# GROUNDING OF CONSTRUCTION PARAMETERS OF PSEUDOFLUIDIZED LAYER DRYER WORKING CHAMBER
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# *ОБОСНОВАНИЕ КОНСТРУКТИВНЫХ ПАРАМЕТРОВ РАБОЧЕЙ КАМЕРЫ СУШИЛКИ ПСЕВДООЖИЖЕННОГО СЛОЯ*

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## ABSTRACT
*A new method for assessing the quality of fluidization is proposed, which allows providing more uniform heating of grain material and intensify its drying process*.

## *РЕЗЮМЕ*
*Предложен новый метод оценки качества ожижения, позволяющий обеспечить более равномерный нагрев зернового материала и интенсифицировать процесс его сушки.*

## INTRODUCTION
Grain harvesting period in many regions of Russia coincides with autumn precipitation falls, thus as a result the harvested grain has high humidity *(Zhuravlev A.P., 2014).*

Now, convection drying of grain material by combustion products of organic matter used as a fuel with comparatively high combustion temperature are used in agricultural industry. The disadvantage of such dryers is high energy consumption *(Tarasenko A.P., 2008; Pilipyuk V.L. 2009).*

This provides the necessity to develop new, less energy consuming, environmentally friendly technologies of grain drying *(Shhitov S.V. et al, 2016; Bibik G.A., 2016; Volkov A.V., 2017).* The application of food dehydration method in pseudofluidized layer allows significantly speeding up the process that is very important for increasing technical and economic indicators of drying installations.

The grain layer description in dryers functioning according to its pseudofluidization principle *(Volzhentsev A.V., 2014; Kalashnikova N.V. and Volzhentsev A.V., 2009)* can be at best estimated only visually, which is not quite objective.

For this reason, there were many attempts to find more precise definition of pseudofluidization quality.

However, in known methods foreign objects should be plunged into pseudofluidized layer. It influences the pseudofluidization nature.

## MATERIAL AND METHODS
The intensity of light flow when determining grain layer uniformity was detected by lux meter Ю-116, the readings of which were recorded by Panasonic NV-GS80EE-S video camera.

The installation response time of test and periodical running time were recorded by dual interruptible stop watch "С-II-16" with clock-driven mechanism.

We suggested the method of determining pseudofluidization uniformity consisting in determining light beam intensity, penetrating through grain layer.

Experimental tests were performed on the developed and manufactured installation presented in figure 1.

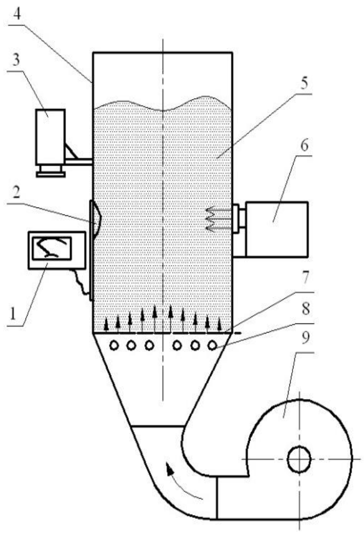



**Fig. 1 – Scheme of experimental installation and devices arrangement to determine the pseudofluidization uniformity degree**

*1 – lux meter; 2 – selenium sensor; 3 – video camera; 4 – drying chamber; 5 – grain layer; 6 – light source; 7 – gas distribution device; 8 – electric heating elements; 9 – ventilator*

Under the influence of heating with electric heating elements *8,* the air flow created by ventilator *9* on grain layer *5* which is located on gas distribution grid *7* the inter-grain contacts become weak, bed void fraction increases and its structure is destructed under certain conditions.

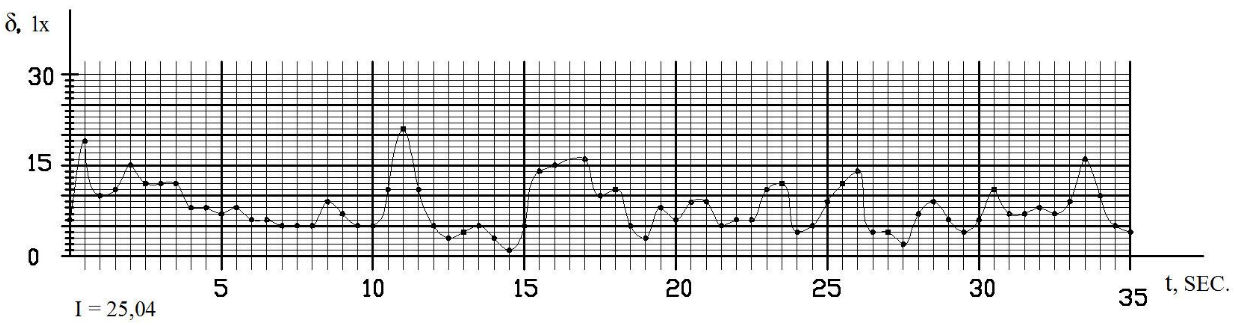
Dense grain layer in working chamber *4* merges into condition that reminds boiling liquid h.e. pseudo-fluidization condition. At that point, the uniformity degree of pseudofluidized grain layer produces the main effect on drying quality.

Light emission produced by directed light source *6* was detected by selenium sensor *2*, registered by lux meter *1* and recorded by video camera *3*.

Oscillograph recordings of lux meter readings have the form presented in figure 4, and allow obtaining detailed amplitude and frequency data. Different lines and hatchings in figure 5 present the processing of these recordings to obtain the necessary information.

Thus, distinguishing definite sufficiently large time interval $T$ , we summarized the area under curve $\delta(t)$ and determined the mean average deviation $\bar{\delta}$ of light emission:

$$\bar{\delta} = \frac{1}{T}\int_0^T \delta(t)dt . \qquad (1)$$




*abscissa – test duration t, sec; ordinate – light flow δ, lux; I – uniformity index (I = 25.04)*

**Fig. 2 – Determining the fluidization uniformity index**

Further we drew the corresponding horizontal that separated areas with $\delta > \bar{\delta}$ (spaces with sign «+») from areas $\delta < \bar{\delta}$ (spaces with sign «–»).

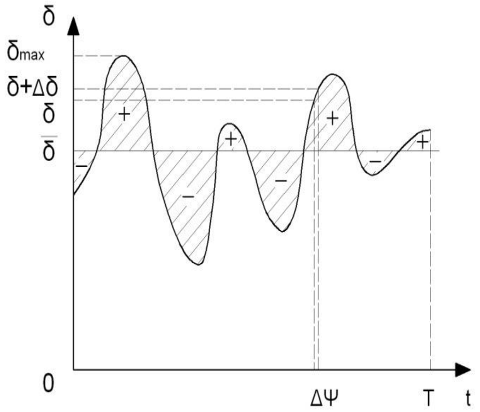



**Fig. 3 – Processing of lux meter readings**

Integrating separately the areas of truncated positive and negative spaces, we determine the average absolute deviation:

$$\left|\Delta\overline{\delta}\right| = \frac{1}{T}\int_0^T \left|\delta(t) - \overline{\delta}\right| dt = \frac{2}{t}\int_0^T \Delta\delta + dt = \frac{2}{t}\int_0^T \Delta\delta\_dt\,. \quad (2)$$

Drawing in the same figure the number of horizontals corresponding to neighbouring values $\delta$ and $\delta + \Delta\delta$, it is possible to add up continuances $\Delta\psi$, during which the light intensity was enclosed in this interval, and to determine this event relative probability $\Delta\omega(\delta) = \sum \Delta\psi / T$.

Uniformity index $I$ is determined as relation of average deviation $\overline{\delta}$, to oscillation frequency $\nu$: $I = \overline{\delta} / \nu$, where v – oscillation frequency.

Uniformity index $I$ was interpreted as the relation of average deviation $\overline{\delta}$, to oscillation frequency $\nu$: $I = \overline{\delta} / \nu$, where $\nu$ oscillation frequency.

According to the experiment, uniformity indexes were connected with pseudofluidization quality in the following way: high degree of uniformity corresponds to index 7, satisfactory – index from 7 to 15, low, with increasing piston flow – from 15 to 32.

## RESULTS

Experimental investigations were done in order to ground the drying chamber structural parameters providing the specified variation limits of uniformity index $I$ of wheat seeds pseudofluidized layer, which was determined according to intensity variation of light beam penetrating through the grain layer. In this regard, it was necessary to study the effect of the variation of diameter *d* and pitch *h* of drying chamber gas distribution grid holes on the uniformity index $I$ of grain seeds pseudofluidized layer.

Hole diameter was chosen according to the following values: d = 2; 2.2; 2.4; 2.6; 2.8; 3 mm. The hole pitch was equal to h = 1; 1.5; 2 mm.

Experimental results of the study of the above-mentioned factors, effects on uniformity index of pseudofluidized material in the drying chamber are presented in the form of characteristic curves in figures 6 and 7. The obtained uniformity index dependences of the fluidized material on holes diameter of gas distribution grid (figure 4) at different pitch of the given holes have linear character.

Sharp decrease of uniformity index $I$ with grid hole diameter increase takes place to the specified value and then its continuous increase occurs. Minimum value of index $I$ corresponds to the grid diameter values arranged in the interval from 2.4 to 2.6 mm.

On the ground of the obtained results it is necessary, in further investigations and also in practical usage, to apply grids with hole diameter from 2 to 3 mm. Further increase of grid hole diameter is unreasonable because of spillage of part of the grain material through them.

Characteristic curves (figure 5) of uniformity index $I$ from grid hole pitch *h* indicates that with increase *h* uniformity index decreases and reaches the minimum value at h = 1.5 mm.

The sequential increase of holes pitches results in gradual increase of uniformity index at any specified values of grid diameter.

We consider that further holes pitches increase in gas distribution grid is impossible because of reduction of grid open space and as a result of considerable increase of its hydraulic resistance. The type of the dependence obtained in the course of investigations with sufficient high accuracy corresponds to the theoretical one.

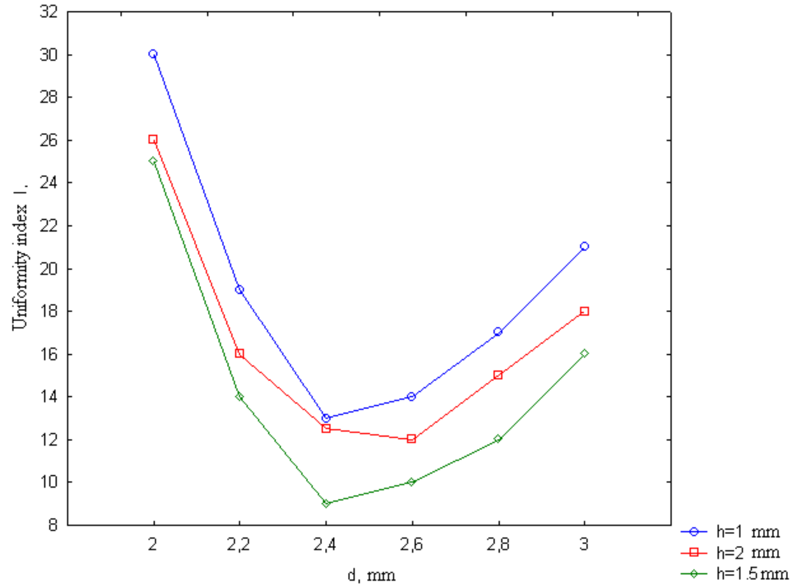



**Fig. 4 – Dependence of uniformity index $I$ on hole diameter *d* of gas distribution grid at different values of holes pitch *h***

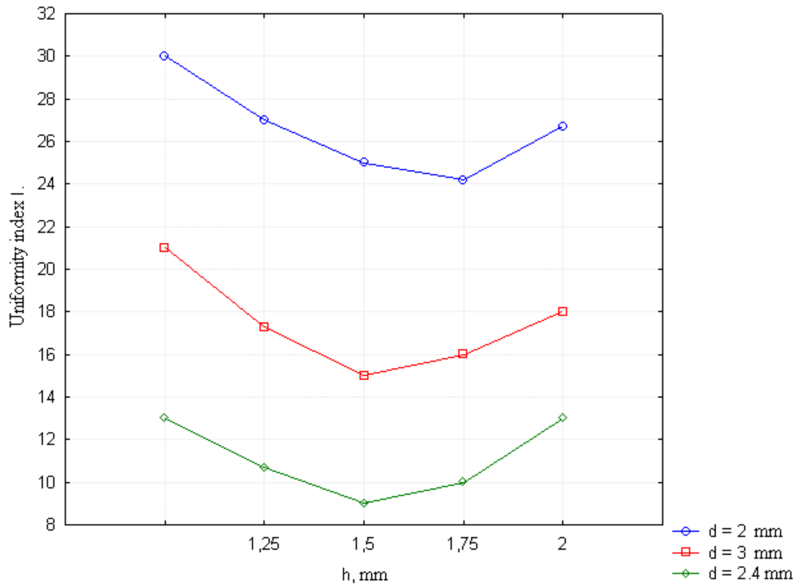



**Fig. 5 – Dependence of uniformity index $I$ on hole pitch *h* gas distribution grid at different values of hole diameter *d***

Pseudofluidization characteristic also depends on the relation of grain layer height L to diameter D. Minimum relation q = L/D was admitted equal to 1, further decrease of this value is unreasonable due to economic reasons, because dryer capacity decreases significantly. Maximum value of height to grain layer diameter relation, which does not violate fluidization stability, was determined by test and was admitted L/D = 2. Characteristic curve analysis of uniformity index $I$ from relation L/D value (figure 6) at different gas distribution grid hole diameters *d* indicates that the process of grain material fluidization at the value of relation L/D = 2 is stable.

Further increase of L/D value results in transition from fluidized state to piston flow and grain material emission from drying chamber, h.e. at L/D > 2, grain drying is impossible.

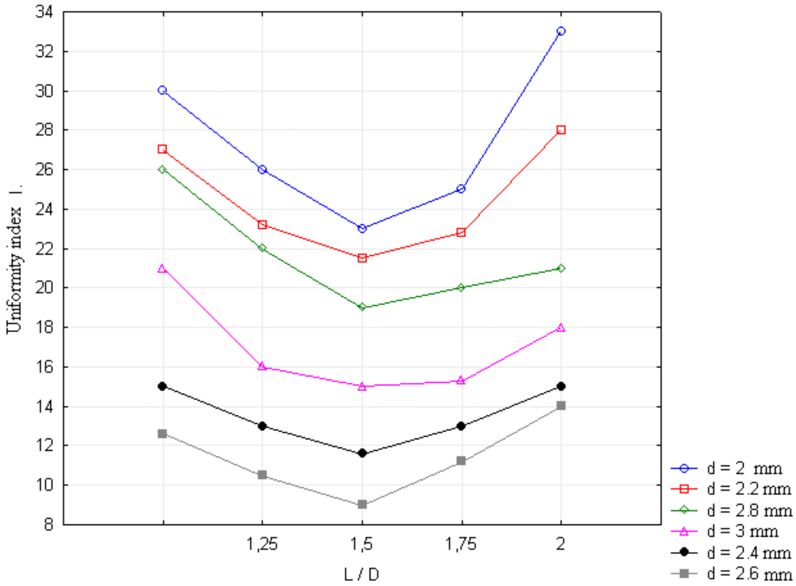



**Fig. 6 – Dependence of uniformity index $I$ on L/D relation value**

The most qualitative fluidization at minimum uniformity index was observed at L/D =1.5.

Thus, while designing experimental dryer it is necessary to limit the relation range L/D from 1 to 2.

To provide the interaction and effect estimation of experimental dryer constructive and operation parameters with pseudofluidized grain layer on fluidization uniformity index, a full factorial experiment was carried out and the regression equation of the following type was obtained:

$$I = 432{,}741 - 240{,}586d - 35.178h + 57.468dq - 200.766q + 39.252d^2 + 72.912q^2 + 11.1h^2 - 21.552dq^2 \quad (3)$$

After substitution of the corresponding values of the main factors, factorial change dependence of fluidization uniformity index *I* by grain dryer is drawn diagrammatically (figure 7).

It is obviously seen from diagramming analysis of the obtained results that grain material most qualitative fluidization can be obtained at gas distributive device holes diameter d = 2.5 mm and holes pitch h = 1,5 mm. Optimal value of grain layer height-diameter ratio can be accepted as *L/D* = 1.5.

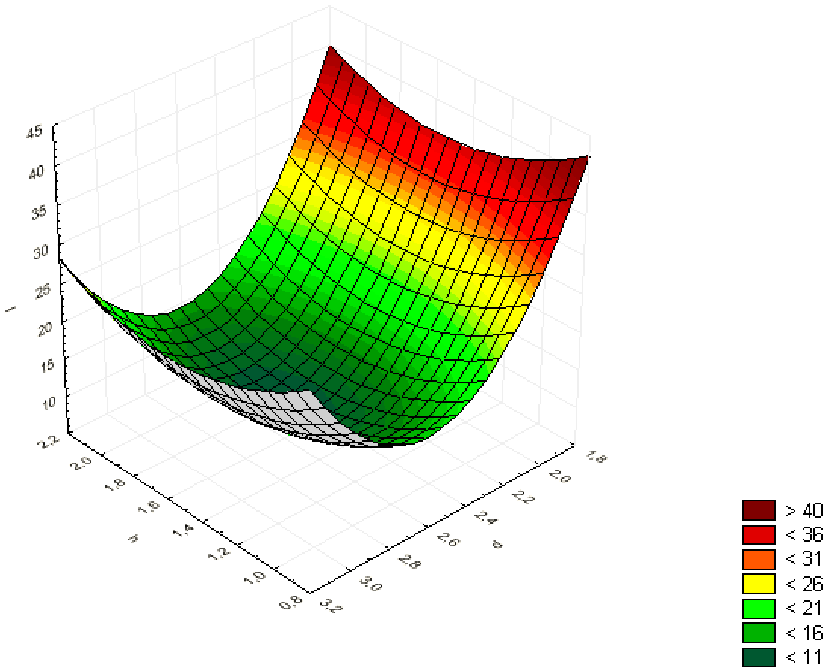



**Fig. 7 – Factorial dependence of pseudofluidization uniformity index by experimental dryer**

## CONCLUSIONS

1. The optimal parameters of gas distribution device of dryers are determined: diameter and holes pitch of the grid, ratio of grain layer height to drying chamber diameter.

2. At the sake of the specified parameters the best distribution of air flow in pseudofluidized grain layer is performed, its uniformity is increased, the active surface values of heat exchange between separate grain and dryer agent are increased, drying enhancement and more uniform heat penetration of grain are carried out.

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