

Office de la Propriété Intellectuelle du Canada

Un organisme d'Industrie Canada

Canadian Intellectual Property Office

An agency of Industry Canada

CA 2885751 A1 2016/09/23

(21) **2 885 751**

(12) DEMANDE DE BREVET CANADIEN CANADIAN PATENT APPLICATION

(13) **A1**

(22) Date de dépôt/Filing Date: 2015/03/23

(41) Mise à la disp. pub./Open to Public Insp.: 2016/09/23

(51) Cl.Int./Int.Cl. *A23B 9/08* (2006.01), *A01F 12/48* (2006.01), *A01F 25/14* (2006.01), *F26B 11/04* (2006.01), *F26B 21/06* (2006.01), *F26B 25/22* (2006.01)

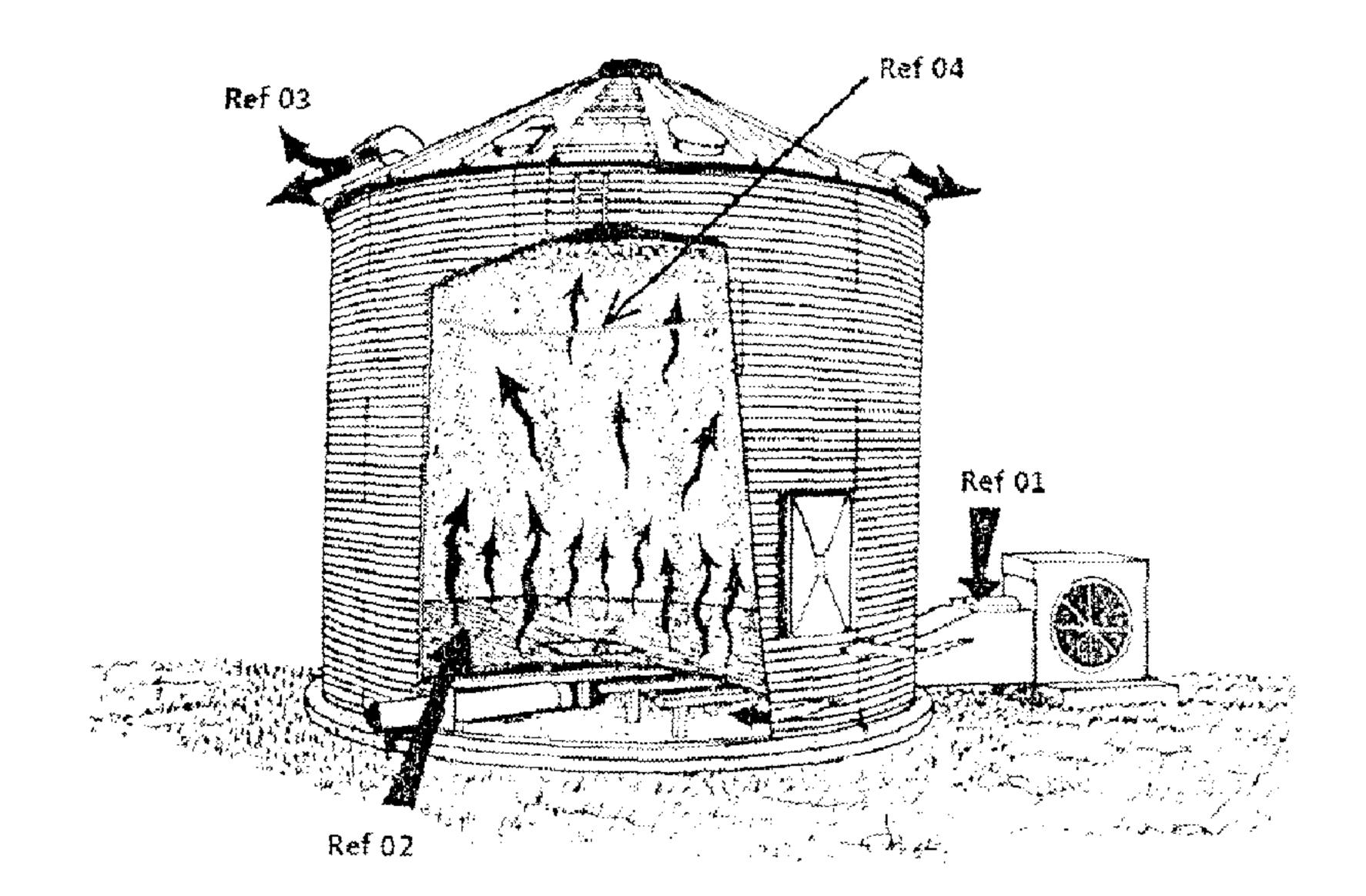
(71) **Demandeur/Applicant:** LIU, FENGMING, CA

(72) **Inventeur/Inventor:** LIU, FENGMING, CA

(74) **Agent:** NA

(54) Titre: SYSTEME DE SECHAGE ET DE STOCKAGE DE GRAIN

(54) Title: GRAIN DRYING AND STORAGE SYSTEM



(57) Abrégé/Abstract:

A computer controlled grain drying and storage system includes a horizontal and rotatable grain drum, a solenoid valve controlled heater/chiller/blower combination unit, and an arrangement of plenum air communication conduits system. An air temperature





(21) **2 885 751**

(13) **A1**

(57) Abrégé(suite)/Abstract(continued):

sensor for the drying airflow provides a temperature signal. A moisture content sensor senses grain moisture content as a function of the dielectric constant of the grain in the drum. A programmable logic controller computer system is interfaced with the temperature sensors, the moisture sensor, the humidity sensors, and grain level sensor, the heater valves, the chiller, the blower and the drum motors controlling unit, the computer is programmed to automatically control the drum rotating, Drying, aerating and cooling process according to a set temperature limit and moisture content for the particular grain to be processed.

GRAIN DRYING AND STORAGE SYSTEM

Abstract of the disclosure

A computer controlled grain drying and storage system includes a horizontal and rotatable grain drum, a solenoid valve controlled heater/chiller/blower combination unit, and an arrangement of plenum air communication conduits system. An air temperature sensor for the drying airflow provides a temperature signal. A moisture content sensor senses grain moisture content as a function of the dielectric constant of the grain in the drum. A programmable logic controller computer system is interfaced with the temperature sensors, the moisture sensor, the humidity sensors, and grain level sensor, the heater valves, the chiller, the blower and the drum motors controlling unit, the computer is programmed to automatically control the drum rotating, Drying, aerating and cooling process according to a set temperature limit and moisture content for the particular grain to be processed.

GRAIN DRYING AND STORAGE SYSTEM

Field of the Invention

The Present invention relates to grain drying and storage systems with rotating drum and, more particularly, to a computer controlled grain drying and storage system which operates in response to the measured moisture contents and temperatures of the grain to be dried and for storage.

Background of the Invention

Once a cereal crop is harvested, it may have to be stored for a period of time before it can be marketed or used as feed or seed. The length of time cereal can be safely stored will depend on the condition it was harvested and the type of storage facility being utilized. Grain binned at lower temperatures and moisture contents can be kept in storage for longer periods of time before its quality will deteriorate.

The moisture content of freshly harvested grain is too high for storage right away. The moisture content must be lowered before storage to prevent spoilage. For corn, a moisture content of 17 to 18 percent is considered the maximum desirable moisture content for short term storage. A moisture content of 15.5 percent is considered optimum by commercial grain elevator operators. For long term storage of the grain, 14 percent is preferred to retard spoilage.

There are a number of types of grain dryers in current use. When dryers operate, generally, large volumes of air at relatively high temperatures are passed through grain in a drying chamber. The removal of too much moisture is wasteful of drying energy and usually results in shrinkage which decreases the sale value of the grain. If the moisture is removed too rapidly, damage to the grain results. But on farms, harvest season time is limited. The moisture content of dried grain is 15.5 percent or higher. Some grain from different sources will be storage in same storage bin with different moisture content of grain layers.

To maximize storage life and prevent moisture migration and buildup, most grain bins in current use are equipped with aeration system (see Fig.ref.01). Aeration is the process of ventilating stored grain at low air flow rates with the purpose of maintaining a fairly uniform grain temperature throughout the bin to prevent moisture accumulation at the top (or bottom) layers of the bin due to natural convection. The principal objective of the aeration system is: the air-blower unit (Ref 01 of Fig.ref.01) blows aerating air into the plenum channel.

Normally air is forced into the bin from the bottom (Ref 02 of Fig.ref.01) through a fully perforated floor and exhausted through the roof vents (Ref 03 of Fig.ref.01).

The key to success is to move the drying zone through the top of the grain mass within the allowable storage time. As shown in FIG.ref 02, at the time grain is first stored, a higher airflow is required to drop down the moisture content of grain to safety level such as 14 percentage as soon as possible. Then the high airflow rate maintains to complete drying grain until the grain temperature drops down to such degree as 15 °C before grain spoils.

At the time grain is first stored, grain moisture content should be fairly uniform throughout the bin, but if the grain from different sources or, with time, localized high moisture zones may develop due to changes in outdoor air temperatures. The low outside temperature cools the grain nearer the wall. This results in a downward air flow through the grain and upward towards the centre of the bin. As the air moves through the grain it becomes warmer and begins to pick up moisture from the grain. Condensation occurs when the warm moist air hits the cool surface of the grain near the centre of the bin, (Ref 04 of Fig.ref.01) thus leading to grain spoilage.

In most types of grain storage methods of the current use, another problem of those grain storage systems is: in order to safely store grain, the aeration system should provide a minimum of 1/10 cubic foot per minute (cfm) of air for each bushel aerated. But the air flow effect is low, because air flow rates pass through all grain layers from chamber bottom to the headspace of bin. And horsepower of blower motor will rapidly increase when grain level increases in the chamber.

Summary of the Invention

The present invention provides a rotating drum and automatic control arrangement for grain drying and storage based on capacitive moisture content and temperature measurement. The drying and storage equipment includes a rotating drum as a bin having two static end-stops, and one separated heating/aerating/cooling combination unit with plenum controlled valves.

The grain is filled into the horizontal drum from front static end-stop, named in-feed end. The drum rotates at between 0.5 and 5 rotations per minute (rpm) without damaging grain. A grain moisture content sensor for moisture content measurement, which is mounted at the static end-stop, contacts with grain in the rotating drum. A grain temperature sensor provides a grain signal.

The grain is discharged from the lower discharge end. Drum is driven by large ring-gears, rubber trunions, or sprockets and chains. The loading and unloading doors and the drive mechanisms introduce a higher degree of mechanical complexity or electrical drives and maintenance requirements relative to other devices if needed.

Air is typically injected into the drums, usually at the feed-in end, to meet process air requirements. The drum is loaded to between 65 to 80% of their total volume. Loading more material into the drum prevents materials inside from tumbling and reduces processing efficiency. A plenum air temperature sensor and a humidity sensor provide the air signal for optimizing the grain drying/aeration/cooling operation.

A heater/chiller/blower combination unit with plenum system provides heated,

aerating or cooled air into the drum for drying and storage grain.

The plenum air temperature signal, air humidity signal, grain temperature signal and grain moisture content signal etc. are entered into the PLC (Programmable Logic Controller) or other kinds of computer. The PLC or computer is programmed to operate the grain drying and storage system with the set parameters, to monitor the system for malfunctions, to respond to such problems by correcting the problem if possible or by shutting the system down and sounding an alarm, to print out report of the operation, and to remote SCADA system (Supervisory Control and Data Acquisition).

An ambient air temperature sensor and an ambient humidity sensor which monitor ambient conditions, provide signals to PLC control system for automatic running system for year-round grain storage. The system is capable of reliable operation without the attention of an operator and is characterized by a high output and high quality of the processed grain.

Objectives of the Invention

The principal objectives of the present invention are: to provide an improved grain drying and storage system; to provide such a system which results in a superior grain product which has a high uniformity of the desired moisture content; to provide a heater/chiller/blower combination unit with plenum system in response to the measured grain moisture content and temperature; to rotate the drum to move the grain from bottom to the top in the drum; to force air to carry the moisture content of grain and/or high temperature air out of the drum to reach the desired moisture content or temperature levels; to provide such a system wherein a startup drying air temperature and a maximum air temperature and the desired grain moisture content are set by an operator and are monitored by the control system to optimize the drying operation; to provide such a system wherein a startup cooling air temperature and a minimum air temperature and the desired grain temperature are set by an operator and are monitored by the control system to optimize the storage operation; to provide such a system which monitors various parameters of the grain drying system and storage and which controls the process in response to such parameters; to provide such a system which will function reliably without human intervention; to provide such a system which includes a computer and network system which collects and responds digital signals and analog signals; to provide such a system which includes soft-touch screens HMI (Human Machine Interface) and PC base monitors to display processing sequence, controls and historic data; to provide such a control system which averages the moisture content readings and which adjusts the temperature of the heated drying air in response to the relationship of each individual reading to the current average to expedite the processing of grain through the drying system; to provide such a control system which adjusts the speed of the blower in response to the relationship of each individual reading to the current average to expedite the processing of grain through the aeration system; to provide such a control system which start/stop the chiller and blower in response to the relationship of each individual reading to the current average to expedite the processing of grain through the cooling system; to provide such a control system which is reliable and energy efficient in operation, and which is particularly well adapted for its intended purpose.

Other objects and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings wherein are set forth, by way of illustration and example, certain embodiments of this invention.

The drawings constitute a part of this specification and include exemplary embodiments of the present invention and illustrate various objects and features thereof.

Brief Description of the Drawings

FIG. 01 is a sectional view of a grain drum and heater/chiller combination blower unit and plenum system in which the grain drying and storage system according to the present invention is installed.

FIG. 02 is a sectional view of front static end-stop, named in-feed end, of the drum in which the grain can be filled into the drum, and the plenum air can be forced into the drum according to the present invention is installed.

FIG. 03 is a sectional view of back static end-stop, named the lower discharge end, of the drum in which the grain can be discharged from the drum, and the moisture and warm air can be exhausted from the drum when drying or aeration operation, or as the outlet for the warm air cycling back to chiller unit, according to the present invention is installed.

FIG.04 is a diagrammatic sectional view of relationship of the rotate drum, both static stop-ends, drum drive motors and base.

FIG.05 is a diagrammatic sectional view of the moisture content sensor installation on the in-feed end.

FIG. 06 is a block diagram illustrating the principal computer interface of the control system.

<u>Detailed Description of the Preferred Embodiment</u>

Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention which may be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure.

Referring to the drawings in more detail

The reference numeral 1 generally designates a computer controlled grain drying and storage system according to the present invention. The exemplary grain drying and storage system 1 generally includes a grain rotate drum 2, front static stop-end named in-feed end 3, back static stop-end named the lower discharge end 4, a air heater and a chiller and a blower combination unit 5, Plenum air control system with ducts and control valves 6, a system

controller or control computer panel 7.

A quantity of wet grain 8 is loaded into the drum 2 from filling windows 19 on in-feed end 3, and heated air from the unit 5 is passed through the top wet grain layer 9 to dry same. The moisture air exhaust from the system exhaust outlet 10, and same time control valve 6-2 is closed for isolation, control valve 6-3 is opened for the moisture air exhausting from the drum, control valve 6-1 is opened for fresh air keep going into the unit 5.

The drum is sitting on 4 drive wheels 11-1, 11-2, 11-3 and 11-4, each drive wheel connected with its gearbox and driven by a motor. The computer adjusts the motors running speed and direction. The motors with the gearboxes drive the drum to rotate in lower speed. Periodically, the wet grain on the bottom of drum is turned over to the top position of the grain in the drum. The moisture content of the grain in drum is measured by moisture content sensor 12; and in response to the measured moisture content, the drying process is continued until the moisture content measured value reach the desired level, such as 14%.

The grain drying and storage drum 2 is not a conventional type of static grain bin, instead of combination by three parts: a static front stop-end 3 and a static back stop-end 4, and rotate drum 2. The drum 2 is a horizontal cylinder which sitting on 4 drive wheels 11-1, 11-2, 11-3 and 11-4, and a base 13. (See FIG. 04) . Although not illustrated, the drum 2 is preferably of foam isolation or a double wall construction for insulation purpose.

Internally, the drum is filled with grain about 70% total volume, the top of the grain in the drum is lower than plenum air inlet 14 and moisture air exhaust outlet 16, inside of the drum, there is a space, named headspace 15, for the air flow.

The Heater/chiller/blower combination unit 5 communicated with the plenum system 6, include air flow duct and control valves 6-1, 6-2 and 6-3. (See FIG.01, FIG.02, FIG.03). The unit 5 includes a fuel burner, or electrical heater to heat air, and include electrical chiller to cooling air, both burner and chiller cooperate with a fan or blower. The heater unit includes fuel valves to control the flow of fuel such as natural gas or the like to the burner; and the unit 5 includes a high fire valve for drying grain purpose, and a low fire valve for remove moisture from grain for long term grain storage purpose. Other type of valves arrangements such as modulating, proportioning, throttling valves, or the like could also be employed for best control and save energy purpose.

When drying grain, the valve 6-1 is open, the fresh air going into the unit 5, and the unit 5 is operative to heat air which is propelled by the blower into the plenum system 6. The heated air expands upon entry into the plenum 6 and is forced into the headspace 15 of drum 2 by the blower. The drying action occurs in the drying zone or top layer of grain 9 with the upper levels receiving virtually no drying action because of saturation of the air with moisture from grain in the drying zone 9. In order to monitoring the drying process, the plenum 6 is provided with a plenum air temperature sensor 17, and the drum may be provided with a grain temperature sensor 18 which is located to sense the temperature of the lower layer of grain 9. A grain temperature sensor would be desirable in a rice and seeds dryer and storage system because the greater sensitivity of rice and seeds than other grains to damage from overheating. The blower may be capable of operating independently of the burner and chiller for long term storage aerating operation to cooling the grain. Such action

is desirable when long term grain storage in drum to prevent spoilage of the grain which would be accelerated because of the elevated temperature.

The grain drying and storage drum 2 is loaded with grain from in-feed window 19, (see FIG. 02) specifically, the in-feed window 19 locate at upper center of in-feed end 3. Grain is unloaded from the discharge gate 20 which locate at lower center of discharge stop-end 4 (see FIG. 03).

The drum 2 is driven by 4 drive wheels 11-1, 11-2, 11-3, 11-4, and the wheels are driven by the gearboxes with motors, the gearboxes reduce motor speed to lower speed, and motor speed adjusted by VFD (Variable Frequency Drive) unit installed inside of the control panel 7. Drum rotate Maximum speed can be set by operator from soft-touch screen on control panel 7 to avoid damage the grain due to drum rotate too fast.

The grain moisture content measuring sensor 12 illustrated in FIG.05, the sensor 12 is a digital microwave moisture sensor, and designed to be installed in bins, soils and conveyors in process control environments . This modern sensor with stainless steel body 12-2 and ceramic faceplate 12-3 construction, the sensor is mounted on the wall of in-feed end 3, measuring the moisture content of grain 8 in the drum.(see FIG.05). the sensor 12 is designed to suit the flow characteristic of the material, when the drum 2 rotating, the grain turning and moving inside of drum, the sensor 12 accurately measures the moisture content of grain 8 as it flows over the ceramic faceplate 12-3, measuring at 25 times per second and with on-board functionality such as signal processing and averaging. The sensor 12-1 provides 4 – 20 mA current loop source to PLC or computer for grain drying and storage processing control. The moisture content measurement shown in FIG. 05 is exemplary, and other automatic sampling arrangements may be employed without departing from the spirit of the present invention.

Plenum system 6 has three control valves 6-1, 6-2 and 6-3. (see FIG.01, FIG.02, FIG.03), for the system 1 running under the different functions: grain drying function, aeration function for long term storage, cooling function for long term storage.

When the system 1 operating under grain drying function, the valve 6-1 is open, fresh air going into the unit 5, the air is heated by the heater, the blower forced the heated air into headspace 15 in the drum 2, the valve 6-2 is closed and the valve 6-3 is open, the air with the moisture from the grain 8 exhausts to outlet 16, due to the valve 6-2 is closed, the moisture air cannot return to the unit 5, the moisture air passes the valve 6-3 which is open and the system air outlet 10 to atmosphere.

When the system 1 operation under aeration function for long term storage, the PLC or computer 7 turn OFF the heater and chiller in the unit5, turn ON the blower in the unit 5, the fresh air passes the valve 6-1 which is open into the unit and forced by the blower into the headspace 15, the aeration air push the existing warm air in the drum 2 out to the outlet 16, due to the valve 6-2 is closed, the warm air cannot return to the unit 5, the warm air passes the valve 6-3 which is open and the system air outlet 10 to atmosphere. The grain is cooled down for the grain safety storage.

When the system 1 operation under cooling function for long term storage, such as summer and ambient humidity is high, isolate the air from ambient into the drum 2 and operating the chiller for cooling the air in the headspace 15 as air condition system, to keep the grain in the drum 2 in desired temperature level such as 15 °C. the PLC or computer turn

OFF the heater and turn ON chiller and the blower in the unit 5, the valve 6-1 is closed to isolate the air from atmosphere into the unit, and the cooled air is forced by the blower into the headspace 15, the cooled air push the existing warm air in the drum 2 out to the outlet 16, due to the valve 6-3 is closed, the atmosphere air is isolated, and the valve 6-2 is open, the warm air return to the chiller in the unit 5 to cool down. The air is cycling between the chiller in the unit 5 and headspace 15 to keep the grain in safety storage temperature level.

The humidity sensor 21 which is mounted on the wall of the discharge end 4, measures the humidity of the air in headspace 15 for best processing control under grain drying operation and aeration operating for long term storage.

An ultrasonic level sensor 24 is mounted on the upper location of the wall of the discharge end 4 to measure the height of grain in the drum 2 for the processing monitor and control.

FIG. 06 illustrates the major components of the control system in the panel 7 of the grain drying and storage system 1. The principal control component is a the microprocessor of PLC unit (Processing Logic Controller) or digital computer 26, it cooperate with soft-touch screen HMI (Human Machine Interface) 27, and signal input model 28, control output model 29. The microprocessor 26 may employ any of a number of suitable microprocessors which are commercially available. Whila the soft-touch screen HMI 27 provides diagnostic information to an operator. The operating equipment such as sensors, valves and alarm light etc of the system 1 is interfaced to the PLC unit by Input/output(I/O) interface unit. In general, the signal input model 28 has the digital moisture sensor 12, Plenum air temperature sensor 17, Grain which in the drum 2 temperature sensor 18, the air humidity sensor 21 which measuring the air humidity level in the headspace 15, a ultrasonic level sensor 24 for measuring the grain height inside of the drum 2. In order to storage grain year-round time long, an atmosphere temperature sensor 22 and an atmosphere humidity sensor 23 provide the ambient condition for the system control.

The I/O unit control output model 29 commands to heater/chiller/blower unit 5, Plenum air system 6, motors which drive the drum 2 to rotate, extra exhaust fan 26, alarm light 30, buzzer 31 for an operator, safety interlock 32 if need for some safety reasons, remote control signals 33 for other equipments which related with the system 1 such as a grain feed in system or devices. The equipments of the system 1 as will be detailed herein below.

FIG.06 illustrates details of the interface as signal input models 28, the sensors monitored by the microprocessor CPU unit 26. The operating equipment of the system 1 is interfaced to CPU unit 26 through the control output models 29. The signal input models 28 may be digital signal input DI model and analog signal input AI model, the control output models 29 may be digital signal DO model and analog signal output AO model. The CPU unit 26, model 28 and model 29 may be any one of a number of commercially devices. Such as Allen-Bradley PLC or Siemens PLC.

The Digital moisture sensor 12 is a microwave moisture sensor, provides 4-20 mA current loop source to analog signal input model 28; the temperature sensor 17 and 18, are preferable RTD with 4-20 mA transmitter, the 4-20 mA signals are provided to the analog input model 28 for monitoring plenum air temperature changing and the grain temperature changing. Same way, when the system operating for long term grain storage, atmosphere

temperature is monitoring by RTD and its transmitter 22. A humidity sensor provides 4-20 mA signal is used as drum air humidity sensor 21, and another humidity sensor 23 is used for monitoring atmosphere humidity for best control. An ultrasonic level transmitter is employed for measuring the grain volume by measuring height of grain in the drum 2.

If need, some digital input signals can be used for monitoring the equipment operating status, such as the heater is ON or OFF, the chiller is ON or OFF, the blower is ON or OFF, the drum 2 is rotating or stop, the fresh air valve 6-1 is Open or Close position, the isolation valve 6-2 is Open or Close position, the exhaust valve 6-3 is Open or Close position.

One specific status sensor is a drum humidity sensor 21 which is positioned in the headspace 15 of the drum and nearby the outlet 16 to determine if humidity level reach the desired humidity level or humidity set-point. If the sensor 21 indicates a very high level humidity of grain, the heater will be started to remove the moisture of the grain; if the sensor 21 indicates a level higher than set-point, the blower will be on in high speed and system operating under aeration mode.

The functions of the system 1 which are controlled by the PLC unit 26 include: the blower, the high fire valve, the low fire valve, the chiller, speed of motor of the blower can be adjusted by a VFD (Variable Frequency Drive), a analog control output model is employed to provide 4-20 mA signal to the VFD for changing the blower's rotate speed. When the system 1 is operating under grain drying mode, the blower should operate as maximum rotating speed.

The high fire valve and the low fire valve are used for effetely remove the moisture of the grain and protect to avoid temperature too high for the grain.

The plenum 6 control valves 6-1, 6-2 and 6-3 are controlled by PLC with programming sequence. When the system is operated as grain drying, the fresh air valve 6-1 is open, the fresh air goes into the heater, and the exhaust valve 6-3 is open, the moisture air of the grain is exhausted through the valve 6-3 to atmosphere; when the system is operated as a aeration period for long term grain storage, the fresh air valve 6-1 is open, the fresh air is forced by blower, while both of the heater and the chiller are OFF, and the exhaust valve 6-3 is open, the existing warm air in the drum 2 is forced out to atmosphere through valve 6-3, and isolate valve 6-2 is controlled to close to avoid the warm air returns back to the blower; when the system is operated as cooling period of grain long term storage, the valve 6-1 and the valve 6-3 are closed, the isolate valve 6-2 is open, the drum and the unit 5, and plenum 6 are enclosed to isolate from the ambient, the air is cooled by the chiller, and is forced by the blower to entry the drum, the warm air return to the chiller through the valve 6-2, and the warm is cooled by the chiller and send back to the drum 2, the cycling is continue until the temperature of the grain is cooled down to desired level or set-point such as 15 °C. Each of these functions is controlled through the PLC or computer output interface models.

The drum cylinder 2 is made by carbon steel or stainless steel, the drum cylinder sitting on four solid steel wheels or solid rubber wheels, the wheels are driven by the motor and gearbox combination units. In drying operation of the system1, the drum with about 70% full of wet grain, an operator turn on the system 1 from HMI 27 on the control panel 7 and sets the desired grain moisture content, the maximum plenum temperature, a blower start-up temperature for plenum 6, and the current time. The system 1 is then controlled by the PLC or computer 26 to take an initial moisture reading and activating the motors of drive

solid wheels to cause the rotating of the drum2. While this is occurring, the heater is ignited, and the PLC control system 26 is set to automatic operation. If the grain is wetter than desired, a waiting period is initiated in proportion to the difference between the measured moisture content and the desired moisture content. The heating unit 5 is cycled in such a manner as to dry the grain 8 most efficiently. If the initial cycle is as dry as or dryer than desired, the drum 2 will be stopped; the grain will be unloaded from the drum 2, or keep the grain in the drum 2 for long term storage. In the automatic mode of operation, moisture readings are taken at selected intervals of time, and the heater unit 5 and the rotating drum 2 are automatically controlled in response to the moisture content and sensed temperatures. The system 1 will shut itself down upon the occurrence of predefined malfunction and display diagnostic messages on HMI 27, or on a remote screen. The grain level sensor 24 senses the grain height in the drum 2 and display on HMI 27, the grain level sensor 24 provides the signal of grain volume in drum 2 to PLC as reference for adjusting the rotating speed of drum 2.

In a preferred mode of operation, an initial moisture content reading is taken. If the reading is wetter than the desired moisture content, a wait period is initiated during which the heater unit 5 is cycled to maintain the start-up temperature. After the initial moisture content measurement, the subsequent moisture readings are averaged up to a selected maximum, for example, four readings including the current reading. After the first reading, as each reading is taken and determined to be wetter than desired, the PLC unit 26 cycles the heater unit 5 to maintain an incrementally higher drying air temperature. As soon as either the current reading or the average moisture content is reduced to the desired moisture content, the buzzer will be ON; an operator will remove grain from drum 2, or forward to next process step for long term storage.

Thereafter, the drying air temperature is adjusted, by cycling the heater unit 5 through the high and low fire valves 5-1 and 5-2, to accommodate variations in the moisture content of the grain in drum 2. The PLC unit 26, therefore, discerns a trend in the moisture content of grain in drum 2 and adjusts the maintained drying air temperature in accordance with short term variations in the moisture content as measured. For example, if the average moisture content is as dry as desired, but the currently measured moisture content is too wet, the maintained drying air temperature is increased. Conversely, if either the average or current moisture drops below the desired moisture percentage, the maintained air temperature is reduced to prevent over-drying. Before each increase in air temperature, the currently maintained drying air temperature is compared to the set maximum temperature to prevent "cooking" of the grain from excessive heat. The object is to adjust the drying air temperature in such a manner as to uniformly dry the grain while operating the drum 2 rotating as continuously as possible. This allows the drying process to proceed as rapidly as possible commensurate with high uniformity of moisture content of the grain in the drum 2. The control method as described herein retains the energy efficiency associated with heater unit 5 controlled by PLC unit 26.

The grain drying and storage system 1 significant advantage over previously employed grain dryer systems and grain storage systems. Drying operation is controlled in relation to directly measured grain moisture content by the sensor 12 rather than moisture content related to temperature measurements which is subject to a greater number of variables.

Start up with the system 1 is faster and more efficiency for the operator since it is not necessary to wait for equilibrium conditions to be established as in systems in which control is based on temperature derived moisture content. The system 1 continuously adjusts the drying temperature for maximum drying rate and monitors the operation to prevent over-drying of the grain.

The monitoring and display of the status of the grain drying processing, if malfunctions occur, alarm lighting will be on, and the historic processing data and alarm records can be checked by the operator through soft-touch screen HMI 27, and can be remotely checked from SCADA system. Because the operation is closely monitored and controlled in response to monitored conditions, greater throughput and efficiency can be attained. Finally, the system 1 does not require a high degree of skill to operate and can run for the most part without human intervention.

Further, it is possible that other types of non-manual moisture measuring devices could be advantageously employed. Therefore, it is to be understood that while certain forms of the present invention have been illustrated and described herein, it is not to be limited to the specific forms or arrangement of parts described and show.

GRAIN DRYING AND STORAGE SYSTEM

Claims

- 1. A method of grain drying and storage comprising the steps of:
 - (a) Providing a grain drying and storage apparatus including grain drying and storage. the drum means for holding grain, the in-feed end and the lower discharge end means to static end-stops for both sides of the drum, the four solid drive wheels with gearboxes and motors means to drive the drum rotating, a heater/chiller/blower unit to communicate air to the drum chamber means to dry grain or aerate grain or cool grain, the grain moisture sensor means for measuring the moisture content of grain, the plenum system means having air communication conduits and control valves interconnected thereto;
 - (b) Conveying fresh air into the heater/chiller/blower unit;
 - (c) Communicating heated air to the drum means to dry grain;
 - (d) Moisture air is removed through exhaust valve to atmosphere;
 - (e) Isolate valve means to block the air return to heater/chiller/blower unit;
 - (f) When system operate on cooling storage, fresh air valve and exhaust valve are closed, and isolate valve is open, the air is limited between the heater/chiller/blower unit, the plenum system and the drum chamber for cycling cool grain, and the air is isolated from the ambient.
 - (g) Periodically directly measuring the moisture content of grain in the drum; and near the inlet of the heated air is measured; near the outlet of air humidity is measured and;
 - (h) Communicating the grain moisture signal, air temperature signal, air humidity signal in the drum to system PLC or computer, PLC means to Programming Logic Controller unit: and
 - (i) Controlling the operation of heater/chiller/blower unit by system control means PLC or computer in response to the moisture content represented by grain moisture signal and
 - (j) Controlling the motors to rotate the drum by PLC or computer in response to the moisture content by grain moisture signal, and controlling the heated air temperature by air temperature signal;
 - (k) The heater and blower of heater/chiller/blower unit and the drum are controlled to stop drying operation in response to grain moisture content being a desired or preselected moisture content level.
 - (I) The blower of heater/chiller/blower unit and the drum are controlled to stop aeration operation in response to the air humidity or/and temperature being a desired or preselected air humidity or/and temperature level.
 - (m) The chiller and blower of heater/chiller/blower unit and the drum are controlled to stop cooling operation in response to the air temperature being a desired or preselected air temperature level under cooling mode for long term storage.
 - (n) Ambient humidity sensor, ambient temperature sensor, wind sensor and rain sensor means to equipments are mounted outside of control panel enclosure for monitoring

atmosphere conditions as the reference for PLC or computer logical control programming for grain storage year-round.

- 2. A method as set forth in claim 1 wherein measuring the moisture content step includes:
 - (a) Measuring the dielectric constant of grain; and
 - (b) Converting the measured dielectric constant of grain to a moisture content percentage of grain as international standard 4-20 mA current signal for PLC unit or computer programming.
- 3. A method as set forth in claim 1 including:
 - (a) Mechanically driving a drum to rotate by four motors combination with gearboxes;
 - (b) four motors combination with gearboxes statically are mounted on the base, and
 - (c) Each motor combination with gearbox connects a solid steel wheel or a rubber wheel,
 - (d) drum sites on the four solid wheels which connected with the motors combination with gearboxes,
 - (e) PLC unit or computer controls the four motors to start and stop same time,
 - (f) Four wheels are started and stopped same time with their motors,
 - (g) The motor speed is reduced to a low speed by the gearbox,
 - (h) The drum is driven by the wheels as a low speed,
 - (i) a VFD unit means to variable frequency drive component for adjusting motor speed, the drum rotating speed is adjusted by VFD unit to desired speed which programming requirement.
- 4. A method set forth in claim 1 including the steps of:
 - (a) entering a desired grain moisture content into the control means, by HMI unit or computer;
 - (b) HMI means to Human Machine Interface which communicating with PLC unit;
 - (c) entering a desired drying air temperature into the control means;
 - (d) controlling the operation of the heater unit by control means to normally maintain the desired drying air temperature; and
 - (e) Upon the moisture signal representing a moisture content which is not greater than the desired moisture content, controlling the heater unit by the control means to stop.
 - (f) Upon the temperature signal representing the air temperature in the drum which is not greater than the desired air temperature in the drum, controlling the blower, the drum by the control means to stop for long term storage.
- 5. In a method for drying and storage, grain is feed from a window which locates at upper position of the static front end-stop, and grain is unload from a discharge gate which locates at lower position of the static back end-stop, the improvement comprising the steps of:
 - (a) Grain is feed from a feed-in window;
 - (b) a ultrasonic level sensor is mounted at upper position of the feed-in end-stop, but inside of the drum;
 - (c) The buzzer or alarm light is on when the grain height in the drum measuring by the ultrasonic sensor is higher than preselected grain level, the operator can stop the grain feeding, or grain feeding devices are stopped by the control means.
 - (d) entering a desired grain level into the control means, the desired grain level is preferred to set 70% or less, make sure the headspace means the space which above

- the grain in the drum is enough for heated or aeration air flow and remove the grain moisture efficiently;
- (e) the dried grain is unload from the discharge gate which on lower position of the back end-stop;
- (f) The discharge gate either is mechanical manual operation mode or automatic operation by electrical devices, or other same function devices.
- 6. A method as set forth in claim 1 include the steps of:
 - (a) The heated air is forced by the blower, and is communicated to a drying zone which is top grain layer in the drum;
 - (b) The heated air absorbs the grain moisture, and exhausts from outlet and exhaust valve which locate at upper of back end-stop wall;
 - (c) An extra exhaust fan means to remove moisture air out from the drum rapidly associate with plenum system.
- 7. A method as set forth in claim 6 wherein the plenum system includes the steps of:
 - (a) Controlled the fresh air valve to open position by the control means;
 - (b) Controlled the heater to operate by the control means, and controlled the high fire valve and low fire valve by the control means which responds to the air temperature signal in the headspace;
 - (c) Controlled the blower to operate by the control means;
 - (d) The heated air is forced by the blower, and entering the headspace of the drum;
 - (e) Controlled the exhaust valve to open position by the control means, the moisture air is exhausted through the exhaust valve and outlet port to atmosphere;
 - (f) Controlled the isolate valve to close position by the control means, the isolate valve blocks the moisture air return to the heater unit through the plenum communication conduit.
 - (g) When the system operating as aeration mode, controlled the heater to stop status, and controlled the blower and the drum to operating status by the control means;
 - (h) Controlled the aeration mode by the control means which responds to grain temperature signal, to normally maintain the desired grain temperature.
 - (i) When the system operating as cooling mode, controlled the chiller to operating status;
 - (j) controlled the fresh air valve and exhaust valve to close position, and controlled the isolate valve to open position by the control means;
 - (k) and controlled the chiller, the blower and the drum to operating status by the control means;
 - (l) Controlled the cooling mode by the control means which responds to grain temperature signal, to normally maintain the desired grain cooling storage temperature for long term storage.
- 8. A system as set forth in claim 2 wherein the moisture sensor includes:
 - (a) a microwave measurement sensor designed to be installed in bins, silos and conveyors in processing control environments;

- (b) the moisture sensor is designed to suit the flow characteristics of the materials;
- (c) fast response to changing conditions with 25 measurements per second;
- (d) The sensor has the stainless steel body and ceramic faceplate construction.
- 9. A system as set forth in claim 7 including:
 - (a) a grain temperature sensor positioned in grain in the drum means for contact with the grain being dried, aerated and cooled; the grain temperature sensor being interconnected with control means whereby PLC unit or computer, the control means in response to the temperature sensed by the grain sensor;
 - (b) An air temperature sensor positioned on headspace in the drum and near the inlet of plenum communication conduit; the air temperature sensor being interconnected with the control means whereby PLC unit or computer, the control means in response to the temperature sensed by the air sensor.
- 10. A system as set forth in claim 1 wherein the humidity sensor includes:
 - (a) An air humidity sensor positioned on headspace in the drum and near the outlet of exhaust port; the humidity sensor being interconnected with the control means, the control means in response to the humidity sensed by the humidity sensor
 - (b) An atmosphere humidity sensor is mounted outside of the system control panel enclosure to monitoring the atmosphere humidity, the atmosphere humidity sensor being interconnected with the control means, the atmosphere humidity sensor provides the signal for programming to avoid the system is operated as aeration mode when atmosphere humidity is higher than air humidity in the drum.
- 11. A method of a isolation for the drum chamber includes:
 - (a) the drum and both static end-stops have foam isolation surface construction, for isolate the grain in the drum with ambient, to avoid heating energy lost when drying grain, and to avoid high atmosphere temperature warming up the grain in the drum when the system is operating on cooling storage mode.
 - (b) A double wall construction of the drum and both static end-stops can be employed for insulation purpose.
- 12. A method of driven for the drum rotating includes:
 - (a) Solid metal or rubber wheels drive the drum by friction; or
 - (b) Drum is driven by large ring-gears; or
 - (c) Drum is driven by rubber trunnions; or
 - (d) Drum is driven by sprockets and chains.

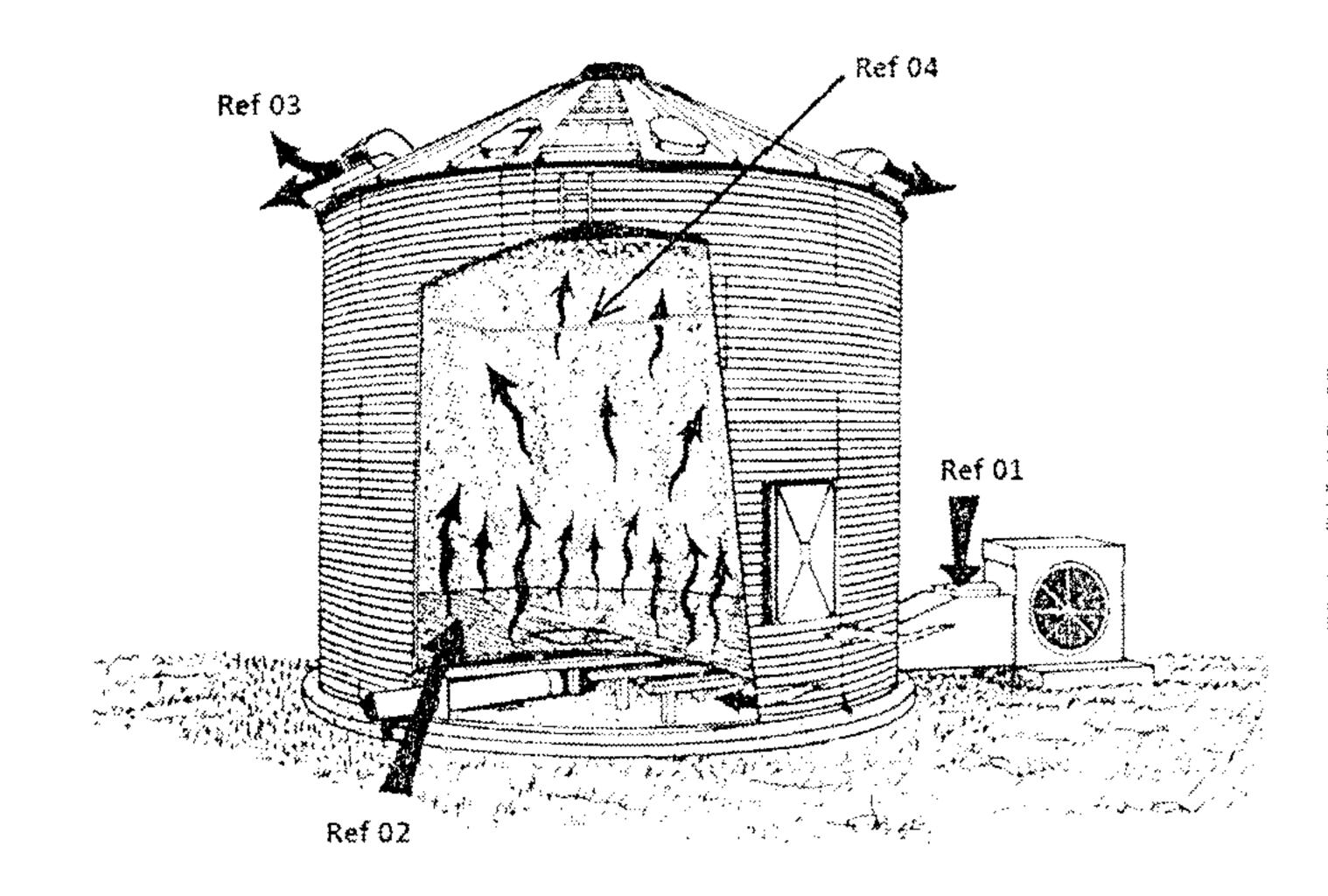


Fig. ref.01

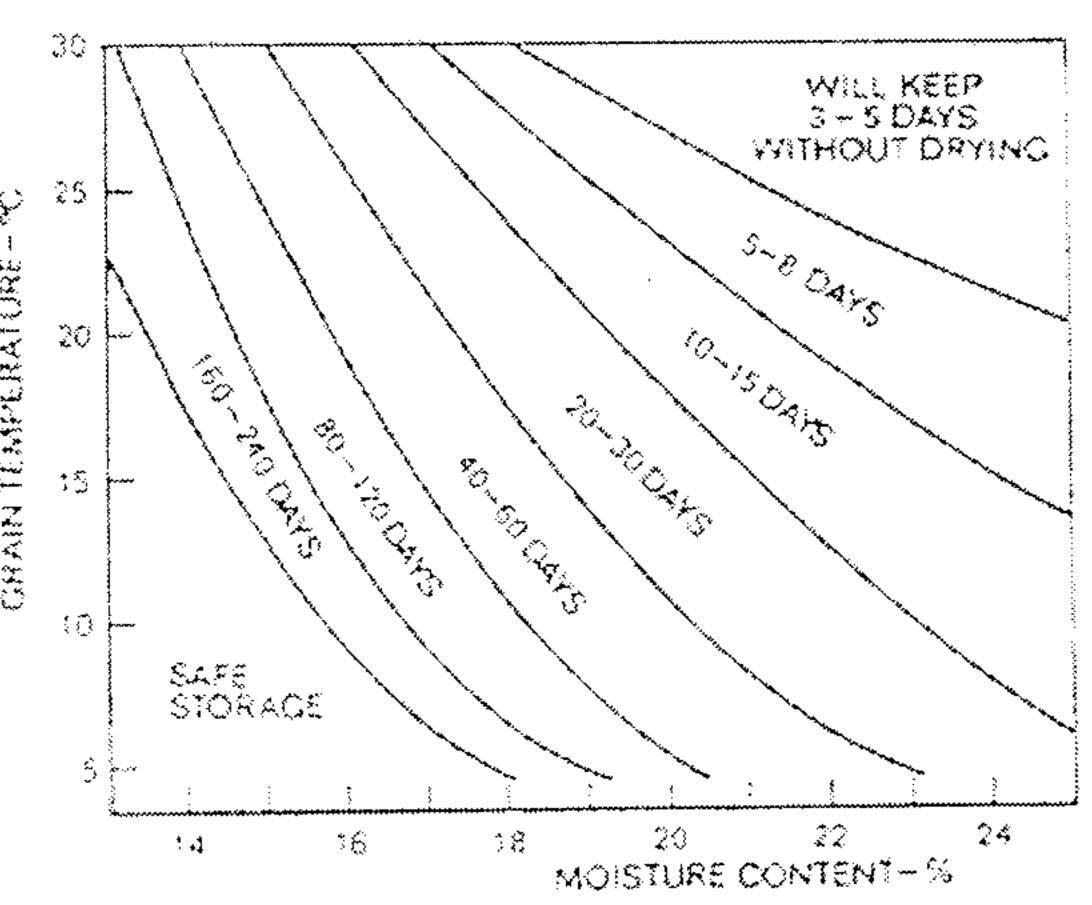
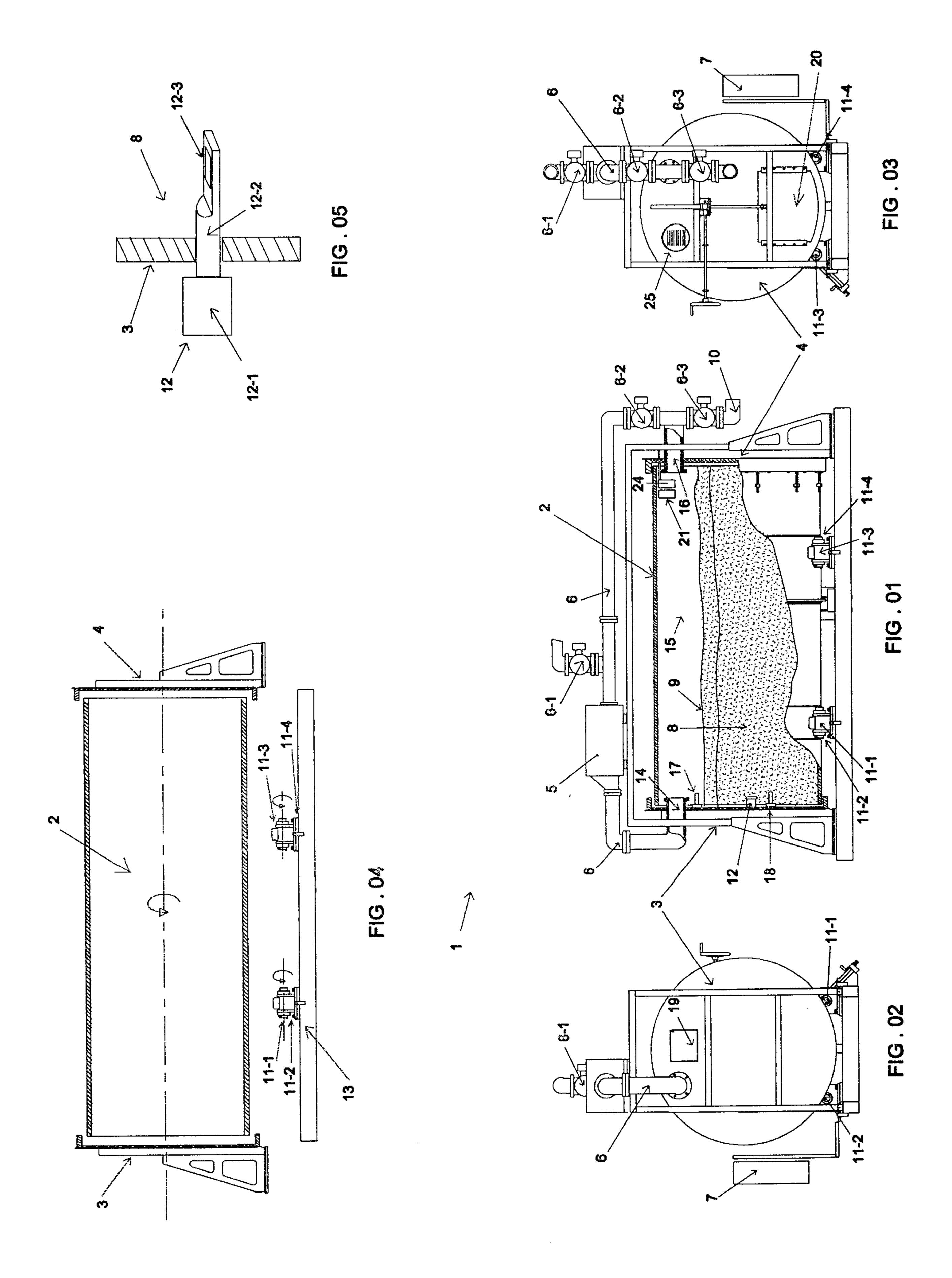


FIG.ref.02



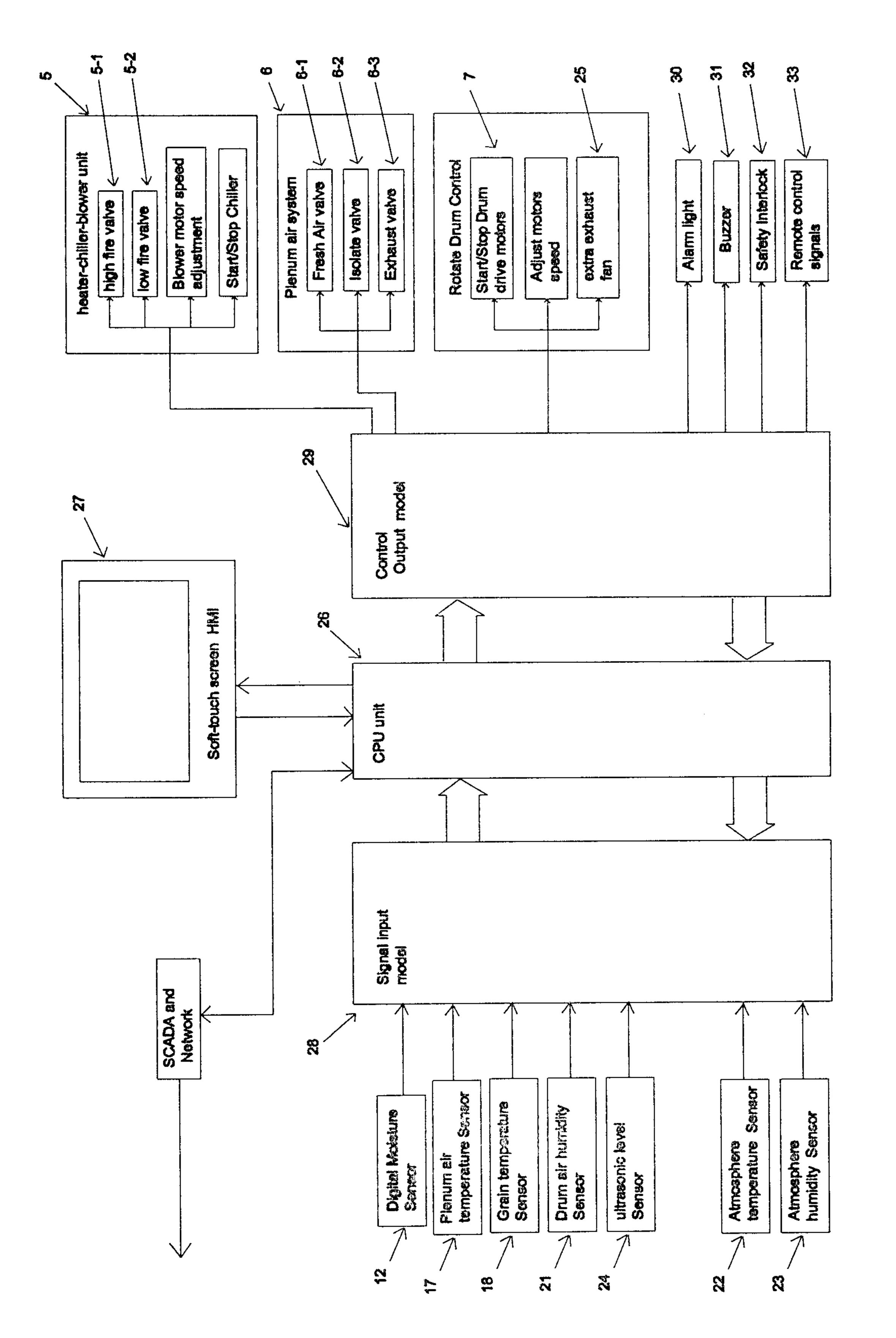


FIG. Q

