GRAIN CROP HEATING ON THE BASE OF MULTI-ELECTRODE COMPOSITE ELECTRIC HEATERS

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ABSTRACT

Crop Heating Electric Device *АПЗЭ-01* based on the multi-electrode composite electric heaters *МКЭ-1* is a modern power effective equipment reducing energy intensity more than to half comparing with the known similar devices.

Keywords: multy-electrode, polymer, composite, heater, resistivity, conductivity.

I. INTRODUCTION

The problem of grain crop heating in the grain crop processing industry has always been topical as it is a complicated technological process demanding high power inputs. Thus, for example, the grain crop heating device *БПЗ* provides crop heating from –5 to +15 °C subject to the capacity of 3.5 ÷ 4.0 t/h due to the dry saturated steam which consumption amounts approximately 110 kg/h. Preparing such volume of heat carrier demands power inputs of about $300 \bullet 10^3$ kJ that is equivalent to the device installed capacity of ~ 85 kW. In the process of the air-to-water conditioner running the heat energy consumption amounts 55.8 kW for heating 1 t/h of crop [1].

Similar devices and well-known ways of the grain crop heating have drawbacks both general and concrete for each separate case:

- low performance of the crop heating process;
- the lack of the automatic control of the crop heating process;
- increased materials consumption of the equipment and laborious equipment servicing and
- impossibility to apply the methods mentioned above in the farming, minor mills in case of the lack of boiler plants, which is connected with the necessity of heating the closed volume of crop transporting within by means of the loop steam pipeline;
- low efficiency which amounts 35 – 40 %.

II. BASIS OF DESIGN CALCULATION OF THE CROP HEATING DEVICE

The subject suggested is the heating system with the crop heating electric device application *АПЗЭ* which presents a two-section upcast with the radiators within – metal sheaths shaped as shelves (further on – radiators) with electric heaters *МКЭ-1* inside (Table 1) [2,3]. The mechanism for the heated crop outflow is placed in the lower part of the upcast (Figure 1).

Table1. Electric Heater *МКЭ-1* Technical Characteristics

No.	Characteristics	Value
1	Dimensions (inner diameter/ outer diameter), mm	200 x 135 x 10
2	Voltage, V	220 ± 10 %
3	Power $P_{n,}$ W	35 ± 3.5
4	Surface Temperature T, ˚C on the condition that T_{amb} = +18˚C	70 ± 5
5	Specific Power, at the most, W/ m^2	1200
6	Insulation Resistance, at the least, MΩ	1000
7	Disruption Voltage, at the least, kV	9
8	Leakage Current, at the least, A	$75 \bullet 10^{-6}$

9	Error-Free Running Time, at the least, h	50000
10	Weight, kg	0.315 ± 2 %

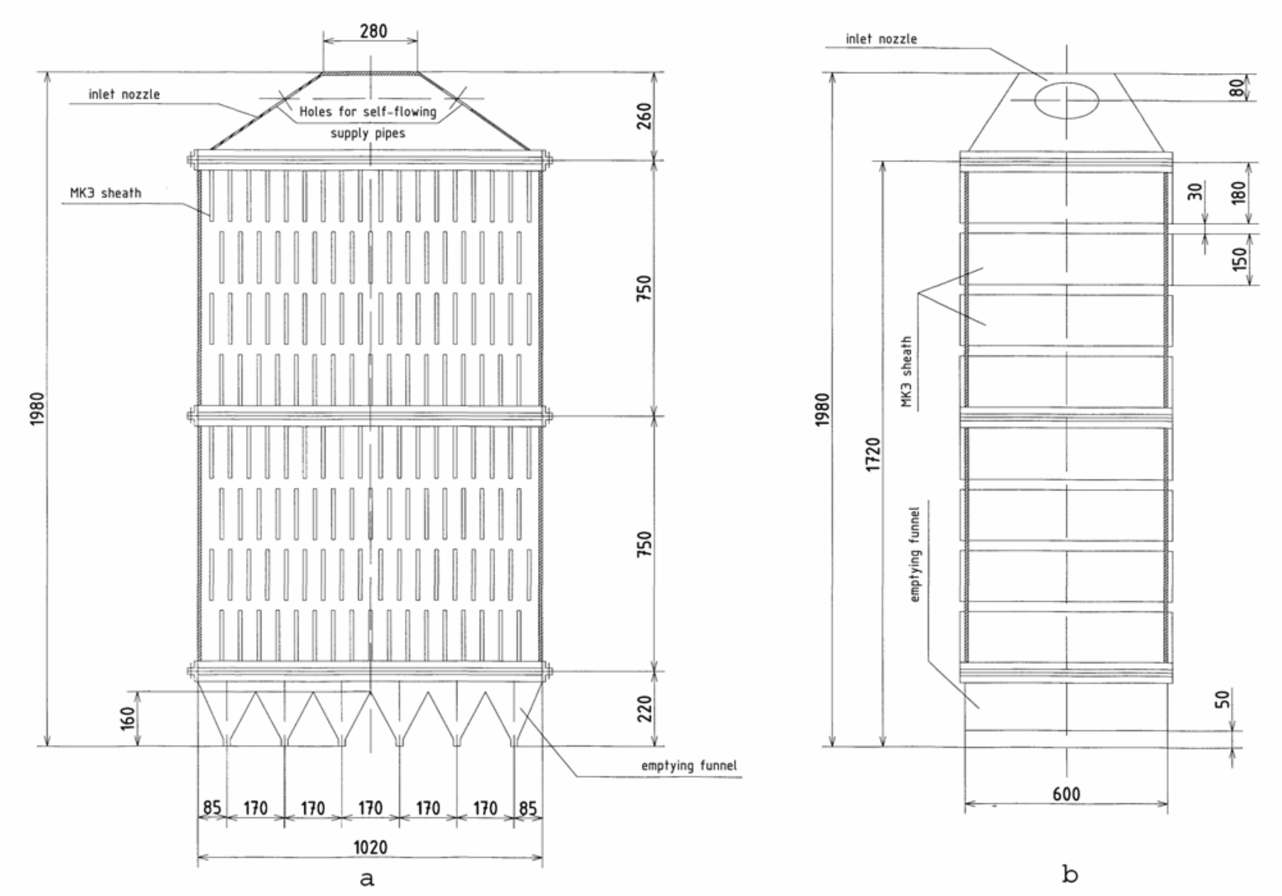

Figure 1. Crop Heating Device *АПЗЭ-01*: a – front elevation, b – side elevation

The grain crop proceeds through the two inlet nozzle holes into the upper and lower sections intersected by the rectangular radiators. Passing between the radiators the grain crop becomes heated and proceeds through the lower bunker with emptying funnels into the conveyer screw. The design calculation of the heating system basic characteristics is the following.

Determination of the device internal volume:

$$V_s = h \bullet a \bullet b = 1.5 \bullet 1.0 \bullet 0.6 = 0.9\ m^3, \quad (1)$$

where h is the height of the *АПЗЭ-01* two sections , m;

a is the section width, m;

b is the section depth, m.

Determination of a single radiation volume:

$$V = l \bullet h_{sh} \bullet b_{sh} = 0.6 \bullet 0.15 \bullet 0.015 = = 0.00135\ m^3, \quad (2)$$

where l is the sheath length, m;

h_{sh} is the sheath height, m; b_{sh} is the sheath depth, m.

156 radiator pieces are applied in the device; their total volume amounts the following:

$$V_r = n \bullet V = 156 \bullet 0.00135 = 0.21\ m3, \quad (3)$$

where n is the radiator number, pieces.

Determination of the payload volume of the crop containing in the heating space:

$$V_c = V_s – V_r = 0.9 – 0.21 = 0.69\ m3. \quad (4)$$

Determination of the weight of the crop containing in the heating space simultaneously:

$$G_h = \gamma \bullet V_c = 0.75 \bullet 0.69 = 0.52\ t, \quad (5)$$

where γ is the bulk packed density of the dry crop, t/m^3 [2];

V_c is the volume of the crop containing in the heating space, m^3.

The electric power of a single electric heater *МКЭ-1* applied in the device amount P_n = 35 W; a single radiator contains three *МКЭ-1* pieces, hence the power of a single radiator is the following:

$$P_r = n_h \bullet P_n = 3 \bullet 35 = 105\ W, \quad (6)$$

where n_h is the number of the electric heaters in an each single radiator, pieces.

The total electric power of the device is the following:

$$P_d = n \bullet P_r = 156 \bullet 105 = 16380\ W \approx 16.4\ kW. \quad (7)$$

The device capacity is determined due to the electric (heat) power input by the following formula [1]:

$$Q_h = G \bullet c \bullet (T_f - T_i) = G \bullet c \bullet \Delta T, \quad (8)$$

where Q_h is the heat consumption (heat power) necessary for the crop heating under the certain device capacity, kW;

G is the weight capacity of the device, kg/s;

T_f and T_i are the crop predetermined (final) and initial temperatures correspondingly, K;

ΔT is the difference of the crop final and initial temperatures, K;

c is the crop specific heat, kJ/(kg • K).

In consideration of the absence of loss of heat through the heat-insulated walls of the *АПЗЭ-01*, the following can be stated:

$Q_h \approx P_d = 16.4$ kW; c = 1.55 kJ/(kg • K);

$T_f = 15$˚C; $T_i = -5$˚C; $\Delta T = 20$˚C = 20 K.

Basing on Formula (8) the device capacity expected can be calculated:

$$G = Q_h/(c \cdot \Delta T) = 16.4/(1.55 \cdot 20) = 0.53 \text{ kg/s} = 1.9 \text{ t/h}. \quad (9)$$

The heating surface determination is the following:

the heating surface square of an each single radiator is the following:

$$F_l = 2 \cdot l \cdot h_{sh} = 2 \cdot 0.6 \cdot 0.15 = 0.18 \text{ m}^2, \quad (10)$$

where characteristics and their values are taken from Formula (2);

the heating surface total square of all the radiators is the following:

$$F = n \cdot F_l = 156 \cdot 0.18 = 28 \text{ m}^2. \quad (11)$$

Basing on the heat transfer equation the expected temperature difference of the radiators and the heated air (crop) in the device can be determined [3]:

$$\Delta T' = \frac{\xi Q_h}{F k_v} = \frac{1.1 \times 16400}{28 \times 28} = 23K = 23\,^\circ\text{C}, \quad (12)$$

where ξ is the assurance factor taken as equal to 1.1;

k_v is the coefficient of the heat transfer from the radiators to the crop, taken as equal to 28 W/(m^2 K).

Thus, the estimated value of the temperature ΔT is approximately equal to the value $\Delta T'$ expected.

Subject to the crop initial temperature the increase of the device capacity is possible.

According to the design capacity the time of the crop heating (remaining in the heating space) is the following:

$$\tau = 60\, G_h / G = 60 \cdot 0.52/1.9 = 16 \text{ min}, \quad (13)$$

where G_h the weight of the crop containing in the heating space simultaneously, t;

G is the device capacity, t/h.

The necessary time of crop containing in the heating space is determined in the dependency on the crop initial characteristics (temperature, moisture) and the ambient characteristics.

It has been stated by the experiment that on the surface of the electric heater *МКЭ-1* with the power of approximately 80˚C, it reaches the operating condition is τ_h = 15 min.

Thus, basing on the derived results the comparative estimate of the devices *БПЗ* and *АПЗЭ* can be formulated as the following (Table 2).

Table 2. Crop Heating Devices Technical Characteristics

No.	Characteristics	Value	
		БПЗ	*АПЗЭ-01*
1	Capacity G, t/h	4.0	1.9
2	Installed Electric Power P_d, kW	–	16.4
3	Installed Heat Power Q, kW	85.0	--
4	Crop Heating Temperature Range ΔT, ˚C	-5 ÷ +15	-5 ÷ +15
5	Heating Time τ, min.	4	16
6	Energy Intensity P_{ei}, kW • h/t	21.0	8.6
7	Energy Carrier (Heated Steam) Temperature T_s, ˚C	110	–
8	Heater Surface Temperature T_h, ˚C	–	80
9	Cost, USD	7000	5000

III. CONCLUSION

Crop Heating Electric Device *АПЗЭ-01* based on the multi-electrode composite electric heaters *МКЭ-1* is a modern power effective equipment reducing energy intensity more than to half comparing with the known similar devices. The designed *АПЗЭ-01* provides the following:

- measuring and registering of the crop temperature at the point of entering the device;
- automatic control, measuring, registering and regulating of the crop temperature at the point of withdrawal;
- slide drive rotary velocity regulating at the point of crop withdrawal which enables the device capacity changing due to the crop characteristics and the device inner temperature;
- installation of the emergency outage *УЗО;*
- emergency outage of the equipment in case of crop extreme temperature at the point of withdrawal.

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