NEW SYSTEM FOR DRYING POULTRY MANURE IN BELT BATTERIES

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SUMMARY

Batteries with manure belts are very popular in the Netherlands on account of their cleanness and minimisation of malodour in the stall.
Normally the manure must be removed 2-3 times per week and dropped in a pit. After this the manure is handled like liquid manure. Liquid manure is easy to handle but it has some disadvantages, in particular high transport costs and odour problems during storage and spreading.
In this report a description is given of an in-house drying system on belt batteries, followed by a composting process in a shed outside the stall.
With the in-house drying system air from outside is blown through polyethylene tubes mounted underneath the ridge of the poultry house by centrifugal fans. When passing through the tubes the air is warmed up by the surrounding stall-air of about 22 °C. It is then blown into perforated ducts and distributed over the manure on the belts (diameter of the perforations: 3 mm).
The diameter of the perforated ducts is important since electrical power consumption depends on ventilation rate and backpressure.
The drying process works well with an air movement of 0.4-0.5 m^3/hen/h with a backpressure of at least 300 Pa in the perforated ducts.
After 5-7 days the manure with a DM-content of about 45% is removed from the belts and transferred by transport belts to a storage shed. During storage much of the moisture evaporates by spontaneous internal heating. Although there is some smell during storage in the shed, especially from ammonia, this system produces a dry and crumbly odourless manure with a DM-content of 55% or higher.
Calculations show that this system of drying is economically more advantageous than drying systems with stall storage.

1. INTRODUCTION

Fresh poultry manure contains 20-23% dry matter. As such this manure can not be applied by means of the generally available manure-spreading equipment. For that reason water is often added in many enterprises. The diluted manure is stored in cellars or silos and, with the aid of good mixing equipment, the manure can be pumped out of the cellar and spread over the land.

The average liquid manure production per hen amounts to about 80 litres, with ca 12% dry matter, per year. If we start out from a hen farm with 25,000 laying hens and a required storage capacity of 6 months, this means a silo or pit of 1,000 m^3. Apart from the investment and operating costs of such silos, the following disadvantages occur in practice:

- mixing costs of the manure;
- transport costs for removal. This plays an important role when the farms have to transport the manure over long distances;
- stench resulting from anaerobic processes in the liquid manure.

Owing to these problems it is understandable that considerable efforts are being made to process manure in a drier form. In the past years this has given rise to methods for drying manure in the stall, including stalls with manure cellars some 3 metres in depth (so-called deep-pit or high-rise stalls) and in stalls with 1.25 m deep channels. In both types of stalls dry manure is obtained by a combined drying and composting process.

The predrying of the manure to about 40% dry matter is done by means of extra internal ventilation or a stall-ventilation system specially designed for the purpose. Heating-up takes place in this (pre)dried manure in the course of storage and temperatures of 40-60 °C have been measured. Moisture evaporates from the manure as a result. The water vapour generated is disposed of by the stall ventilation system. Manure with more than 50% dry matter is obtained after a period of six months or longer in stalls with an efficient drying system. This manure is practically odourless thanks to the aerobic heating-up process. Annual production amounts to about 25-30 litres or 15-20 kg per hen.

In spite of this good result these manure-drying systems have made little headway. This is due in the first place to the cost of electric power, which often exceeded the price obtained in selling the manure. Then the nuisance caused by the smell of ammonia in the stall during periods of limited stall ventilation and that caused by vermin, such as mice, flies and beetles.

In recent years many stalls have been equipped with batteries with manure belts.

This type of battery is based on the processing of liquid manure. By removing the manure from the belts 2-3 times a week and storing it in properly closed cellars, good stall hygiene can be achieved.
The present report describes how this type of battery has been adapted so as to combine the advantage of the favourable stall climate with the production of dry, odourless manure.

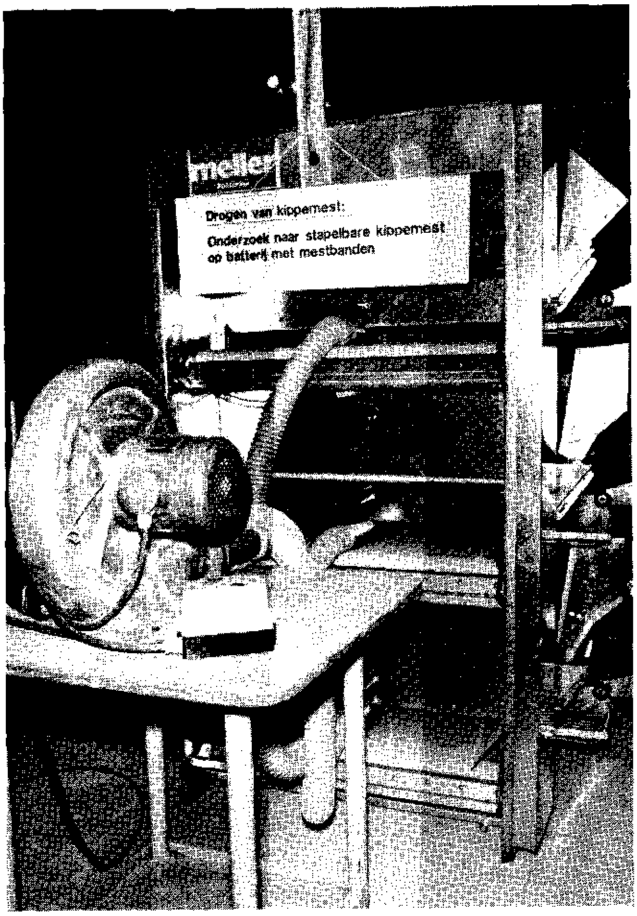

Fig. 1. Prototype set-up for drying manure in batteries

2. THE DRYING SYSTEM WITH MANURE-BELT BATTERIES

The system is based on two-phase drying:

A. Predrying on the manure belts by means of air,

B. Postdrying in covered-over storage by spontaneous internal heating.

2.1 Predrying on manure belts by means of air

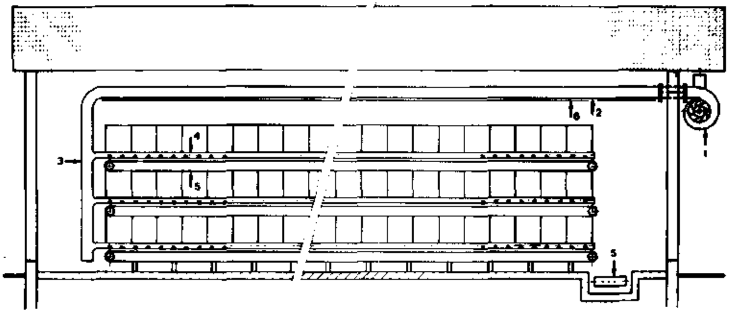

Fig. 2. Schematic representation of the drying system

1. centrifugal fan
2. polyethylene tube (≥ Ø 600 mm)
3. distributor duct
4. perforated duct (≥ 100 mm)
5. manure removal belt
6. condensation gutter

Fig. 2 gives a schematic drawing of the drying system. Air is sucked in from outside through a wide-mesh filter (e.g. wire gauze) by a centrifugal fan. A number of variations on this version are conceivable, including one compared to several fans. The air is blown to the distributor duct through polyethylene tubes, 600 or 700 mm in diameter. During through-flow the air heats up by heat-exchange with the surrounding stall air. Condensation occurs on the outside of the tube, particularly in cold weather. The dripping water is caught in a gutter and led off out of the stall. The warmed and relatively dry air is blown into the perforated ducts suspended above the manure belts over the whole length of the battery. These polyethylene or p.v.c. tubes have two holes of 3 mm Ø at either side at intervals of 100 mm. Depending on the length and cross-section of the duct, the air is blown into it from one or from both sides. It has been found from experience that 2-mm holes get blocked up very quickly and tests have shown that 4-mm holes cause high pressure loss.

The ventilation capacity required for drying amounts to 0.4-0.5 m^3/hen/h at a backpressure of 500-1000 Pa. The pressure is determined from the volume of air, the length and cross-section of the perforated ducts. For good drying, the pressure at the end of the perforated duct must be at least 300-350 Pa. This is the lowest pressure at which the air can be blown out of the holes at a speed

Fig. 3. In this stall a centrifugal fan has been connected to each battery

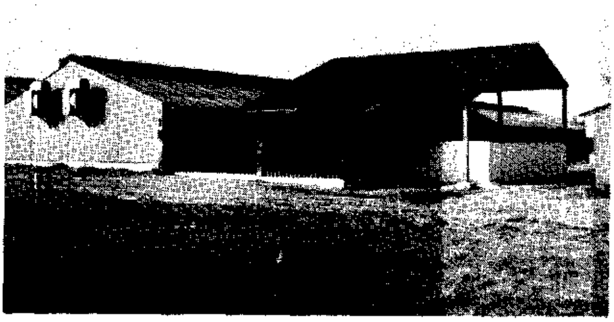

Fig. 4. Stall with manure drying and roofed-over manure storage

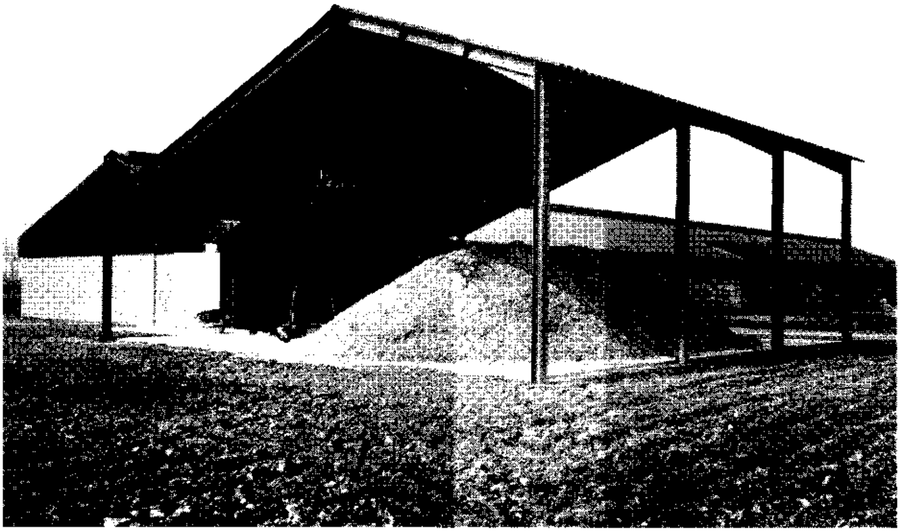

Fig. 5. Roofed-over manure storage where further drying takes place by means of spontaneous heating

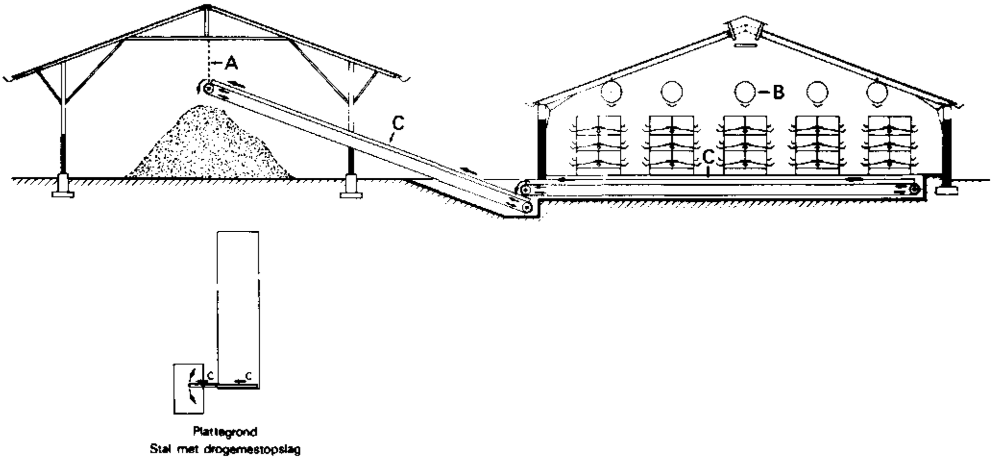

Fig. 6. Cross-section of a stall with manure drying and storage outside the stall

of ca 20 m/s, so that it can be distributed over the manure on the belt at a speed of 0.5-2 m/s. The forced airstream causes evaporation of moisture from the manure.

In the batteries using this drying system the space between cage floor and manure belt has been increased so that the manure can collect there for about 7 days. This is important in order to get a favourable ratio between the amount of fresh manure and the amount of drier manure. Compared to belt batteries using liquid manure, the time required for cleaning out the manure is reduced by half. After drying, the manure with a dry-matter content of about 45% is removed from the belts and transferred by transport belts to a covered storage place.

2.2 Postdrying in a covered store by spontaneous internal heating

Such storage is required in the system to ensure the obtaining of homogeneously dry manure. Manure with a dry-matter content of about 45% is unsuitable for transport and storage in the open air. Anaerobic processes readily take place in such manure, the result being a sticky, malodorous manure which is difficult to process.

Spontaneous internal heating starts quickly in the stored manure. In the top layer in particular, high temperatures (> 60 °C) have been measured, those in the layers below varying between 30 and 50 °C. The drying is promoted by the fact that a new layer of manure is dropped on to the heating pile every week. The thinner the layer, the faster the manure dries. For that reason, in addition to the advantage of greater manure storage, a swivelling conveyor is to be recommended.

During the composting process much moisture is evaporated and a slight smell of ammonia is perceptible. After a successful spontaneous heating process has taken place, manure is obtained with a dry-matter content of at least 55%. This manure is suitable for transport and storage in the open air and can be easily applied by means of conventional manure spreaders.

The minimum manure-storage requirement is not less than a 6 weeks' capacity, a hardened floor and a roof. In such storage the water vapour is quickly removed by the wind and attack by rain is prevented. In more closed storage places, adequate ventilation must be provided via walls and roof-ridge, large doors being required for removal of the manure.

3. SYSTEM DETAILS

Perforated ducts in batteries with manure belts can be about 100 m in length. The diameter can be small if a compact structure is chosen for the battery. In order to ensure good drying, 6-10 m^3 of air per metre of duct have to be transported every hour. This standard has been derived from 0.3-0.5 m^3 of air/hen/h and a load of 20 hens per tier metre. There has to be a minimum pressure of 300 Pa in the duct system in order to blow the air over the manure at the requisite speed.

In order to gain more insight into the effect that duct-diameter has on air distribution, static pressure and power consumption, tests were done with ducts having a cross-section of respectively 60, 80 and 100 mm and lengths ranging from 10 to 60 metres. The perforation consisted of two 3-mm diameter holes every 100 mm. At every test the effort was made to adhere to the norm of 6 and 10 m^3 of air/ h /metre of duct.

It was established from the measurements that:

- In wider ducts the pressure is distributed more uniformly over the whole length than is the case in the narrower ones;
- At 6 m^3/h the required minimum pressure is unattainable in many cases;
- At 10 m^3/h in long, narrow ducts the pressure at the end of the duct is too low;
- The power consumption at 0.5 m^3 is higher than at 0.3 m^3. In narrow ducts with high backpressure the energy consumption is particularly high.

Although the conclusion can be drawn from these data that wider ducts are preferable, it was not possible to determine the most suitable diameter as regards duct length, ventilation capacity desired, minimum static pressure and energy consumption. Subsequently a computer program based on an accurately performed test has made it possible to answer these questions. The results of the test are given in Table I.

In case of a too low pressure at the end of the perforated duct the ventilation capacity must be increased or air must be blown in from both sides in order to maintain the required pressure. In the first case this means higher power consumption, in the second, extra provisions for distributing the air in front of and behind the battery.

In the following paragraphs the perforated ducts and the relevant formulas will be dealt with. Finally a computation program has been made with which calculations have been carried out that provide information on the installation of the system of ducts.

Table I. Variation of the static pressure (P_{st}) in a polyethylene duct of 100-mm diameter with two holes 3 mm in diameter every 0.1 m. Pressure in Newton/m^2, distance in metres.
1 N/m^2 = 1 Pa $\approx$ 0.1 mm H_2O

length	30	40	50	60	70	m
Q = airstream volume	234	339	402	479	591	m^3/h
0	314	412	467	553	797	
5	294	373	406	471	667	
10	283	341	347	392	545	
15	277	322	316	345	475	
20	275	310	288	302	404	
25	275	306	273	275	349	
30	275	302	263	251	310	
35		302	255	235	275	
40		302	255	224	251	
45			255	216	235	
50			255	216	224	
55				216	220	
60				216	216	
65					216	
70					216	

The end pressures given in the table are not comparable without comment as the airstream volume Q could not be precisely set at the norm of 8 m^3/h per running metre, that is 240-320-400-480 and 560 m^3/h. In this case the measured end pressures would have been: 289-269-252-217 and 194 Pa. The longer the duct the lower the end pressure in spite of the "correct" volume of air.

3.1 Theory on flow in perforated ducts

In the case of flow in ducts one is concerned with <u>static pressure</u>, <u>dynamic pressure</u> and <u>total pressure</u>.

The static pressure finds expression in the force vertically exerted on the duct wall (P_{st}). The dynamic pressure is the product 0.5 x density (kg/m^3) x square of the speed (m^2/s^2) (P_{dyn}). The total pressure $P_{tot} = P_{st} + P_{dyn}$.

If no losses occur on account of friction and eddying, P_{tot} remains constant over the whole length, P_{dyn} is reduced and P_{st} increases by the same amount. In a part of a duct where the speed is constant, the static pressure decreases, owing to friction along the wall.

The result of the effects of changes in pressure, friction and eddying is that the pressure at the end of long ducts of limited diameter is in most cases much lower.

The air velocity component vertical to the duct wall in an exhaust opening can be calculated from the local static pressure:

$v_{\emptyset}$ = $\sqrt{(2.P_{st}/(\rho.\zeta)}$, where:

P_{st} = static pressure compared to space outside the duct (N/m^2)

ρ = air density (kg/m^3)

ζ = coefficient of resistance

At this speed the volume of exhausted air can be calculated in accordance with:

$Q_{\emptyset}$ = $0.25 \times \pi \times D_{\emptyset}^2 \times v_{\emptyset} \times \varepsilon$, where:

$Q_{\emptyset}$ = volume flow in hole (m^3/s)

$D_{\emptyset}$ = diameter of holes (m)

ε = coefficient of contraction

The friction is expressed in loss of pressure.

In the application here described the following relation applies:

ΔP = $\lambda(L/D)0.5.\rho.v^2$, where:

λ = coefficient of friction. This depends on the relative roughness of the duct wall and the Reynolds number (Re) (= speed x diameter divided by the kinematic viscosity).

L = length of the duct or part of the duct (m)

D = diameter of duct (m)

v = speed in the duct (m/s)

ΔP = pressure loss over distance L (N/m^2)

3.2 Pressure reduction in the duct

A computer program can be written on the basis of the foregoing relations in order to determine at every exhaust opening:

- the static pressure (P_{st})
- the speed in the duct (v)
- volume of exhaust air (Q_{0})

The following data must first be fed in:

- length and diameter of the duct
- pitch spacing and diameter of the holes and number of holes per pitch
- static pressure at the end of the duct
- temperature and humidity of the air
- the coefficients ε, ζ, λ and η (static regain)

It has been found from research done by BAILEY and DAWSON that these coefficients are functions of velocity and/or pressure. In the computational model the values given have been derived from the results shown in Table 1. The constants are:

- static regain	η	= 0.75
- coefficient of contraction	ε	= 0.72
- coefficient of friction	λ	= 0.0155 to 0.016
- coefficient of resistance	ζ	= 1.03

3.3 Fan power

The power of the fan motor which is drawn from the mains is equal to

$N = P_{tot} \times Q/\eta_{vent}$

P_{tot} = total pressure loss of the whole air distribution system (N/m^2)

Q = volume flow (m^3/s)

η_{vent} = total yield fan (with motor)

N = power absorbed (W)

Every section of the system contributes to the power requirements by a part equal to the volume of flow times the total pressure loss.
Table II only shows the share per perforated duct. If there are 5 batteries,

each with 3 ducts, then multiplication is by 15. Then the pressure loss with the relevant volume of flow in the air-conducting system has to be determined. In general they have rather large dimensions, so that only a small part of the total power required, about 20 to 30%, is used up in this air-conducting system.

3.4 Calculations

In Table II (1-4) the calculations are given for perforated ducts differing in length and diameter and an end pressure of 300 Pa.
From Table II (1) it is seen that the velocity at the beginning of the duct of small diameter is much higher than is the case with larger ducts. In longer ducts, particularly those of smaller diameter, the velocity increases considerably, whereas in wider ones velocity remains restricted.
Table II(2) gives the ratio of the static pressure at the beginning of the duct to that at the end. This ratio remains the same, irrespective of the desired end pressure. With the aid of this table the initial pressure can be calculated by multiplying the number of a given duct length and duct diameter by the end pressure.
In Table II (3) the ventilation capacity needed to maintain a pressure of 300 Pa at the end of the duct is given. From the Table it is evident that the ventilation norm is exceeded in all cases. This applies namely to narrow ducts. In these cases the pressure at the beginning of the duct is much higher than at the end. Because of the difference in pressure there is great inequality in the air distribution over the initial and the final part of the duct. In consequence of this, the manure in the first section of the battery is drier than in the last part. Because of the high initial pressure the drying will demand a higher power consumption.
The wider the diameter chosen for the duct, the less the decrease in volume flow, so that, for a given length it makes little difference if one takes a still wider duct. Although greater duct diameters require less power consumption there are namely factors which have an unfavourable effect, such as:

- In the wide duct the initial pressure is practically the same as the end pressure ((Table II (2)). This means that over the whole length the pressure is practically equal to the minimum pressure. Under unfavourable conditions,

Table II. Velocity, pressure ratio, volume flow and consequences as regards the fan power in the case that the perforated duct has differences in diameter and length. Static pressure at the end of duct 300 Pa and ventilation capacity 8 $m^3/h/m$ duct.

length duct m	duct diameter [mm] 60	80	100	125	150	175
	1. Velocity at the beginning of the duct (m/s)					
30	28.53	14.05	8.74	5.55	3.85	2.82
40		20.05	11.92	7.45	5.14	3.77
50		27.76	15.49	9.43	6.45	4.72
60			19.67	11.54	7.81	5.68
70			24.68	13.85	9.21	6.66
80			30.79	16.42	10.70	7.67
	2. Ratio of static pressure at the beginning to that at the end of the duct					
30	3.278	1.430	1.118	1.030	1.008	1.002
40		2.235	1.347	1.097	1.033	1.012
50		3.857	1.776	1.222	1.079	1.032
60			2.499	1.424	1.154	1.064
70			3.666	1.731	1.266	1.113
80			5.504	2.174	1.423	1.181
	3. Volume flow at the beginning of the duct m^3/h					
30	290.4	254.2	247.1	245.1	244.9	244.2
40		362.8	337	329.1	327	326.4
50		502.3	438	416.6	410.3	408.7
60			556.1	509.8	496.8	491.8
70			697.8	611.9	585.9	576.7
80			870.6	725.4	680.7	664.1
	4. Fan power (W) per perforated duct Total output fan 0.6*)					
30	197	64	44	37	35	35
40		152	76	55	49	47
50		375	137	81	66	61
60			252	119	88	77
70			471	179	117	96
80			890	272	156	120

*) For transformer-regulated fans: 0.5 - 0.6; not regulated: 0.6 - 0.7. (In accordance with specifications of fan manufacturer)

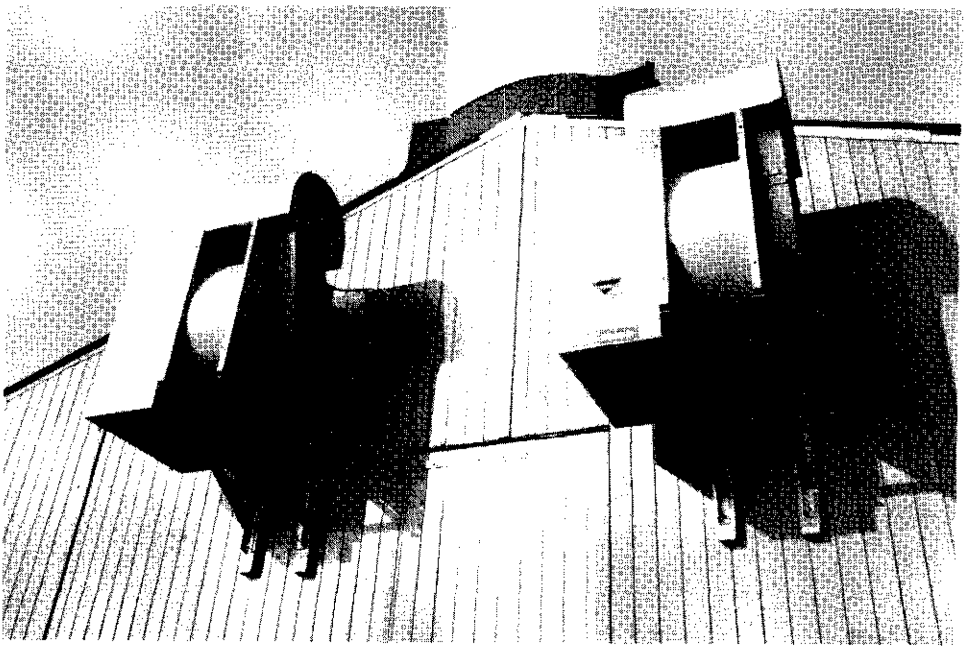

Fig. 7. Two fans are used in this stall to dry the manure on several batteries

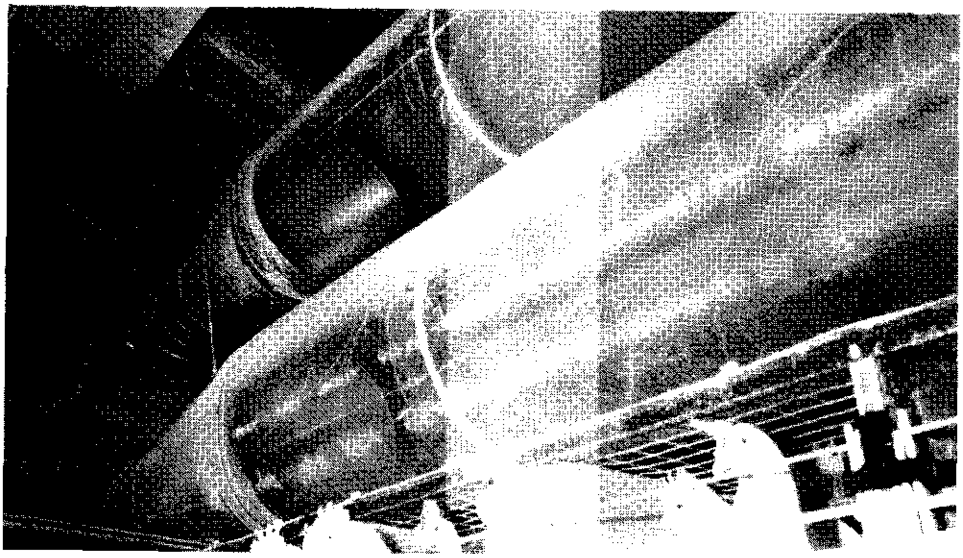

Fig. 8. The air is conveyed to the distributor through the heat-exchanger tube suspended above the battery. Condensation and heating take place during transport.

e.g. poor drying properties of the air or diarrhoea of the animals, there is a great risk that the manure will not dry sufficiently.

- In the winter in particular, and at night, fan capacity must be reduced in order to maintain the desired stall temperature. Especially in wide ducts, owing to the smaller volume of air, the pressure over the whole length drops below the minimum pressure, with the result that drying of the manure throughout the duct is unfavourably affected. An advantage of wide ducts is that, in summer, the ventilation capacity can be increased to more than the norm with a slight increase in the power required. In such a case the drying system is considered as an extra ventilation system to some extent.

From Table II (4) it can be seen that power consumption in ducts of slight diameter is higher than in wider ones and that power consumption also rises faster in narrower ducts at greater duct lengths. Although power consumption is least in the widest ducts, in the event of reduction of the ventilation capacity the pressure over the whole length will become too low, while in narrow ducts the pressure over a long part of the duct is more than 300 Pa. From the above it follows that both volume flow and static pressure ratio are important factors. For a good drying result a static pressure ratio of 1.2 - 1.3 is advisable. In Table II (2) the most suitable combination of length and diameter of the duct can be found. In Table II (4) the appropriate fan power is given.

3.5 Heat-exchanger tubes

In the first instance a centrifugal fan is placed directly on the distributor duct. However, the stall air sucked in is so polluted with dust, feathers, etc. that the holes are very soon clogged up. Installation of a dust filter quickly gives rise to a loss of capacity. Dust filters are no solution to the problem, in particular from the viewpoint of practical objections and the high investments involved.

In the set-up now used the fans are mounted at the end of the stall and outside air is blown through tubes made of plastic foil to the distributor duct. During transport, the air in the tube is warmed up and, particularly in wintertime, condensation takes place on the outside of the tube.

The warming-up and condensation on a 600-mm foil tube were measured in order to gain insight into the above-mentioned phenomena. The results have been compared with the theory on this area. In view of the agreement established, a computer program was made, by means of which the desired information can be calculated. With this program the condensation threshold was computed for a stall (stall temperature 22 °C and relative humidities of respectively 60 and 70%) at outdoor temperatures of 0 and -5 °C, using 600 and 700-mm tubes. The calculation is shown in Fig. 9 .

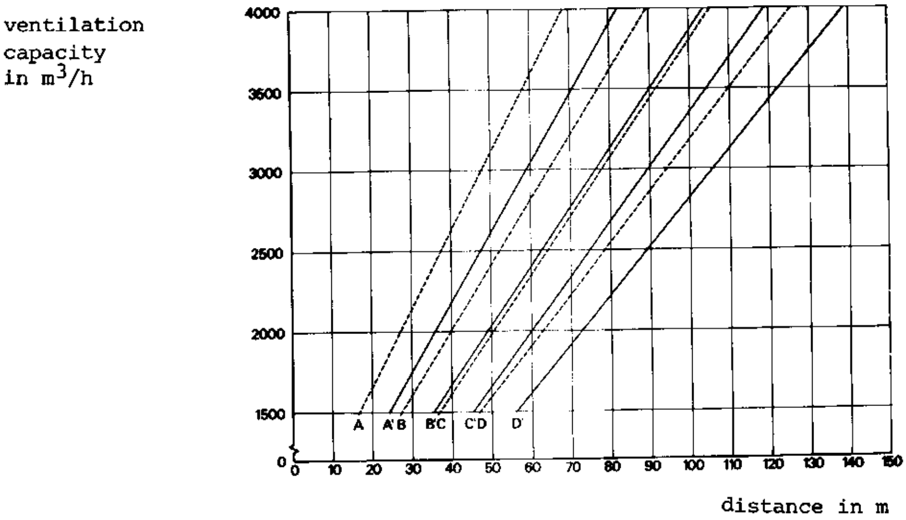

Fig. 9 . Condensation threshold at different ventilation capacities

Explanation of the symbols:

	Ø tube in mm	outdoor temp. in °C	Rel.hum. at 22 °C in %
A	700	0	60
A'	600	0	60
B	700	-5	60
B'	600	-5	60
C	700	0	70
C'	600	0	70
D	700	-5	70
D'	600	-5	70

From the figure it is found that the condensation threshold shifts when the ventilation capacity increases. In addition, the tube cross-section, the outdoor temperature and the relative humidity of the air in the stall each has a part to play.

Table III shows the calculated distance which, at a ventilation capacity of 2500 m^3/h, is required for warming the air up to about 10 °C.

Table III. Heating up the outdoor air at 2500 m^3/h

Ø tube in mm	outdoor temp. in °C	Rel.hum. at 22 °C in %	Warming up in °C	Condensation threshold in m
600	0	70	10.2 (50.0 m)	75.1
700	0	70	10.3 (50.4 m)	64.9
600	-5	70	10.7 (69.6 m)	89.5
700	-5	70	11.0 (70.6 m)	79.5
600	0	60	9.3 (47.2 m)	47.2
700	0	60	10.7 (56.1 m)	37.4
600	-5	60	9.3 (62.9 m)	62.9
700	-5	60	11.7 (79.2 m)	52.8

From the table it is found that the distance over which heating up takes place at a stall temperature of 22 °C, is mainly influenced by the outside temperature and much less by tube cross-section and relative humidity of the air in the stall. Moreover, it is evident that the air has to travel a long distance to reach 10 °C. Faster warming-up is possible by increasing the area of the heat-exchanging surface. This can be achieved by using a number of smaller tubes instead of one large one. In Table IV a ventilation capacity of 2500 m^3/h, warming-up to 10 °C and the condensation threshold are calculated.

Table IV. Comparison of heating-up output and condensation threshold in a 600-mm tube compared to four 300-mm tubes

Ø tube in mm	Number of tubes	Outdoor temp.	Rel.hum. in % at 22 °C	Required distance in m for warming-up to 10 °C	Condensation threshold in m
600	1	0 °C	70	50.0	75.1
300	4	0 °C	70	23.4	35.1
600	1	-5 °C	70	69.6	89.5
300	4	-5 °C	70	32.3	41.5

From the above data can be seen the great influence exerted by the heat-exchanging surface on the rate at which warming-up takes place and the short distance over which condensation occurs. A practical objection to this set-up is, however, the space in the stalls, which is too restricted for installation of a large number of tubes. Where more heating is needed, a compact heat-exchanger or additional heating equipment has to be installed.

4. PRACTICAL RESULTS

4.1 Drying and power consumption

Manure drying in 5 stalls, each with a population of about 25,000 hens kept in 3 and 4-tier batteries, was investigated over the period of one year. Although the drying system evinces differences in matters of detail, the ventilation output is based on at least 0.4 m^3/hen/h at a backpressure of more than 300 Pa at the end of the duct. In all cases the ventilation capacity can be reduced, particularly to prevent low temperatures at night and in the winter. In a number of different weeks, after 5-7 days drying, samples of fresh and belt-dried manure were collected for determination of dry-matter content and the kWh consumption was ascertained.
In Table V a survey is given of the measured data.

From Table V it is found that, on average the dry-matter content of the belt-dried manure amounts to 40-45%. Moreover, the power consumption was found to be more than 1 kWh/hen/year. To ensure that the internal spontaneous heating is successful, a dry-matter content of 45% is recommended.
The dry-matter contents are affected by various things:

- the dry-matter content of fresh manure;
- the drying properties of the air; in general the drying conditions are better in summer than in winter;
- the ventilation capacity.
  In winter, in particular in stalls with insufficient insulating, or stalls with poorly closing inlets, the ventilation is reduced to prevent the stall temperature from going down.
- cutting down on the use of energy; trying to save too much can lead to poor drying results.
- blocking up of the perforated ducts. Blocking has been found to occur in winter at the beginning of the ducts. In such cases condensation has formed on the ducts, leading eddying dust to adhere to them and blocking up the holes.

Table V. Survey of average dry-matter contents (in %) and kWh consumption (in kWh/hen/year)

	October 1983			December 1983			March 1984			May 1984		
	Dry-matter content		kWh	Dry-matter content		kWh	Dry-matter content		kWh	Dry-matter content		kWh
	fresh manure	belt-dried manure		fresh manure	belt-dried manure		fresh manure	belt-dried manure		fresh manure	belt-dried manure	
Average	21.0	43.1	1.05	21.3	44.5	1.15	20.2	40.2	1.05	21.3	46.3	1.27
Spread	19.4-22.4	39.9-45.4	0.83-1.30	19.2-22.8	40.2-48.8	0.93-1.84	19.1-21.7	36.4-45.4	0.89-1.22	19.5-22.7	43.0-48.6	0.94-1.60

4.2 Composition of the manure

As experience with in-house manure-drying systems has shown, about 50% of the organic matter and nitrogen can be lost during prolonged storage in the stall. Particularly when the ventilation is restricted, there is a perceptible smell of NH_3 in such stalls. On the other hand, in stalls having the manure-belt battery system, the stall climate is good, even in the winter period. During the heating-up process some nitrogenous matter does escape from the store in the form of ammonia.

In Table VI the fertilizing value is given of a number of samples of fresh manure, belt-dried manure and belt-dried heated manure.

Table VI. Averaged composition (in %) of, respectively fresh, belt-dried and belt-dried heated manure

Sort of manure	Averaged contents in the material in %				
	Dry matter	Crude ash	N	P_2O_5	K_2O
Fresh manure	23.3	6.50	1.20	0.85	0.58
Belt-dried manure	45.0	12.42	2.34	2.01	1.08
Belt-dried heated manure	54.5	19.10	2.66	3.14	1.81

On the basis of the data given in Table VI a daily fresh manure production of 0.150 kg/hen and supposing that the quantity crude ash during drying and heating does not change, the manure production and fertilizing value has been calculated.

Table VII. Survey of the manure production and fertilizer elements in kg/hen/year

	Quantity of					
Sort of manure	Manure	Crude ash	Org.matter	N	P_2O_5	K_2O
Fresh manure	54.8	3.84	8.60	0.62	0.48	0.30
Belt-dried manure	27.2	3.84	8.48	0.63	0.52	0.34
Belt-dried heated manure	18.3	3.84	7.16	0.53	0.57	0.32

Table VII shows that by drying the manure the weight is reduced by 50%. This weight loss is caused by evaporation. During the storage period of about 8 weeks in the heating process, next to a further reduction in weight because of evaporation, also organic matter and nitrogen are lost. In Table VII it is shown that this amounts to 16.7 and 14.5%.
With respect to the fertilizing value of the manure it must be remarked that the drier the belt-dried manure, the shorter the heating process and consequently the slighter the loss of organic matter.

5. INVESTMENTS AND ANNUAL COSTS

There are three drying systems in use in the Netherlands, namely:
- stalls with cellars (deep-pit and high-rise stalls);
- stalls with channels;
- stalls with flat floors and manure-belt batteries.

The investments and annual costs have been calculated for these three systems.

5.1 Investments

A comparative calculation for the sub-structure of the stalls housing a population of 25,000 laying hens in 3 and 4-tier batteries has been made for different drying systems. The calculation also takes account of the equipment for drying and removing the manure.

Table VIII. Investments (in Dutch guilders) for 3 dry-manure stall types

	High-rise stall		Channel stall		Stall with manure-belt batteries	
	3-tier	4-tier	3-tier	4-tier	3-tier	4-tier
Total	198300	169200	195600	162300	126800	115200
Per hen	7.93	6.77	7.82	6.49	5.07	4.61
Ratio	172	147	170	141	110	100

From Table VIII is can be seen that the stall with the manure-belt batteries is much cheaper than the two other types.

5.2 Annual costs

Table IX gives the annual costs calculated for the systems stated in Table VIII. The calculation takes into account the following percentages for depreciation, interest and maintenance:

11% - structural provisions
17% - equipment

Of still greater importance, however, are the costs of power for the fans. From the tests it is found that drying to 45% dry matter is possible at a power consumption of about 1.5 kWh/hen/year. At a price of 0.22 D.guilders/kWh this is 0.33 D.guilders/hen/year. Here it must be said that the dry manure is not a waste product, but a manure which is in demand and can command a price of 10-15 D.guilders per m^3. An annual production of 30 litres/hen thus practically covers the energy costs.

Table IX. Annual costs (in D. guilders) for 3 types of stall with dry manure

	High-rise stall		Channel stall		Stall with flat floor and manure-belt batteries	
	3-tier	4-tier	3-tier	4-tier	3-tier	4-tier
Manure processing/ hen/year	0.91	0.78	0.95	0.81	0.67	0.61

From the table it is clear that the costs in the stall with manure-belt batteries are much lower.

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