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ARGUMENTATION OF THE OPERATING REGIMES AND OF THE CONSTRUCTIVE-TECHNOLOGICAL PARAMETERS OF THE AUTOMATED ECOLOGICAL INSTALLATION WITH NATURAL AND ARTIFICIAL COLD FOR MILK COOLING

255.01 – TECHNOLOGIES AND TECHNICAL MEANS FOR AGRICULTURE AND RURAL DEVELOPMENT

SUMMARY OF THE DOCTORAL THESIS IN TECHNICAL SCIENCES

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The defense of the thesis will take place on 15.01.2021 at 13.00 in the meeting of the Doctoral Commission within the Doctoral School of the Partnership of Agricultural Education and Research Institutions of the State Agrarian University of Moldova at: nr. 56, Mircești str., MD-2049, Chisinau, Faculty of Agricultural Engineering and Auto Transport, 3rd floor, room 318.
The doctoral thesis and the abstract can be consulted at the Republican Scientific Library of the State Agrarian University of Moldova and on the website of ANACEC of the Republic of Moldova (www.anacip.md).

The abstract was sent on 10 December 2020.

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CONCEPTUAL GUIDELINES OF THE RESEARCH

The topical issue and importance of the problem addressed. Refrigeration systems with artificial cold for milk cooling at the current stage are not environmentally suitable, as they use different types of freon, with a high installed electrical power and relatively high specific electricity consumption.

It is known that in the technique of food preservation, even a small reduction in electricity consumption to the consumer is extremely important. For example, it is known from the literature that saving 1 kWh of cold to the consumer allows to save 9 kWh at the power plant with the efficiency η = 0,45, using a power supply line with η = 0,9 and a refrigeration system with η = 0,32. Installations with natural and artificial refrigeration have several advantages compared to refrigeration installations with artificial cold, namely:

- are more environmentally friendly, because they exclude the use of freon as a refrigerant during the cold period of the year, thus corresponding to the Vienna Convention and the Montreal and Kyoto Protocols, which impose some ecological measures in the field of food preservation by replacing refrigeration agents that destroy the ozone layer in the atmosphere;
- electric power of about 1,6 – 1,7 times lower and a reduced electricity consumption in the limits from (78,1 ... 104,1) kW h / t to (14,0 ... 17,0) kW h / t.
- simple construction;
- higher level of reliability.

Studies in the field allow to state that the issue of improving the performance of installations with natural and artificial cold for milk cooling is intensely addressed both in the works of scientists from abroad and researchers from the Republic of Moldova. In this sense, we can mention the works of local researchers L. Volconovici, M. Cernei, V. Cretu, A. Volconovici, as well as of foreign researchers B. Horbaniuc, Gh. Dumitrascu, A. Musin, Iu. You, A. Ucevatchin and others. In the works of the nominated authors, solutions are proposed for the use of natural and artificial cold in the process of milk cooling and storing fruits and vegetables at the system level, especially in the Republic of Moldova, with limited primary energy reserves.

Therefore, the issue of increasing the performance of the installation with natural and artificial cold for cooling milk is not only relevant, but also necessary, especially for the Republic of Moldova.

The purpose of the paper.

The aim of the paper is to display the argument of the operating regimes and the constructive-technological parameters of the automated ecological installation with natural and artificial cold for cooling of milk.

Research objectives.

To achieve the purpose of the paper, research objectives to improve technical, energetic and economic indices include:

- reduction of the electrical power of the combined refrigeration system by using natural and artificial cold;
- the significant reduction in the specific consumption of electricity required for cooling milk;
- reducing the use of different types of freons and freon oils.

In terms of application, the following objectives were expected to be achieved:

- studying the use of natural and artificial cold in the cooling process of milk;
- analysis of operating regimes and argumentation of constructive and technological parameters of installations with natural and artificial cold for cooling milk;

- identification of the duration and efficiency of use of installations with natural cold with seasonal action on the territory of the Republic of Moldova;

- elaboration of the mathematical model of the installation with natural and artificial cold for cooling the milk;

- elaboration of functional-structural schemes, automatic graphs and algorithms for the operation of the automated refrigeration installation with low electricity consumption for cooling milk in flow coolers and capacitive coolers;

- evaluation of the resources for reducing electricity when using natural and artificial cold to cool milk;

- evaluation of the effectiveness of the use of installations with natural and artificial cold for cooling milk, taking into account the failure of electrical equipment;

- elaboration of the necessary experimental samples and carrying out laboratory and production experiments with the evaluation of the technical, energetic and economic indices at the Didactic-Experimental Complex of SAUM.

Research hypothesis: increasing the efficiency of using the cold accumulator to cool milk in the cold period of the year, as well as the cold accumulator and the refrigeration system in the hot period of the year, which allows to ensure the necessary amount of cold in the accumulator outside the peak hours. The use of the cold accumulator, also during the hot period of the year, when cooling the accumulator water from the refrigeration system creates favorable possibilities for reducing the electrical power of the refrigeration system as well as for reducing the specific electricity consumption compared to using only the refrigeration system, and in the cold period of the year the use of the battery with cold to cool the milk creates possibilities for the essential reduction of the specific consumption of electricity and allows not to use different types of freons.

According to the hypothesis accepted in the thesis, the mathematical model of the installation with natural and artificial cold used in the milk cooling process was elaborated, based on which the constructive and technological parameters of the respective installation can be proved, as well as the battery life. with natural cold during the cold period of the year.

Synthesis of research methodology.

The research methodology in the thesis consists in determining the energy efficiency of the refrigeration installation for the technological substantiation of the automated ecological equipment with natural and artificial cold for milk cooling. The problem of cold accumulation is conditioned by the need of saving energy resources. The main reasons for the topicality of this problem are the relatively high costs of generating cold, as well as the significantly cheaper tariff for electricity at night.

The constant increase in the price of electricity and refrigeration leads to an increase in the cost price of milk and dairy products, respectively. In connection with these reports, increasing the efficiency of refrigeration equipment and developing technologies to produce freon-free refrigeration is of great state importance, as it will significantly reduce electricity consumption and ensure environmental safety by reducing the harmful action of freons on the ozone layer. Methodologically, when creating the main schemes of the installation, the benefits of the combined refrigerating machines equipped with batteries with natural cold were taken into account, as follows:

- compact construction of the compressor-condenser block and the minimum need of freons;
- high cold storage power and low compressor inclusion frequency;
- the possibility of interaction with natural cold receivers;

- reduction of the established capacity and cost of artificial cold sources.

The use of combined refrigeration systems, equipped with accumulators with natural cold increases the reliability of cooling systems and ecological safety, allows re-equipping households with combined refrigeration systems, created on a modern construction basis, which will: reduce capital and operating costs to cool milk by reducing the established capacity of compressors, evaporators, auxiliary equipment; reducing the cost and consumption of energy for cold production by using the preferential night tariff, a lower condensing temperature of the refrigerant, including at night, the use of natural cold, outdoor air and groundwater to cool the refrigerant; increasing the reliability of the cooling system due to the existence of the operative cold reserve.

The recommendations for optimizing the dairy farm are presented through the mathematical model developed.

The scientific novelty and originality consists in: improving the operating regime of the installations with natural cold with seasonal action in the lines with flow cooling; determining the optimal values of the size of the refrigeration installation with natural and artificial cold for cooling milk based on the mathematical model developed and, in correlation with the law of atmospheric air temperature distribution for the area in the center of the Republic of Moldova; identification of technological resources to reduce electricity by using natural and artificial cold to cool milk; evaluation of the performance of installations with natural and artificial cold for cooling milk according to equipment failures.

Summary of thesis chapters.

The first chapter of the thesis presents an introductory study in researching the problem of using natural and artificial cold in the cooling process of milk with the mention of researchers who have significant results in developing combined plants with natural and artificial cold for cooling milk. The block diagram of the "Tandem" and "Elocica" type technological lines are the reference points in performing the comparative analysis of the use of natural and artificial cold in technological practice. The economic efficiency by saving electricity is the basis for highlighting the research methods chosen in the paper and conceptually justifies the mathematical model used to define the automatic graphs of the refrigeration system.

Chapter two has as object of study the improvement of the working regimes and the substantiation of the constructive and technological parameters of the natural refrigeration installation with seasonal action for milk cooling. Technical schemes are elaborated and presented, which are subsequently made in functional machines with the calculation of the constructive and functional parameters of the battery with natural cold. The optimal values of the size of the refrigeration installation with natural and artificial cold for cooling milk are defined based on the mathematical model developed and in correlation with the law of atmospheric air temperature distribution for the central area of the Republic of Moldova. Displaying the number of sections in the battery with natural cold is a useful result in the practical realization of the machine.

Chapter three represents the result of the elaboration of the automated installation with natural and artificial cold based on the use of automatic graphs. The chapter presents the values of the parameters of the functional equipment for cooling milk with the evaluation of the economic effect of saving electricity through the nomogram for determining the electrical power of the refrigeration system in accordance with the proposed mathematical model. There are presented the results of the calculation of the risks of production losses depending on the average annual milk productivity of farms and the use of different types of refrigeration systems, as well as automated installations with natural and artificial cold.

Implementation of scientific results. The research results were implemented within the cross-border project MIS ETC 1549 "Promoting sustainable production and implementing good practices in cattle farms in the cross-border areas of Romania, the Republic of Moldova and Ukraine". The theoretical component of the research is implemented in the project 20.80009.5107.04 "Adaptation of sustainable and ecological technologies for food production and storage in terms of quantity and quality depending on the integrity of the crop system and climate change" for 2020-2023. The theoretical approach of the research is used in the lecture courses "Renewable energy sources in the agricultural sector" and "Design of electrification systems in the agricultural sector" for students of years 3 and 4 of the Faculty of Agricultural Engineering and Auto Transport within SAUM.

Approval of scientific results. The main results of the research were presented, discussed and approved in the annual reports during the extended meeting of the department "Electrification of Agriculture and Basics of Design", Faculty of Agricultural Engineering and Auto Transport of SAUM, 2016-2019.

The materials presented in the thesis were presented at the following scientific events: Moldova International Energy Conference-2016 Regional Development Aspects Edition III. Chisinau, Republic of Moldova: ASM, September 29-October 1, 2016; International Scientific Symposium "Efficient use of hydro-land resources in current conditions - achievements and perspectives" dedicated to the 65th anniversary of the founding of the Faculty of Cadastre and Law, Chisinau 2016; Инновации в сельском хозяйстве, Theoretical and scientific-practical journal, Following the results of the 7th International Scientific and Technical Conference of Young Scientists and Specialists. Moscow (22) / 2017; International Scientific Symposium "Achievements and Perspectives in Agricultural Engineering and Auto Transport", dedicated to the 85th anniversary of the founding of the State Agrarian University of Moldova Chisinau 2018; Energy Saving Technologies. XI Republican Scientific and Practical Conference with International Participation November 20-21, 2019 К 75-летию со дня основания БПФ ГОУ «ПГУ T.G. Shevchenko, Bendery 2020; International scientific and technical conference "Doctrine of food security of Russia: refrigeration technologies as the basis for storing agricultural products" June 29, 2020. MGUTU named after K. G. Razumovsky, Moscow, Russia.The most relevant results of the thesis were presented in the national journals “Agricultural Science”, of SAUM (2016-2020), and “Journal of Engineering Science” of TUM (2020) and the international journal, EMERG - Energy. Environment. Efficiency. Resources. Globalization”, AGIR Publishing House, Romania (2020).

The research results for 2020 of the project "Adapting sustainable and ecological technologies for food production and storage in terms of quantity and quality according to the integrity of the crop system and climate change" were discussed and approved by the SAUM Senate at the meeting on 27.11. 2020.

The main results of the scientific research were published in the monograph “The use of cold for cooling milk and storing fruit and vegetable products”, SAUM.

Thesis publications. The results of the research on the doctoral thesis are reflected in 24 scientific papers, including a monograph, 7 articles in international journals, 16 articles in national journals

The volume and structure of the thesis. The thesis consists of 3 chapters; has a base volume of 117 pages; contains 15 tables, 47 figures. 6 annexes. The list of cited bibliographic sources includes 113 titles.

Key words: Natural and artificial cold installation, milk cooling, combined action installation, refrigeration installation, cold accumulator, SAUM didactic-experimental complex, structural - functional scheme, operating algorithm, automatic graphs, mathematical model, specific consumption of electricity.

THESIS CONTENT

The **Introduction** defines the topicality of the thesis, the purpose and objectives of the paper, the scientific novelty, the theoretical importance and the applicative value of the paper, the main results of the paper, the implementation of the results and their approval.

1. GENERAL NOTIONS ON THE USE OF NATURAL AND ARTIFICIAL COLD IN THE COOLING PROCESS OF MILK

In Chapter 1 of the thesis were investigated the basic concepts and the essence of using natural and artificial cold installations.

Chapter 1 includes:

- general characteristic and model of biotechnological monitoring of primary milk production and processing in the Didactic-Experimental Complex of SAUM, Fig. 1;
- study on refrigeration installations for milk cooling;
- study on the use of natural and artificial cold for milk cooling, Fig. 2 and Fig. 7.

Fig. 1 Didactic farm, SAUM

(a) **(b)**

Fig. 2 Combined refrigeration system for milk cooling with natural (a) and artificial cold(b)

The SAUM didactic farm was founded with the support of the Project financed by the European Union with the name "Promotion of Sustainable Production and Implementation of Good Practices in Cattle Farms in the Cross-Border Area - Romania, Moldova and Ukraine". Most of the quantity of milk is sold to the Dairy Products Enterprise ÎCS ”Lapmol” SRL, t. Calarasi, and part of it is used for raising calves and in laboratory lessons that are held in the laboratory to determine the quality of milk and dairy products.

The biotechnological monitoring allows optimizing equipment productivity, reducing the electricity costs, increasing the operating time and reducing the risk of emergencies.

Traditional systems applied for milk cooling consist of refrigeration systems with compressor and milk coolers [1].

Currently, the most commonly used are flow coolers. Their main advantages are high milk cooling efficiency and low operating costs.

By means of flow coolers, the milk is cooled to a temperature of + 6 °C. Ecological systems and installations for milk cooling are shown in Fig. 3.

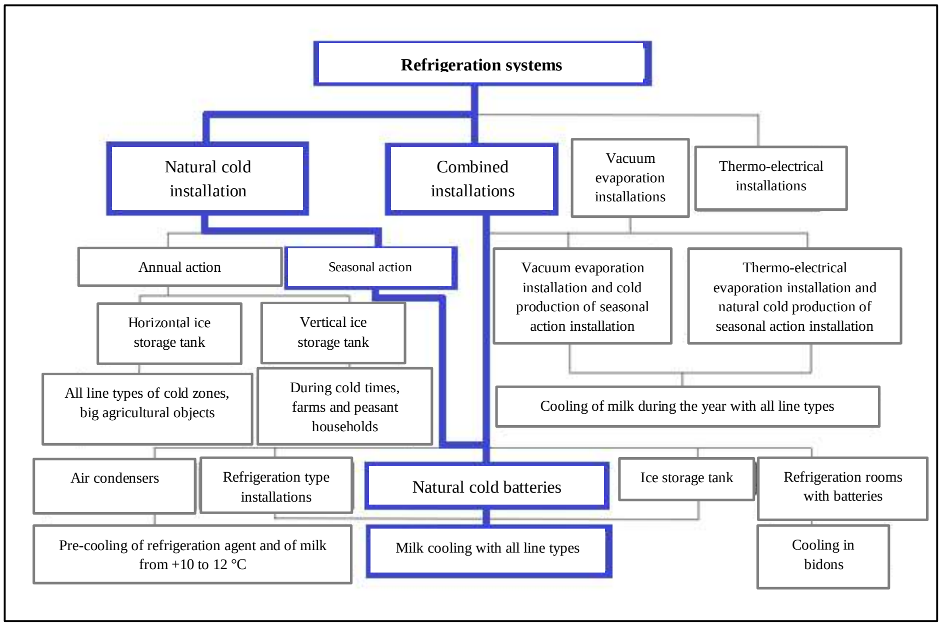


Fig. 3 Ecological systems and installations for milk cooling

The installation with natural cold (Fig. 2 a) is used to cool the milk at atmospheric air temperature t ≤ 4ºC. In the warm period of the year, for t ≥ 4 ºC the combined refrigeration system is used (Fig. 2 b).

A specific feature of all primary milk processing lines is the presence of the refrigeration system, which has the highest electrical power of all line components.

In all types of refrigeration systems, freons, which are environmentally harmful, serve as refrigerants. [2,3] In addition, refrigeration plants contain a lot of metal, mainly expensive metals - copper, aluminum.

Of all the types of refrigeration systems, only the ТХУ types create real possibilities for the heat regeneration of milk, which can be used for sanitary and technological needs of the farm.

Defects in the operation of refrigeration plants account for more than 80% of all defects in the primary milk processing line [3]. It was found that:

- the biggest annual technological damage in the primary milk processing lines is caused by the refrigeration installation and its control system, Fig. 4;

- in combined source lines, the use of water accumulators considerably reduces technological damage during the cold period of the year. Unlike the refrigeration system, the operating reliability of water accumulators is at least 2 times higher.

The main advantages of using water accumulators in common with refrigeration installations are:

- saving electricity and water;

- ensuring a high reliability of cooling systems as a result of the cold reserve accumulated in the batteries, maintenance and repair;

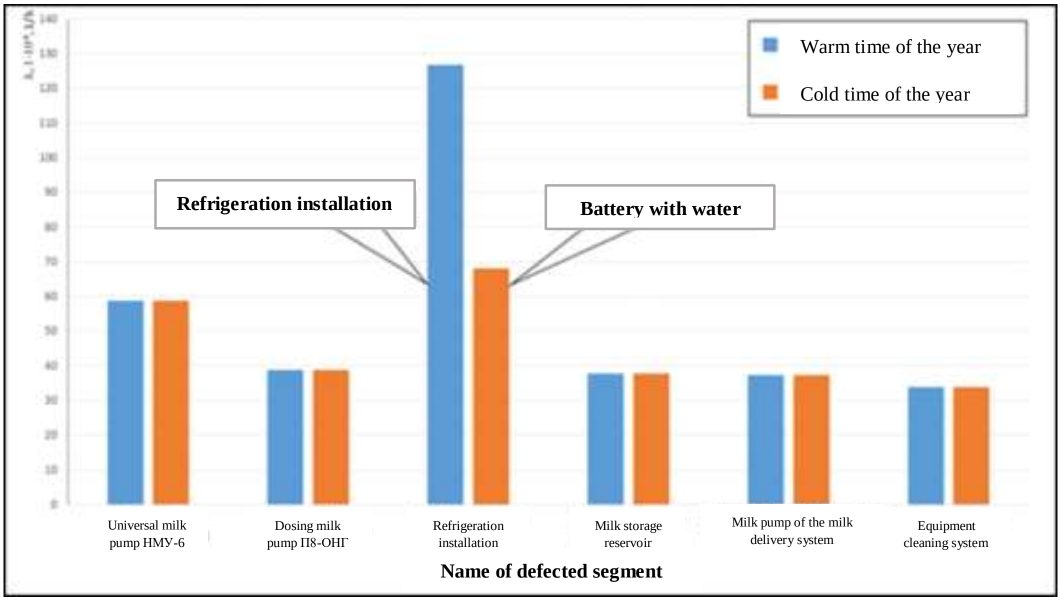


Fig. 4 Fault situations when the electrical equipment of the primary milk processing line fails

- the possibility to use the preferential tariff for electricity, applied at night. Thus, when using the cold accumulated between 22.00 - 6.00, the cost of electricity, according to ANRE, is reduced by 40%, [4] Fig. 5;
- the low-cost price of the cold used to cool the milk;
- improving the ecological situation based on the reduction of the volume of freons and freon oils used;
- low noise level.

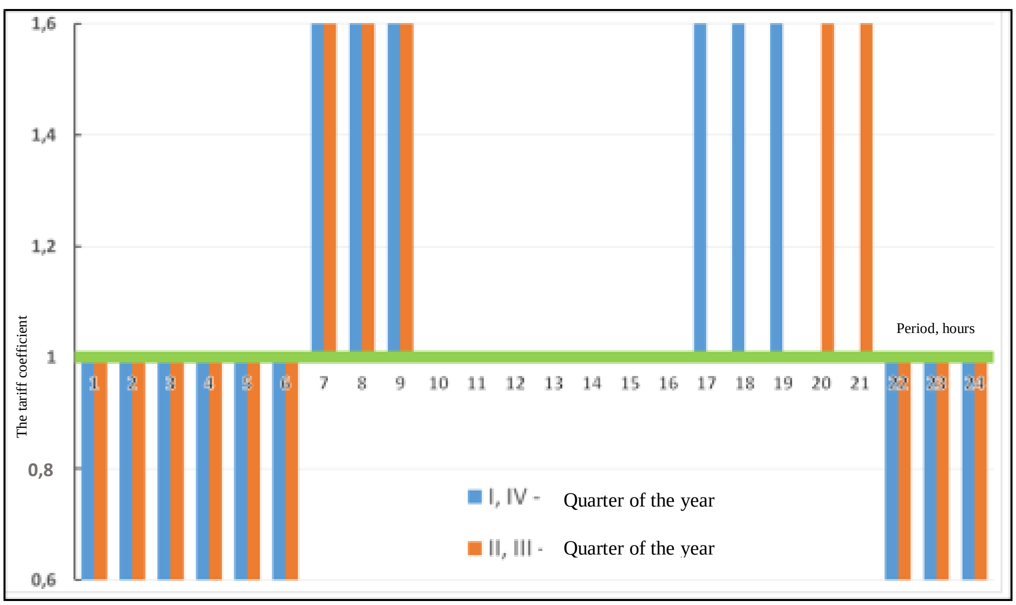


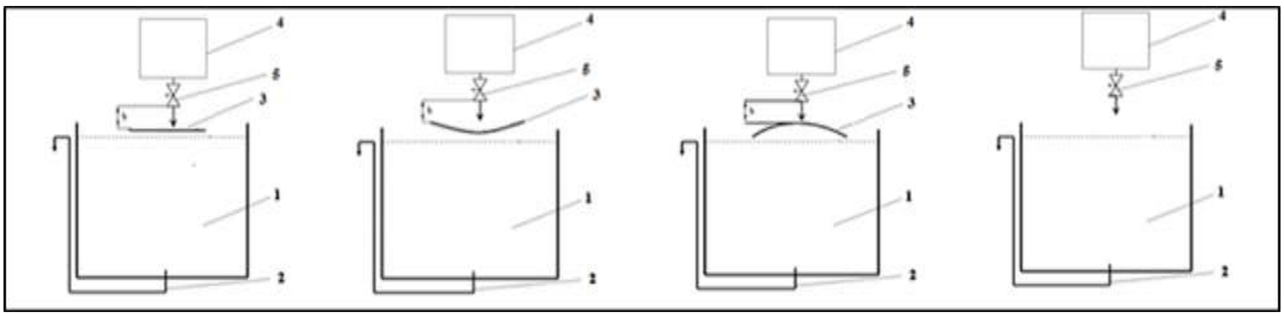
Fig. 5. Cost of Electricity According to Differentiated Rates depending on the Consumption Period

2. INCREASING THE PERFORMANCE OF INSTALLATIONS WITH NATURAL AND ARTIFICIAL COLD FOR MILK COOLING USED IN THE REPUBLIC OF MOLDOVA

Chapter 2 - includes:

- improving the operating regime of seasonal natural refrigeration installations in flow-cooled lines [5,6];
- study on the water-cooling regime in the accumulator with natural cold in the intervals between milking;
- determining the duration and efficiency of use of installations with natural cold with seasonal action on the territory of the Republic of Moldova;
- the mathematical model of the modernized installation with natural cold for cooling the milk with seasonal action;
- the identification of technological resources to reduce electricity by using natural and artificial cold to cool milk [7, 8, 9, 10];
- the evaluation of the performance of installations with natural and artificial cold for milk cooling according to equipment failures.

• It has been established that to ensure the water non-mixing regime it is more efficient to use the water tank with horizontal septum Fig.6. (a) In this case, K useful is within the limits of 0,9 ... 0,97 and the multiplicity coefficient of water and milk consumption is within the limits of 3,1 ... 3,3.



a) horizontal septum b) concave septum c) convex septum d) without septum

Fig. 6. The experimental model of the cold accumulator with septa of various shapes

The installation includes: 1 - water tank; 2 - water drain pipe; 3 - sept; 4 - water vessel; 5 –ventil; h - height of free fall of water.

- In lines with flow cooler, for two milking it is necessary to ensure the ratio between the horizontal surface - S of the battery and its volume - V, equal to or greater than 0,17. (Fig. 7).

Fig. 7. The battery with natural cold for cooling the milk used at the Didactic-Experimental Complex of SAUM

Experimentally, the water was cooled from 8 ºC to 4 ºC, for t = 11,1 hours (Fig. 8), so less than 12 hours expected.

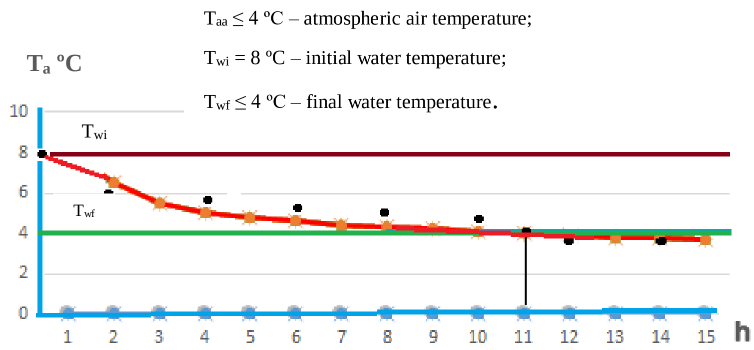


Fig. 8. Variation of water-cooling temperature in accumulator with natural cold in the intervals between milking F (T) = f (t))

• The change of the temperature of the environment – T depending on the time t is not a continuous process, but an alloying one, therefore, for its description, it is necessary to present the graph of the distribution of the factor T depending on the factor t [10, 11 12].

- The operation of the water accumulator in the atmospheric air temperature range from – 15 ºC to +5 ºC was analyzed, based on the law of atmospheric air temperature distribution F (t) and its approximation for the center of the Republic of Moldova, presented in Fig. 9.

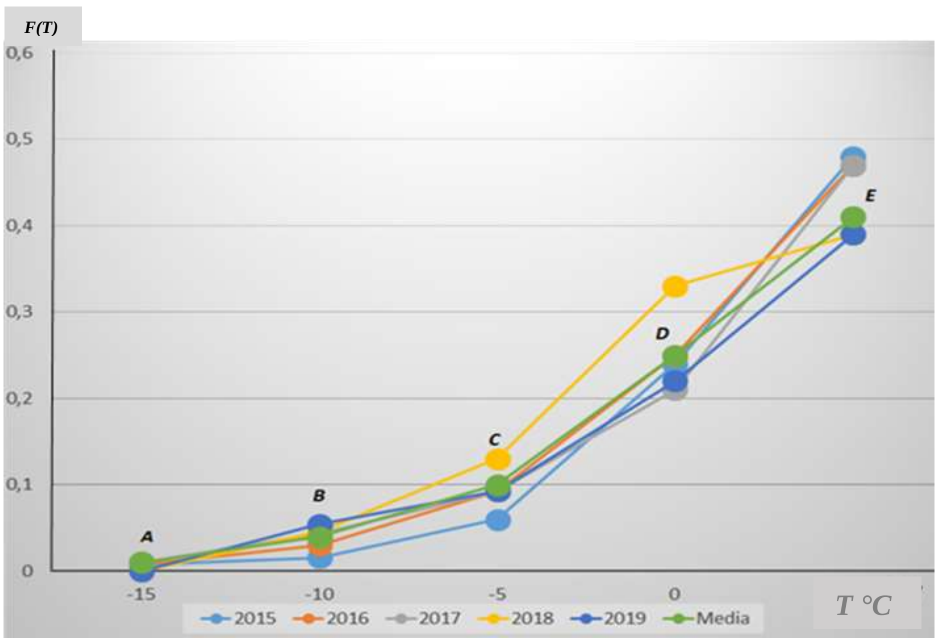


Fig. 9. Law on the Distribution of Atmospheric Temperature F(T) and Its Approximation

At T ≥ +5^{0}C the system is disconnected, because it is not possible to cool the milk to the required level - below 6 ^{0}C.

In this case, it was sufficient to examine the distribution of atmospheric air temperatures in the range indicated, Table 1.

Table 1 Number of days respectively with $t \le -15$ °C, $t \le -10$ °C, $t \le -5$ °C, $t \le 0$ °C, $t \le 5$ °C

Year	Number of days				
	$T \le -15\ ^0C$	$T \le -10\ ^0C$	$T \le -5\ ^0C$	$T \le 0\ ^0C$	$T \le 5\ ^0C$
2015	3J **3/0,008**	5J+1F **6/0,016**	7J+10F+5D **22/0,060**	29J+19F+10M+1A +1O+6N+22D **88/0,24**	31J+28F+31M+17 A+17O+20N+30D **174/0,48**
2016	3J **3/0,008**	11J+2D **13/0,03**	18J+1F+2N+12D **33/0,093**	27J+12F+8M+17N +28D **92/0,25**	31J+26F+28M+7A +23O+28N+29D **172/0,47**
2017	4J **4/0,1**	13J+3F **16/0,043**	20J+12F+0M+0A+0O +0N+1D **33/0,093**	31J+22F+4M+1A+ 0O+3N+17D **78/0,21**	31J+28F+29M+20 A+11O+24N+29D **172/0,47**
2018	1 1/**0,003**	6J+4F+4M +1N+2D **17/0,046**	14J+6F+13M+8N+8D **49/0,13**	24J+26F+20M+1A +3O+19N+28D **121/0,33**	31J+28F+24M+3A +6O+21N+31D **144/0,0,39**
2019	0 **0/0**	2J **2/0,005**	22J+4F+1M+2N+ 5D **34/0,09**	28J+16F+9M+1O+ 10N+18D **82/0,22**	31J+28F+24M+10 A+5O+15N+29D **142/0,39**

Note: I-January; F-February; M-March; A-April; O-October;
N-November; D-December.

A / B where A is the number of days corresponding to the air temperature (-15; -10; -5; 0; 5), and B - 365 days a year.

The monthly distribution of atmospheric air temperature t for the center of the Republic of Moldova was obtained based on the analysis of systematic meteorological data of the Meteorological Center of Chisinau for seven months (January, February, March, April, October, November and December) of 2015-2019. As a result of the analysis of the atmospheric air temperature distribution in these graphs, Fig.7 and Table 2, the number of days was determined:

- with $T \ge 5\ ^0C$, during the day;
- with $T < 5\ ^0C$, at night;
- with $T < 5\ ^0C$ during 24 h.

Table 2. Number of days with $t \ge 5^0C$, day, with $t < 5^0C$ at night and with $t < 5^0C$ for 24 hours,

Month	*Nº of days with $T \ge 5\ ^0C$*	*Nº of days,* with $T < 5\ ^0C$, at night	*Nº of days,* with $T < 5\ ^0C$ during 24 h
2015			
January	7	31	24
February	11	28	17
March	29	31	2
April	30	17	0
October	31	17	0
November	24	20	0
December	16	30	14
Total	148	174	**57**
2016			
January	8	31	23
February	23	26	3

March	27	28	1
April	30	7	0
October	31	23	0
November	7	28	21
December	10	29	19
Total	136	172	67
2017			
January	2	31	29
February	7	28	21
March	31	29	0
April	30	20	0
October	31	23	0
November	4	28	24
December	10	29	19
Total	125	**188**	83
2018			
January	11	31	20
February	5	28	23
March	17	24	7
April	30	3	0
October	31	6	0
November	12	21	9
December	4	31	27
Total	110	144	**86**
2019			
January	3	31	27
February	11	28	17
March	3	24	21
April	30	10	0
October	31	5	0
November	22	15	0
December	23	29	6
Total	123	**142**	71

Table 2 shows that the natural cold installation with seasonal action can be used from:

- 57 to 174 days for 2015;
- 67 to 172 days for 2016;
- 83 to 188 days for 2017;
- 86 to 144 days for 2018;
- 71 to 142 days for 2019.

A substantial contribution (from 142 days to 188 days) brings the use of the installation with natural cold with seasonal action at night. During the day, this potential is much lower (from 57 days to 86 days).

• Based on the improvement of the operating regime of IFN with seasonal action in the lines with flow and capacitive coolers, the study of the water cooling regime in the intervals between milking, the substantiation of the constructive parameters of the machine, the identification of ways to increase the service life, the determination the mathematical model for evaluating the performance with seasonal action was elaborated for the duration of their use on the territory of the Republic of Moldova [13].

The mathematical model of the natural cold installation includes the following functional relations:
– in milk cooling regimes:
$V_a = f(V_l)$ - for vertical and horizontal septa,
where:
V_a - the volume of water in the installation with natural cold (accumulator), m^3;
V_l - volume of milk, m^3;
– in water cooling regimes:
$S_{ev} = f(V_a)$ - for the water-cooling regime in the interval between milks,
where:
S_{ev} - surface of water evaporation in the accumulator, m^2;
– duration of use of the IFN natural cold installation during the cold period of the year for the central area of the Republic of Moldova: $\tau = f(T)$
where: τ - duration of use of the installation with natural cold, days;
T - atmospheric air temperature, *T ºC*.
In milk cooling lines with flow cooler:
a) for vertical partitions:

$$V_a / V_l = 3{,}6 \quad (1)$$

where: $K_{util} = 0{,}83$- utilization coefficient and n = 5- number of septa;

$$V_a / V_l = 3{,}33 \quad (2)$$

where: $K_{util} = 0{,}9$ and n = 9
b) for horizontal partitions:

$$V_a/V_l=3{,}1...\ 3{,}3 \quad (3)$$

where: $K_{util}=0{,}9...\ 0{,}97$ and n=1
Water cooling regime in the interval between milking:

$$S_{ev}/V \geq 0{,}17 \text{ for two milking} \quad (4)$$

where:
S_{ev} – surface of water evaporation in the accumulator, m^2
V – the volume of water in the battery, m^3
Duration of use of the IFN natural cold installation for the center of the Republic of Moldova:

$$F(T)=0{,}1+0{,}006T;\ for\ -15 \leq T\ ^{\circ}C \leq -10 \quad (5)$$

$$F(T)=0{,}16+0{,}012T;\ for\ -10 < T\ ^{\circ}C \leq -5 \quad (6)$$

$$F(T)=0{,}25+0{,}03T;\ for\ -5 < T\ ^{\circ}C \leq 0 \quad (7)$$

$$F(T)=0{,}25+0{,}032T;\ for\ 0 < T\ ^{\circ}C \leq 5 \quad (8)$$

where:
F(T) – function (law) of atmospheric air temperature distribution;
T ˚C – atmospheric air temperature.

The number of days for $T \leq 4\ ^0C$ the duration of use of the installation with natural cold is $\tau = 149$ days.

The optimal constructive parameters after the minimum consumption of materials are:
I. for a parallelepiped-shaped accumulator-cooler:
a) for the partial realization of the non-mixing regime of the water in the accumulator with vertical septa, when $K_{util} = 0{,}83$ and n = 5

$$\begin{cases} h_{opt} = \sqrt[3]{0{,}3 \cdot V} \\ S_{opt} = \sqrt[3]{5{,}81 \cdot V^2} \end{cases} \quad (9)$$

b) for the partial realization of the non-mixing regime of the water in the accumulator with vertical septa, К $_{util}$=0,9 and n=9

$$\begin{cases} h_{opt} = \sqrt[3]{0,28 \cdot V} \\ S_{opt} = \sqrt[3]{4,94 \cdot V^2} \end{cases} \quad (10)$$

c) for the partial realization of the non-mixing regime of the water in the accumulator with the horizontal septum, К $_{util}$= 0,97 and n=1

$$\begin{cases} h_{opt} = \sqrt[3]{0,258 \cdot V} \\ S_{opt} = \sqrt[3]{4,25 \cdot V^2} \end{cases} \quad (11)$$

II. for the cylinder-shaped accumulator-cooler:

a) for the partial realization of the non-mixing regime of the water in the accumulator for vertical septa, when К util =0,83 and n = 5

$$\begin{cases} h_{opt} = \sqrt[3]{0,38 \cdot V} \\ S_{opt} = \sqrt[3]{7,37 \cdot V^2} \end{cases} \quad (12)$$

b) for the partial realization of the non-mixing regime of the water in the accumulator for vertical septa, $К_{util}$=0,9 and n=9

$$\begin{cases} h_{opt} = \sqrt[3]{0,35 \cdot V} \\ S_{opt} = \sqrt[3]{6,27 \cdot V^2} \end{cases} \quad (13)$$

c) for the partial realization of the non-mixing regime of the water in the accumulator with horizontal septel,

$К_{util}$= 0,97 and n=1

$$\begin{cases} h_{opt} = \sqrt[3]{0,32 \cdot V} \\ S_{opt} = \sqrt[3]{5,39 \cdot V^2} \end{cases} \quad (14)$$

Dependence of the specific electricity consumption for cooling the milk on the number of cold days in the year n with the cooling time of the water in the cold storage of 6 and 8 hours respectively [14]:

a) for 6 hours, respectively:

$$Wsp = \frac{0,14}{n} \quad \text{for 100 t of milk} \quad (15)$$

$$Wsp = \frac{0,07}{n} \quad \text{for 200 t of milk} \quad (16)$$

$$Wsp = \frac{0,06}{n} \quad \text{for 300 t of milk} \quad (17)$$

$$Wsp = \frac{0,05}{n} \quad \text{for 400 t of milk} \quad (18)$$

$$Wsp = \frac{0,04}{n} \quad \text{for 500 t of milk} \quad (19)$$

b) for 8 hours, respectively:

$$Wsp = \frac{0,18}{n} \quad \text{for 100 t of milk} \quad (20)$$

$$Wsp = \frac{0,09}{n} \quad \text{for 200 t of milk} \tag{21}$$

$$Wsp = \frac{0,08}{n} \quad \text{for 300 t of milk} \tag{22}$$

$$Wsp = \frac{0,05}{n} \quad \text{for 400 t of milk} \tag{23}$$

$$Wsp = \frac{0,05}{n} \quad \text{for 500 t of milk} \tag{24}$$

- It was found that the specific consumption of electricity when cooling the milk varies within the limits:

from 78,1 kW h / t (without the application of natural cold to an annual milk production of 100 t) to 14,0 kW h / t (with the application of natural cold to an annual milk production of 500 t) with a duration for cooling the water in the accumulator with a 6-hour cold (Ist situation), Fig.10;

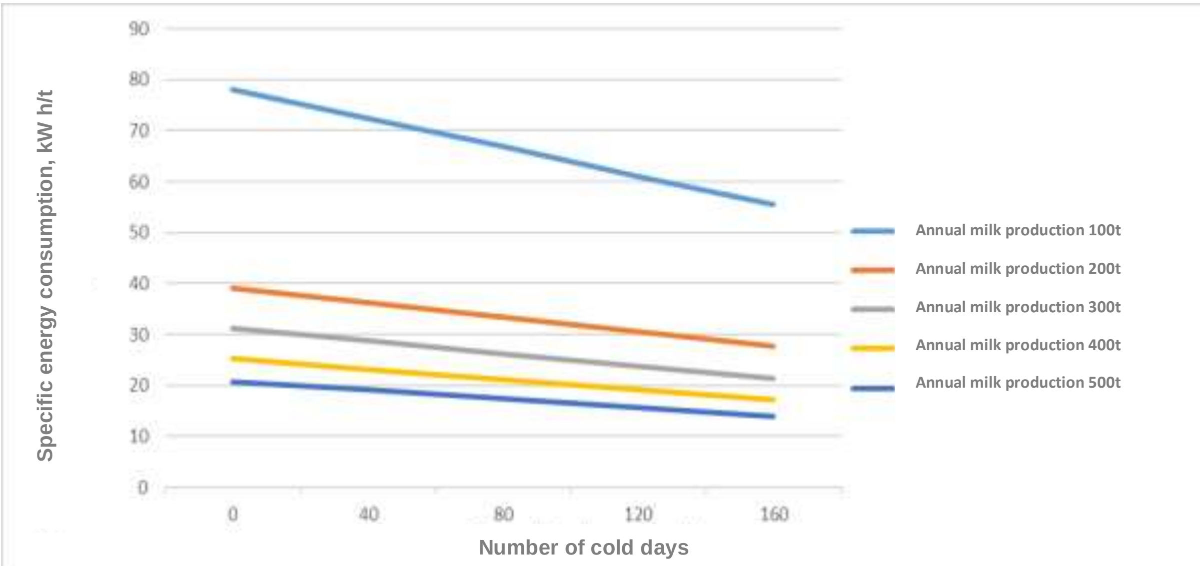


Fig. 10. The dependence of specific electricity consumption for the milk cooling on the number of cold days in the year (duration of cooling water from the cold accumulator, being 6 hours)

- from 104,1 kW h / t to 17,0 kW h / t with the cooling time of the water from the cold accumulator of 8 hours (2nd situation), Fig. 11

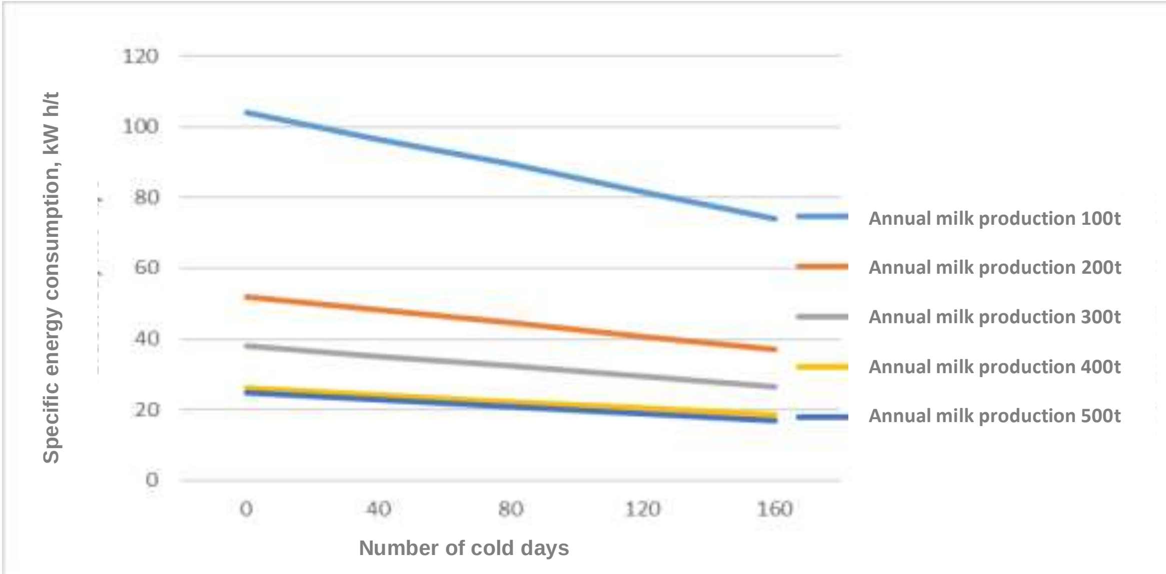
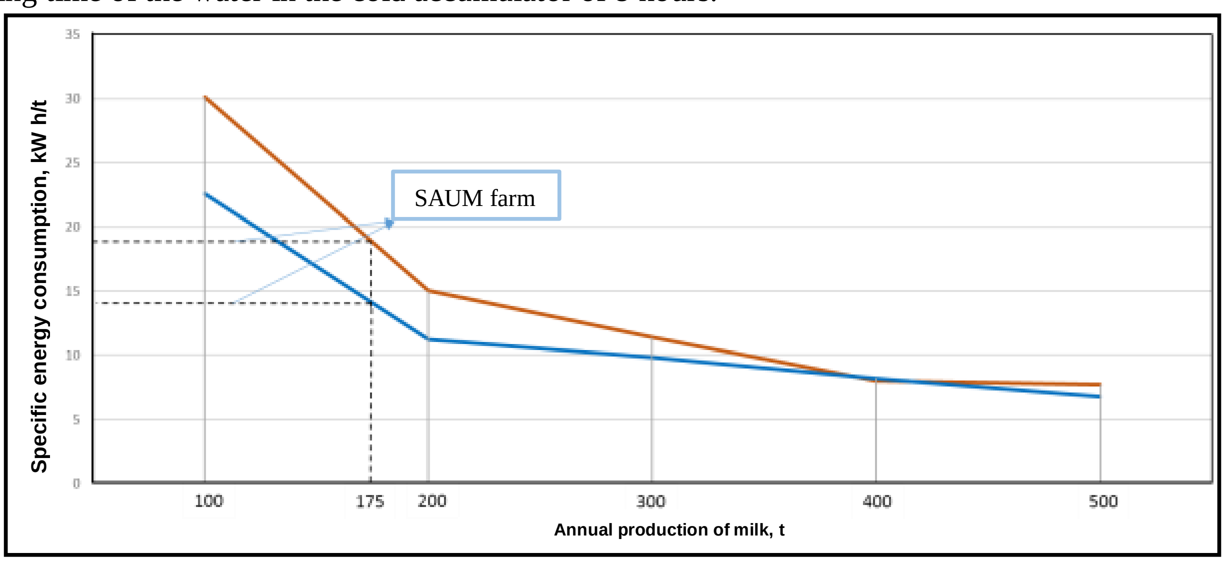


Fig. 11. The dependence of specific electricity consumption for cooling the milk on the number of cold days in the year (cooling time of water in the cold accumulator being 8 hours)

As a result of the calculation of the optimization of the parameters of the technological process of milk cooling, it results that the greatest reduction of electricity is obtained from the application of natural cold at an annual milk productivity of less than 300 t (Fig. 12) [15].

For example, at an annual milk production of 100 t, the saving of electricity will be 22,6 kW h / t, the cooling time of the water in the cold accumulator being 6 hours, and 30,1 kW h / t, cooling time of the water from the cold accumulator being 8 hours. At an annual milk production of 400-500 t. Cooling time of the water in the cold accumulator, practically, does not influence the reduction of energy consumption for cooling the milk, it being 0,7-0,9 kW h / t.

For the SAUM cattle farm, with an annual milk production of 175 t, the electricity saving will be 14 kW h / t, at a cooling time of the water from the cold accumulator of 6 hours, and 18,5 kW h / t at a cooling time of the water in the cold accumulator of 8 hours.



Ist situation (water-cooling time from the battery 6 hours);

IInd situation (water-cooling time from the battery 8 hours);

Fig. 10 The dependence on the difference in specific energy consumption for cooling milk (with and without the application of natural cold) on annual milk productivity.

It has been determined that at the average annual milk productivity between 6000 kg - 7000 kg,

- the risk of profit loss is measurable with operating expenses and can make up of 11% to 44% of operating expenses, Table 3;
- loss risk record changes the distribution of places of preference, Table 4;
- the volume of annual milk productivity influences the distribution of preferential seats, Table 4;
- in all the conditions examined, we have no option where the lowest amount of operating expenses corresponds to the lowest risk value for profit losses, Table 4.

Table 3. The risk of profit loss at an average annual milk production of 6000 kg and 7000 kg

№	Loss of profit for average annual milk production 6000 kg, %	Loss of profit for average annual milk production 7000 kg, %
1	34	44
2	29	27
3	17	16
4	37	27
5	14	12
6	11	13

Table 4. The average annual milk production 7000 kg/7,0 t

№ of the situation	Equipment	Operating expenses (lei)	Place	Risk of loss of profit	Cost (lei)	Place
1	2	3	4	5	6	7
1	Thermos reservoir РИМ-2,2 Thermo-refrigeration plant ТХУ-16 Seasonal installation (cold battery)	99729	3	43560	143289	4
2	Thermos reservoir РПО 2-01 "ПАКО" Thermos reservoir РПО-2,5 Thermo-refrigeration plant ТХУ- 14 Seasonal installation (cold battery)	118801	6	31680	150481	6
3	Thermos reservoir РПО-2- 01 Thermos reservoir В1-ОМВ- 2Б Thermo-refrigeration plant ТХУ-14 Seasonal installation (cold battery)	89702	1	16830	106532	2
4	Thermos reservoir МКА-2000Л-2Б Thermos reservoir РПО-2,5 Thermo-refrigeration plant ТХУ 14 Seasonal installation (cold battery)	117128	5	31284	148412	5
5	Thermos reservoir МКА-2000-2Б Thermos reservoir В1-ОМВ-2Б Seasonal installation (cold battery)	106052	4	16830	122882	3
6	Thermos reservoir NEREHTA – 1000 l Seasonal installation (cold battery) at the didactic-experimental complex of SAUM	92700	2	11220	103920	1

3. STUDY OF THE COMBINED MODERNIZED INSTALLATIONS FOR MILK COOLING WITH NATURAL AND ARTIFICIAL COLD AS A CONTROL OBJECT

Chapter 3 of the thesis outlines the conceptual approach to the structural-functional scheme of automatic graphs and the operating algorithms of the low-energy refrigeration plant for milk cooling [16,17].
Chapter 3 includes:

- contributions to the development of the structural-functional scheme of automatic graphs and algorithms for the operation of the refrigeration plant for the milk cooling of low-energy;
- structural-functional scheme, automatic graphs and algorithms for the operation of the natural and artificial receiver-cold battery for milk cooling in the flux cooler;
- structural and functional scheme, automatic graphs and operating algorithms of the natural and artificial cold installation for milk cooling in capacitive cooler;
- automated low-electricity technology lines used in primary milk processing;
- assessment of the operating and technological indices of natural and artificial cold installations;
- contributions to the development of mathematical models of automated primary milk processing technology lines.

• In the Republic of Moldova, the most efficient are the natural and artificial cold installations (combined action). The functional-structural scheme of the natural and artificial cold plant for cooling milk in a flux cooler or capacitive cooler is shown in Figure 11 [18,19].

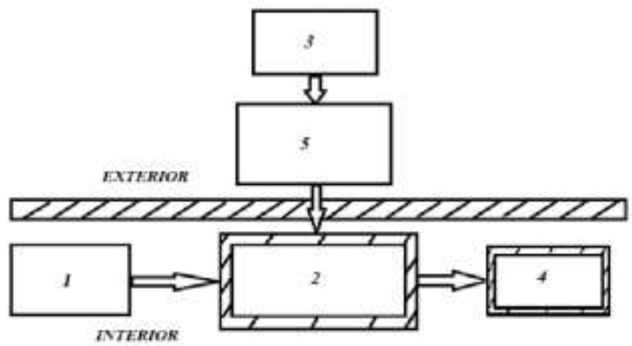


Fig. 11 Structural and functional scheme of refrigeration plant and water battery for milk cooling in flow cooler or capacitive cooler using natural and artificial cold

1 – refrigeration plant; 2 – cold battery with thermal insulation installed inside the farm; 3 – sprayer; 4 – flow cooler or capacitive cooler for milk cooling; 5 - cold battery installed outside the farm.

The control parameters of the milk cooling process in the flow-through cooler by using natural and artificial cooling are:

- water temperature in the accumulator installed outside the farm;
- water temperature in the insulated accumulator installed inside the farm;
- atmospheric air temperature;
- temperature of cooled milk.

Subsequently, automatic graphs and algorithms for the operation of the refrigeration plant were developed using natural and artificial cold [21].

As an example, Figure 12 shows the automatic graph of the refrigeration plant.

The automatic graph of the M_{19} refrigeration installation in the milk cooling mode is presented in Fig.4

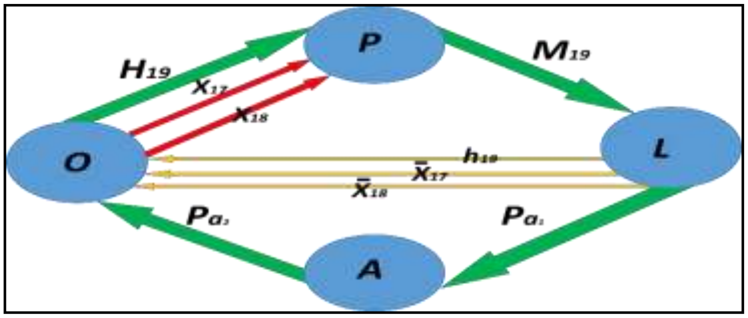


Figure 4. Automatic graph of the M_{19} refrigeration installation,

where: O; P; IT; A – operating conditions of the M_{19} refrigeration installation, stop, start, operation, and fault, respectively

M_{19} - refrigeration installation (compressor 1);

H_{19} and h_{19} - start and stop command, respectively;

H_{19} - lack of stop signal;

$\bar{h}_{19}$ - lack of signal from the stop button;

x_{17} and x_{18} - presence of signals from the transducers 17 and 18;

$\bar{x}_{17}$ and $\bar{x}_{18}$ - lack of signals from the transducers 17 and 18;

$\bar{h}_{19}$ - lack of signal from the stop button;

Pa_1 and Pa_2 - presence of fault signals;

$\overline{P}a_1$ and $\overline{P}a_2$ - lack of fault signals.

The operating algorithm of the refrigeration installation developed based on the automatic graph presented in Fig. 4 has the form:

$$Y_{19} = (x_{17} \cdot x_{18} + H_{19}) \cdot \overline{h_{19}} \cdot \overline{Pa_1} \cdot \overline{Pa_2} \cdot M_{19} \qquad (25)$$

It has been established that, actually, the atmospheric air temperatures (recorded at the Didactical-Experimental Complex of SAUM) are 1-2 ºC lower than atmospheric air temperatures recorded at the State Hydrometeorological Service, Figure 13. This relatively small difference in atmospheric air temperatures contributes to increasing the battery life with cold in the autumn/spring period. The duration of use of the cold battery is increased, in autumn – by 5 days, and in spring – by 9 days, in total by 14 days. Even in October and April, in the center of the Republic of Moldova, the plant for milk cooling with natural cold can be used because the cooling time of the water is several hours, for example. from 4 to 13 hours, for $T \leq 4$ ºC.

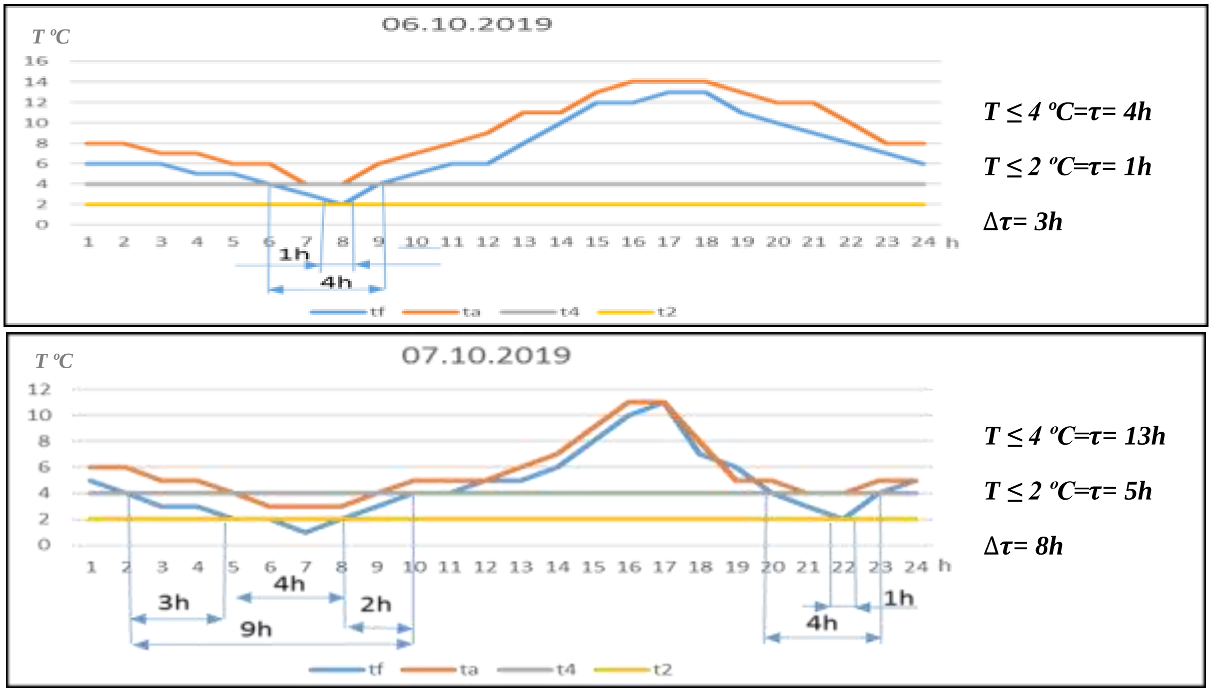


Fig. 15 Atmospheric air temperatures for 24 hours

tf - actual atmospheric air temperatures (registered at the Didactic-Experimental Complex of SAUM)

ta - atmospheric air temperatures according to data of the State Hydrometeorological Service

t2 - atmospheric air temperature T ≤ 2 ºC

t4 - atmospheric air temperature T ≤ 4 ºC

τ - the cooling time of that water for atmospheric air temperatures T ≤ 4 ºC and T ≤ 2 ºC;

At the SAUM teaching farm, the specific consumption of electricity was experimentally determined when cooling milk with the use of the natural cold battery during the cold period of the year, which constitutes about 0,5 kWh/t, Table 5.

The power of the refrigeration plant N_{if} shall be reduced from 2,5 kW to 0,8 kW.

Table 5. Specific electricity consumption when cooling milk (kWh/t) with the use of the natural cold battery during the cold period of the year (T ≤ 4 °C)

Date	The amount of produced milk daily, t	Daily electricity consumption, kWh	Specific electricity consumption, kWh/t
01.05.20	0,6	0,25	0,42
02.05.20	0,5	0,25	0,5
03.05.20	0,5	0,25	0,5
04.05.20	0,5	0,25	0,5
05.05.20	0,5	0,25	0,5

CONCLUSIONS AND RECOMMENDATIONS

1. The natural cooling plant is used for milk cooling at the atmospheric air temperature of $T \leq 4$ ºC, and during the warm period of the year, the combined refrigeration plant is used (which includes the refrigeration plant and the natural cold plant) at the temperature of $T > 4$ ºC.

The main advantages of using the natural cold plant in common with the refrigeration plant are:

- saving up electricity and water;
- reducing the volume of freons and freon oils used;
- ensuring a higher operating reliability;
- the possibility of using a different electricity tariff, which according to ANRE is reduced by 40%.

2. It has been established that:

- during the cold period of the year, the specific electricity consumption for the milk cooling, when using the proposed natural cooling plant constitutes 0,5 kW h/t, compared to 15-25 kW h/t consumption during the usage of typical refrigeration plants;
- the cooling of the water with the natural cooling plant (for atmospheric air temperature of $T > 4$ ºC), in comparison with the cooling from the refrigeration plant allows reducing the electrical power of the refrigeration plant by approximately 1,6-1,7 times;
- ensuring the non-mixing of the water in the natural cold plant allows the extension of the usage duration of the plant during the cold period of the year, from 16 to 59 days per year for the central part of the Republic of Moldova.

3. It was found that:

- when cooling milk from 30 ºC to 6 ºC, it is required: a section of the plant with natural cold at atmospheric air temperatures $T \leq 0$ ºC, two sections of the plant for $0 < T \leq 2$ ºC, and four sections for $2 < T \leq 4$ ºC;
- when cooling milk from 17 ºC to 6 ºC, there is needed a section of the plant with natural cold at atmospheric air temperature $T \leq 2$ ºC and two sections for $2 < T \leq 4$ ºC;
- for the farm of SAUM (with 30 milking cows), the optimal parameters of the installed battery are: $h_{opt} = 0,7$ m and $S_{opt} = 0,9$ m^2.

4. The performed mathematical model of the natural and artificial cold installation is displaying the following parameters: - the technological parameters of the installation, as well as the duration of their use during the cold period of the year, based on the analysis of the systematic meteorological data of the meteorological center of Chisinau (for the period of 2015 – 2019) and the proof of the law of distribution of outdoor air temperature and its approximation.

5. The parameters for controlling the cooling process of milk with the use of natural and artificial cold are:

- the temperature of the milk at the entry and the exit of the coolers;
- water temperature in the natural and artificial cold plant;
- atmospheric air temperature.

Based on the selection of the control parameters, the development of automatic graphs and the formation of the operating algorithms of the nominated installations, the automation of natural and artificial cold plants proves to ensure the cooling of the milk to the required storage temperature of 4-6 ºC, both in stream coolers and in capacitive coolers.

6. Milk cooling technology with the application of natural cold proves to reduce the specific consumption of electricity. As the calculations have shown, if the parameters of the plant are adjusted to the volume of milk (that is eventually cooled), then a reduction in the specific electricity consumption of 1,4 – 1,48 times can be achieved, in comparison with the traditional technologies. In order to reduce the specific electricity consumption, it is necessary to adjust the standard installations by connecting installations with a lower capacity and to correct and adjust the parameters of the installed battery of natural and artificial cold.

7. In order to reduce the electricity consumption (approximately 7,5 kW h/t) it is necessary to regulate the cooling time of the water in the cold battery according to the daily milk production, in particular, for small farms, peasant households and milk collection points with an annual milk productivity up to about 300 tons. It has been established that for an annual milk productivity of 400-500 tons, the cooling time of the water in the installed battery with cold, practically does not influence the reduction of the specific electricity consumption for milk cooling, which constitutes about 0.6-0.8 kW h/t.

8. For the SAUM farm with an average annual milk productivity of 175 tons, the electricity saving will be 14 kW h/t at a water-cooling time of 6 hours and 18,5 kW h/t at a water-cooling time of 8 hours. When using an installation of natural cooling with a volume of 1 m^3, a cooler tank "NEREHTA" with a capacity of 1000 L and with an electrical power of 2,5 kW, the electrical power of the refrigeration plant of the SAUM farm is reduced by approximately 60%, which constitutes up to 1,5 kW. When varying the volume of the installed battery with cold from 0 to 2 m^3, then the power of the refrigeration plant N_{if} shall be reduced from 2,5 kW to 0,8 kW.

9. During the cold period of the year, the use of the installed battery with natural cold for milk cooling allows the reduction of the specific electricity consumption by 37,5 times, compared to the use of only the refrigeration plant. At the same time, during the warm period of the year, the combined use of the installed battery with natural cold and refrigeration system, allows reducing the specific electricity consumption by 1,9 times. For the years 2019 and 2020, it has been established that the atmospheric air temperature at the site of the installation of the cold battery is 1-2 ºC lower than the atmospheric air temperatures recorded at the weather station in Chisinau. This relatively small difference in the atmospheric air temperatures contributes to the increasing of the battery life with natural cold in the autumn/spring period by 5 and 9 days, respectively.

10. It was found that:

- the risk of profit loss is measurable with the operating expenses and can make up from 11 to 44% of the operating expenses for the average annual milk productivity between 6000 - 7000 kg;
- the evidence of the risk of profit loss changes the distribution of preferred places;
- the volume of annual milk productivity influences the distribution of preferred places;
- under all the conditions examined, there is no such option, when the lowest amount of operating expenses would correspond to the lowest risk value of profit losses.

The following recommendations are proposed for the implementation of natural and artificial cold technology:

1. Natural and artificial cold installations can be used in different sectors of the agro-industrial complex, such as the zootechnical sector, the preservation of vegetables, fruits and the creation of baroclimate systems with an artificial atmosphere of gaseous space.

2. To propose the Agriculture Intervention and Payments Agency to promote the construction of natural cold installations by subsidizing the agricultural producers, who are ready to implement the milk cooling system in the technological process.

3. To recommend the researched mathematical model to the specialists in the field, as a criterion for optimizing the technological constructive parameters of shared water accumulators and refrigeration plants for saving electricity.

4. Within the local zootechnical sector, to propose to promote the scientific results obtained in the realization of milk cooling technology with the application of natural and artificial cold through applications, meetings of specialists in the field and conferences.

5. To introduce in the study plan of the State Agrarian University of Moldova, the theoretical approach of the carried out research, and specifically in the lecture courses: "Renewable energy sources in the agrarian sector" and "Designing electrification systems in the agrarian sector" for the students of year 3 and 4. Also, to be introduced in the lecture course "Automation of technological processes in agriculture" for the MSc students, having the specialization of "Electro-technologies in rural environment" at the faculty of Agricultural Engineering and Auto Transport.

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24. **Anatolie Daicu,** Augustin Volconovici, Ala Chirsanova, Onorin Volconovici,Victorin Slipenchi, Ina Volconovici, Combined automated installation deployment for milk cooling. În Journal of Engineering Science, Vol. XXVII (3) 2020 pp. 65-75, DOI: 10.5281/zenodo.3949666 UDC 004.9:621.565:637.

25. **Anatolie Daicu,** Augustin Volconovici, Mihail Cernei, Vasile Leu, Victorin Slipenchi, Onorin Volconovici, Ala Chirsanova, Structural and functional diagram, automatic graphs and operating algorithms of the natural and artificial cold receiver/accumulator for milk cooling. În Journal of Engineering Science, EMERG, Volume VI, Issue 4/2020 ISSN 2668-7003, ISSN-L 2457-5011.

ADNOTARE

la teza de doctor în științe tehnice cu tema „Argumentarea regimurilor de funcționare și a parametrilor constructivi - tehnologici ai instalației ecologice automatizate cu frig natural și artificial pentru răcirea laptelui", Daicu Anatolie, Chișinău, 2020

Teza este constituită din introducere, trei capitole, concluzii generale și recomandări, bibliografie cu 113 titluri, 6 anexe, 117 pagini de text de bază, 47 de figuri, 15 tabele, 127 formule. Rezultatele cercetărilor sunt reflectate în 24 de lucrări științifice, inclusiv o monografie, 8 articole în reviste internaționale, 15 articole în reviste naționale.

Cuvinte-cheie: instalație frigorifică, acumulator cu apă, frig natural, răcirea laptelui, model matematic, eficiență energetică, grafuri automate, algoritm de funcționare.

Scopul lucrării constă în argumentarea metodologiei de răcire a laptelui cu frig natural și artificial prin identificarea parametrilor constructivi și tehnologici ai instalației ecologice automatizate.

Obiectivele cercetării: îmbunătățirea indicilor tehnici, energetici și economici ai instalației frigorifice combinate prin utilizarea frigului natural și a celui artificial; reducerea puterii electrice a instalației frigorifice combinate; reducerea esențială a consumului specific de energie electrică necesară la răcirea laptelui; perfecționarea regimurilor de funcționare și argumentarea parametrilor constructivi și tehnologici ai instalațiilor cu frig natural și artificial pentru răcirea laptelui; evaluarea eficacității utilizării instalațiilor cu frig natural și artificial pentru răcirea laptelui ținând cont de defectarea echipamentelor electrice.

Noutatea și originalitatea științifică constă în fundamentarea metodologică a utilizării frigului natural și artificial în cadrul utilajului de răcire a laptelui și a dimensiunii acumulatorului cu frig care permite argumentarea parametrilor constructivi și tehnologici ai instalației ecologice automatizate.

Problema științifică importantă soluționată: îmbunătățirea indicilor tehnici, energetici și economici ai instalației frigorifice combinate prin utilizarea frigului natural și a celui artificial în baza modelului matematic elaborat și în corelație cu legea distribuției temperaturii aerului atmosferic pentru zona din centrul Republicii Moldova.

Semnificația teoretică a lucrării constă în contribuția metodologică la determinarea parametrilor optimali ai instalației frigorifice combinate pentru Republica Moldova, care asigură o economisire a resurselor energetice.

Valoarea aplicativă a lucrării: a fost modernizată instalația frigorifică cu frig natural și artificial cu argumentarea parametrilor constructivi tehnologici optimali ai acumulatorului cu frig.

Implementarea rezultatelor științifice. Rezultatele cercetărilor au fost implementate în cadrul proiectului transfrontalier MIS ETC 1549 „Promovarea producției sustenabile și implementarea bunelor practici în fermele de bovine din zona transfrontalieră România, Republica Moldova și Ucraina". Componenta teoretică a cercetării este implementată în cadrul proiectului 20.80009.5107.04 „Adaptarea tehnologiilor durabile și ecologice de producere și păstrare a fructelor sub aspect cantitativ și calitativ în funcție de integritatea sistemei de cultură și schimbărilor climatice " pe perioada 2020-2023. Abordarea teoretică a cercetărilor efectuate se utilizează în cursurile de prelegeri „Surse regenerabile de energie în sectorul agrar" și „Proiectarea sistemelor de electrificare în sectorul agrar" respectiv pentru studenții anului 3 și 4 a facultății de Inginerie Agrară și Transport Auto în cadrul SAUM.

АННОТАЦИЯ

докторской диссертации на соискание ученной степени доктора технических наук с темой „ Обоснование режимов работы и конструктивно-технологических параметров автоматизированной экологической установки с естественным и искусственным холодом для охлаждения молока”, Дайку Анатолие, Кишинев, 2020

Структура диссертации состоит из введения, содержит три главы, общие выводы и рекомендации, библиографию из 113 названий, 6 приложений, 117 страниц основного текста, 47 рисунка, 15 таблиц, 127 формул. Результаты исследования отражены в 24 научных статьях, в том числе в одной монографии, 7 статьях в международных журналах и 16 статьях в национальных журналах.

Ключевые слова: холодильная установка, аккумулятор воды, естественный холод, охлаждение молока, энергоэффективность автоматные графы, алгоритм функционирования.

Цель исследования заключается в обосновании методологии охлаждения молока с применением естественного и искусственного холода с определением конструктивных и технологических параметров автоматизированной экологической установки.

Задачи исследования: улучшение технико-энергетических и экономических показателей комбинированной холодильной установки за счет использования естественного и искусственного холода; снижение электрической мощности комбинированной холодильной установки; значительное снижение удельного расхода электроэнергии на охлаждение молока; совершенствование режимов работы и обоснование конструктивных и технологических параметров установок естественного и искусственного холода; оценка эффективности использования установок естественного и искусственного холода для охлаждения молока с учетом выхода из строя электрооборудования.

Научная новизна и оригинальность заключается в обосновании методологии использования естественного и искусственного холода для охлаждения молока, что позволяет аргументировать конструктивные и технологические параметры автоматизированной экологической установки.

Важная научная проблема, которая решена в диссертационной работе это улучшение технико-энергетических и экономических показателей комбинированной холодильной установки за счет использования естественного и искусственного холода на основе разработанной математической модели во взаимосвязи с законом распределения температуры атмосферного воздуха для центра РМ

Теоретическая значимость работы заключается в методологическом вкладе в определение оптимальных параметров комбинированной энергосберегающей холодильной установки для РМ.

Практическая ценность работы заключается в модернизации установки естественного и искусственного холода с обоснованием оптимальных конструктивных и технологических параметров аккумулятора холода.

Внедрение научных результатов. Результаты исследования внедрены в рамках институционального проекта MIS ETC 1549 «Содействие устойчивому развитию и внедрение передовой практики на животноводческих фермах в приграничной зоне Румынии, Республики Молдова и Украины». Теоретическая составляющая исследования внедрена в проекте 20.80009.5107.04 «Адаптация устойчивых и экологических технологий производства и хранения плодовой продукции с точки зрения количества и качества в зависимости от целостности системы растениеводства и изменения климата» на период 2020-2023 гг. Теоретические исследования использованы в курсах лекций «Возобновляемые источники энергии в аграрном секторе» и «Проектирование систем электрификации в агропромышленном комплексе» для студентов 3 и 4 курсов факультета сельскохозяйственной инженерии и автомобильного транспорта, ГАУМ.

ANNOTATION

for the Ph thesis in technical sciences" Argumentation of the operating regimes and of the constructive-technological parameters of the automated ecological installation with natural and artificial cold for milk cooling", Daicu Anatolie, Chisinau, 2020

The structure of the thesis includes introduction, three chapters, conclusions and recommendations, list of references from 113 sources, 6 appendixes, 117 pages of the main text, 47 figures, 15 tables, 127 formulas. The research results are reflected in 24 scientific papers, including a monograph, 7 articles in international journals, 16 articles in national journals.

Key words: refrigeration system, water accumulator, natural cold, milk cooling, energy efficiency automatic graphs, operating algorithm.

The main goal of this research consists in the argumentation of the methodology of cooling milk with natural and artificial cold by defining the constructive-technological parameters of the automated ecological installation.

The objectives: improving the technical, energetic and economical indices of the combined refrigeration system by using natural and artificial refrigeration; reducing the electrical power of the combined refrigeration system; the significant reduction in the specific consumption of electricity required for cooling milk; improving the operating regimes and proving the constructive and technological parameters of the installations with natural and artificial cold for cooling the milk; evaluation of the effectiveness of the use of installations with natural and artificial cold for cooling the milk taking into account the failure of electrical equipment.

The scientific innovation consists in the methodological substantiation of the use of natural and artificial cold in the milk cooling machine and in the size of the cold accumulator which allows the argumentation of the constructive and technological parameters of the automated ecological installation.

The important scientific problem solved: improving the technical, energetical and economical indices of the combined refrigeration installation by using natural and artificial cold based on the mathematical model developed and in correlation with the law of atmospheric air temperature distribution for the area in the center of the Republic of Moldova.

The theoretical importance of the paper consists in the methodological contribution to the determination of the optimal parameters of the combined refrigeration installation for the Republic of Moldova, which ensures a saving of energy resources.

The practical importance: the refrigeration system with natural and artificial cold was modernized with optimizing the technological constructive parameters of the cold accumulator.

Implementation of scientific results. The research results were implemented within the institutional project MIS ETC 1549:" Promoting sustainable production and implementing good practices in the farms from the cross-border area Romania, the Republic of Moldova and Ukraine". The theoretical component of the research is implemented within the project 20.80009.5107.04:" Adaptation of sustainable and ecological technologies for fruit production in terms of quantity and quality according to the integrity of the crop system and climate change" for the period of 2020-2023. The theoretical approach of the research is used in the lecture courses "Renewable energy sources in the agricultural sector" and "Design of electrification systems in the agricultural sector" for students of years 3 and 4 of the Faculty of Agricultural Engineering and Auto Transport within SAUM.

DAICU ANATOLIE

ARGUMENTATION OF THE OPERATING REGIMES AND OF THE CONSTRUCTIVE-TECHNOLOGICAL PARAMETERS OF THE AUTOMATED ECOLOGICAL INSTALLATION WITH NATURAL AND ARTIFICIAL COLD FOR MILK COOLING

255.01 – TECHNOLOGIES AND TECHNICAL MEANS FOR AGRICULTURE AND RURAL DEVELOPMENT

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