



# Developing Multigenerator Plants for Separating Rabbit Wool from Conies

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## Abstract

According to statistics, the amount of rabbit wool produced in Russia, China, and France is 21, 180, and 2.5 tons, respectively. The development of rabbit raising in several Russian regions offers large prospects to farming enterprises. However, high-quality treatment of conies on farming enterprises is impossible; this is why, conies are subject to disposal. Consequently, the study's relevance is conditioned by disposed cony amounts. The scientific problem is to reduce operating costs of separating rabbit wool from conies and collect the raw material while preserving its quality in the farming enterprise environment. The priority microwave technology of separating rabbit wool from conies is distinguished by analyzing the results of tests conducted by many authors for implementing electrophysical methods of treating multicomponent raw materials, animal skins included. The goal of this work is to separate decontaminated rabbit wool from conies by developing the microwave technology and multigenerator radiation-tight plants with low-capacity air-cooled magnetrons for continuous operation. This article is intended to discover efficient design configurations of resonator chambers ensuring the fulfillment of most of the criteria of designing ultrahigh frequency (UHF) plants. The efficient design of the plant processing chamber was chosen by analyzing the parameters of the electrodynamic system with different unconventional resonators. The four UHF plants described herein have unconventional resonators ensuring the continuous collection of wool from conies, with electromagnetic safety ensured without below cutoff waveguides. The length and diameter calculation procedure for using waveguides is presented. The first and the second UHF plants with prismatic resonators do not ensure multiple exposure but maintain impermeability to radiation. The third plant with a prolate spheroid and a disk conveyor ensures a duty ratio below 0.5, which excludes cony shrinking; however, additional units are needed to maintain electromagnetic safety. The fourth plant with a biconical resonator allows meeting all the basic criteria of UHF plant design.

**Keywords:** Electromagnetic field, Resonator, Bicone, Spheroid, Electrophysical factors

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## 1 Introduction

According to the target program "Development and Scaleup of Rabbit Raising Production in Russia in 2014-20", it is necessary to increase the rabbit meat output and stock to 50,000 tons per year and 750,000 heads, respectively. In the farming enterprise environment HQ cony treatment is impossible; therefore, selling conies is unprofitable. The rabbit raising production at farming enterprises can be made more profitable not only by improving productivity and reducing fodder costs but also by selling rabbit wool collected from conies. Not only does using hair coat reduce the prime cost of meat but it also provides additional sources of raw materials for felt industry. This is why, it is a relevant task to develop engineering tools and technologies using ultrahigh-frequency electromagnetic field (UHFEMF) energy to separate rabbit wool from conies at reduced operating costs.

The scientific problem is to reduce operating costs of separating rabbit wool from conies and collect the material while preserving its quality in the farming enterprise environment.

The goal of this work is to separate decontaminated rabbit wool from conies by developing the microwave technology and multigenerator radiation-tight plants for continuous operation at low operating costs.

The means of practical significance are:

- UHF plant developed, made, and tested in factory conditions and equipped with a prolate spheroidal resonator; the plant is designed to ensure electromagnetic safety during continuous selective heating of conies with the flesh side impregnated with predough to weaken the hair coat holdability in the skin;

- discovered efficient modes of using the UHFEMF to treat the raw materials impregnated with special predough.

## 2 Materials and Methods

The study materials were the experience accumulated by the school of science from (2-4, 14). The efficient design for the process chamber of the UHF plant was selected by analyzing the parameters of the electrodynamic system with a cylindrical, coaxial, toroidal, ellipsoidal, biconical, spheroidal, and asteroid resonator. The predough weight was calculated, taking into account the average weight of one cony equal to 400-450 g. The consumption of each component was calculated given that the share of consumed mustard and rye flour was 27 % of the cony weight. The unwooling degree and quality of the conies from the reference and the test sample were evaluated by the histomorphologic skin test. The wool's qualitative characteristics were evaluated against microbiological indicators. This study is based on the seminal works in the theory and practice of raw materials treatment by such renowned scientists as Borodina I. F., Strebkova D. S., Ginsburg A. S., etc., and in the theory of cavity resonators by such scientists as Atabekova G. I., Bessonova L. A., Pchel'nikova Yu. N., Drobakhina O. O., Plaksina S. V., etc.

## 3 Results and Discussion

The flowchart of basic UHF plants (1, 13, 17) includes the following components:

- 1) Power supply source for converting mains voltage to high voltage necessary to run a magnetron (HV rectifier or stepup transformer with a voltage adjuster and filament supply);
- 2) UHF generator for converting main frequency power to UHF power;
- 3) Resonator chamber;
- 4) Resonator chamber's electrodynamic system ensuring a preset distribution of UHF energy in the chamber space;
- 5) Auxiliary parts for evenly heating up raw materials;
- 6) Devices for preventing UHF energy leaks from the plant to the surrounding environment;
- 7) Remote control.

We are upgrading the resonator chamber with an UHF input device and a raw materials conveyor for continuous operation and with electromagnetic safety ensured by means of several low-power air-cooled magnetrons. In particular, plants with unconventional resonators for separating rabbit wool from conies have been designed and described.

The analysis of available methods of skin unwooling by means of different chemical preparations allows making the following inferences (6, 7):

- double treatment using salts, alkali, and sulfides destroys the hair bulbs, and the hairs are released and removed within five to seven hours;

- if to soak conies for five to seven days in lime cream with sodium hydroxide, soda, sodium sulfide, unwooling takes place and the hair structure changes, which makes the raw material low-value;

- if to apply in sequence alkali sulfide and lime solutions (pH > 7), the hair holdability in the dermis weakens within five to six hours but the hairs remain strong;

- conies limed with lime and sodium bisulfite are unwooled within four to six hours;

- conies treated using a homogenized fermented mix of rye flour, water, yeast, mustard flour, and salt (predough) are unwooled within five to six hours.

The exposed methods take much time to apply; that's why, the conventional technology, in which the flesh side is permeated with predough, was combined with the MW technology to speed up the separation of wool from conies.

The engineering problem is to reduce operating costs while adopting on rabbit raising farms the technology of separating hair coat from conies by selective treatment in the UHFEMF in continuous mode; preserve the quality of hair coat, intensify the process, and make the production more ecofriendly (20-24).

The developed operation and process procedure of separating hair coat from conies involves:

- preparing brine solution or predough in the form of a homogenized fermented mix of rye flour, water, yeast, mustard flour, and salt with an accurate concentration of components;

- processing the conies removed from rabbits into a furrow slice and taking steps for veterinary and sanitary supervision;

-placing the conies on the conveyor belt and turning on the pump for pulverizing predough or brine solution on the flesh side;

-turning on the conveyor and the UHF generators for thermally treating the conies moving through the resonator to a skin temperature of 32 to 40°C;

-turning on the pneumatic pump to collect the wool separated from the rabbit skin and discharging the unwooled conies;

-ensuring the veterinary and sanitation supervision of the wool;

-tracking the plant's adjustable parameters, including conveyor speed, generator capacity, energy costs;

-turning off the plant when the line of treated conies ends;

-discharging the wool from the cyclone storage and transporting it to the production shop;

-sanitary treatment of equipment.

The analysis of weak points of various resonator design configurations (5, 10-12, 15-16) was used to develop four UHF plants with unconventional resonators ensuring continuous collection of wool from conies and with electromagnetic safety ensured without below cutoff waveguides. The first and the second UHF plant with prismatic resonators do not ensure multiple exposure but retain impermeability to radiation. The third plant with a prolate spheroidal resonator and a disk conveyor ensures a duty ratio below 0.5, which excludes cony shrinking; however, additional units are needed to maintain electromagnetic safety. In addition to unconventional resonators and magnetrons, the plants have units for permeating the cony flesh side with predough or brine solution, which speeds up the weakening of the hair coat holdability in the dermis of conies treated in the UHFEMF. The fourth plant with a biconical resonator meets all the basic criteria, including process continuity with a duty ratio below 0.5, even heating of raw materials, high electrical intensity, electromagnetic safety, low energy costs.

### 3.1 UHF Plant with Astroid Resonator for Separating Wool from Conies in Continuous Mode

The plant shown in Fig. 1 has horizontal prismatic resonator 1 with slits (this is an open resonator). Astroids are used as the resonator bases. The working strand of grid dielectric conveyor 6 is extended through the resonator slits along the upright diagonal and passes between pressing and guide rollers 7 mounted at the front of the conveyor. There is also drum 5 with pegs at the end of the conveyor. A probe with pneumatic duct 4 is mounted above the drum. Brine solution pulverizer 10 is mounted at the junction of the two upper facets of the resonator. Magnetrons 2 are mounted in the middle on the upper facets of the prism. The diameter and length of the cylinder conventionally escribed in the prism are equal to an aliquot half of wavelength. The height of slits 3 near the resonator's face interfaces does not exceed 25 % of wavelength, and the cross-section of these slits does not overlap the throat of the open resonator.

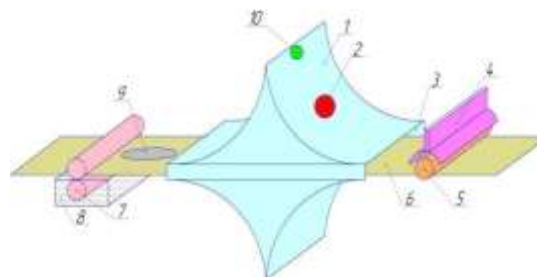


Figure 1: UHF plant with a resonator for separating wool from conies in continuous mode: 1 is the prismatic resonator with astroids at the base; 2 is the magnetrons; 3 is the slit closed with a non-ferromagnetic mesh; 4 is the pneumatic duct; 5 is the drum with pegs; 6 is the dielectric grid conveyor; 7 is the guiding and pressing rollers; 8 is the bath with brine solution; 9 is the cony; 10 is the brine solution pulverizer

### 3.2 UHF Plant with Prismatic Resonator for Sanitary Treatment of Hair-Type Raw Material by Exposure to Electrophysical Factors

The plant is shown in Fig. 2 and consists of horizontal hexagonal shielding prism 11 of four equally large faces and two opposite small faces with slits. Together with the two opposite faces with slits the impellers mounted inside the prism in parallel with the four equal faces with larger area form a hexagonal prismatic resonator to the inside of which the magnetron emitters are directed.

Like the air-conditioner impeller, these impellers are made from a non-ferromagnetic material. Some of the impellers are mounted closer to the faces with slits of the shielding prism and do not rotate, whereas the other impellers are set in rotation by two electric motors. For this purpose, the impeller shafts are equipped with idle gears engaged in cohesion with each other and respective guiding gears mounted on the electric motor shafts. Two guiding gears are mounted on each shaft of the electric motors setting the impellers in rotation. The working dielectric strand of the conveyor is extended through the slits in the faces. The idle strand of the conveyor is found under the hexagonal prism. The UHF generator magnetrons and the kilohertz frequency power sources working according to d'Arsonval's principle are mounted on the outside of the shielding prism base. There are also electric gas discharge bulbs energized by kilohertz frequency power sources and mounted inside the stationary impellers along their blades.

### 3.3 UHF Plants with a Prolate Spheroidal Resonator for Separating Hair Covering from Conies

Cylindrical resonator 1 with half-spherical bases (Fig. 3) is horizontally installed on mounting frame 7. There are also two slits along the generatrix of the cylindrical resonator. They are turned towards one another at one level, and their size is 25 % of wavelength. Horizontal rotating disk 5 projects through the slits because its diameter exceeds the cylindrical resonator diameter. Moreover, the projection perimeter exceeds half the perimeter of the disk part in the resonator. This will ensure a duty ratio (heating duration related to cycle duration, heating/cooling) below 0.5 for equaling the temperature in each elementary particle of the

raw material.

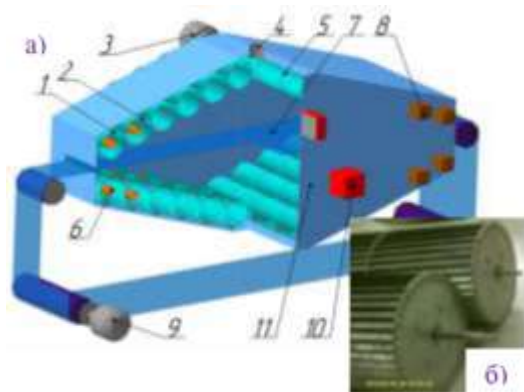


Figure 2: Plants for sanitary treatment of wool raw material by exposure to electrophysical factors: a) is the 3D graphic presentation; b) is the impellers; 1 is the hexagonal prismatic resonator; 2 is the impellers; 3 is the impellers electric drives; 4 is the air duct; 5 is the rings for clamping impeller blades; 6 is the electric gas discharge bulbs; 7 is the dielectric grid conveyor; 8 is the kilohertz frequency power sources; 9 is the conveyor electric drive shaft; 10 is the UHF generators magnetrons; 11 is the hexagonal shielding prism.

Disk 5 is made from PTFE and holds on support bearings 9 fixed onto the mounting frame. Inside the cylindrical resonator dielectric pressing ring 6 is rigidly and coaxially clamped above the disk to the inside of the resonator. Cony 13 is carried between the ring and the disk. Pulverizers 4 with a pump for viscous liquid are mounted on the one side above the disk projections, whereas pneumatic pump 14 is mounted on the other side. Driving crown 12 engaged in cohesion with guiding gear 11 clamped to the shaft of gear motor 10 is rigidly mounted on the disk. Inspection window 3 is cut on the cylindrical resonator generatrix and closed with a metal mesh lid. The mesh openings do not exceed 3 mm in size, which excludes any possibility of microwave energy penetrating through these openings. UHF energy emitters 2 on the magnetrons mounted on the generatrix are directed to cylindrical resonator 1. Drawoff nozzle 8 is clamped on one side of the half-spherical base of the resonator. The mesh-type non-ferromagnetic louvers on the generatrix are designed to restrict the UHF radiation flow through the slits and not shown in Fig. 3.

The process procedure develops as described below. Close the metal mesh lid of inspection window 3 upon the sanitary treatment of resonator 1; close drawoff nozzle 8. The inspection window allows visually tracking the thermal treatment of conies and protects against microwave radiation. Start gear motor 10, which will make PTFE disk 5 rotate by means of gear 11 engaged in cohesion with driving crown 12. Then start pneumatic pump 14 and the pump of predough pulverizer 4. Rub into the cony flesh side the predough made as a homogenized mix of rye flour, water, yeast, and mustard rye, then put cony 13 with its flesh side up on the projection of the rotating PTFE disk on the side of the pneumatic pump. While the disk is rotating, the cony is dragged down dielectric pressing ring 6.

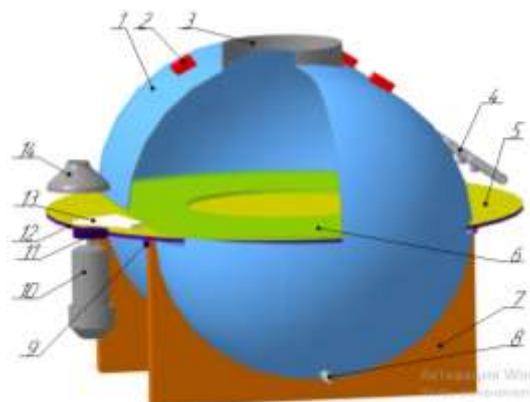


Figure 3: 3D graphic presentation of a microwave plant with a disk conveyor for separating wool from conies (in section): 1 is the cylindrical resonator with half-spherical bases; 2 is the UHF energy emitters; 3 is the inspection window closed with a metal mesh lid; 4 is the pulverizer with a viscous liquid pump; 5 is the rotating PTFE disk; 6 is the dielectric pressing ring; 7 is the mounting frame; 8 is the drawoff nozzle; 9 is the support bearings; 10 is the gear motor; 11 is the guiding gear; 12 is the driving crown; 13 is the cony; 14 is the pneumatic pump.

Turn on the generators, whose UHF emitters 2 excite an S-band EMF in the cylindrical resonator. The cony's exposure to the UHFEMF ensures selective heating of hair bulbs, epidermis, and dermis treated with the predough. This integral influence of the dielectric heating on the flesh side permeated with the predough speeds up the weakening of the hair coat holdability in the cony dermis. The pressure and temperature of the skin components evens outside the cylindrical resonator on the projection of the rotating disk, which excludes any cony shrinking; in addition the predough is pulverized onto the flesh side with the help of the pulverizer and the viscous liquid pump. Then the cony is exposed to the UHFEMF for the second time and the hair coat separated from the skin is collected at the exit from the cylindrical resonator and carried to the cyclone. The skin is carried to the tare. The plant runs in continuous mode, which is why the operator lays the conies pre-permeated with the predough onto the rotating disk projection. This double exposure to the UHFEMF ensures that the conies are treated in sparing mode and, when the PTFE disk rotates, the separated hair coat is not scattered in all directions because it is pressed by dielectric ring 6. After the treatment of the conies is finished, turn off the equipment as follows: predough pulverizer pump 4, UHF generators 2, gear motor and pneumatic pump 14. The non-ferromagnetic mesh louver on the slits restricts the UHF radiation flow. Then open the lid of inspection window 3, open drawoff nozzle 8, expose the resonator's internal surface to sanitary treatment. Then cover the fresh skin with predough on the flesh side and expose to the UHFEMF with a dose of 0.2 kWh/kg. Affected by endogenous heat, the homogenized fermented mix (predough) in the UHFEMF reduces the holdability of the hairs in the hair bursa, and they are separated from the dermis within few minutes, depending on the condition of the original raw material. The specific features of mustard rye

stem from the hydrolyzing influences of starch-derived acids, high fat content in starch, and from the influence of enzymes in conies. According to the histomorphologic evaluation of the unwooling degree of the conies with the flesh side permeated with predough, the exposure to the UHFEMF destroys the hair bulb and fully loosens the epidermis layer, which weakens the hair coat holdability in the dermis and ensures quite an easy separation of wool from conies at a minor inlet pressure of the pneumatic pump. This being the case, the structural properties of the downy raw material are retained.

### 3.4UHF Plant with Biconical Resonator for Separating Hair Covering from Conies

As shown in works by Drobakhin O. O. et al. (9, 19), an open biconical resonator helps maintain continuous operation mode at a high radiation Q-factor. The resonator's having areas, where the exponential law of EMF changes is strongly pronounced, allows cutting cone vertices with significant losses in the basic Q-factor. These resonators have a fairly high Q-factor because there is no degeneration of parasitic oscillations. A properly chosen vertex angle of the cone may

form an electrical field concentrated in the center of the resonator. The full wave reflection is observed on the surfaces formed near the vertices, which is why the radiation flow from open ends becomes much less intensive. The expansion of the cone part angle increases the Q-factor; the resonator length is adjusted at permanent cone base diameters. The UNF plant designed following the specified guidelines contains a symmetrical biconical resonator (Fig. 4) with a loaded conveyor strand coaxially installed inside. The cone vertex region contains slits. The magnetrons are mounted in the cone base region with a perimeter-wise shift, whereas the pneumatic duct is mounted above the loaded conveyor strand. Conies with the predough-permeated flesh side are carried by means of the conveyor. The steamed cony in the UNFEMF creates the conditions for skin softening, pore widening, rapid hair bulb destruction, and wool release. The pneumatic pump ensures the transportation of the separated downy raw material to the cyclone. The design of the resonator in question helps maintain the only working type of oscillations at 2 450 MHz and minimally reduces the loaded Q-factor at an increase in the resonator filling coefficient.

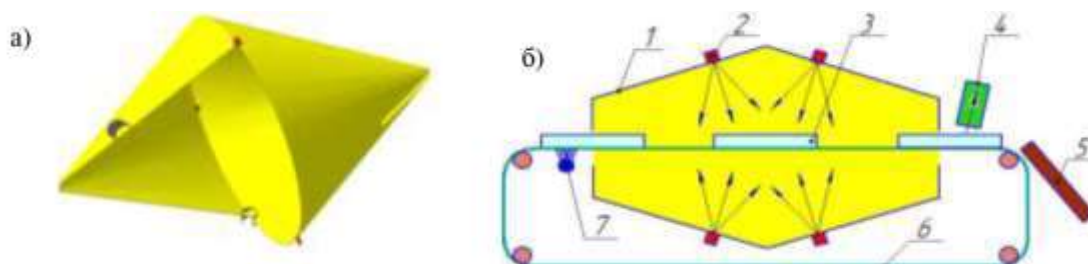


Figure 4: Process chart of separation of wool from conies in continuous mode in a plant with a biconical resonator: a) is the resonator; b) is the plant layout: 1 is the symmetrical biconical resonator; 2 is the magnetrons; 3 is the conies; 4 is the pneumatic duct; 5 is the unwooled cony; 6 is the conveyor; 7 is the predough or brine solution pulverizer

The adopted basic Q-factor of 9 000 should be calculated via the geometrical volume and surface area of the biconical resonator, taking the slits into account. The biconical resonator layout shown in Fig.4 was made up especially for the purpose. The design dimensions of the resonator were preset, and such parameters of the truncated biconical resonator were calculated as its volume (350 l), surface area (30,900 cm<sup>2</sup>) and basic Q-factor (9 647). Surface layer thickness  $\Delta$  of the biconical resonator fabricated from aluminum is  $1.8 \cdot 10^{-5}$  m. (8, 17, 18). As per calculation, the basal diameter of the biconical resonator is taken equal to wavelength, i.e., 85.68 cm, and the cone height and the central axis length are taken equal to 100 and 200 cm, respectively. If to take the grid conveyor width equal to 36 cm and take into account that the slit height necessary for letting pass the conveyor with the cony is 6 to 10 cm, the biconical resonator length will be 125 cm. Moreover, the critical section diameter is  $0.72 \cdot 85.68 = 30.85$  cm. Then a truncated cone will be formed with a 10x36 cm slit in the smaller base. To let the conveyor pass, it is necessary to cut the truncated cone generatrix to a depth of 5.15 cm. The truncated cone generatrix tilt is 67 degrees.

According to the calculations, a decrease in the resonator height does not affect its resonant frequency but significantly reduces its basic Q-factor. The basic Q-factor of the truncated biconical resonator is only 10 % lower than the biconical resonator Q-factor of 10,816; i.e., there is no significant change in the Q-factor. Because of the rough resonator surface and the slit, the actual basic Q-factor of the truncated biconical resonator will be 10 to 20 % lower than the design Q-factor, i.e., about 7 000 to 9 000. Thus the 350 l truncated biconical resonator with a basic Q-factor of 9 000 and with 3 200 W magnetrons will ensure an electrical intensity of 1.2 to 1.5 kV per cm in a volume of up to 55 l and reduce the total microbial number by 100 %. The main specifications of the designed plant are given below: the UHF generator power consumption is 4.8 kW, the expected output is 35 to 45 pcs. per hour, and the unit energy OPEX are 0.25 to 0.39 kWh per hour.

The horizontally mounted symmetrical biconical resonator is assembled from two casings so that their bases are interfaced (Fig. 4). The loaded strand of the dielectric grid belt conveyor is mounted coaxially inside the resonator. Conies are laid onto the loaded strand unfolded, with the flesh side looking to the grid belt.





Figure 5: UHF plant for separating rabbit wool from conies

The idle strand of the conveyor is mounted beyond the resonator with slits in the vertex region the sizes of which are dovetailed the wavelength for making the plant impermeable to radiation and achieving a fairly high basic Q-factor of the resonator. The slits shall not be higher than 25 % of wavelength; thus the propagation of EMWs beyond the resonator will be limited. The slits shall be wider than the grid belt. The magnetron emitters are mounted perimeter-wise in the cone basal region with a shift by 120 degrees. The pneumatic duct is located on the generatrix of one cone, whereas the brine solution pulverizer is mounted under the loaded strand on the generatrix of the other cone. The nozzle for drawing off waste brine solution is mounted in the region of the resonator's maximum basal diameter. As the waves originating in the middle of the resonator propagate away from the center, their propagation constants decrease. This being the case, the waves are almost completely reflected by the surfaces formed at the cone vertices. Since these surfaces are found in the resonator, the radiation flow from the open slits considerably weakens. Resonators can have any section dovetailed with wavelength. The low longitudinal currents in the walls of such resonators allow achieving the maximum basic Q-factor. The slits in out-of-limit regions allow continuously loading the resonator with the raw material.

Since a bicone is hard to fabricate in the lab, a cylindrical resonator with half-spherical bases was taken as a basis. That resonator was used as a working chamber able to meet the main criteria of UHF plant design, including process continuity, highly intense electromagnetic field sufficient for disinfecting the wool, high basic Q-factor, electromagnetic safety (Fig. 5). The most efficient system is the UHF plant with an output of 35 to 45 pcs. per hour, a power consumption of 5.55 kW, and an energy OPEX of 0.3 kWh per hour. The resonator specifications are provided in Table 1. With an output capacity of 700 to 800 W in each magnetron and the inspection window open, the plant can generate radiation of more than 5 000  $\mu\text{W}/\text{cm}^2$  in intensity. All the slits can be treated as sources of UHF radiation leaks. A leak is defined as significant when the orifice diameter in the inspection window exceeds 2 mm. The UHF energy emitted through the narrow slits with a width below 25 % of wavelength is below the MPL when the slits are situated along the lines of current flow in the resonator. There are two safe radiation standards for plants with UHF energy supply:

at 0.5 m away from the plant operated for eight hours the radiation density shall not exceed 0.01 mW/cm<sup>2</sup>. According to UHF radiation flow capacity analyses using a OZ-33M measuring instrument in relation to the distance to the plant and measuring height, the operator's electromagnetic safety is ensured for three hours of work right near the conveyor without a shielding mesh and for the whole day of work near the conveyor with this mesh.

Table 1: UHF plant specifications

|                                          |                |
|------------------------------------------|----------------|
| Power consumption of four generators, kW | 4.8            |
| Output, kg/h;<br>pcs./h                  | 15-20<br>34-45 |
| Conveyor electric motor capacity, kW     | 0.25           |
| Conveyor speed, m/s                      | 0.015-0.2      |
| Pneumatic pump capacity, kW              | 0.25           |
| Magnetron cooling fan capacity, kW       | 0.25           |
| UHF plant power consumption, kW          | 5.55           |
| Unit energy OPEX, kWh/kg                 | 0.3            |
| Dimensions, m                            | 1.2x1.0x2.15   |

According to the Sanitary Standards of Protecting Attending Personnel against Electromagnetic Radiation, the maximum permissible level (MPL) of the UHFEMF at continuous round-the-clock exposure is 10  $\mu\text{W}/\text{cm}^2$ . At an exposure for eight and two hours the MPL is 25 and 100  $\mu\text{W}/\text{cm}^2$ , respectively; this being the case, the UHFEMF MPL shall not exceed 1000  $\mu\text{W}/\text{cm}^2$  (2).

According to the analysis of the propagation of an S-band wave beyond the UHF plant by G. B. Belotserkovskiy's method (3), the spherical wave generated in space by the emitter has an amplitude pro rata with the distance from the UHF plant and the phase also lags behind pro rata with the distance to the plant. The fabricated test model of the UHF plant for separating rabbit wool from conies should be checked for impermeability to radiation. For this purpose, the capacity flow density was analyzed using a PZ-31 or PZ-33M electromagnetic radiation measuring instrument with a measurement limit of up to 18,000 mHz, 615 W/m, depending on the distance from the plant and the measuring height. The relation of the standard safe capacity flow density to the plant operation time is presented in Fig. 6. The empirical equation of the maximum permissible radiation

level related to the duration of exposure to UNFEMF ( $\tau$ ) is recorded as

$$\text{MPL} = 73.283 e^{-0.374 \tau}, \mu\text{W}/\text{cm}^2. \quad (5)$$

With an increase in the distance from the resonator or from waves of leading systems, the emitted energy flow weakens inversely pro rata with the squared distance. This is why, it is possible to find the safe boundary at which the radiation is below normal (Fig. 6).

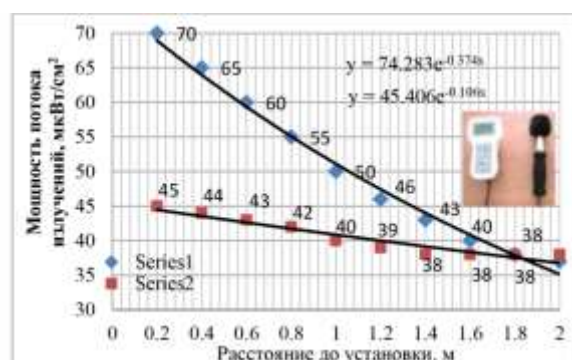


Figure 6: Changes in the radiation flow capacity against the distance to the plant and measuring height: 1) w/o shielding mesh, 2) with shielding mesh

|                                     |                                                    |
|-------------------------------------|----------------------------------------------------|
| Мощность потока излучения, мкВт/см² | Radiation flow capacity, $\mu\text{W}/\text{cm}^2$ |
| Расстояние до установки, м          | Distance to the plant, m                           |

The UHF radiation capacity set against the distance to the plant shall not exceed  $50 \mu\text{W}/\text{cm}^2$ ; in this case the personnel attending the plant can work five hours a day. It is known that any shielding system relies on the radiophysical principles of reflecting or absorbing electromagnetic energy. The full reflection of electromagnetic waves is guaranteed by means of highly conductive materials; the full absorption of these waves is possible only in poorly conductive dielectric materials with large losses. Taking into account the properties of the raw material, the parameters of the radiation source, and the peculiarities of the process, it is recommended to apply an aluminum shielding material.

To prevent the radiation flow through loading and drawoff nozzles in UHF plants running in continuous mode, it is possible to use below cutoff waveguides. These are non-ferromagnetic pipes with a small diameter and a preset length. Such waveguides do not let pass UHF energy given that the pipe radius is 10 to 15 times shorter than wavelength (17). Let us consider a below cutoff waveguide with radius  $R=1.5$  cm at a wavelength of 12.24 cm and determine at each centimeter of the pipe length the specific attenuation of lower modes  $H_{11}$  as  $L=16/R$ .  $L = 16/1.5 = 10.67$  dB/cm. If the resonator's UHF oscillation capacity is 0.8 kW and the permissible capacity outside the below cutoff waveguide equal to  $0.8 \mu\text{W}$ , the attenuation on pipe length  $l$  shall be by  $0.8 \text{ kW}/0.8 \mu\text{W} = 10^6$  times or by 60 dB. Then the below cutoff waveguide length shall be  $l = 60/L = 60/10.67 = 5.62$  cm. The calculations suggest that the safe radiation level is

achievable for below cutoff waveguide of 6 cm in length and 3 cm in diameter. The radiation flow through the slits designed for carrying the raw material through the cavity resonator can be restricted in other ways as well, including using biconical resonators with slits in cone vertices at the critical cross section level.

## 4 Conclusion

1. The elaborated scientific concept makes for separating rabbit wool from conies by selective exposure to the UHFEMF.
2. The suggested unconventional approach to the design configuration of resonator chambers in UHF plants with low-capacity magnetrons of 800 W ensures a reduction in microbial content and a continuous weakening of the wool holdability in conies the flesh side of which is soaked in predough.
3. The elaborated efficient form of predough is a homogenized fermented mix of rye wheat (27 % of cony weight), water, yeast, mustard flour (27 %), and salt (1.5 %). This mix is intended for permeating White Giant rabbit conies exposed to the UHFEMF up to a heating temperature of 35 to 40°C.
4. The four described UHF plants have unconventional resonators ensuring continuous collection of wool from conies, while providing electromagnetic safety with below cutoff waveguides. The first and second UHF plans with prismatic resonators do not ensure multiple exposures but maintain impermeability to radiation. The third plant with a prolate spheroidal resonator and a disk conveyor ensures a process duty ratio below 0.5, which makes cony shrinking impossible. However, additional units are needed to preserve electromagnetic safety. The fourth UHF plant designed and fabricated with a truncated biconical resonator allows meeting all the basic operational criteria.
5. As shown by the calculation and measurement of the UHF radiation flow capacity using a PZ-33M, the MPL of  $50 \mu\text{W}/\text{cm}^2$  is not exceeded, which means that the personnel can work near the UHF plant for up to four hours daily.

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