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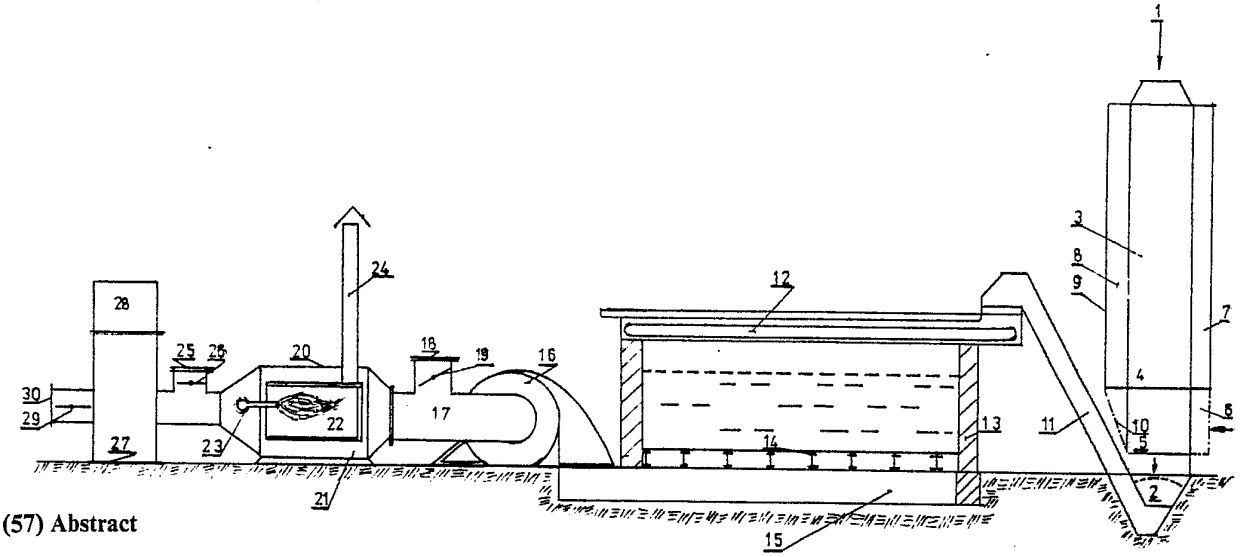

(57) Abstract

The apparatus for carrying out the process comprises a pre-drier of continuous or batch-type operation, further a series of aerable grain sections receiving the pre-dried grain, wherein the grain can be dried to an end-moisture enabling long-lasting time of storing. The drying space of pre-drier (3) can be increased by a cooling zone (5) at the same time supply and blowing off air channels (8, 7) can be enlarged by corresponding parts of them (6, 10), there is further an elevator (11) serving for uniform spread of the uncooled grain through support of a conveyer (12) within storage structure (13) having an air-permeable platform (14) in each of the sections A to E in succession; further, there is a sorption air drier (27) equipped with regenerator (28) to draw off moisture content of ambient air, flap-valve (29) regulating incoming air, air heater (20) equipped with burner (23), means-suitably a flap-valve (26) admitting ambient air, mounted in the channel section between air heater (20) and air drier (27), further a fan (16) blowing drying medium under platform (14), fitting, suitably a flap-valve (19) - admitting ambient air through opening (18) connected to suction channel section, finally the grain storage structure (13) has sections (A to E), this latter separated by partition walls (31) and can successively but separately apiece be brought into contact with the drying air stream in air channel (15) by means of lock plates (32).

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Process and apparatus for pulsating drying of granular materials with capillary pores, especially of grain crops of means of a pre-dried medium

Technical field

This invention relates to a process of drying granular materials with capillary pores, especially of grain crops, in the cours of which, in order to draw off the water, two individual, with each other in series operating drying steps are applied, wherefrom in the first step water contained in the surface and in the capillaries are drawn off, while in the second ones, drawing away of so called bounded moisture takes place.

Further the invention relates to the apparatus carrying this process into effect, consisting of a grain pre-drier with continuous or intermittent operation, and of a series of grain compartments to be aerated, receiving the pre-dried grain where it is dried to an end-moisture content enabling long-lasting storage.

Background art

Materials to be dried consist in practice mainly of agricultural grain crops, for the drying of which there are many kinds of processes and apparatus in wide use performing them. These are generally characterized by continuous or batch-type operation depending on the fact whether the grain stream is continous or batches are dryed in each cycle. In each case ambiant air is the drying medium, which after being warmed up is passed over the layer of grain in the apparatus at least once, sometimes twice but in rare cases several times. In order to compensate cooling of the drying medium during the drying process, especially when passing over is manifold, interim heating is frequently required. The aim is that moisture to be drawn off the grain should be drawn away with the least amount of drying medium and by spending possibly moderate quantities of fuel.

Dryer-structures of above category are described in French Patents Nos 2300 981, 2284 845, 1477 608, 2402 170, 2444 907, 2463 373, in USA

Patents Nos 1127 974, 3129 073, 3406 463, 4004 351, 4048 727, in British Patents Nos 376 871, 1224 794, 1437 578, in German Patent No 481 282, and in the Hungarian Patent No 183 005.

In most cases of known processes and apparatus, quality of the dried grain is unfavourably influenced by applying too hot drying medium at the beginning of the drying procedure, whereby the capillary poral structure will shrink capillaries become narrower, drawing off moisture falling in the bounded moisture zone of the drying procedure is, therefore, difficult having a low degree of efficiency and high temperatures develop having adverse effect on the inner core of the grain.

Because of aforesaid natural organic materials partly decompose. According to the Hungarian Patent No. 183 005 mild drying of the grain is realized in the initial phase, in consequence of which the drying procedure accelerates in the bounded moisture zone and because of more intense evaporation, warming up of the grain is also slight. Owing to this fact decomposition of the inner core is negligible.

Mutual disadvantage of the above mentioned or similar dryers is that drying is performed until desired end moisture is reached, staying time in the dryer will, therefore, increase, exploitation of the drying apparatus will be poor, in consequence of the heavyweight construction performance unit.

After drying in all cases storage will be the next operation when the grain is not immediately processed, e.g. by milling.

For the storage large vertical or horizontal silos, granaries are generally used, wherein the dry grain is kept up to the time, when it will be transported to a new place of use.

The grain dryed to about 14% can by using airing equipment be kept in

such storages up to the new harvesting. Storages are also known where grain being dried not to 14% but to a more moist grade of 18 to 20% are kept. Those are collectively known as "moist storages". In this respect different procedures were developed, such as

- moist stored grain is preferably sealed airtight;
- moist stored grain is treated with preservatives;
- moist stored grain is ventilated with cooled air;
- abovementioned are applied in combination.

In any mentioned case, however, storage time is limited, only local utilisation is possible, e.g. for animal keeping, but impairment in the quality of the grain has to be taken into account.

Dryers are known, which are combined with ventilated storage connected in series on the grain-line, such as e.g. the dry-aeration process, but here moisture of the grain drawn off is almost at the rate enabling prolonged keeping, aerated space is essentially a cooling zone set out of the dryer, for long-lasting keeping of the grain, however, the already mentioned aerated storage spaces are also needed.

Disclosure of Invention

Object of this invention is to provide a drying process, whereby above-mentioned troubles and disadvantages are eliminated, i.e. exploitation of the dryers is substantially improved, further the storage bins can be fitted with the equipment, enabling total after-drying which by itself renders long-lasting keeping of the grain possible without any demage, reducing at the same time total power consumption of drying below all known rates. The process according to the invention can advantageously be applied with substantially all already existing dryers and the connected grain storage equipment, needed according to the invention, can be sited in each case. This invention can, of course, be implemented also in case of newly constructed grain storages as well, in particular advantageously combined with dryers in which capillary poral structure of the grain is subject to no or only slight shrinkage. This is the case of dryer according to the Hungarian Patent No 183 005.

Several recognitions led to establishment of this invention. Firstly it was identified that within the dryer itself there is no need to reach end-moisture required by prolonged storage, further the dried grain has not to be cooled at a temperature needed for long-lasting storage, meaning 3 to 50°C above ambient temperature. Owing to this recognition, only moisture content accumulated in the macro- and micro-capillary structure of the surface or near to surface has to be drawn away from the grain, resulting in substantial increase in the dryer's capacity.

Increase in drying capacity is further instrumental in using also the drying space formerly serving for cooling, for removing the surface moisture from the grain. Both effects jointly result in about doubling of the drying capacity, considering grain of average moisture. In case of any functioning or new dryer, doubling in exploitation by volume compared to the previous can be attained. Besides, heat consumption of any kind of dryer can be improved, whatever extent it had earlier, because drawing off surface moisture is always feasible with lower heat consumption than former simultaneous removal of surface- and bounded moisture had required.

The invention is based further also on the recognition that in case of any drying process and any sort of grain, especially in case of those where surface and the capillary poral structure near to the surface of the grain does not shrink, feeding of heat energy into drying medium required to draw off bounded moisture, can, also by maintaining continuity of drying, be intermittent.

After conveying pre-dried grain into the storage space, as long as the grain does not cool to a predetermined temperature - the so called equilibrium temperature - it is sufficient that the grain is ventilated with ambient air at ambient temperature and its humidity is reduced or corresponds to that of ambient air. During this period, hence, heat-demand of drying is covered by the heat cumulated in the grain, as well as from time to time by the power required to produce dry air.

This warming up is slight, getting even less the greater extent moisture of aerating air is drawn off.

A further recognition is related to aforementioned, i.e. that there is an unambiguous correlation to be drawn up also mathematically, between mass-stream, absolute moisture content and temperature of the aerating air, temperature of the grain developing during drying as well as the moisture content in the grain dried with said parameters. E.G. Mass-stream as compared with grain quantity measures 0.1-0.3-fold at a drying medium temperature of 48°C and absolute moisture of the drying medium of 4 g/kg, i.e. 10% relative humidity, at a grain-temperature of about 28°C, equilibrium grain-moisture belonging to these parameters is only 4%. If an end-moisture of 14% is aimed at, it is sufficient to keep characterized drying medium in pre-dried state in a fraction, i.e. about 30% of total drying time and according to aforesaid in a part of this time-share even heating is unnecessary. When drawing moisture content off the drying medium in an even greater extent, i.e. down to 2 g/kg, time-share can further be diminished. In consequence of this recognition, in the next i.e. third period, drawing moisture content off the drying medium will be unnecessary, as diffusion started in the first two periods will further continue, its intensity determined by the very low partial pressure of the stream in the drying medium, when momentarily outer partial pressure rises in the presence of non-dried drying medium, or drying medium-feed is perhaps stopped, partial steam pressure will slowly rise in the outer space in consequence of vapor leaving the grain.

In the third section, therefore as an offset, at best to the ventillation energy consumed, moisture content of the grain, yet, decreases.

After these fourth period follows, during which grain will be aired with undried air heated to 36°C, in order to reach grain temperature of 28°C mentioned in the example, and then the period with dried, hot drying air can start, as described above, being the second period.

The bulk of grain stored in said way and aired with ventilating air of periodically varying medium state, moving along with the aerating medium, loses its moisture content progressively, drawing moisture gradually off the still moist layers, succeded by already dried ones, until total grain mass gets uniformly dry. In this relation application range of this invention is based upon a further recognition, i.e. that duration of drying a bulk of grain and end-moisture to be reached during drying may properly be determined by described choice of drying medium parameters and mass-stream. Total time of drying can namely not exceed fouling-free storing period of the grain suited to actual moisture content and at temperature and reaching the point of complete dryness, can not bring about overdrying not even on surfaces where the grains will be exposed to longest contact with the drying medium. This latter would impair energy-efficiency of the process. The ration of 0.1 to 0.3 kg/kg mass-stream relating to weights of air and grain results in a maximum of 110 hours drying time at 40°C drying medium temperature, when stored in maize has a moisture content of 20% and a layer of 3 m height. This period is securely below starting time of fouling. Drying air dried upto maximum 2 g/kg absolute moisture content at 40°C temperature as well, cannot result in overdrying with said periodical, i.e. pulsating current of air. Interrelation between equilibrium temperature, equilibrium grain moisture and relative moisture of drying medium is introduced in Fig.1. On ordinate T_E equilibrium temperature, on absciss M_E equilibrium moisture content values are showing, calculated on dry basis.

Values of absolute moisture content by fi-constant of drying medium are indicated from 2 g/kg up to 10 g/kg. The set of curves present points of fi-constants. It is shown that e.g. equilibrium grain temperature of 5% (d.b.) can be attained at a drying medium moisture rate of 2 g/kg at already 20°C grain temperature, while the same can be secured in the case of absolute moisture content of 10 g/kg, at grain temperature of about 42°C only. At the same time, should it be needed to attain grain moisture of 15%, it has to be realized by a drying medium streaming in only one third of the time, and thus energy-feeding is also required in only one third of the time.

According to our recognition, this time and power consumption can be further diminished by other said manipulations. It should be remarked here that to equilibrium grain temperature t'_E a higher drying medium temperature than that is belonging. The known interrela on between drying medium temperature and equilibrium temperature of the grain was deduced from the physical properties of the grain and moist air, to be found in the literature cited.

Recognized complex and above described interrelationship between drying properties of the grain, and the mass-stream of drying medium, as well as temperature and absolute humidity, though enable in the bounded moisture phase of the drying to render energy feed of drying intermittent and to stop temporarily the airing agent current, as to periodical drawing off or maintaining moisture of drying medium.

Abovesaid procedures altogether are called "pulsation drying". As to be seen, recognized correlation enable important savings in power consumption as compared to known removal of bounded moisture, and an exchange of grain drying-storage technologies used upto now is also feasible with equipment to be implemented less expensive, and with better exploitation, or existing equipment can be adapted into such ones.

Recognitions mentioned were based on international research carried out for about 35 years, dealing with static and dynamic properties of moisture attaching to various grain and in the course of which terms of equilibrium moisture content, equilibrium temperature, mass-streams of the drying medium and grain, as well as interrelations between drying medium parameters, such as temperature and relative or absolute moisture content, has been gradually revealed, in relation of the different grain sorts, (maize, wheat, barley, rice etc.).

In the past almost three decades, these correlations have been mathematically modelled and thus computer processing could begin. In recent years, this mathematical modelling, also mentioned in Hugnarian Patent No 183 005, enabled the constant performance of the drying apparatus, ad-

justing its water evaporation capacity to prevailing starting and prescribed end-moisture by microprocessor control. Preliminary checks of recognitions according to the present invention were practicable altogether by computer analysis developed for this purpose grounded on internationally known principles and the executed experiments. More important works about research and mathematical modelling were reviewed in the paper by J.L.Parry: "Mathematical modelling and Computer Simulation of Heat and Masstransfer in Agricultural Grain Drying: A Review" (Journal Agr. Engng. Res. 1985) and in its 84 abstracts from 1938 on, but they can get known from numerous other sources as well.

We proceed according to the invention as follows: we apply in the course of drying in first of the two separate steps a drying medium of low temperature and of relatively high moisture content in order not to, or only slightly shrink capillary poral structure of the grain, so that fouling time belonging to the remaining grain moisture after this first drying period be longer than the timely beginning of fouling setting in at the temperature of the second drying period while time requirement upto end-drying, being shorter than the decomposition-free storing time characteristic of the given grain sort including material delivery time between the individual drying phases, further in the course of the second drying, i.e. up to end-moisture, a drying medium having timely varying parameters is applied in a pulsating way, i.e. in a manner that temperature and own moisture content are varying periodically, sometimes streaming of the drying medium is interrupted, finally that pulsating parameters and intensity of streaming, experimentally determined values of equilibrium moisture and that of equilibrium temperature, during evaporation, are mathematically modelled on the basis of known principles and used to determining time and/or sequence of the individual pulsation periods.

Variable drying medium parameters, the predetermined value of own moisture content during pulsation is processed by an air drier suitably operating on the sorption principle, and regeneration heat, continuously produced by air drier is used to heat the drying medium itself.

It is advantageous when drying zone of the grain dryer used in the first step of drying, is enlarged by engaging the cooling zone, hereby increasing drying volumen of grain drier, as well as mass-stream belonging to the same drying temperature.

The first step, serving only for drawing off surface moisture, can be implemented through minor structural changes in any grain drier operating on known principles, while its former mass-stream significantly increases. Thus, any grain dryer can be advantageously used as the first step, where drying medium gets into contact with the entering moist grain in a manner that it has before at least once passed over the layer of grain.

In case of the second step, drying can be effected within the bin serving for prolonged storing and parameters of the drying medium, such as temperature and moisture content are varying in time, moreover streaming of the drying medium can be temporarily interrupted. During a considerable time there is no need of energy feed, i.e. to heat the drying medium.

So long as the first step of the process the grain drier operates continuously, drying medium in the second step, parameters of which are varying in an already known manner, gets into contact with only determined masses of the pre-dried grain issued out of first phase. Aggregate of these masses forms the total dried material quantity brought about.

Data needed from time to time to implement process according to the invention, such as

- prescribed or necessary starting moisture of the grain;
- prescribed end-moisture of the grain;
- storing data of the grain

are determined by fundamentals prevailing at the site of implementation.

On the other hand

- temperature, mass-stream of the drying medium;
- its absolute moisture content;

- equilibrium temperature and equilibrium moisture of the grain belonging to above;
- periods of pulsation

have to be determined by experimental drying the grain had been subject to. It is though possible, as mentioned before, to develop mathematical interrelations modelling the process, beside or instead of the experiments relating to any grain in question. Mathematical modelling is fit for determining practical values in possession of the basic data from the very first, and to computer control the drying process in the course of implementation in an optimal way.

In connection with the process according to the invention, it should further be mentioned that there are several methods to be applied for drawing moisture off the drying medium. It is, thus, feasible for example, to draw away needed extent of moisture in a manner that drying air is cooled to the dew-point corresponding to remaining moisture content to be attained, then warmed up to the necessary temperature, while condensation heat occurring is serviceably utilized in the drying process. It is, however, possible to use different absorbents, such as silica-gel, hygroscopic salt cristals, or absorbing liquids, e.g. sulphuric acid, glycol, salt solutions, in order to attain desired moisture content. In case of drawing off moisture by adsorbents and absorbents, it is expedient to utilize heat got lost during regeneration, to a large extent in the drying process itself. Such kind of processes, however, similarly to grain dryers complementing the pulsation process, constitute no subject of this invention.

Brief Description of Drawings

The invention will be explained more in detail in the following with reference to the accompanying drawings, wherein:

Fig.1 is a diagram showing the relationship between equilibrium temperature and equilibrium moisture belonging to different relative moisture of the drying medium;

Fig.2 is a cross-sectional view of an equipment performing the process according to the invention, shown diagrammatically;

Fig. 3 is a plan view of a drying medium producing equipment which is intended for use with the invention, shown diagrammatically.

Best mode of carrying out the Invention

In Fig.2 equipment performing the process is shown and the markings contained are used further on. Moist, newly harvested grain, by way of example maize, is fed through inlet 1 into drying space 3 and discharged therefrom through outlet 2 desiccated to 20%. Original size of drying area 3 is marked by part 4 , which is enlarged by part 5 as cooling becomes needless. For this reason, inlet air channel formerly 7 is increased by part 6 . From outlet exhaust 8 , the moist drying medium, having performed its task, is discharged at port 9 . The exhaust outlet 9 is enlarged by part 10 .(The increment of the air channels is indicated by a dot line.) Bucket lifting set 11 lifts the dry uncooled grain which is discharged at place 2 , to a conveyor 12 spreading the grain in a uniform, by way of example, layer 3 m high within storage 13 . The grain is placed on an air-permeable wire-mesh construction platform 14 , spreading the blown drying medium through airchannel 15 uniformly over the whole surface. The drying medium is pressed by fan 16 into channel 15 . Suction channel 17 is provided with two slots. Through slot 18 ambiant air is drawn into the sytem, dependent upon the fact whether flap valve 19 is kept open or cbsed. Flap valve 19 is kept closed in the drawing, therefore, streaming takes place from air space 21 of oil-fired air heater 20 . In open position of flap valve 19 , ambiant air drawn in through aperture 30 loses its moisture content at a predetermined rate in air drier 27 and then passes to air heater 20. From this place, under the heating effect of the furnace chamber 22 warmed up by oil-burner 23 , the air is sucked at a prescribed temperature into suction channel 17 . Flue 24 exhausts combustion products. Regenerator 28 serves for continuous or intermittent dewatering of the active ingredient in air drier 27. Reutilization of the heat released during regeneration is not depicted. In case flap valve 29 is kept closed, open flap valve 26 admits ambiant air through aperture 25 into the system, into air heating space 21. After having been warmed up in air heater 20 , ambiant air is drawn into suction tube 12.

As to be seen from embodyment by way of example, drying medium in different states may have access to air channel 15 , such as

- direct ambient air,
- warm ambient air,
- dried cold air,
- dried warm air,
- whatever rate of mixture of above.

During drying any flow can of course temporarily be stopped. Parameter (temperature and absolute humidity) of the drying agent, its medium stream applied in individual drying phases as well as the combination to be chosen from abovementioned five options for the given grain, and its course in time are set according to experiments or rather to an adapted computer program elaborated on the results of experiments.

Whatever be the chosen combination and course in time, amount of heating presents itself, however, always lower, than in case of not applying pre-dried drying air, total time of warm drying medium-use is yet always shorter than needed in dryers with continuous, non-pulsating operation.

All these mean, that the total expended amount of heat will also be lower, because of the double effect significantly lower than in any of the known drying apparatus. The lower character of the rate of heating results at the same time, in improvement of the quality of the grain, as compared to known equipment, because natural composition of the organic substances is in this way better preserved.

In order to construct an equipment performing the process, not only varying parameters of a drying agent and period of running with the individual parameters are to be known in pulsation drying, but also the data concerning the size of space and type of fitting of what technical data are needed for obtaining a given or required performance.

As we already referred to, parameters of the second phase of pulsation drying are basically determined by the fact of how much time is available

to avoid organic fouling of the grain pre-dried in the first phase. Two tables below show results of the experiments done. First table deals with bread grain, second one with combine harvested maize (shelled during harvesting).

Table 1.

Storage time of bread grain

Moisture content per cent	Storing temperature 5	10	15	20	25	30	°C days
	Storing period						
14	+	+	+	85	40	30	
15	+	+	77	33	21	15	
16	+	133	33	18	11	7	
18	127	32	15	8	5	1	
19	92	20	12	6	4	-	
20	39	13	5	1	-	-	
22	24	10	2	-	-	-	
24	20	7	-	-	-	-	

+ means long-lasting storing time

Table 2.

Storage time of combine harvested maize

Moisture content per cent	Storing temperature -5	0	+5	10	15	20	25	°C days
	storing period							
16	100	90	80	70	60	50	40	
17	90	80	64	50	40	30	23	
18	75	60	45	37	30	22	14	
19	53	43	33	25	18	14	8	
20	40	32	23	17	12	8	4	
22	30	20	13	9	6	4	2	
24	18	15	10	7	4	2	1	

These data and experiments determine periods in which drying in the

second phase has to be completed. In case of combine harvested maize e.g. with moisture content of 20%, stored at 15°C this storing does not exceed 5 days (120 hours). Furtheron harvesting performance has to be known to which apparatus should apply. If this performance is 10 t/h, first step of drying has to be designed accordingly, while holding capacity in the second step should be about 1600 m^3 for a period of 120 hours, needing a ground space of 533 m^2, supposing a storage layer of 3 m. Considering a total quantity of 6000 tons of grain, about 2700 m^2 useful storage groundspace will be required, serviceably fitted of 5 box-like sections of 533 m^2 each.

Figure 3 shows a drying medium producing equipment, layout of which enables linking with all storage sections of 533 m^2, by means of air-channel 15. Correspondingly conveyor 12 is connected to elevator 11 in such a way that all storage sections can be filled up (or discharged). By means of partition walls 31 and movable lock paltes 32 individual storage sections can in succession constitute the second step of the drying process. At the beginning of thedrying season pre-dried grain, delivered by elevator 11 is fed into section "A". Connected lock plate 32 is kept open until the storage section gets filled up and dried. During drying of section "A", section "B" is filling, then lock plate 32 of section "A" is closed and lock plate of section "B" is opened, etc. It is to be considered in the course of designing the apparatus that the grain after being discharged from the first phase, is fully exposed to said fouling process upto finishing drying in the second step. Consequently either end-moisture in first step or drying time to be applied in second step has to be selected properly.

Power consumption of the grain drier introduced by way of example, follows from the total consumption of the two steps. In the mentioned example, 6000 tons of maize are dried from 30% moisture content to 14% moisture content, while drying is effected in the first step from 30% to e.g. 20%, and in second step from 20% to a moisture content of 14%. Total time-need of this process amounts to 600 hours. Accordingly, in first step from 750 tons, in second step from 6000 less 750= 5250 tons of grain 367,5 tons of water is drawn off.

Supposing an efficient drying in frist step, by use of e.g. 3.344kJ/kg specific heat, total heat demand of first step amounts to $2,5x10^9$ kJ. In the second step, supposing there is an airing in the first quarter of the time by ambiant air of about e.g. 15°C, in the second quarter of time an intermediate heating is effected by ambiant air heated to 45°C, in the third quarter of time medium feed is completely discontinued, and thereafter in the fourth quarter of time, drying with air heated to 45°C, desiccated to an absolute humidity of 2 g/kg, energy demand of the second step is as follows:

Air demand as per 1 m^2 storage is 160 kg/h, therefore, considering 533 m^2, this makes 85,280 kg/h. If ambiant air has an absolute moisture content of 8 g/kg and temperature of 15°C, then

- heat requirement of 85,280 kg/h ambiant air supply at 45°C amounts during 150 hours to $0,385x10^9$ kJ;
- heat demand of 85.280 kg/h air supply at 45°C, having a moisture content of 2 g/kg, amounts likewise appr. $0,385x10^9$ kJ;

Heat need of air drying in order to draw 76.752 kg water off within 150 hours

- with a specific heat requirement of 8000 kJ/kg water, $0,614x10^9$kJ,
- with a specific heat demand of 2800 kJ/kg water, $0,168x10^9$kJ.

Total heat demand within the second step makes $1,384x10^9$kJ and $0,938x10^9$ kJ respectively with the two values of heat demand relating to the air drying.

Specific heat consumption of drying in the second step amounts to 3684 kJ/kg water, or with a more favourable use of heat in air drying, 2552 kJ/kg water.

Specific heat requirement of the total grain drying process, amount, with a less favourable heat consumption in air drying, to 3475,6 kJ/kg water, while with more favourable heat consumption in air drying it makes 3076,5 kJ water.

The results show that economy of heat demand of the process greatly depends on the applied method of air drying. It is to be noted that even with a rather unfavourable heat consumption in air drying, a relatively advantageous total heat-consumption can be recorded for the total procedure of grain drying. One cause of this is that in the first step of the process according to the invention, heat consumption of drying is in any case more economical than that to be attained in known grain drying processes considering total drying, another cause is, however, rests in the second step where heat feed in only needed in part of the time.

By application of an air drying process with advantageous heat demand, according to above, good results are rendered even better. As such an efficient air drying process is known, it can based on above values be stated, therefore, that beside improvement of the characteristics of drying according to this invention, energy consumption is getting also better than with other possible processes.

The realized embodyment, by way of example gives also a notion of the fact that usual establishments of grain drying and storage can because of their better use by applying present invention be implemented with more favourable economy so far known.

The apparatus according to this invention can be implemented differing from the realised embodyment by way of example. Thus e.g. dryer of the first step can be any type of continuously operated drier, which is shaped according to principles of procedure of the present invention. But it may, likewise, be any non-continuously operated, intermittently running drier, drying in batches, where cooling of the grain is not effected or not operated. Second step can instead of a horizontal structure, be vertical, be of metal or concrete, having an inner execution enabling intermittent drying medium feed. In order to run the system continuously, measurement of the ambient parameters of air varying in time, of the sort of grain varying in time and of moisture of the grain can be done with individually mounted indicators, being

continuously employed by the operator, operation, however, can also be automatic, when measuring instruments give electric or other signals, to be used by means of algorhythm included in computer software for automatic control of the apparatus. Steam or heat carrying oil can serve as a source of energy of the airdrier to be applied, or execution can be apt for so called direct firing as well. Any sort of heat energy to be used can be produced e.g. by means of liquid or gaseous hydrocarbons or solid combustibles, which can probably be agricultural wastes.

Claims

1. Process for drying granular materials with capillary poral structure, especially grain crops, in the course of which two separate drying steps operating in series are used, whereby in first step water content cumulated on the material surface and in the capillaries is drawn off, while in second one the so called bounded moisture is drawn away, c h a r a c t e r i z e d i n that in the first step capillary poral system of the grain is not or only slightly shrinking by drying medium of suitably low temperature and of suitably chosen relative moisture in a way that after this first drying fouling time derived from remaining grain moisture is longer than timely beginning of fouling setting in at the temperature of second drying, while time requirement of drying upto end-moisture, considering also time need of material convey between the individual drying steps will be shorter than the storing time devoid of fouling characteristic of the given produce, further that during second drying, i.e. upto end-moisture, drying medium having timely varying parameters in the course of drying is applied pulsating, in a way that temperature and own moisture content of the drying medium will change periodically, from time to time streaming of the drying medium is suspended, finally that pulsating parameters and streaming intensity of drying medium, equilibrium moisture content and equilibrium temperature of the grain during evaporation is determined by experiments, in given cases mathematical modelling is used, based on known principles, to determine time and/or sequence of the single pulsation periods.

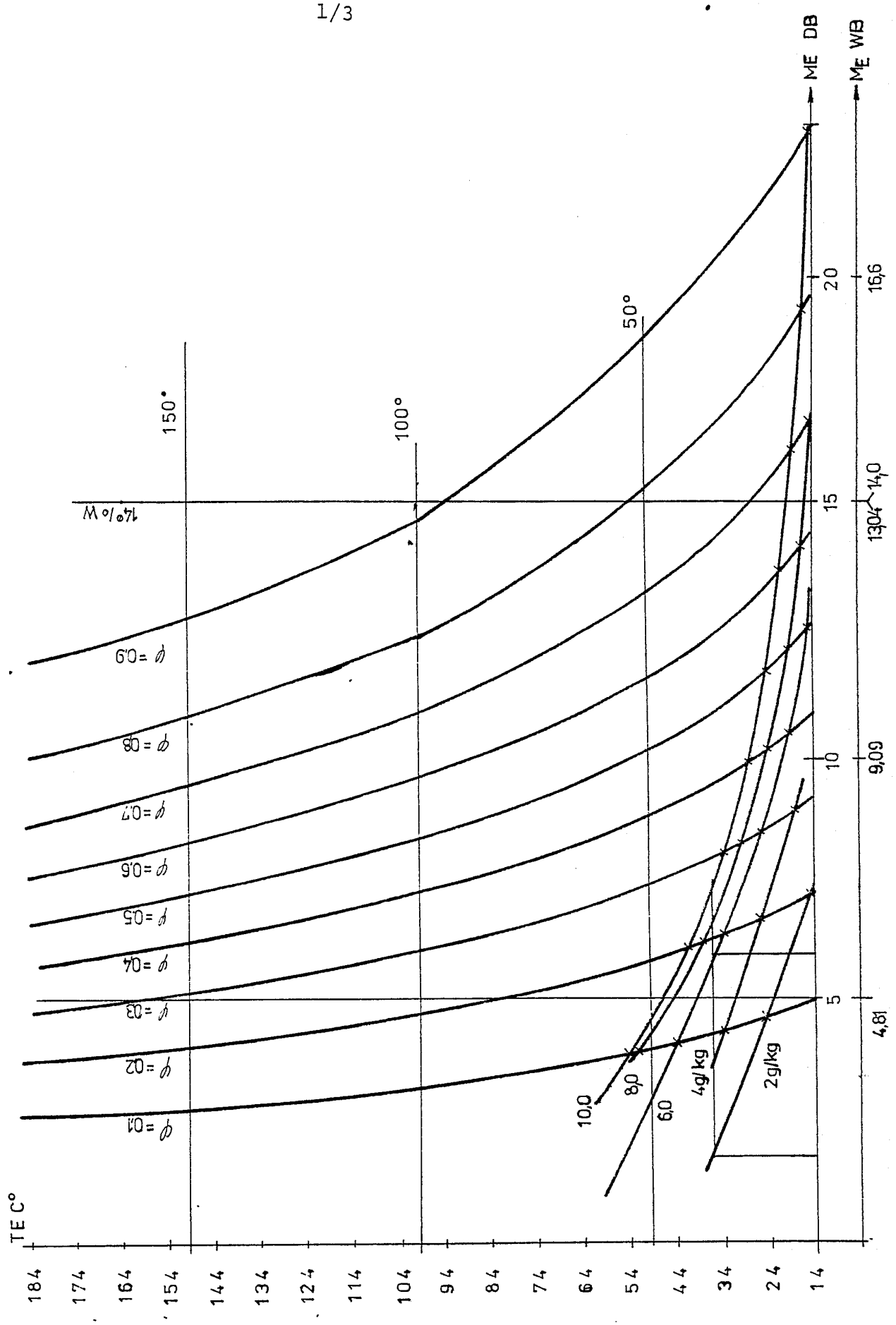
2. Process as claimed in Claim 1, c h a r a c t e r i z e d i n that from pulsating variable drying medium parameters, preset value of own moisture content is adjusted by an air-drier operating on the sorption principle and continuously developing regeneration heat of said air-drier is used for heating the drying medium itself.

3. Process as claimed in one of Claims 1 or 2, c h a r a c t e r i z e d i n that a grain drying zone in the first step of drying is enlarged in size by engaged cooling zone, whereby drying volume of the drier, as well as grain mass-stream belonging to same drying temperature is increased.

4. Apparatus for carrying out the process as claimed in Claim 1 to 3, consisting of a pre-drier of continuous or batch-type operation, further of a series of aerable grain sections receiving the pre-dried grain, wherein the grain can be dried to an end-moisture enabling long-lasting time of storing c h a r a c t e r i z e d i n that the drying space of pre-drier 3 can be increased by a cooling zone 5 , at the same time supply and blowing off air channels 7, 8 can be enlarged by corresponding parts of them 6, 10 there is further an elevator 11 serving for uniform spread of the uncooled grain through support of a conveyer 12 within storage structure 13 having an air-permeable platform 14 in each of the sections A to E in ssuccession; there is further sorption air drier 27 equipped with regenerator 28 to draw off moisture content of ambiant air, flap valve 29 regulating incoming air, air heater 20 equipped with burner 23 ,means-suitably a flap valve 26 - admitting ambiant air, mounted in the channel section between air heater 20 and air drier 27 , further a fan 16 blowing drying medium under plaform 14 fitting, suitably a flap-valve 19 admitting ambient air through opening 18 connected to suction channel section, finally the grain storage structure 13 has sections (A to E), this latter separated by partition walls 31 and can successively but separately apiece be brought into contact with the drying air stream in air channel 15 by means of lock plates 32.

5. Apparatus as claimed in Claim 4, c h a r a c t e r i z e d i n that the second step of drying is of a metal or a constructed structure, - e.g. a vertical cylindersilo -, whereto uncooled, pre-dried grain discharged from first drying step can be filled into sections (A to E) in batches corresponding in volume to said sections, further that grain batches taken in by the individual section-units can be aerated separately or in sequence by drying medium having pulsating parameters.

6. Apparatus as claimed in Claim 4 or 5, c h a r a c t e r i z e d i n that its drier 3 , regenerator 28 and air heater 20 operated with heat energy generated from waste-energy carrier.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2g/kg
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Fig.1

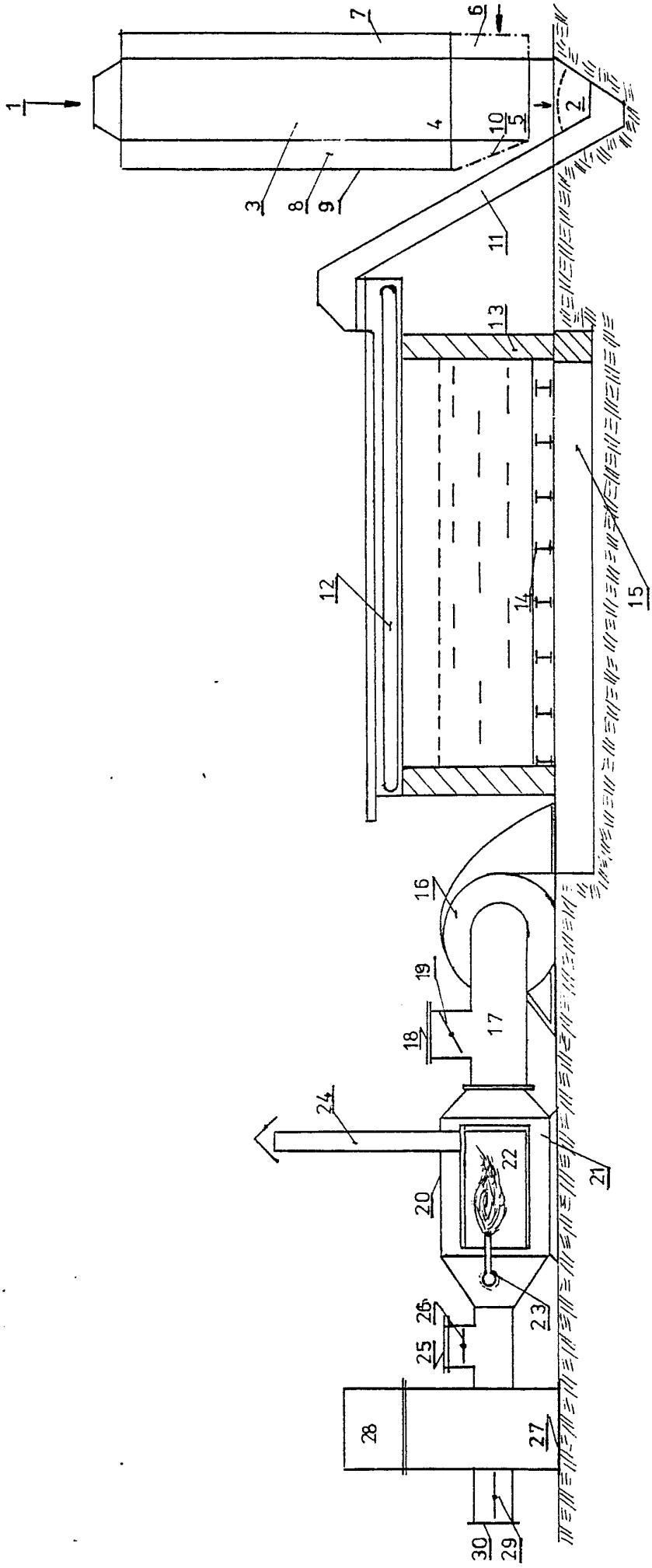
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Fig.2

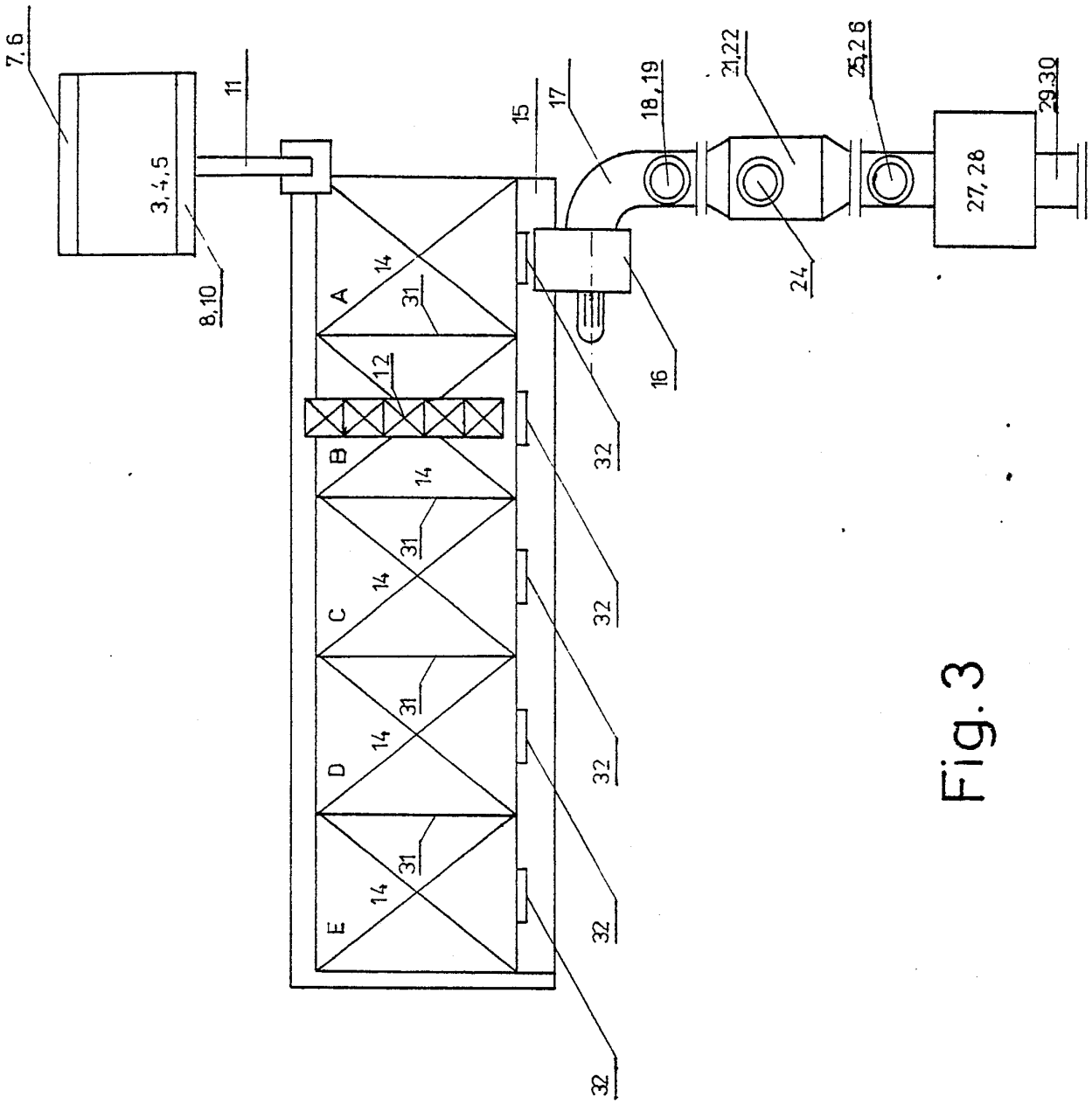
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Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No PCT/HU 87/00025

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: F 26 B 3/14

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
Int.Cl.[4]:	B 20 B 1/00, B 02 B 1/08, F 26 B 3/14, F 26 B 17/12 F 26 B 19/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	WO, A1, 84/01 502 (OKTOBER 6), 28 April 1983 (28.04.83), see page 1, lines 17-28; page 7, lines 7-23. & HU, A, 183 005 (cited in application)	(1,4)
A	US, A, 4 045 882 (BUFFINGTON), 06 September 1977 (06.09.77), see abstract.	(1,4)

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* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
10 August 1987 (10.08.87)	17 August 1987 (17.08.87)
International Searching Authority	**Signature of Authorized Officer**
AUSTRIAN PATENT OFFICE	

Anhang zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

Annex to the International Search Report on International Patent Application No. PCT/HU 87/00025

Annexe au rapport de recherche internationale relatif à la demande de brevet international n°.

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned International search report. The Austrian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

La présente annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche internationale visé ci-dessus. Les renseignements fournis sont donnés à titre indicatif et n'engagent pas la responsabilité de l'Office autrichien des brevets.

Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
WO-A1-83/01 502	28/04/83	US-A -4 555 858	03/12/85
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		EP-A1-0 091 451	19/10/83
		HU-B - 183 005	28/12/83
		PL-A1- 238 687	06/06/83
US-A -4 045 882	06/09/77	CA-A1-1 071 398	12/02/80
		US-A -4 126 946	28/11/78