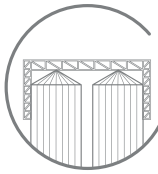
TMS
INDUSTRIAL REFRIGERATION

TKS Series
Grain Cooling Units



Grain Silos

Grain has been one of the most important food sources for thousands of years. It is cultivated and harvested with care. Excess grains are stored in silos and unladed to be used or shipped when the need comes out during the year. According to the Food and Agriculture Organization of the United Nations (FAO), the annual degradation of grain harvested worldwide is over 20%. These losses are caused by poor storage conditions of grains in silos such as high temperature, humidity which brings insect infestation, fungal and bacterial activities. In order to prevent losses and to preserve the grains for a long time, the storage conditions of the grains should be followed and controlled.

There are many factors to be considered in the storage of grains. The most important one is the control of humidity and temperature of the grain to be stored and the storage environment. Another factor is the amount of foreign matter in the stored grain, microorganisms and insects. Failure to fully pay attention to the grain storage conditions causes the grains both qualitative and quantitaive losses.

Grain cooling has improved greatly in recent years worldwide and become an indispensable part of modern storage systems today. Temperature values increasing with climatic changes and grain quality related expectations; increased the use of non-chemical cooling, drying and ventilation systems in grain storage.

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The Effect of Temperature Increase on Grain

Heat is a deadly enemy for grain. Grain is a living organism even though its biological activity is low. As it respire, it absorbs oxygen in the environment and emits carbon dioxide, water and heat. This causes an increase in temperature and humidity. Increasing temperature causes large amount of grain losses. Grain structure deterioration, dry matter loss, protein denaturation, starch destruction, water vapor formation and germination occur. A storage temperature of less than 10 degrees ensures that all biological growth in the grain is minimal. This slows down and stops the life cycle of the grain. The rule states that a seed's lifespan in storage is doubled for each 5°C decrease in temperature (within the range of 0 to 50°C) and for each 1% decrease in seed moisture (within the range of 5 to 14%)

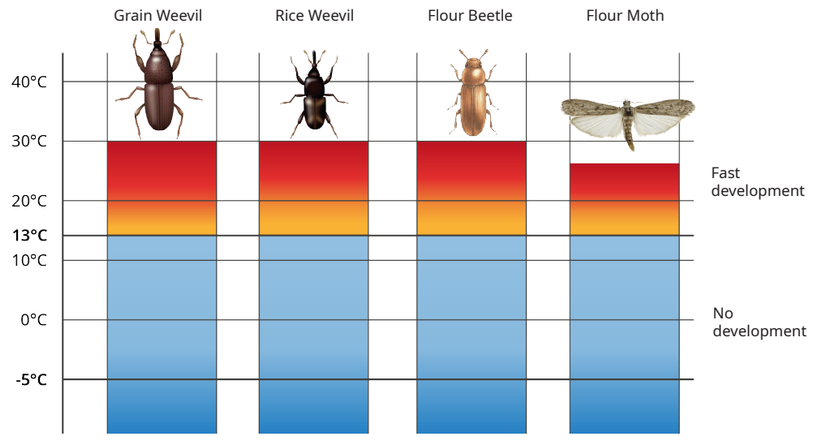
Grain respriation formula for the chemical process:

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + 677.2\ \text{kcal/mole}$$

Carbonhdyrates + Oxygen → Carbon dioxide + Water + Heat

Another negative factor in preserving the grain is pest and parasite activities. The development and reproduction of pests such as Sitophilus granarius, known as grain weevil, and Tribollium confusum, known as flour beetle, depends on the temperature and humidity in the silo. These types of pests usually begin to occur when the ambient temperature rises to 13 degrees and above. In order to prevent the insects from reproducing and to remain them dormant during storage, the air temperature in the silo should be kept below 15 degrees.

With the TKS Series cooling process, the temperature and the humidity in the silo is kept under control and the grain is stored for a long time in fresh and healthy environments. Thus, risk-free storage is ensured until the stored grain to be sold or consumed. With the offered cooling technology, there is no need for chemical solutions. And thus, unhealthy factors on products are eliminated.



Humidity

The relative humidity ratio is as important as the temperature of the air directed into the silo. Therefore, it must be controlled. If the relative humidity ratio of the air, in the area where the grain is stored exceeds, 70%, it can lead to mold growth, which also causes the temperature to increase due to mold respiration.

Each grain type has a value in which the intra-grain moisture is in equilibrium against the different relative humidity ratios of the air. The curve obtained by plotting these values is called the equilibrium moisture content (EMC) curve. Equilibrium values varies depending on the type of grain, the ambient air temperature, and the relative humidity ratio. EMC represents the moisture content of the grain at which it will eventually stabilize, if weather conditions remain stable for a long period of time. In this way, depending on the ambient conditions of the stored grain, the moisture values of the grain can be estimated or the moisture value of the grain can be controlled by changing the ambient conditions. For this process, psychometry diagram, on which moisture balance content (EMC) curves of different grains, can be used. By changing the relative humidity of the air directed into the silo, EMC of the stored grain can be increased or decreased.

In addition, regarding with the most consumed grains, tables showing the EMC, according to the ambient temperature and relative humidity ratio have been prepared. [3], [7] As an example, tables for wheat, and barley are given in Table-1a and Table-1b. The moisture balance value of the grain can be seen from these tables. For instance, for wheat, it is read from Table 1a that the EMC is 14.5% in an environment at 15 °C and 65% relative humidity. The moisture balance value shows the ratio of the moisture mass in the wheat to the total mass.

Psychometry Diagram

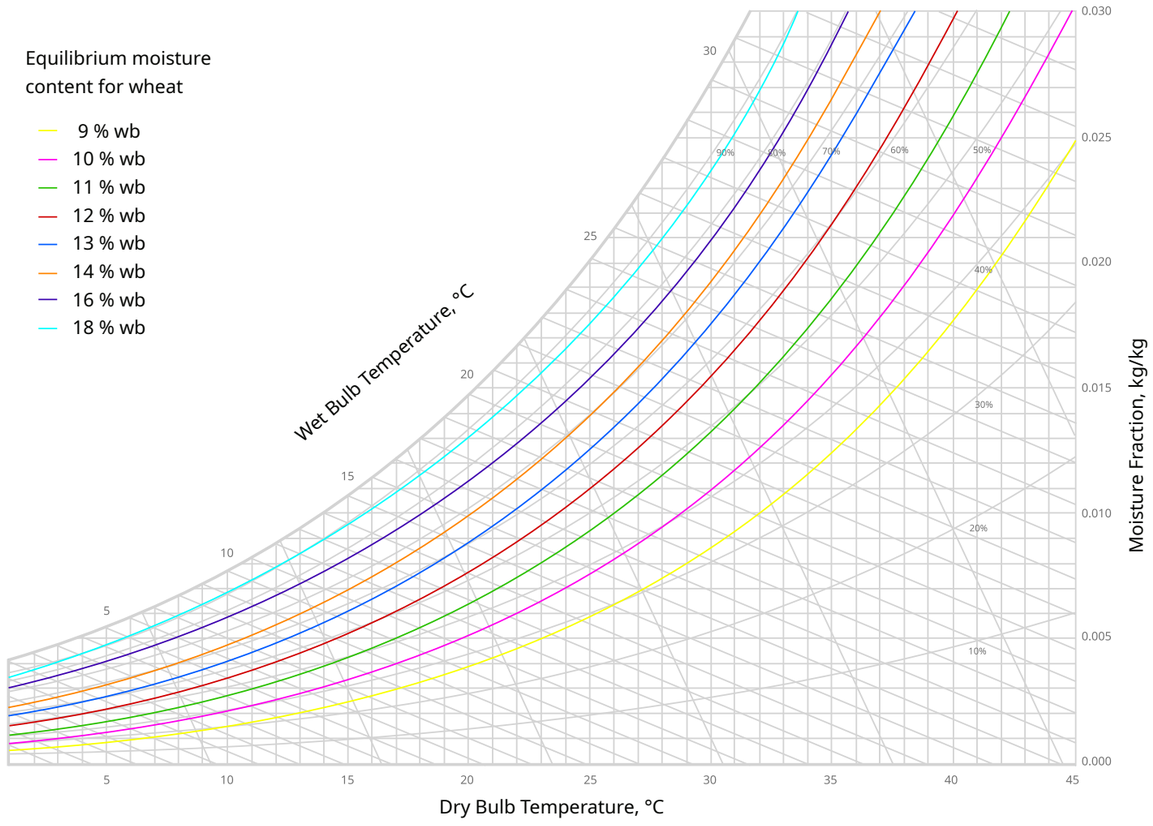


Figure: Psychometry diagram with different moisture values and equilibrium moisture content (EMC) curves for wheat [*]

[*] P.Burrill, DPI & F "Aeration for grain cooling and drying: How to use the Psychrometric chart to select suitable air", https://storedgrain.com.au/how-to-use-the-psychrometric-chart-to-select-suitable-air-burrill-dpiq/

Equilibrium Moisture Content For Wheat

Temperature °C	Relative Humidity (%)										
	35	40	45	50	55	60	65	70	75	80	85
-2	11.5	12.2	13.0	13.7	14.5	15.3	16.0	16.9	17.7	18.7	19.8
2	11.1	11.9	12.6	13.4	14.1	14.9	15.6	16.4	17.3	18.2	19.3
5	10.9	11.7	12.4	13.1	13.8	14.6	15.3	16.1	17.0	17.9	19.0
8	10.7	11.5	12.2	12.9	13.6	14.3	15.1	15.8	16.7	17.6	18.7
10	10.6	11.3	12.0	12.7	13.4	14.2	14.9	15.7	16.5	17.4	18.5
13	10.4	11.1	11.8	12.5	13.2	13.9	14.6	15.4	16.2	17.1	18.2
15	10.3	11.0	11.7	12.4	13.1	13.8	14.5	15.2	16.1	17.0	18.0
18	10.1	10.8	11.5	12.2	12.9	13.6	14.3	15.0	15.8	16.7	17.7
22	9.9	10.6	11.3	11.9	12.6	13.3	14.0	14.7	15.5	16.4	17.4
26	9.7	10.4	11.1	11.7	12.4	13.0	13.7	14.4	15.2	16.1	17.1
28	9.6	10.3	11.0	11.6	12.3	12.9	13.6	14.3	15.1	15.9	16.9

Table 1: showing different equilibrium moisture content (EMC) values, ambient temperature and relative humidity values for wheat [*]

Equilibrium Moisture Content For Barley

Temperature °C	Relative Humidity (%)										
	35	40	45	50	55	60	65	70	75	80	85
-2	8.9	9.6	10.3	11.0	11.7	12.4	13.1	13.9	14.8	15.8	16.9
2	8.8	9.5	10.2	10.9	11.6	12.3	13.0	13.8	14.7	15.6	16.7
5	8.7	9.4	10.1	10.8	11.5	12.2	12.9	13.7	14.6	15.5	16.6
8	8.7	9.4	10.0	10.7	11.4	12.1	12.9	13.6	14.5	15.4	16.5
10	8.6	9.3	10.0	10.7	11.4	12.1	12.8	13.6	14.4	15.4	16.5
13	8.6	9.3	9.9	10.6	11.3	12.0	12.7	13.5	14.3	15.3	16.4
15	8.5	9.2	9.9	10.6	11.2	11.9	12.7	13.5	14.3	15.2	16.3
18	8.5	9.2	9.8	10.5	11.2	11.9	12.6	13.4	14.2	15.1	16.2
22	8.4	9.1	9.7	10.4	11.1	11.8	12.5	13.3	14.1	15.0	16.1
26	8.3	9.0	9.7	10.3	11.0	11.7	12.4	13.2	14.0	14.9	16.0
28	8.3	9.0	9.6	10.3	11.0	11.6	12.4	13.1	13.9	14.8	15.9

Table 2: showing different equilibrium moisture content (EMC) values, ambient temperature and relative humidity values for barley [*]

[*] "Equilibrium Moisture Content Charts for Grain Storage Management" Prairle Agricultural Machinery Institute (PAMI), https://pami.ca/wp-content/uploads/2021/10

Temperature and Humidity Movement inside the Silo

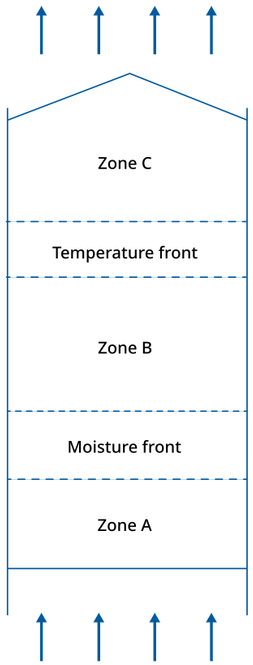


Figure : Schematic representation of the zones and fronts formed inside the silo as a result of the air directed into the silo [*]

When air is passed over the grain inside the silo, 3 zones and fronts are formed in the silo. The figüre on the left shows schematically the zones formed inside a silo, where the aeration process continues.

The temperature and relative humidity values in the lowest region are the same as the values of the air directed into the silo (Zone A). At the top region, temperature and relative humidity values are the same as the initial conditions (before the air is directed into the silo) (Zone C). The region in between has a value between the values in the lowest and highest regions (Zone B). The movement of these zones moves in the same direction as the air flow. The fastest moving part of the region is called the leading edge and the slowest moving part is called the trailing edge. As long as the air is directed into the silo, after a certain period of time, the temperature and relative humidity values in the whole silo reach the air values directed into the silo.

Temperature and humidity fronts are formed in the area between Zone A and Zone C inside the silo. The reason for the formation of fronts inside the silo is that the temperature moves relatively faster than the relative humidity.

Example

The temperature and relative humidity values in the zone C, are equal to the initial conditions in which the wheat was stored. Wheat in this region has a temperature of 35 °C and a relative humidity of 12%.

Zone A has the same conditions with the air directed into the silo. When the condition of 11 °C (dry bulb temperature) and 90% relative humidity is seen on the psychometric diagram, it is read that the temperature of the wheat in this region is 11 °C and the equilibrium humidity is 18%.

For 11 °C (dry bulb temperature) and 90% relative humidity, the wet bulb temperature is read 10 °C on the curve. This is also the saturation temperature of the air. In order to calculate the values of the grain in the B zone, the wet-bulb temperature curve in the diagram is matched with the grain moisture equilibrium curve. The temperature read at the intersection point is 15.5 °C. For a more detailed estimation, the rule that the grain internal moisture balance changes by 1% for every 28 °C temperature difference is applied. By applying this rule, the humidity of zone B is approximately 0.70% ((35-15.5)/28=0.70) lower than zone C is calculated. In this case, the equilibrium moisture content of the grain for the zone B is 11.3% (12-0.7=11.3). In the diagram, the dry bulb temperature is 16.7 °C for 11.3% on the wet bulb curve. Thus, it is seen that the temperature of the wheat for the B region is 16.7 °C and the equilibrium humidity is 11.3%.

[*] S.Navarro, R.Noyes, “The Mechanics and Physics of Modern Grain Aeration Management”, CRC Press, 2002

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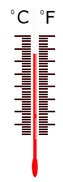
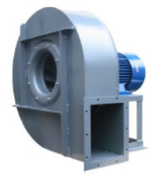
Technical Details

TKS Grain cooling units are specially designed considering the operating conditions and customer requirements. **Cereal cooling capacity** can reach up to 1200 tons per day with the help of compressors of capacity between 100 kW and 320 kW.



During the operation of the unit, the air conditioned at the desired temperature and humidity values, is transfered into the silo. With the additional heating value, the humidity value of the air can be kept under control. **Dehumidification** can be provided by reheat battery and electric heater, respectively. In addition, grain drying can be done with the **hot-gas bypass system**. Thanks to the valves and drivers that can be controlled proportionally, the desired conditions can be generated precisely.

High pressure centrifugal fans are used to cool the air received from the outside and guide it into the grain silo. Air can be directed into the silo without any problem even at counter pressures up to 6.000 Pascals. Thanks to the inverter driver, the air flow can be regulated between 35% and 100%.



Since independent two **compressors** are used for the cooling cycle of our units, the cooling process continues uninterruptedly incase possible compressor failure. In addition, if the cooling requirement decreases, single compressor will be turned off for energy saving. Both hermetic scroll or semi-hermetic compressors can be applied based on customers preference.

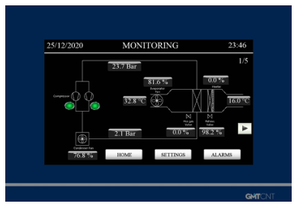
Remote control and monitoring of the units as they operate in the field is possible. Thanks to Modbus, Ethernet or GSM technologies, the instant status of the unit can be kept under control. Necessary information can be provided at the time of malfunction, thus allowing the user to intervene quickly and solve problems. Users can save the operation data of the unit via USB.

The connection of the unit to the silo can be easily made with **flexible air hoses**. Depending on the distance of the unit to the silo, air hoses can be provided as 5 m, 10 m or 15 m.

In line with the user set operational conditions, the units operates fully automatically. Thanks to **PLC**, all equipments are controlled according to the desired setting values. With the PID control algorithm, the required operating conditions are met precisely.

Trailer design makes the units move easily among the silos in the field. Moreover, by the help of the locked structure and braking system, the unit can be safely controlled.

7 ”**HMI touch panel** and user-friendly software on the unit makes it easily controlled and instant status can be monitored. By selecting alternative operating modes on the unit, it is possible to operate it in line with different purposes. **Modes of operation**;



Normal Cooling Mode: It automatically fulfills the set values in normal operating mode. All control processes are adjusted by PLC. The system capacity is regulated according to the required cooling requirement. According to the set unit outlet temperature and additional heating values, the evaporator fan air flow rate increases or decreases to achieve the desired value. Likewise, compressor and condenser fans work in this direction depending on the outdoor temperature conditions.

Super Cooling Mode: In super cooling mode, compressors and evaporator fan operate at maximum cooling power. In this mode, the unit operates for 30 minutes regardless of the outdoor temperature.

Only Heating Mode: In only heating mode, the unit does not perform any cooling operation. Only electrical heaters and evaporator fan will operate on the unit.

Only Fan Mode: In this mode, the unit does not perform any cooling operation. Only the evaporator fan will operate to ventilate the silo. In this mode, the evaporator fan air flow will be at the maximum level.

Silent Cooling Mode: In silent cooling mode, the noise level in the unit is reduced. However, the cooling power decreases a little depending on the ambient temperature compared to normal cooling operation.

Working Principle

TKS Units are connected to the silo with flexible air ducts. The cooled and dehumidified air is blown into the channels in the silo by the high pressure fans of the TKS Unit. Thus, the ambient temperature and humidity are kept at a value optimal for the preservation of the grain. Exhaust fans on the silo roof ease the cold air to move towards the ceiling. The heated air is exhausted to the outside atmosphere air.

Advantages of TKS Grain Cooling Units

- It allows the grain to be stored in optimal storage circumstances in all weather conditions.
- Ventilation through the traditional method of fans are eliminated.
- Keeps grain quality at maximum level.
- Grain losses are reduced as it stops or slows down the grain life cycle.
- It prevents parasites, fungus and mold.
- Inhibiting insect infestation, minimizes the use of chemical processes.
- It reduces pre-storage drying costs.
- It allows the grain to preserve its mass on the first day of storage.

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General Specifications*

up to **1500** tons
cooling performance/day

100 kW - **320** kW
cooling range

up to 6000 Pa
blowing pressure

Suitible operating range for
Cold, Mild and Tropical
Climates

TMS
"Tailor Made Solutions"
designed and produced
according to your needs

Dust Resistant
Durable design against dust

- Hermetic scroll or semi-hermetic reciprocating options.
- High pressure centrifugal fans overcome the counter pressure up to 6000 Pa.
- Large and replaceable air filter.
- Reheat and electric heater for dehumidification.
- Hot gas bypass system for drying.
- Remote control and monitoring by various alternatives.
- Fully automatic control.
- Purposive operation modes (normal, silent, only fan, only heating, supercool)
- Easy transportation with trailer
- Audible and visible alarm
- Robust construction for cereal fields
- Redundant cooling advantage in case of emergency (one compressor failure)

Nomenclature

Configure your product*

Product Type Code — *Product Specification Code*

TKS 100 **D M 0 2 1**

Grain Cooling Unit

Compressor Cooling Capacity
100 kW
160 kW
240 kW
320 kW

1: With tyres
2: With trailer

0: No flexible air duct
1: 5m flexible air duct
2: 10m flexible air duct
3: 15m flexible air duct

0: No data acquisition
1: Data acquisition by USB

M: Remote control and monitoring by modbus
E: Remote control and monitoring by ethernet
G: Remote control and monitoring by GSM

D: Hermetic Scroll compressor
B: Semi - hermetic reciprocating compressor
G: Semi - hermetic reciprocating compressor

***Please contact us for further customization requests.**

Technical Specifications

General				
Serial	TKS			
Product	TKS 100	TKS 160	TKS 240	TKS 320
Application Area	Grain Cooling & Drying			
Performance				
Cooling Capacity (Ton/Day) [1]	220 - 430	280 - 550	360 - 800	530 - 1500
Compressor Cooling Capacity (kW) [2]	100	160	235	320
Heating Capacity (kW) [3]	24	30	30	45
Air Flow Rate (m3/h) @1000Pa	13000	18000	25000	32000
Max. External Static Pressure (Pa)	6000	6000	6000	6000
Refrigerant	R407C	R407C	R407C	R407C
Max. Operating Temperature	45°C	45°C	45°C	45°C
Capacity Control	0-50-100	0-50-100	0-50-100	0-50-100
Structural Features				
Structure	Epoxy coated Aluminium Profile and Galvanized Steel Body			
Compressor	Hermetic Scroll/ Semi-Hermetic Reciprocating (Optional)			Semi-Hermetic Reciprocating
Number of refrigerant circuits	1	1	1	1
Number of Compressors	2/1	2/1	2	2
Condenser	Air Cooled			
Condenser Fan Type	Axial			
Condenser Fan Motor	Direct Driven			
Number of Condenser Fans	2	2	4	4
Blower Fan Type	High Pressure Centrifugal			
Blower Fan Motor	Direct Drive			
Drain Pan	Stainless Steel			
Heater	Electric Heater			
Air Hose Diameter / Quantity (Ø mm)	1 x Ø 356	1 x Ø 600	1 x Ø 600	1 x Ø 800
Drain connection size(inch) / quantity	2 x 1"	2 x 1"	2 x 1"	2 x 1"
Electrical Features				
Compressor Power Input (kW)	2x12	2x16	2x23	2x30
Blower Fan Max.Power Input (kW)	30	30	37	55
Condenser Fan Max. Power Input (kW)	2 x 2,3	2 x 1,9	4 x 1,9	4 x 2
Total Power Input (kW) [4]	83	100	124	168
Total Max. Current (A)	175	210	300	340
Circuit Breaker (A)	140- 200	175- 250	220- 320	280- 400
Power Supply; standard	400VAC/3Ph/50Hz	400VAC/3Ph/50Hz	400VAC/3Ph/50Hz	400VAC/3Ph/50Hz
Weight & Dimension				
Dimensions (LxWxH - mm)	4600x1550x2500	4700x2150x2500	5650x2150x2500	5950x2250x2900
Net Weight (kg) [5]	2650	3000	3850	4900

1. Cereal cooling capacity is given in outdoor temperature 20 ° C and 52% humidity conditions. Daily grain cooling capacity may vary depending on the climatic conditions and the type of grain in the silo. Please contact us for grain cooling capacity in your operating values.
2. Compressor cooling capacity values calculated for 10° C evaporation and 45° C condensation temperatures.
3. Electric heater capacity is given.
4. Power consumption values belongs to nominal operating conditions, it may vary at different temperatures. Please contact us to see the power consumption in your operating values.
5. Weight may vary depending on options selected. Optional features to be added may vary in weight values.

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Application Examples