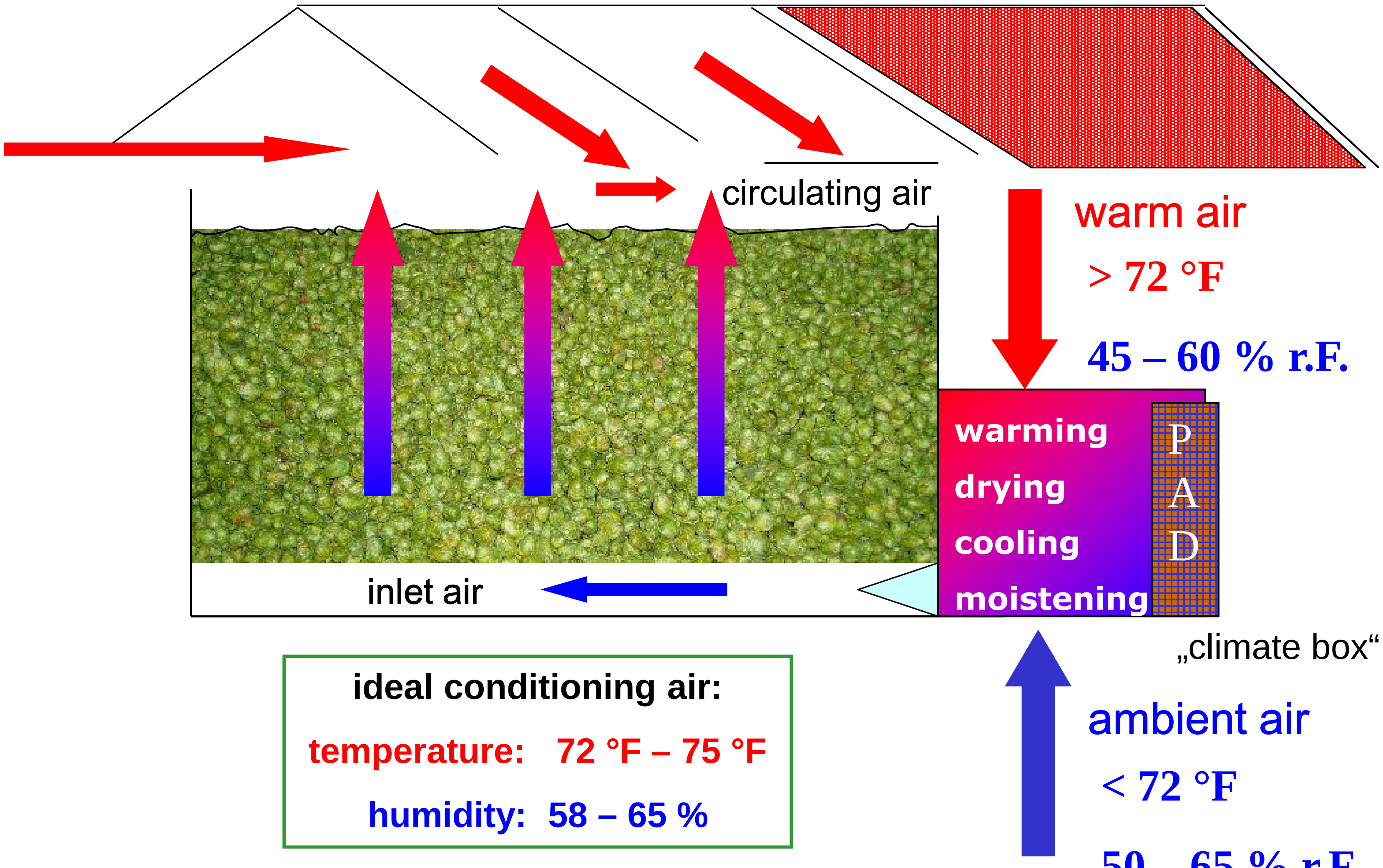
• for 6 to 8 years implementation of results in practical use by several companies

Hop Drying in Germany

Hop Drying in Germany

excursus: conditioning

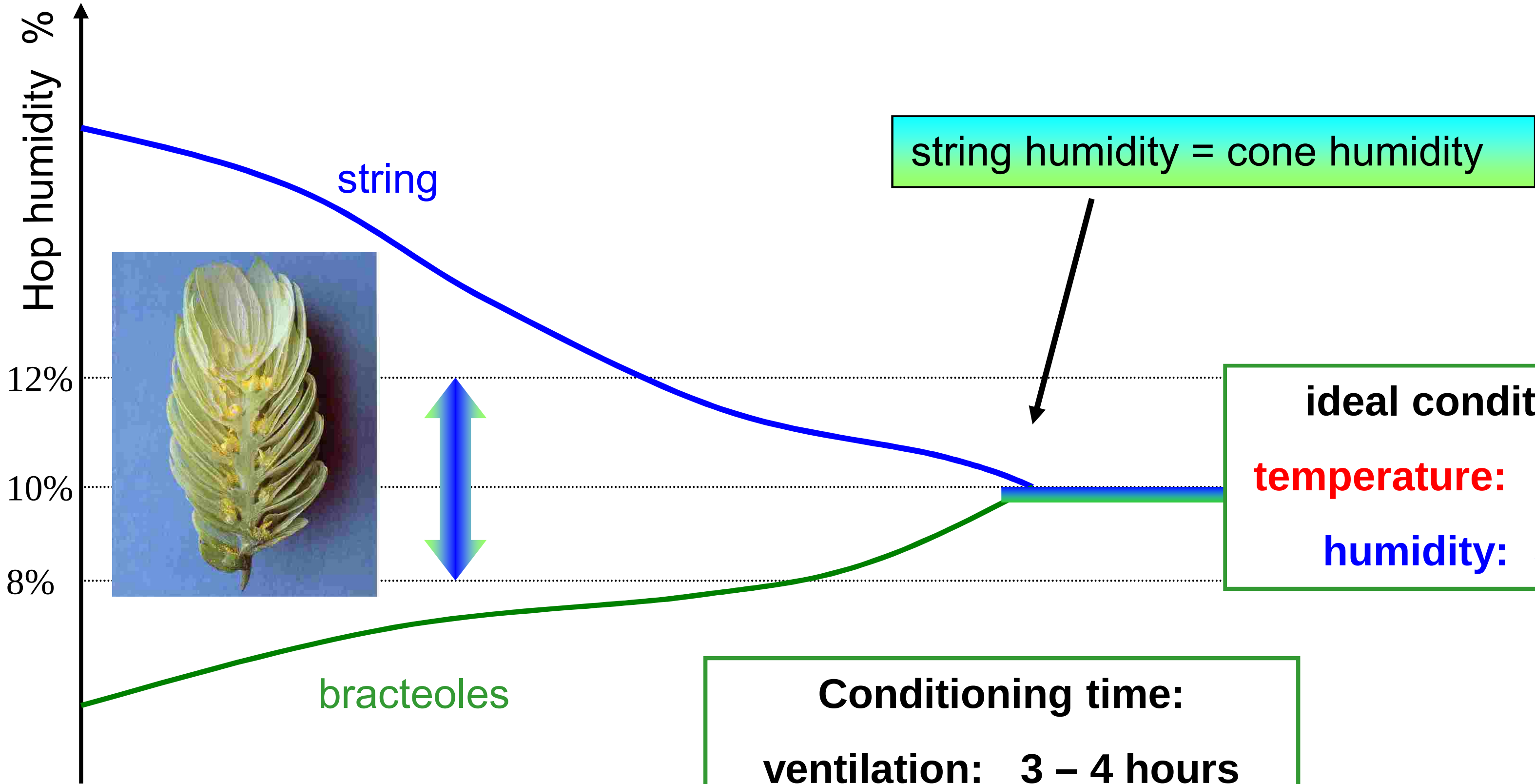
Hop Drying in Germany



source: J. Münsterer, LfL Bayern

Hop Drying in Germany

Temperature is responsible for water delivery of the string!



ideal conditioning air:

temperature: 72 °F – 75 °F

humidity: 58 – 65 %

Conditioning time:

ventilation: 3 – 4 hours

resting: 1 – 2 hours

source: J. Münsterer, LfL Bayern

Hop Drying in Germany

…finally baleing:

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Quality saving Hop Drying

Requirements to a hop kiln:

1. saving quality = first priority!
2. Performance – volume per day
3. Efficiency regarding energy consumption

Points 2 and 3 are subordinates, both can be optimized as long as point 1 is assured!

Quality saving Hop Drying

How can quality be aussured?

➔ temperature must not be too high (damage by kilning, a cooked/over-dried aroma)

➔ avoid too much kilning (damage of cone structure, waste of energy)

➔ avoid water condensation on the top layer (loss of color, spoiled cones)

➔ water needs to transported away from the cone as fast as possible!

Quality saving Hop Drying

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➔ Water needs to transported away from the cone as fast as possible!

Therefore it is necessary to know some kilning physics! Most important parameters are:

- kilning temperature
- airspeed measured in m/s
- ratio of temperature to airspeed
- water content of fresh air (kiln entering) and waste air (kiln exit)

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Parameters of Hop Drying

- kilning temperature between 62° C (144° F) and 67° C (153° F)
- air speed in m/s

    ➔ calculated from difference of temperature, kiln area and diesel consumption per hour

- ratio of temperature to airspeed

    ➔ high airspeed causes channeling (blow holes) in the top layer

    ➔ high temperature with low airspeed causes water condensation and settling of the top layer, leading to "stewing"

Parameters of Hop Drying

Perfect ratio of airspeed and kilning temperature:

• temperature **62° C** (144° F), airspeed from **0.30 to 0.35 m/s (1.0 ft/s)**

• temperature **67° C** (153° F), airspeed from **0.40 to 0.45 m/s (1.3 ft/s)**

• temperatures above 70° C (158° F) can harm hops due to over kilning! In most cases the air speed will be too low to allow water evaporation (from bracts to air) properly. Due to this the evaporative cooling effect at the cone is not high enough.

When airspeed is controlled modularly, speeds of more than 0.45 m/s (1.65 ft/s) are possible.

At higher speeds blow holes in the top layer occur without optimization of wind distribution!

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water condensation in the top layer

Higher temperatures result in a higher rate of water migration from strig to bracteoles, which increases kiln air humidity.

An airspeed too low results in the kiln air becoming saturated with water prior to reaching the upper bed.

As kiln air absorbs water the air cools down. Cooler air can not absorb (hold) as much water and therefore the water from the air may condense in the top layer. This causes higher air resistance (denser hop bed), decreased airspeed and hop quality suffers due to heating of the hops in with moist air.

Parameters of Hop Drying

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How can you avoid condensed water in the top layer?

• by measuring air humidity [%] in the exhaust air!

➔ air humidity must not be above 90 % for any length of time!

• by measuring temperature in the exhaust air!

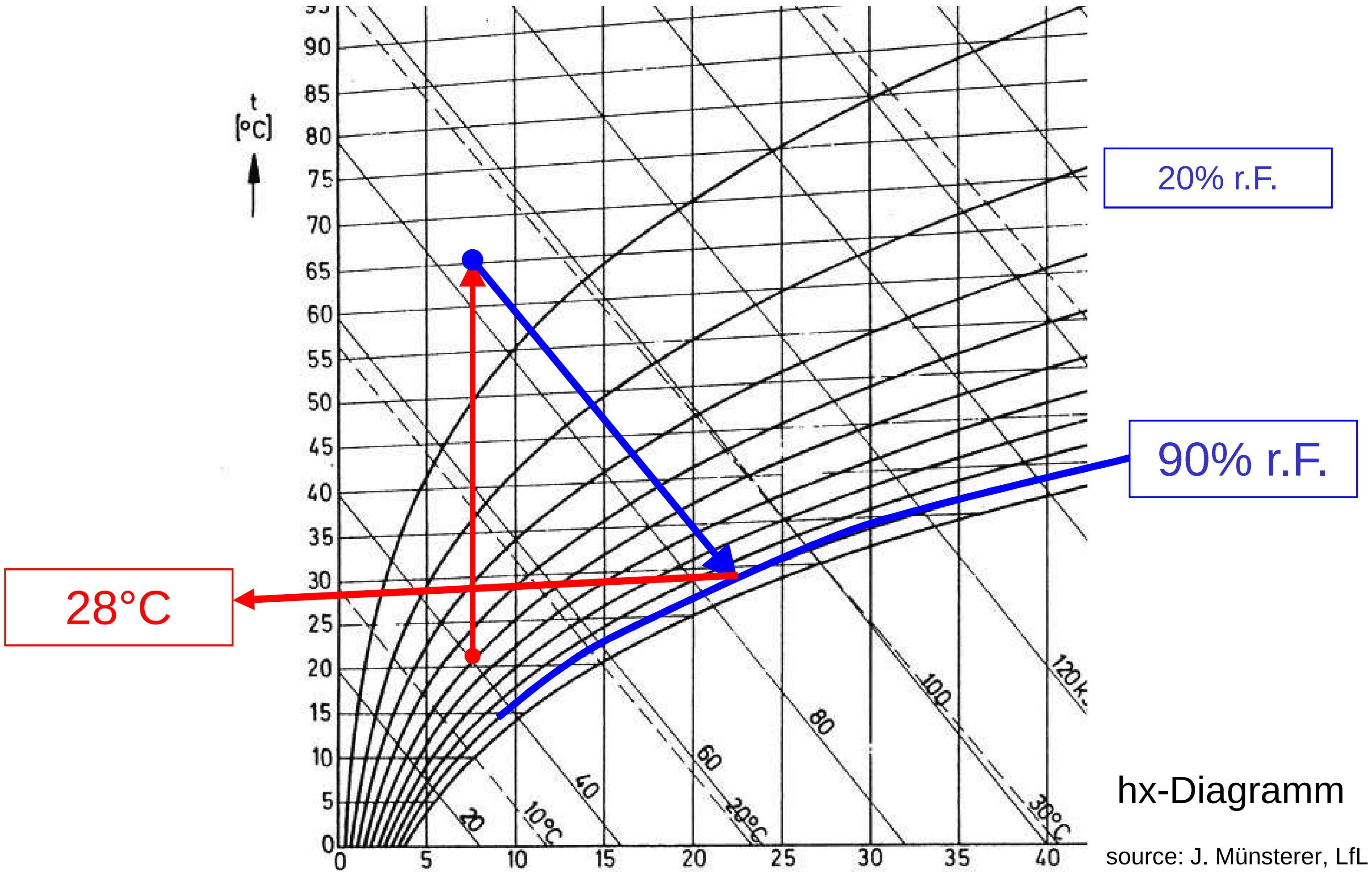
➔ at a kilning temperature of 65° C (149° F) temperature of exhaust air must reach 28° C (36° F) after a short while!

➔ at a kilning temperature of 67° C (153° F) temperature of exhaust air must reach 30° C (86° F) after a short while!

➔ at lower kilning temperatures this is correspondently less!

Parameters of Hop Drying

temperature and air humidity of exhaust air



hx-Diagramm

source: J. Münsterer, LfL Bayern

Parameters of Hop Drying

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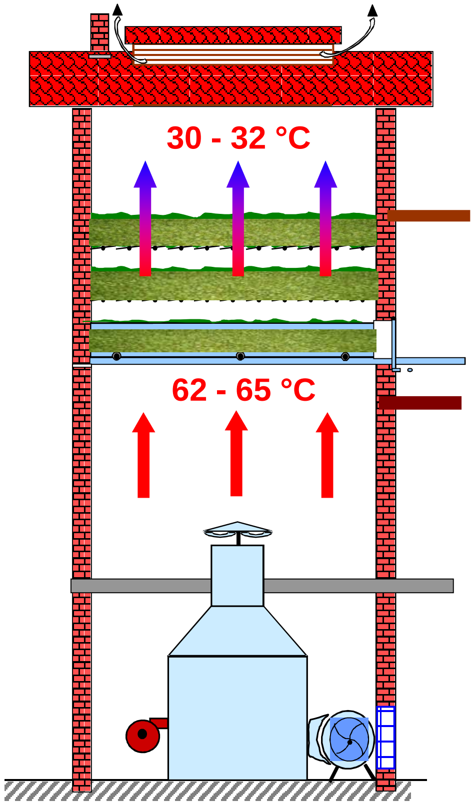
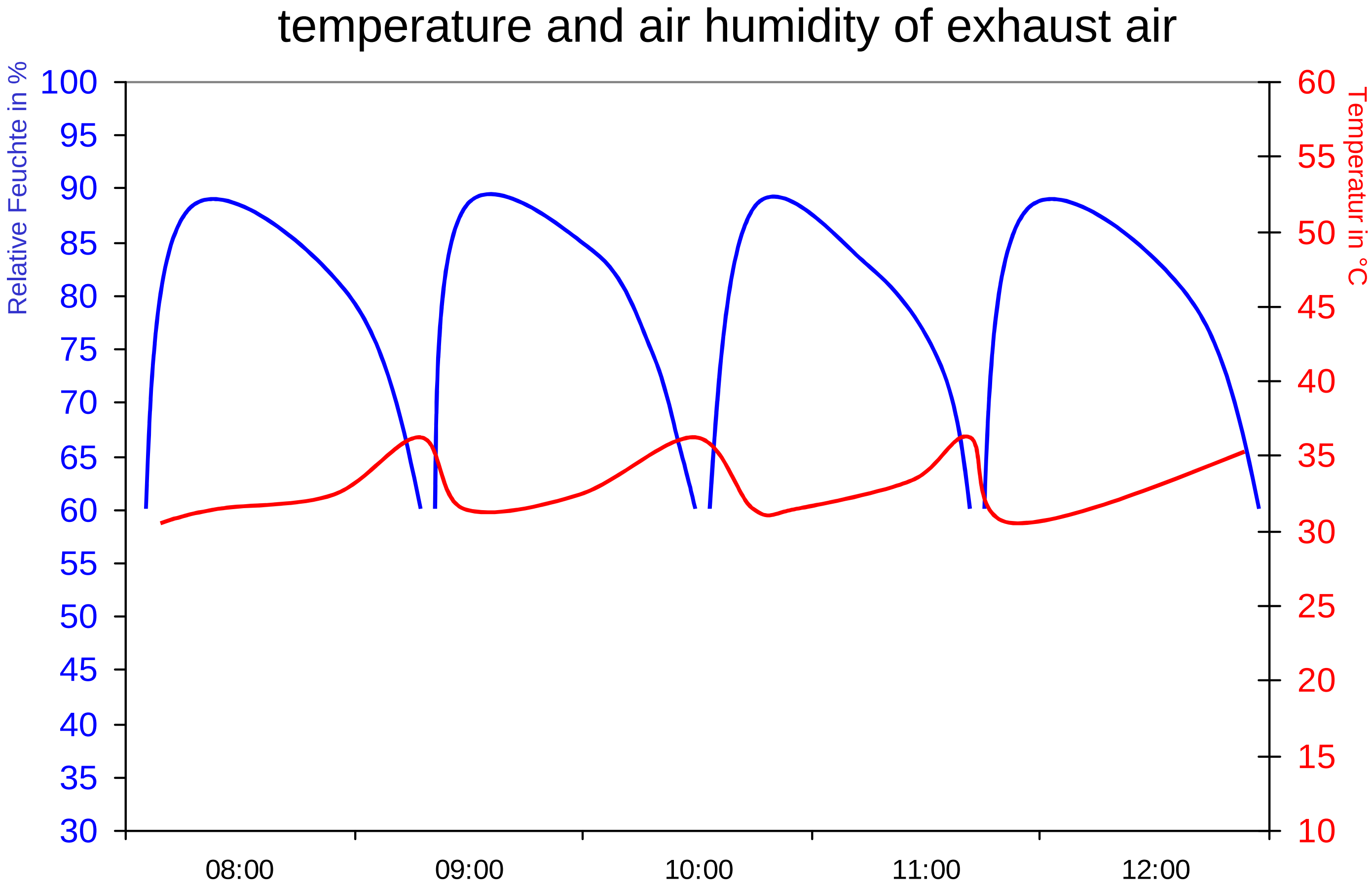
temperature and air humidity of exhaust air



scheme of a hop kiln



source: J. Münsterer, LfL Bayern

Parameters of Hop Drying

In modern kilns airspeed can me modulated and raised so far such that water is taken out sufficiently/efficiently from the top layer, and the kilning process takes place more homogeneous.

If it is not possible to increase airspeed because the performance limit of the fan is already reached, it is necessary to lower the dumping height. this raises airspeed as well.

Lowering temperature slows down water transport from the string to bracteoles. Consequently less water is discharged from the cone and absorbed by the kilning air. Due to this the kilning air can still absorb water in the top layer of the kiln.

In both cases water condensation is avoided!

Parameters of Hop Drying

kiln bed depth

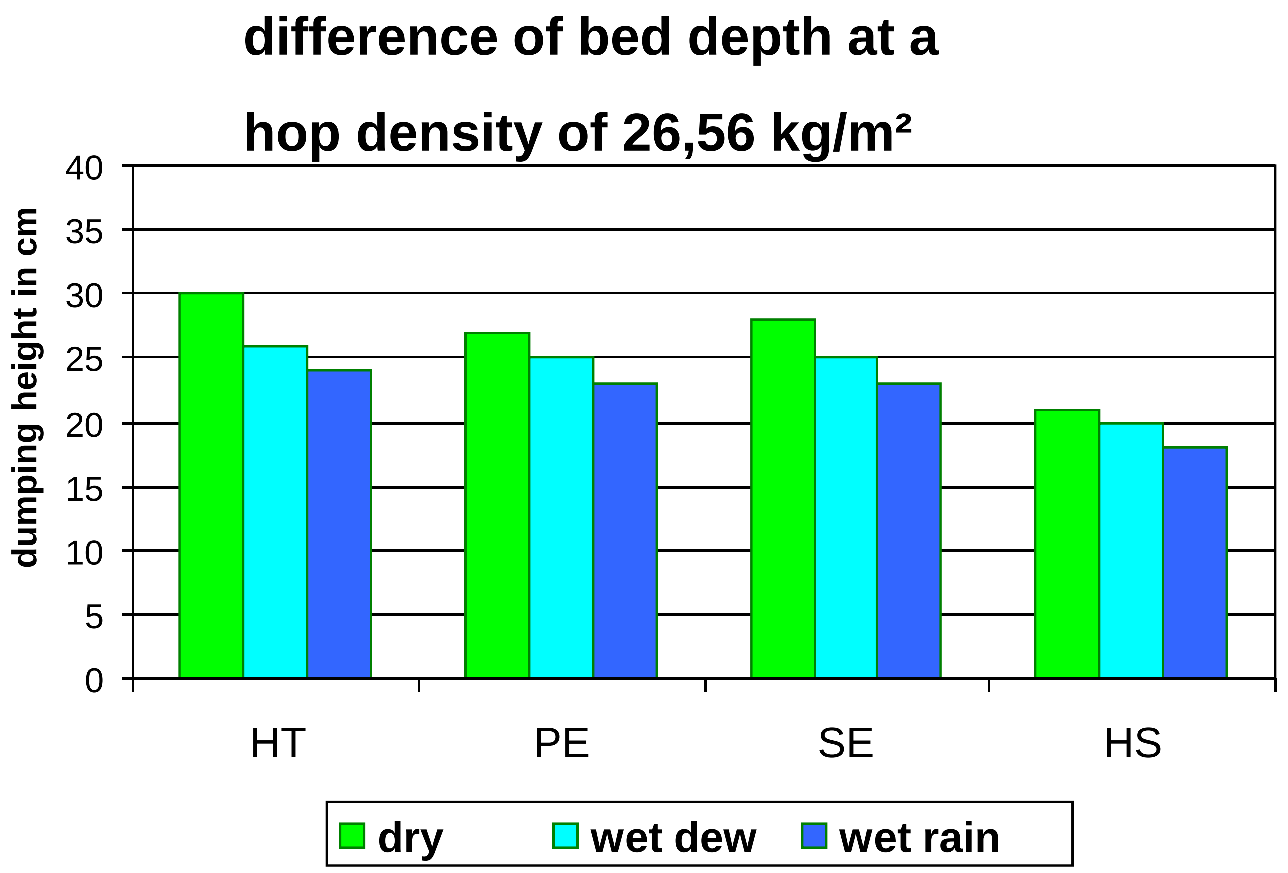
Kiln bed depth needs to be correlated with hop bed weight.

It is important to know if the green hops are dry (without surface moisture), wet from dew or wet from rain.

When the kiln is filled by weighing in the green hops, parameters can be reached best.

Nevertheless in most cases it is easier to steer the kilning process with the help of the other parameters.

bed depth



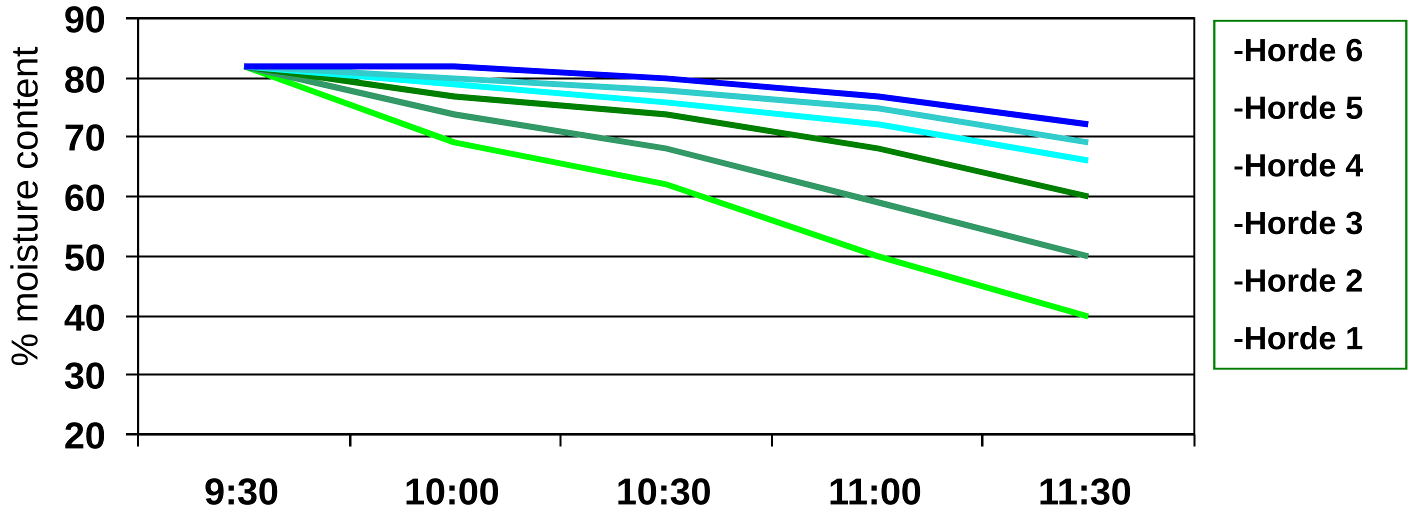
source: J. Münsterer, LfL Bayern

Parameters of Hop Drying

bed depth

trials with bed depths

made 1984 in mico kilns



micro kiln:	1.3 x 1.3 ft
kilning temperature:	144 °F
dumping height per tier:	0.16 ft
total height:	1.0 ft

source: J. Münsterer, LfL Bayern

Parameters of Hop Drying

summary:

For perfect kilning the three parameters

dumping height – airspeed – kilning temperature

need to be in the right proportion!

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Parameters for improvements

approach for optimization:

evaluating current kiln situation

- heating capacity in kW per m²
- fan capacity in W/m²
- calculate airspeed in m/s

Parameters for improvements

parameters for optimized kilns:

- heating capacity approx. 30 kW and m² (10.8 ft²)
- fan capacity of 900 to 1000 W/m² (10.8 ft²)
- airspeed at least 0.45 m/s (1.65 ft/s) reachable
- be able to regulate fan via frequency changer (variable speed fan)

new kilns in Germany even have

- 42 kW and m² (10.8 ft²) heating capacity
- 1200 W/m² (10.8 ft²) fan capacity
- up to 0.70 m/s (2.3 ft/s) airspeed

Parameters for improvements

necessary data for calculating and optimizing a kiln:

- intake temperature, kilning temperature, exhaust air temperature
- diesel consumption / diesel fuel gauge

➔ **calculating airspeed**

excursus: calculating airspeed

airspeed

as a function of oil consumption and temperature

temperature balance between kilning air and intake air in °C	oil consumption in l/h and m² kilning area																				LfL Pflanzenbau
	1,0	***1,1***	***1,2***	***1,3***	***1,4***	***1,5***	***1,6***	**1,7**	[illegible]	***,9***	***2,0***	***2,1***	***2,2***	***2,3***	***2,4***	***2,5***	***2,6***	***2,7***	***2,8***	***2,9***	***3,0***
20	0,37	0,40	0,44	0,48	0,51	0,55	0,59	[illegible]	[illegible]	,70	0,73	0,77	0,81	0,84	0,88	0,92	0,95	0,99	1,03	1,06	1,10
22	0,33	0,37	0,40	0,43	0,47	0,50	0,53	0,57	0,60	0,63	0,67	0,70	0,73	0,77	0,80	0,83	0,87	0,90	0,93	0,97	1,00
24	0,31	0,34	0,37	0,40	0,43	0,46	0,49	0,52	0,55	0,58	0,61	0,64	0,67	0,70	0,73	0,76	0,79	0,82	0,85	0,88	0,92
26	0,28	0,31	0,34	0,37	0,39	0,42	0,45	0,48	0,51	0,54	0,56	0,59	0,62	0,65	0,68	0,70	0,73	0,76	0,79	0,82	0,85
28	0,26	0,29	0,31	0,34	0,37	0,39	0,42	0,44	0,47	0,50	0,52	0,55	0,58	0,60	0,63	0,65	0,68	0,71	0,73	0,76	0,78
30	0,24	0,27	0,29	0,32	0,34	0,37	0,39	0,42	0,44	0,46	0,49	0,51	0,54	0,56	0,59	0,61	0,63	0,66	0,68	0,71	0,73
32	0,23	0,25	0,27	0,30	0,32	0,34	0,37	0,39	0,41	0,43	0,46	0,48	0,50	0,53	0,55	0,57	0,60	0,62	0,64	0,66	0,69
34	0,22	0,24	0,26	0,28	0,30	0,32	0,34	0,37	0,39	0,41	0,43	0,45	0,47	0,50	0,52	0,54	0,56	0,58	0,60	0,62	0,65
36	0,20	0,22	0,24	0,26	0,28	0,31	0,33	0,35	0,37	0,39	0,41	0,43	0,45	0,47	0,49	0,51	0,53	0,55	0,57	0,59	0,61
38	0,19	0,21	0,23	0,25	0,27	0,29	0,31	0,33	0,35	0,37	0,39	0,40	0,42	0,44	0,46	0,48	0,50	0,52	0,54	0,56	0,58
[illegible]	0,18	0,20	0,22	0,24	0,26	0,27	0,29	[illegible]	[illegible]	,35	0,37	0,38	0,40	0,42	0,44	0,46	0,48	0,49	0,51	0,53	0,55
40	0,17	0,19	0,21	0,23	0,24	0,26	0,28	**0,31**	[illegible]	,33	0,35	0,37	0,38	0,40	0,42	0,44	0,45	0,47	0,49	0,51	0,52
[illegible]	0,17	0,18	0,20	0,22	0,23	0,25	0,27	0,28	0,30	0,32	0,33	0,35	0,37	0,38	0,40	0,42	0,43	0,45	0,47	0,48	0,50
46	0,16	0,18	0,19	0,21	0,22	0,24	0,25	0,27	0,29	0,30	0,32	0,33	0,35	0,37	0,38	0,40	0,41	0,43	0,45	0,46	0,48
48	0,15	0,17	0,18	0,20	0,21	0,23	0,24	0,26	0,27	0,29	0,31	0,32	0,34	0,35	0,37	0,38	0,40	0,41	0,43	0,44	0,46
50	0,15	0,16	0,18	0,19	0,21	0,22	0,23	0,25	0,26	0,28	0,29	0,31	0,32	0,34	0,35	0,37	0,38	0,40	0,41	0,42	0,44
52	0,14	0,15	0,17	0,18	0,20	0,21	0,23	0,24	0,25	0,27	0,28	0,30	0,31	0,32	0,34	0,35	0,37	0,38	0,39	0,41	0,42
54	0,14	0,15	0,16	0,18	0,19	0,20	0,22	0,23	0,24	0,26	0,27	0,28	0,30	0,31	0,33	0,34	0,35	0,37	0,38	0,39	0,41
56	0,13	0,14	0,16	0,17	0,18	0,20	0,21	0,22	0,24	0,25	0,26	0,27	0,29	0,30	0,31	0,33	0,34	0,35	0,37	0,38	0,39
58	0,13	0,14	0,15	0,16	0,18	0,19	0,20	0,21	0,23	0,24	0,25	0,27	0,28	0,29	0,30	0,32	0,33	0,34	0,35	0,37	0,38
60	0,12	0,13	0,15	0,16	0,17	0,18	0,20	0,21	0,22	0,23	0,24	0,26	0,27	0,28	0,29	0,31	0,32	0,33	0,34	0,35	0,37

Quelle: Münsterer Jakob - Arbeitsbereich Hopfen - IPZ 5a Tel. 08442/957-400 Fax. 08442/957-402 Stand 2007

Parameters for improvements

necessary data for calculating and optimizing a kiln:

- intake temperature, kilning temperature, exhaust air temperature
- diesel consumption / diesel fuel gauge

➔ **airspeed is calculated**

- air humidity of exhaust air / measuring dewatering (water removal)

➔ **water content of exhaust air**

Parameters for improvements

determining water content in exhaust air

• microcontroller measure necessary parameters real time

➔ new parameter **„dewatering“**

• dewatering of hops in every single tier. Removal of water is calculated and displayed continuously

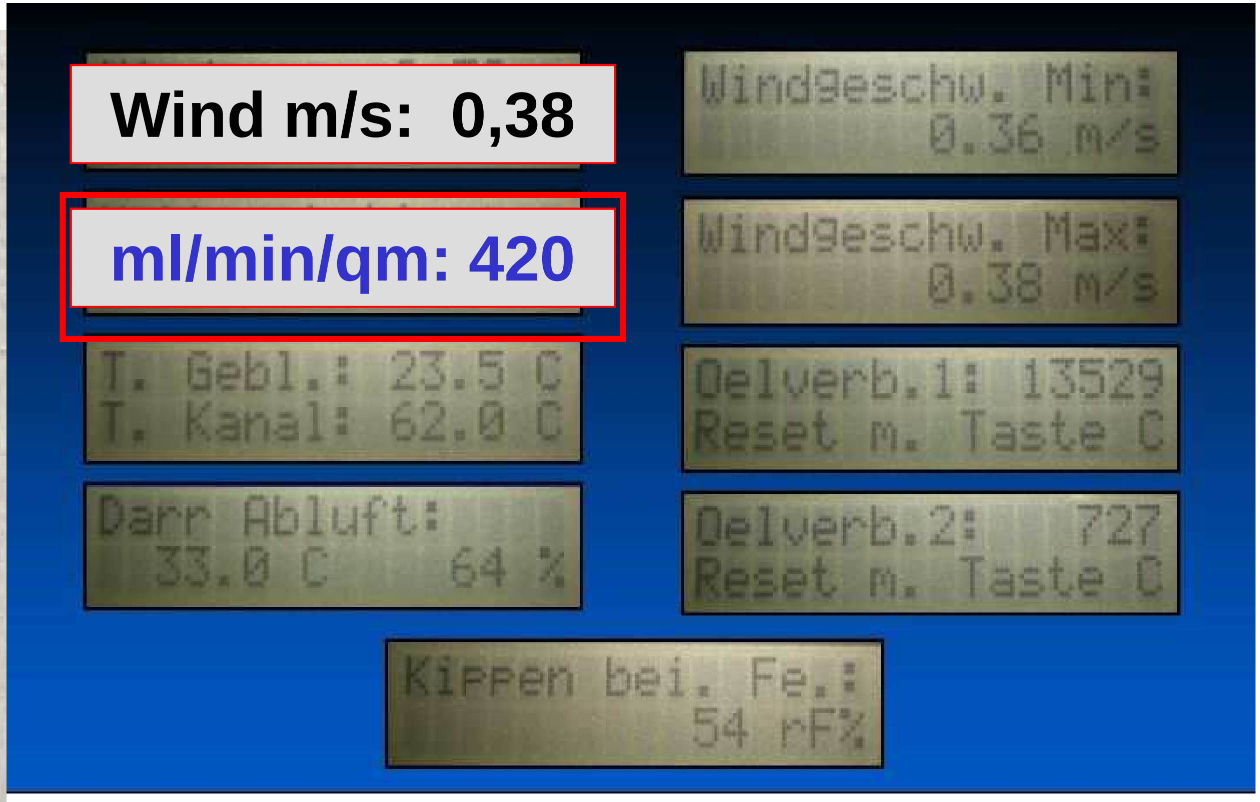
„Dewatering“ is measured in

ml of water per m² (10.8 ft²) kiln area and minute

source: J. Münsterer, LfL Bayern

Parameters for improvements

determining water content in exhaust air



AUTOMATISIERUNGSTECHNIK Euringer & Friedl GmbH

LfL Pflanzenbau
Bayerische Landesanstalt für Landwirtschaft

Parameters for improvements

necessary data for calculating and optimizing a kiln:

- intake temperature, kilning temperature, dump air temperature
- diesel consumption / diesel fuel gauge

➔ **airspeed is calculated**

- air humidity exhaust air / measuring dewatering

➔ **water content of exhaust air**

- monitoring drying process

➔ **wire in the bottom drawer**

Parameters for improvements

wire in the bottom drawer

source: J. Münsterer, LfL Bayern

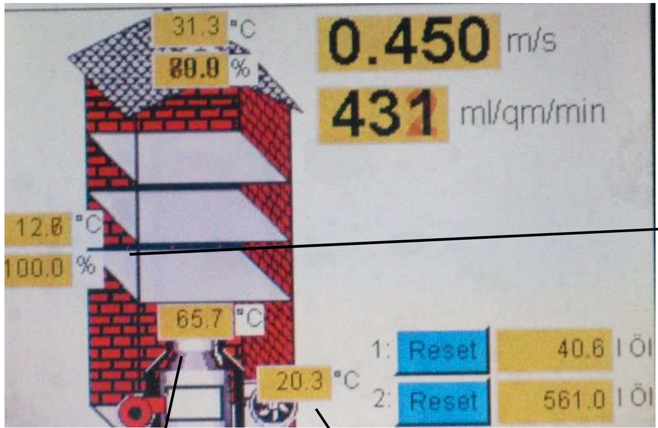
Parameters for improvements

wire in the bottom drawer

source: J. Münsterer, LfL Bayern

Parameters for improvements

measuring points in a hop kiln



top layer:

determination of tilting time via air humidity in dump air

bottom drawer:

determination of drying process via wire in bottom drawer

burner

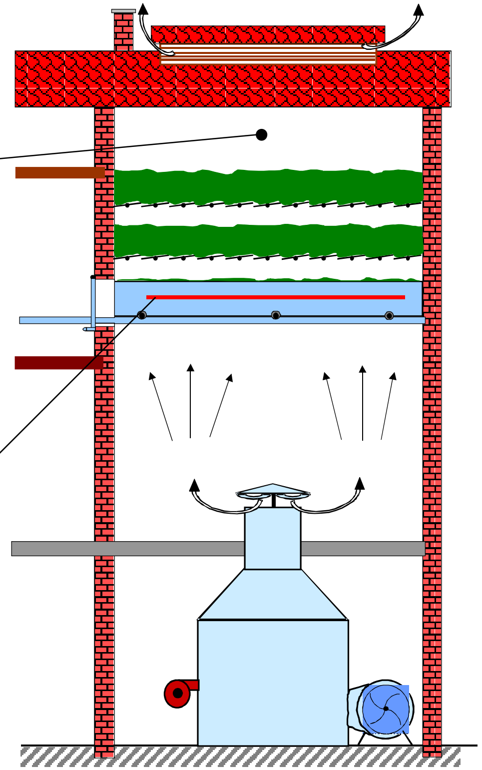
measuring diesel consumption with help of a diesel gauge

below bottom drawer

measuring kilning temperature

air intake

measuring intake temperature



scheme of a hop kiln

source: J. Münsterer, LfL Bayern

Parameters for improvements

necessary data for calculating and optimizing a kiln:

- intake temperature, kilning temperature, exhaust air temperature
- diesel consumption / diesel fuel gauge

➔ **airspeed is calculated**

- air humidity exhaust air / measuring dewatering

➔ **water content of exhaust air**

- surveying drying process

➔**wire in the bottom drawer**

Resultant **kiln performance in kg/m² (2.2 lbs/10.8 ft) and hour** and **energy consumption per kg (2.2 lbs) dry hops** can be calculated!

Parameters for improvements

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➔ optimizing kiln performance = optimizing diesel consumption

By optimizing water evacuation in all layers of a kiln, **kiln performance** can be raised up to **10 kg per m² (2.05 lbs per ft²) and hour** and diesel consumption can be reduced to less than 40 l (10.6 US Gal) per 100 kg (220 lbs) dry hops (approx. 9.5 US Gal per 200 lbs bale).

With the help of **modern drive and control technology** (calculation water evacuation, modular driving) and the application of **modern air distribution devices** it is possible to reduce oil consumption down to 34 l (9,0 US Gal) per 100 kg (220 lbs) dry hops. At the same time a **performance increase up to more than 12 kg per m² (2.5 lbs per ft²) and hour** at a **diesel consumption of 0.04 US Gal/lbs** is possible.

Parameters for improvements