March 19, 1968 C. M. KLINE ETAL 3,373,503

GRAIN DRYING PROCESS AND APPARATUS

Filed Jan. 3, 1967 4 Sheets-Sheet 1

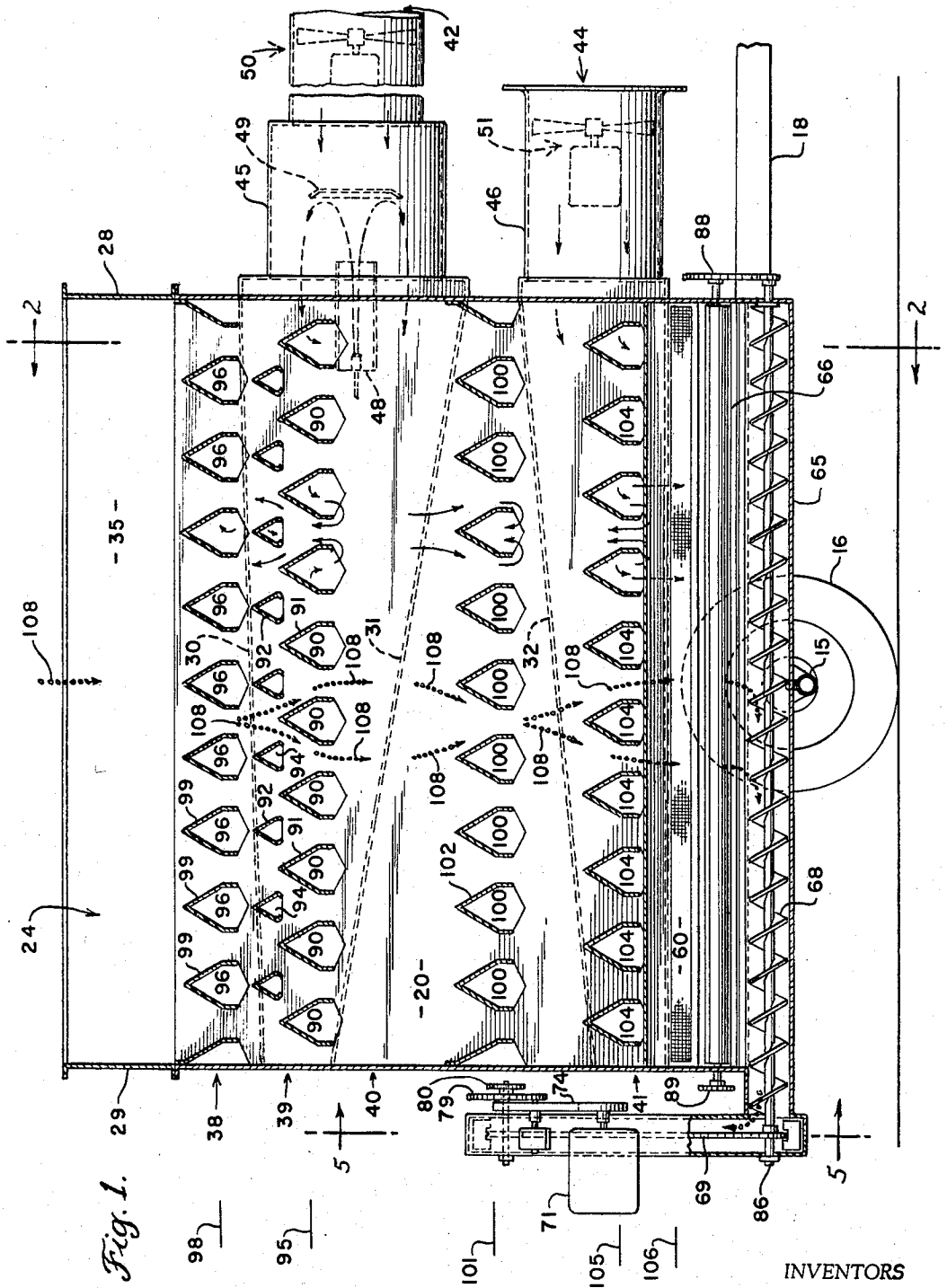


Fig. 1.

INVENTORS
CHARLES M. KLINE
& ALBERT M. BEST
BY Walter V. Wright
AGENT

March 19, 1968 C. M. KLINE ETAL 3,373,503

GRAIN DRYING PROCESS AND APPARATUS

Filed Jan. 3, 1967 4 Sheets-Sheet 2

Fig. 2.

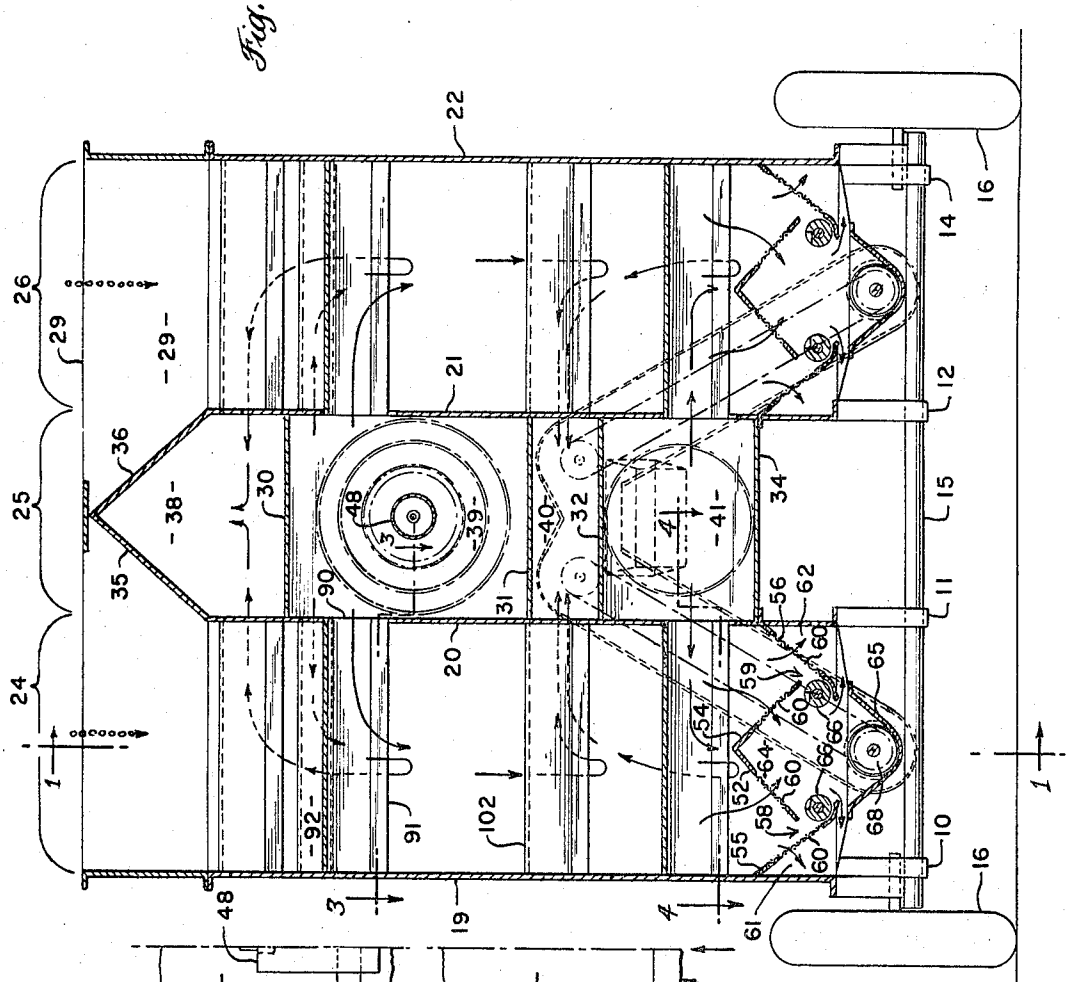


Fig. 3.

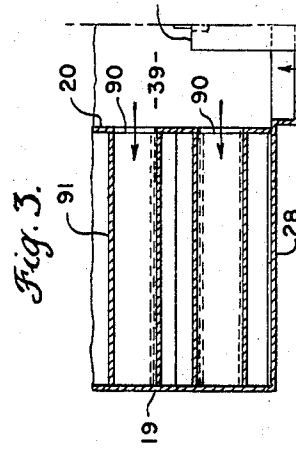
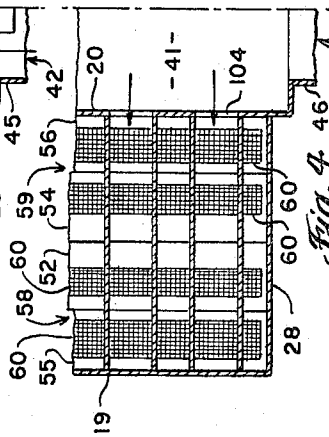


Fig. 4.



INVENTORS
CHARLES M. KLINE
& ALBERT M. BEST
BY Walter V. Wright
AGENT

March 19, 1968 C. M. KLINE ETAL 3,373,503

GRAIN DRYING PROCESS AND APPARATUS

Filed Jan. 3, 1967 4 Sheets-Sheet 3

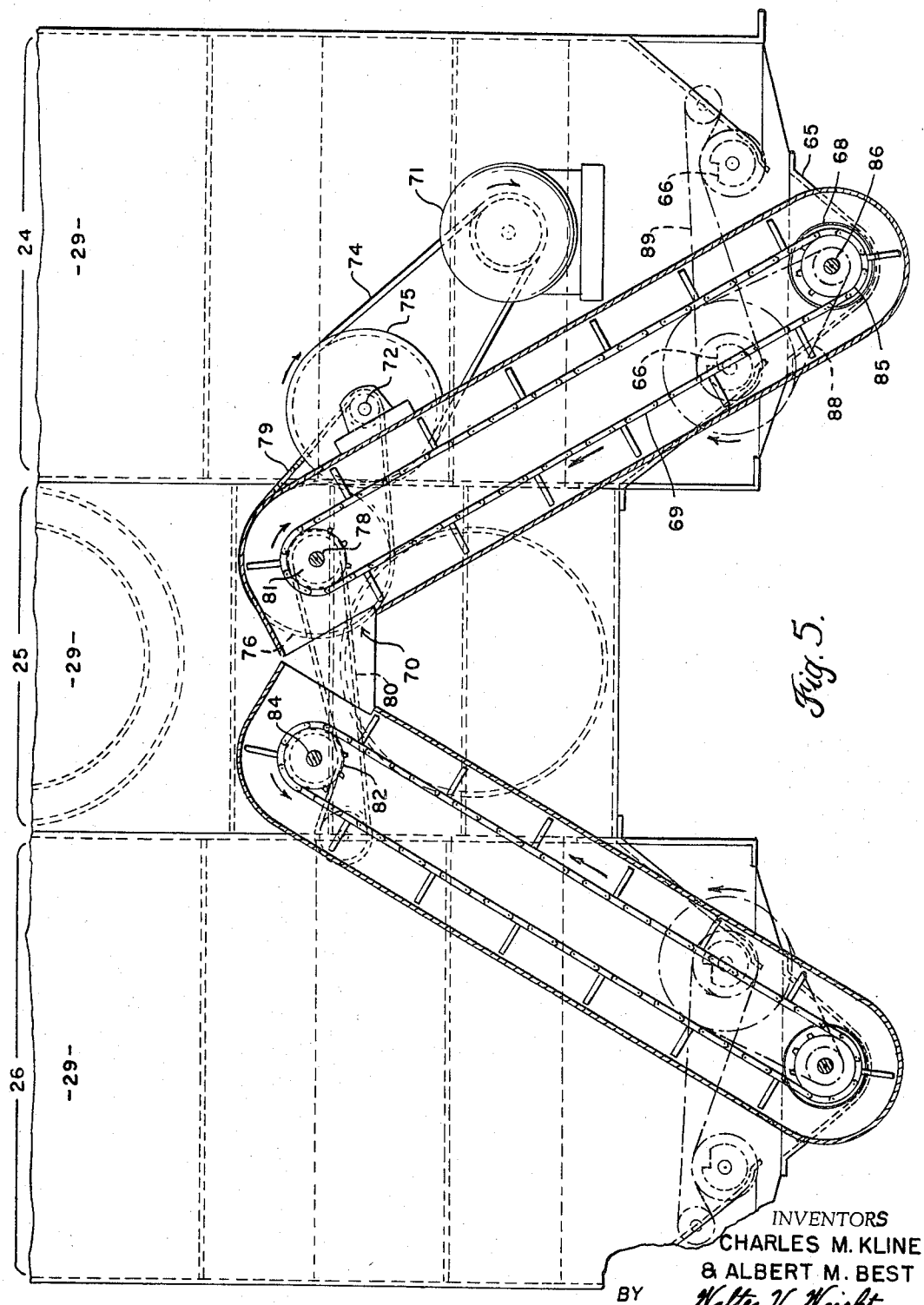


Fig. 5.

INVENTORS
CHARLES M. KLINE
& ALBERT M. BEST
BY Walter V. Wright
AGENT

March 19, 1968 C. M. KLINE ETAL 3,373,503

GRAIN DRYING PROCESS AND APPARATUS

Filed Jan. 3, 1967

4 Sheets-Sheet 4

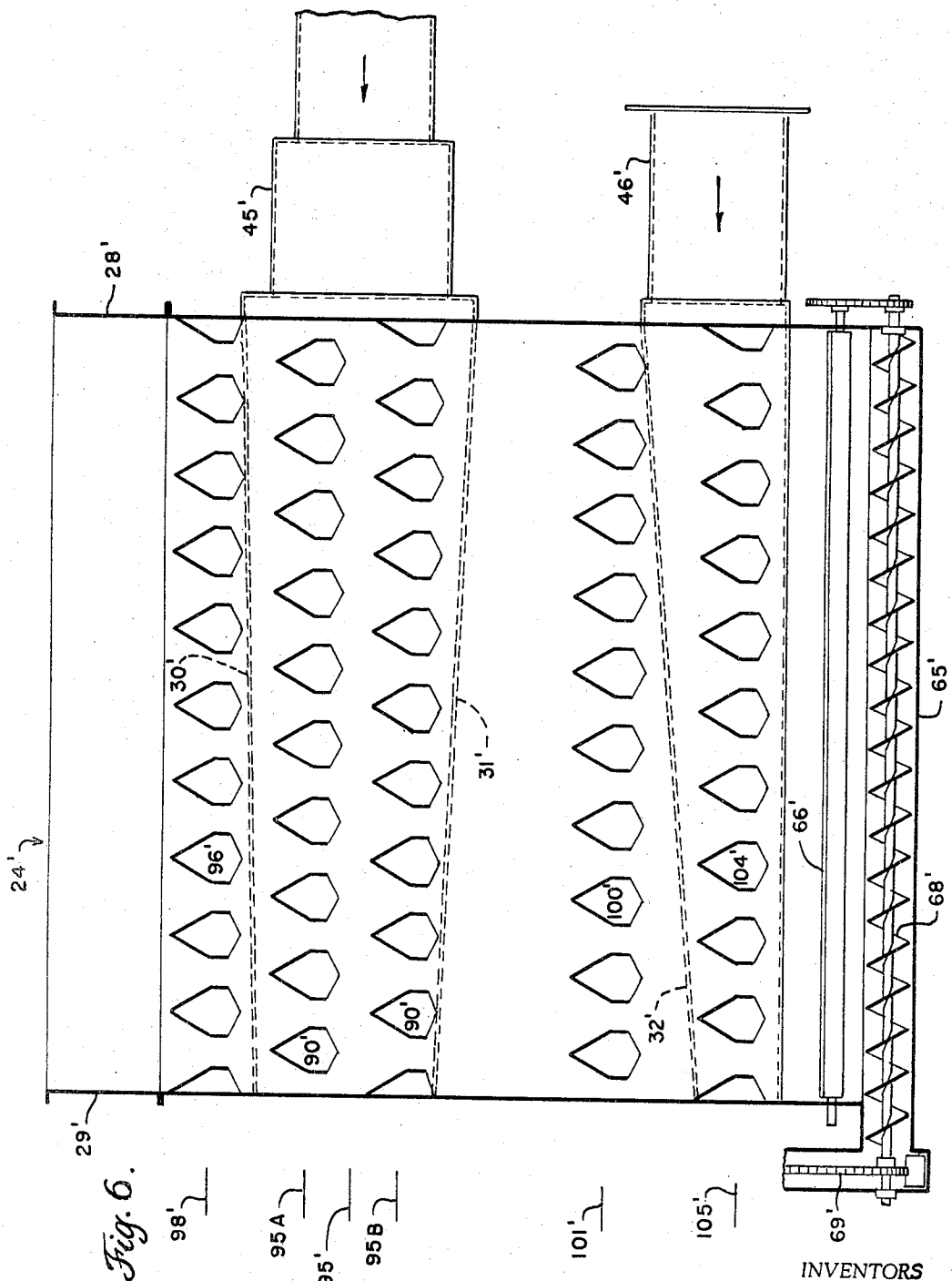


Fig. 6.

INVENTORS
CHARLES M. KLINE
& ALBERT M. BEST
BY Walter V. Wright
AGENT

United States Patent Office 3,373,503 Patented Mar. 19, 1968

3,373,503

GRAIN DRYING PROCESS AND APPARATUS

Charles M. Kline, Reinholds, and Albert M. Best, New Holland, Pa., assignors to Sperry Rand Corporation, a corporation of Delaware

Filed Jan. 3, 1967, Ser. No. 606,968
9 Claims. (Cl. 34—33)

ABSTRACT OF THE DISCLOSURE

A continuous grain flow grain drying process and apparatus having air inlet and exhaust ducts particularly relatively located to enable the use of considerably higher drying air temperatures than those of conventional grain driers.

Background of the invention

Before grain can be safely stored in bulk storage bins, or the like, the moisture content of the grain must be lowered below certain limits. Excessive moisture results in heat and spoilage of the grain in storage.

The usual grain drying process consists of placing the grain in a confined area and forcing hot dry air into and through the area to carry off moisture from the grain. Although the process is basically simple, it involves a difficult balancing of the wide ranging variables of drying air temperature and drying time. The hotter the air, the more efficiently it removes moisture from the grain and the shorter the required drying time, but the more likely it is to produce stress cracks in the hulls of the grain kernels where the hot dry air contacts the cold wet grain. Lower air temperatures reduce the probability of grain cracking, but remove moisture less efficiently and, therefore, increase the cost of moisture removal by requiring more air and longer operating times. The longer the operating time, the greater the likelihood of some kernels becoming overheated and charred. The quality and value of the grain decreases as the percentage of cracked and charred kernels increases.

In an effort to minimize kernel cracking and charring, conventional operations have generally settled upon the use of conservative air temperatures and extended drying times. In order to achieve a satisfactory grain volume capacity with these time and temperature proportions, conventional operations have been commonly built to massive physical proportions. Thus, conventional drying apparatus is usually expensive to construct and operate. It also lacks mobility because of its size.

Summary of the invention

The present invention comprises a grain drying process and apparatus which safely enables the use of considerably higher air temperatures than those used in conventional systems. In other systems, as in the present invention, the air temperatures and drying times must be varied somewhat in accordance with the type of grain being dried and other factors, such as the percentage of moisture in the grain and the ambient air temperature and relative humidity; consequently, specific temperature figures are, per se, of little value for purposes of comparison. It may be more significantly stated that the present invention involves the use of air temperatures

in a range which would be likely to produce considerable kernel stress cracking or charring in conventional systems for a given set of conditions. For one example, air in the 300–350° F. temperature range may be employed to dry shelled corn, according to the present invention, to a quality equal to, or better than, that of corn dried by conventional systems using 180° F. air.

This is accomplished by gravitating a stream of the grain to be dried downwardly through a vertical passage. Thus, the size of the apparatus has little relationship to the total volume of grain to be dried. It need be constructed only large enough to accommodate the portion of grain in the stream. The hot air is delivered to a single relatively narrow horizontal zone of the vertical grain passage. In this zone the drying efficiency is very high. The grain gravitates through the single high temperature zone in a relatively short time interval, before damage can occur. The natural flow characteristics of air through grain are utilized to strategically locate two horizontal zones, respectively above and below the hot air inlet zone where the air is exhausted from the passage. The exhaust ducts are located so that a major portion, approximately two-thirds, of the hot air travels upwardly from the hot air inlet zone through the stream of grain to the upper exhaust zone. The remaining one-third portion of the hot air travels downwardly from the hot air inlet zone parallel with the direction of flow of the stream of grain to the lower exhaust zone. The duct arrangement of the present invention considers not only the effects of the hot air on the grain, but also considers and utilizes the conditioning effect of the grain on the hot air to enable the use of maximum temperature drying air.

The downwardly gravitating stream of grain is first contacted by the drying air at the level of the upper air exhaust zone. By the time the air has risen from the hot air inlet zone to the upper exhaust zone, it has picked up moisture from the grain and its temperature has been reduced by the heat given up to the grain. As the stream of grain gravitates downwardly through the upwardly flowing hot air, it contacts progressively hotter, drier air until the grain reaches the horizontal level of the hot air inlet zone. This gradual but thorough preheating conditioning of the grain prevents the grain from undergoing sudden drastic temperature changes when it moves into the high temperature air inlet zone, thereby avoiding the formation of stress cracks in the grain. After passing through the hot air inlet zone, the grain travels downwardly toward the second air exhaust zone along with the remaining portion of hot air which travels downwardly to the lower exhaust zone. In travelling downwardly between the air inlet zone and the lower air exhaust zone, the air continues to remove moisture from the grain, but at a progressively reduced rate as the lower exhaust zone is approached. By the time the grain kernels have reached the lower hot air exhaust zone, drying is virtually complete and the kernel temperature has been gradually reduced, by the hot air which had been conditioned by the moisture received from the grain and by the evaporation of some of this moisture. The grain will not be subject to stress cracking if contacted by air at ambient air temperatures. The present invention also provides for ambient air to be forced into, through and out of the stream of grain

at strategically located horizontal zones below the drying zone if it is desired to cool the grain to a temperature suitable for immediate storage. The utilization of the conditioning effect of the grain upon the air to control the rate of increase and decrease of kernel temperatures enables the safe use of such high initial air temperature.

The capacity of this operation is high relative to the size of the machine. The apparatus is of small size and of simple construction since relatively few ducts are employed and these are located in specific horizontal zones. The cost of moisture removal is low since the high air temperatures are very efficient in removing moisture from the grain. Additional economies are realized in all the moving mechanical components of the apparatus, such as fans and motors, because of the reduced size of the apparatus. The total volume of air employed is low and the drying time is minimized without increasing grain damage relative to conventional systems. Drying capacity competitive with custom drying operations is achieved by the present process utilizing an inexpensive, mechanically simple apparatus of a size that is readily portable in trailer form.

Brief description of the drawings

FIG. 1 is a longitudinal sectional view of the grain drying apparatus of the present invention taken on the line **1**—**1** of FIG. 2;

FIG. 2 is a sectional view taken on the line **2**—**2** of FIG. 1;

FIG. 3 is a fragmentary sectional view taken on the line **3**—**3** of FIG. 2;

FIG. 4 is a fragmentary sectional view taken on the line **4**—**4** of FIG. 2;

FIG. 5 is a fragmentary enlarged sectional view taken on the line **5**—**5** of FIG. 1; and

FIG. 6 is a diagrammatic longitudinal sectional view similar to FIG. 1 illustrating a modified embodiment of the apparatus.

Description of the preferred embodiments

The base frame of the apparatus of the present invention is in the form of a trailer and includes longitudinally extending bottom frame rails **10**, **11**, **12**, and **14** best seen in FIG. 2 of the drawings. The longitudinal frame rails are interconnected by transverse frame members, one of which is visible in FIGS. 1 and 2 and indicated by the reference numeral **15**. The base frame is supported on ground wheels **16** and may be towed over the ground by a draft tongue **18**, visible in FIG. 1.

As best seen in FIG. 2, the main body of the drying apparatus is divided into three vertical sections by longitudinally extending vertical walls **19**, **20**, **21**, and **22**. The three vertical sections are identified at the top of FIG. 2 by the reference numerals **24**, **25**, and **26**, respectively. Except for certain openings in center section **25**, which will be explained later, the forward and rear ends of the apparatus are closed by vertical end walls **28** and **29**. The outer sections **24** and **26** constitute vertical grain drying passages while the center section **25** is divided into a pair of plenum chambers and a pair of air exhaust passages by horizontal dividing walls **30**, **31**, **32**, and **34**. The top of the central section **25** is closed by downwardly diverging wall plates **35** and **36**.

In FIG. 2, the space between wall plates **35** and **36** and horizontal divider wall **30** constitutes a discharge air passage **38**. The space between divider walls **30** and **31** constitutes a plenum chamber **39**. The space between divider walls **31** and **32** constitutes an air exhaust passage **40**. The space between divider walls **32** and **34** constitutes a plenum chamber **41**. The air passages **38** and **40** of the central section **25** are open at the ends through end walls **28** and **29**. The plenum chambers **39** and **41** are closed at the back end of the apparatus by end wall **29** and have openings **42** and **44**, respectively (see FIGS. 3 and 4) through the front wall **28** of the unit.

The plenum chamber inlet openings **42** and **44** are defined, respectively, by tunnel-like housings **45** and **46**. As may be seen in FIG. 1, a burner **48** and a heat deflector shield **49** are mounted in the inlet tunnel to upper plenum chamber **39**. A fan, indicated by the reference numeral **50**, is also mounted in the tunnel **45** to force air into the upper plenum chamber. Obviously, the air is heated by the burner **48**. A second fan **51** is supported in the lower plenum chamber entrance tunnel **46** to force cool air into lower plenum chamber **41**. Note in FIG. 1, that the divider walls **30**, **31**, and **32**, while they are horizontal in the transverse direction, have a vertical tapering relationship to each other in the fore-and-aft direction. The tapering of the walls **30**, **31**, and **32** of the plenum chambers **39** and **41** from the fan, or forward, end of the device to the rear wall **29** provides for substantially uniform air pressure throughout the length of the plenum chambers.

It will be apparent in FIG. 2 that the outer vertical passages **24** and **26** are identically constructed. The central air passage and plenum chamber section **25** serves both grain drying passages **24** and **26** identically. The following description of vertical drying passage **24** is equally applicable to drying passage **26**. A pair of downwardly diverging walls **52** and **54** near the bottom of vertical passage **24** coact with a pair of downwardly converging walls **55** and **56** to define, respectively, a pair of grain discharge openings **58** and **59**. Each of the walls **52**, **54**, **55**, and **56** is provided with a screen panel **60** (see FIG. 4) which allows air to pass through the wall while being impervious to the grain. The passages **61**, **62**, and **64** which underlie the walls **55**, **56**, **52**, and **54** are open to the atmosphere to exhaust the air passing through screen panels **60** from the device.

An auger housing **65** underlies the bottom of grain drying passage **24**. The sides of the auger housing form continuations of the downwardly converging bottom walls **55** and **56**. Two metering rolls **66** are disposed in the passages **58** and **59** through which the downwardly gravitating grain is discharged from drying passage **24**. The metering rolls **66** regulate the rate at which grain can pass through the discharge openings **58** and **59**. As may be seen in FIG. 1, the metering rolls **66** discharge the grain downwardly into an auger **68** disposed in the auger housing **65**. The metering rolls and the auger extend the full length of the grain drying device. Rearwardly of end wall **29** is an upwardly inclined drag conveyor **69** which elevates the grain from auger housing **65** and discharges it from the device through a discharge opening **70** visible in FIG. 5. From the discharge opening **70** the grain is allowed to drop into an additional conveyor or container not constituting a part of the present invention.

The drive for the metering rolls, auger, and drag conveyor can be followed most clearly in FIG. 5 wherein drive power is supplied from an electric motor **71** to a jack shaft **72** via a V-belt **74** and large diameter pulley **75** on the jack shaft. The jack shaft **72** drives a large sprocket **76** fixed on a shaft **78** via an endless chain **79**. The shaft **78** constitutes the upper shaft of the drag conveyor **69**. An endless chain **80** is entrained about sprockets **81** and **82** mounted, respectively, on shaft **78** and on the upper shaft **84** of the drag conveyor for vertical drying passage **26**. The drag conveyor chain **69** drives a sprocket **85** at the lower end of the drag conveyor. Sprocket **85** is fixed on a shaft **86** which, as may be seen in FIG. 1, constitutes an extension of the shaft of auger **68**. The inboard metering roll **66** is driven from shaft **86** by an endless chain **88** which may be seen in FIG. 1 at the front of the machine and which is indicated in FIG. 5 in phantom lines. The outboard side metering roll **66** is driven by an endless chain **89** from the inboard metering roll. The endless chain **89** is indicated in phan-

tom lines in FIG. 5 and may be seen in FIG. 1 at the rear of the drying apparatus in general.

In FIGS. 1 and 2 it may be seen that a series of ducts **90** interconnect the upper plenum chamber **39** and the grain drying passage **24**. The ducts **90** are arranged in a single horizontal zone as may be seen in FIG. 1, and this zone has a predetermined elevation indicated by the line **95** at the left of FIG. 1. Each duct **90** has an inverted wedge shaped covering **91** which extends transversely across drying passage **24** between the vertical walls **19** and **20**. A horizontal series of grain deflecting baffles **92** are also visible in FIG. 1. These baffles **92** are primarily for the purpose of controlling the down flow of grain in the passage **24**. However, each baffle **92** overlies a small opening **94** through wall **20** into plenum chamber **39**. Thus, the openings **94** do serve to conduct a certain amount of air from plenum chamber **39** into the hot air inlet zone of ducts **90**. The term "elevation" as employed herein denotes the linear level of a horizontal air duct zone in vertical grain drying passage **24** at which the mass of air passing through the ducts in that horizontal zone may be said to be concentrated. Thus, the elevation of the air inlet duct zone comprising ducts **90** and openings **94** under baffles **92** is indicated by the line **95** seen at the left side of FIG. 1 of the drawings. A horizontal series of ducts **96** may be seen in FIG. 1 above ducts **90** and baffles **92**. The ducts **96** interconnect grain drying passages **24** and the uppermost air discharge passage **38** of central section **25**. As will be seen in FIG. 1 the ducts **96** are located in a single horizontal zone and the elevation of their zone is indicated by the line **98** at the left side of FIG. 1. Each duct **96**, like the air inlet ducts **90**, is covered by an inverted wedge shaped grain deflecting shield **99**. A third horizontal series of ducts **100** connect grain drying passage **24** with air discharge passage **40** of the central section **25** of the crop drier. The ducts **100** are located in a single horizontal zone whose elevation is indicated by the line **101** at the left side of FIG. 1 of the drawings. Each of the ducts **100**, like the previously described ducts, is covered by a grain deflecting baffle **102** of inverted wedge shaped configuration. A fourth horizontal series of ducts **104** communicates between grain drying passage **24** and lower plenum chamber **41**. The elevation of this horizontal duct zone is indicated by the line **105** at the left of FIG. 1 of the drawings. One additional line indicated by the reference numeral **106** is identified at the left side of FIG. 1 of the drawings. This line **106** indicates the elevation of the exhaust zone afforded by the screen panels **60** in the previously described sloping walls **52**, **54**, **55**, and **56** at the bottom of the grain bin.

In operation, the passage **24** is initially filled with wet grain and a "head" of grain is maintained at the top of the device to keep passage **24** full as grain is withdrawn from the bottom and carried away by auger **68**. The operation of metering rolls **66** and auger **68** causes the column of grain in passage **24** to gravitate steadily downwardly as indicated in FIG. 1 by the arrows **108**. Hot dry air enters the grain column from upper plenum chamber **39** at ducts **90**. Approximately two-thirds of the total volume of heated air rises upwardly through the downwardly flowing grain column and is discharged through ducts **96**. As this volume of air progresses upwardly from ducts **90** toward ducts **96**, it gives up heat to the grain and becomes progressively cooler. The coldest wettest grain comes in contact with the air initially in the zone of ducts **96**. Since the air at the level of ducts **96** has been cooled somewhat from having travelled upwardly through the grain, it does not cause an abrupt temperature change on the grain kernel surfaces at ducts **96**. Instead, it begins a gradual warming of the cold wet grain. As the grain gravitates toward the level of ducts **90**, it comes into contact with progressively hotter drier air. The grain is thereby gradually preheated and the kernel temperature equalized in preparation for contact with the air having the highest temperature at the level of ducts **90**. This kernel preheating operation safely enables the use of higher air temperatures than those practical with conventional driers.

The remaining one-third of the volume of air entering through ducts **90** travels downwardly parallel with the grain flow to the level of exhaust ducts **100**. Due to moisture evaporation and the time interval involved in traversing the greater distance between ducts **90** and **100**, the temperature of both the air and grain is gradually reduced as the level of exhaust ducts **100** is approached. There is no sudden temperature change. At the level of ducts **100**, drying has been accomplished plus some reduction of kernel temperature.

Ambient temperature air has meanwhile been entering ducts **104** from lower plenum chamber **41**. Approximately two-thirds of the volume of air entering ducts **104** travels downwardly and exhausts through screen panels **60**. The remaining one-third of this air volume travels upwardly through the grain and exhausts through ducts **100**. This air is gradually warmed by the heat it picks up from the grain between ducts **104** and **100** so that at the level of exhaust ducts **100** it has nearly reached the temperature of the grain moving downwardly to ducts **100**. Again, the grain is subjected to no sudden temperature changes. The grain is progressively cooled between ducts **100** and **104**. Below ducts **104**, the final blast of cooling air travelling from ducts **104** through screen panels **60** reduces the grain to temperatures suitable for immediate bulk storage. The volume of air travelling in each direction from the air inlet zones is controlled by the location of the air exhaust zones, based on flow characteristics of air through grain.

As may be seen in FIG. 1, the vertical spacing between the duct zone elevations **95** and **101** is substantially twice as great as the distance between elevations **95** and **98**. The distance between elevations **105** and **101** is substantially twice as great as the distance between elevations **105** and **106**. This proportional spacing has been found to yield a most uniformly gradual transition of grain from an initial cool wet condition through the desired hot dry condition and then to the resultant cool dry final state. This results in maximum drying efficiency, low operating cost, low apparatus construction cost, and minimum grain damage. At no time are any cold wet kernels subjected to the hottest air; and at no time are any hot dry kernels subjected to the coolest (ambient air temperature) air.

The embodiment illustrated in FIG. 6 is essentially the same as that of FIG. 1. Similar elements have been identified by the same reference numerals as in FIG. 1 accompanied by "prime" symbols. In the FIG. 6 embodiment the horizontal hot air inlet zone has simply been widened in the vertical direction in comparison to the FIG. 1 embodiment. This has been accomplished by providing two horizontal series of inlet ducts **90'** for the single hot air inlet zone. The preheating zone, which is indicated by the vertical distance between elevation lines **98'** of the upper exhaust zone and upper elevation line **95A** of the hot air inlet zone, is the same as in the FIG. 1 embodiment. The final drying and precooling zone, indicated by the vertical distance between elevation lines **95B** and **101'** is also the same as in the FIG. 1 embodiment. The elevation of the drying zone, in general, is at **95'** which is also approximately twice as close to the elevation **98'** as it is to the elevation **101'**.

The major difference between the two embodiments is that in the FIG. 6 embodiment the grain is afforded a soaking period in the major drying zone. The soaking period is provided by the distance between the elevation **95A** of the upper series of hot air inlet ducts **90'** and the elevation **95B** of the lower series of horizontal air inlet ducts **90'**. There is essentially no air movement between the elevations **95A** and **95B** since the pressure of the incoming air is equal at these two elevations. The soaking period enables a better equalizing of moisture within the kernels between the two periods of maximum tempera-

ture exposure at the levels of ducts 90'. Kernel temperatures are rendered more uniform by the provision of a "tempering zone" between the two levels of air inlet ducts 90'. The kernel temperature may be reduced slightly in this area because of the movement of moisture to the exterior surface of the kernels and subsequent evaporation. This increases the drying effectiveness of the operation in the zone between elevations 95B and 101'.

While this invention has been described in connection with a particular embodiment thereof, it will be understood that it is capable of modification, and this application is intended to cover any variations, uses, or adaptations following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains, and as fall within the scope of the invention or the limits of the appended claims.

Having thus described our invention, what we claim is:

1. A grain drying process comprising, gravitating a stream of grain to be dried downwardly through a vertical passage, forcing high temperature air into said stream of grain in a first concentrated horizontal zone, exhausting a major portion of said air from said stream of grain at a second concentrated horizontal zone located a predetermined distance in the upstream direction from said first horizontal zone thereby filtering a major portion of said air upstream through said stream of grain to preheat the grain prior to arrival of the grain at said first horizontal high temperature air inlet zone, exhausting the remaining portion of said air from said stream at a third concentrated horizontal zone located substantially twice said predetermined distance in the downstream direction from said first zone whereby said remaining portion of said air travels downstream with said stream of grain to control the cooling rate of grain moving downwardly out of said first horizontal high temperature air zone to prevent the formation of stress cracks in said grain.

2. The grain drying process recited in claim 1 characterized by the fact that the temperature of said air forced into said first zone is high enough to produce stress cracks in the outer surface of kernels of ambient air temperature grain if the grain were introduced directly into said air inlet zone.

3. The grain drying process recited in claim 1 further characterized by the steps of forcing air at ambient air temperature into said stream of grain at a fourth concentrated horizontal zone located a predetermined distance in the downstream direction from said third horizontal zone whereby a first portion of said forced ambient temperature air filters upstream through said stream of grain from said fourth horizontal zone to said third horizontal zone to pre-cool the grain prior to its arrival at said fourth horizontal zone, exhausting said portion of said forced ambient temperature air at said third zone, exhausting the remaining portion of said forced ambient temperature air from said stream of grain at a fifth horizontal zone located substantially half as far downstream from said fourth horizontal zone as the distance between said third and fourth horizontal zones whereby said remaining portion of said forced ambient temperature air travels downstream from said fourth horizontal zone with said stream of grain to substantially cool the grain to ambient air temperature as the grain gravitates to said fifth horizontal zone.

4. Grain drying apparatus comprising the combination of structure defining a generally upright columnar passage open at the top to receive moist grain for drying and open at the bottom to discharge dry grain whereby grain introduced into said passage at the top gravitates downwardly through said passage, a first series of air outlet ducts for discharging air from said columnar passage to the exterior of said structure when said passage is filled with grain, said first series of outlet ducts being disposed in a horizontal zone at a predetermined elevation in said columnar passage, a second series of outlet ducts for discharging air from said columnar passage to the exterior of said structure, said second series of outlet ducts being disposed in a horizontal zone in said columnar passage at an elevation spaced below said predetermined elevation of said first series of outlet ducts, a series of inlet ducts for admitting air from the exterior of said structure into said columnar passage, said series of inlet ducts being disposed in a horizontal zone between said first and second series of air outlet ducts and at an elevation located substantially twice as far above the elevation of said second series of outlet ducts as below the elevation of said first series of outlet ducts, and means for heating air and delivering the heated air to said series of air inlet ducts whereby the heated air contacts the grain in said columnar passage at maximum temperature as the grain gravitates through the horizontal zone of said series of inlet ducts, said air travelling upwardly and downwardly through the grain in said passage from said inlet zone to said first and second series of outlet ducts thereby providing grain preheating and precooling zones in said passage above and below said high temperature air inlet zone to prevent the formation of stress cracks in said grain.

5. Grain drying apparatus as recited in claim 4 including a second series of air inlet ducts for admitting air from the exterior of said structure into said columnar passage, said second series of inlet ducts being spaced below said second series of outlet ducts, and means for delivering ambient air to said second series of air inlet ducts to further cool the grain in said passage after it gravitates through the horizontal zone of said second series of air outlet ducts.

6. Grain drying apparatus comprising the combination of structure defining a generally upright columnar passage having an inlet opening at the top to receive moist grain for drying and a discharge opening at the bottom to discharge dry grain from said passage, a first series of air outlet ducts for exhausting air from said columnar passage to the exterior of said structure, said first series of outlet ducts being disposed in a first horizontal zone at a predetermined elevation in said columnar passage, a second series of outlet ducts for exhausting air from said columnar passage to the exterior of said structure, said second series of outlet ducts being disposed in a second horizontal zone in said columnar passage at an elevation spaced below said predetermined elevation of said first series of outlet ducts, a first series of inlet ducts for admitting air from the exterior of said structure into said columnar passage, said first series of inlet ducts being disposed in a single horizontal zone between said first and second series of air outlet ducts and at an elevation located substantially twice as far above the elevation of said second series of outlet ducts as below the elevation of said first series of outlet ducts, a second series of inlet ducts for admitting air from the exterior of said structure into said columnar passage, said second series of inlet ducts being disposed in a horizontal zone between said second series of outlet ducts and said discharge opening at the bottom of said passage and at an elevation located substantially twice as far below the elevation of said second series of outlet ducts as above said discharge opening, means on said structure for heating air and delivering the heated air to said first series of air inlet ducts, and means delivering unheated ambient air to said second series of air inlet ducts.

7. Grain drying apparatus as recited in claim 6 wherein said grain discharge opening at the bottom of said columnar passage is defined by downwardly converging walls, said walls having portions pervious to air and impervious to grain.

8. Grain drying apparatus as recited in claim 7 including power driven rotary metering means operatively associated with said grain discharge opening at the bottom of said columnar passage to control the rate of discharge of grain through said discharge opening thereby control-

ling the rate at which the grain in said columnar passage gravitates downwardly therethrough.

9. Grain drying apparatus as recited in claim 8 wherein said structure includes a conduit disposed to receive grain from said metering means, a passageway communicating with said air pervious grain impervious portions of said walls for directing air to the exterior of said structure, and conveyor means in said conduit to deliver grain outwardly from under said passage defining structure.

References Cited

UNITED STATES PATENTS

558,508	4/1896	Metcalf	34—170
2,946,132	7/1960	Armstrong	34—170
3,300,873	1/1967	Bussell et al.	34—170 X

FREDERICK L. MATTESON, JR., *Primary Examiner.*

A. D. HERRMANN, *Assistant Examiner.*