UDC 637.02: 637.5:613.292

DETECTING AND WITHDRAWING OF FOREIGN INCLUSIONS AS CRITICAL CONTROL POINTS OF HACCP PLANS FOR MEAT PROCESSING FACILITIES

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Developing and implementation of HACCP systems in the meat industry implies special CCP corresponding to physical hazards, such as bones and structural elements of machines and mechanisms made of metal, glass, plastics, and other hard materials, since the fragments of those can pose a threat to the health and life of consumers in case of getting into the finished product, and, therewith, into the human body. Concerning CCP set at the different stages of meat processing, two technological operations are typical – reception of fresh or frozen meats and surveying prepared and ground meats before or during stuffing the sausage casings. There are different methods of foreign fragments detection in food stuffs, operating on the base of different physical principles, and two of them, fluoroscopy (X-rays) and electrometric methods based on inductance, capacitance and electric contact, are typical for the detectors used in meat processing. Electrometric detection devices are the most practical as metal detectors but specific needs of meat processing cause the necessity to use detection appliances these being more universal and accurate than electrometric devices. The analysis made shows that for nonmetal inclusions, namely bone fragments, detection, fluoroscopic (X-ray) detectors are rational.

***Key words:** bone fragments, critical control points, electrometric detectors, fluoroscopic (X-ray) detectors, HACCP, metal detectors, nonmetal detectors.*

ВИЯВЛЕННЯ ТА ВИДАЛЕННЯ СТОРОННІХ ВКЛЮЧЕНЬ, ЯК КРИТИЧНІ КОНТРОЛЬНІ ТОЧКИ У ПЛАНАХ НАССР ДЛЯ М'ЯСОПЕРЕРОБНИХ ПОТУЖНОСТЕЙ

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Розробка і впровадження систем НАССР в м'ясній промисловості вимагає запровадження особливих ККТ, що відповідають фізичним небезпекам, таким як кістки і структурні елементи машин і механізмів з металу, скла, пластмас та інших твердих матеріалів, оскільки фрагменти цих матеріалів можуть становити загрозу для здоров'я і життя споживачів в разі потрапляння до готового продукту і, далі, до організму людини. Стосовно ККТ, встановлених на різних етапах переробки м'яса, то найбільш характерними є дві технологічні операції - приймання свіжого або замороженого м'яса і контроль м'ясної маси до або після наповнення ковбасних оболонок. Існують різні методи виявлення сторонніх фрагментів у харчових продуктах, базовані на використанні різних фізичних принципів, два з яких - флюороскопія (рентгенівське випромінювання) і електрометричні методи, засновані на індуктивності, ємності та електричному контакті, є типовими для детекторів, використовуваних в м'ясній промисловості. Електрометричні пристрої виявлення є найбільш

практичними в якості металодетекторів, але конкретні потреби перероблення м'яса обумовлюють необхідність використання детекторів, які є більш універсальними і точними, ніж електрометричні пристрої. Проведений аналіз показує, що для неметалічних включень, а саме фрагментів кісток, використання рентгеноскопічних детекторів є раціональним.

Ключові слова: *детектори неметалів, електрометричні детектори, кісткові фрагменти, критичні контрольні точки, металодетектори, рентгеноскопічні детектори, HACCP*

The problem of product safety has always been the most important in the daily practice of meat industry specialists, and systems of sanitary and industrial control, these being carefully worked out, served to solve the said problem. Proper implementation of the procedures stipulated by these systems required the availability of appropriate technical means and the involvement of numerous personnel, since these systems functioned on the principle of inspection control of raw materials and their transformation in the course of production, packaging, storage and distribution [1]. The inspection control systems are reliable enough, but not operational and too costly. That is why, the HACCP systems based on the need to optimize the costs of product safety were proposed and are now known to all food processors. Both domestic and world practices show that the overwhelming majority of problems with the safety of food products arises from the unsatisfactory quality of raw materials and improper modes of its processing, unauthorized changes in formulations laid down by technological documents, non-compliance with the requirements for the sanitary condition of personnel, technological equipment and production facilities. Thus, the conceptual core of the HACCP system is a careful analysis of possible biological, chemical and physical risk factors, so that the possibility of occurrence of incidents in established critical control points (CCP) is consistently minimized.

In Ukrainian, HACCP systems have already become mandatory for large profile meat processing enterprises. The Law of Ukraine «On Amendments to Certain Legislative Acts of Ukraine Concerning Foodstuffs» [2] determined the terms for the development, implementation and application of permanent procedures based on the principles of hazard analysis and control system at critical points. Since September 20, 2017, the new version of the Law of Ukraine «On Basic Principles and Requirements for Food Safety and Quality», introduced in the Law of Ukraine [2], requirements for the introduction of the HACCP systems became mandatory for the facilities that operate with food products containing raw ingredients of animal origin (except for small-scale facilities). For all small-scale facilities the introduction of HACCP systems will become mandatory from September 20, 2019.

In 2012, the Ministry of Agrarian Policy and Food of Ukraine issued the Order [3], according to which the introduction and application of permanent procedures based on the principles of the Food Safety Management System became mandatory. When an enterprise does not comply with the norms of Order [3], the enterprise's activities in the production of food products could be discontinued, and the enterprise was subject to redevelopment. In 2017, the Ministry of Agrarian Policy and Food of Ukraine issued the Order [4] specifying the rules for state audit of compliance by market operators with the requirements of legislation regarding permanent procedures based on the principles of the hazard analysis system and control at critical points.

It is of great importance that proper administrative control of the order of implementation and operational functioning of HACCP systems at food enterprises, including meat ones, would take place without undue pressure on producers and impeding their economic activities. HACCP systems have become a universally recognized tool for ensuring food safety because they create opportunities to achieve its highest possible level together with simplifying control measures and minimizing the costs of implementing the said systems. During those years when the introduction of HACCP systems was still voluntary, some experience of implementing these systems in domestic enterprises had been accumulated. Often this experience was rather negative. In particular, under domestic conditions, there was a distinct trend not to simplify, but to complicate the security control system, incl. an excessive number of prerequisites, an unjustified designation of control points, an attempt to extend the HACCP plans to product quality control, etc. The said trends were also characteristic for the activities of many specialized organizations and enterprises implementing

quality and safety management systems at production facilities and tending to show excessively rigorous control in the attempt to compensate the absence of carefully and responsibly performed risk analysis precisely corresponding to the peculiarities of each specific company.

The success of implementation of HACCP systems at large-scale meat processing enterprises was due to their adequate financial, technical and organizational capacity, while the introduction of these systems at small-scale meat processing plants, as it had been expected, faced with significant difficulties caused by the lack of funds, poor qualification of personnel, organizational and methodological problems, etc.

Certainly, successful implementation of HACCP systems is associated with significant expenses. For example, the program for the implementation of the HACCP system for meat processing and poultry processing enterprises in the United States, launched in 1996, provided for the implementation during 20 years and total costs of 2.3 billion USD (in 2018 prices it is about 3.7 billion USD) [5]. In 2011, the specialists of the International Finance Corporation made the calculation of the necessary costs for the implementation of HACCP systems in Ukrainian [6]. These expenses consist of three articles. Costs for creating prerequisites (if no capital construction or reconstruction is planned, collection points are being built, there is no need for new transport, no export is planned) for an average capacity enterprise (in 2011 prices) amounted to 31.25 thousand USD, costs for the development and implementation of HACCP – to 5.63–6.25 thousand USD, total current expenses – 6.25 thousand USD. The procedure of the implementation of the HACCP system in a medium-sized meat processing plant can last up to two years, due to the need to develop and implement monitoring systems, record results, determine the form and range of corrective actions, and implement the documentation system in workplaces.

A principal trait of developing and implementation of HACCP systems in the meat industry is the special emphasis on preventing microbial spoilage, so the vast majority of critical control points (CCP) are assigned in accordance with the temperature extremes above which there is a sharp increase in pathogenic microorganisms. HACCP systems are intended to control processes, thus, in many cases, potential hazards and, accordingly, CCP are determined by the operation of processing equipment. There are also physical hazards associated with the said operation, such as structural elements of machines and mechanisms made of metal, glass, plastics, and other hard materials, since their fragments can pose a threat to the health and life of consumers in case of getting into the finished product, and, therewith, into the human body. Characteristic, as for meat processing, physical hazard also consists in fragments of bone tissue formed as a result of the work of meat cutting equipment and met in ground meat products. That is why effective detection and removal of foreign inclusions is an obligatory element of HACCP systems introduced at meat processing enterprises [7].

Purpose of the article is summarize information on the place of detecting and expelling foreign fragments in the frames of development and implementation of HACCP systems which will soon become obligatory for all the meat processing facilities notwithstanding their scale. Accordingly, designs, performances, specifications and industrial practices of use of such appliances shall be also taken into account.

Experiment and research methods. Within the framework of the research fulfilled, the principles of a systematic approach to the study of factual materials, normative and legal acts, normative documents as well as technical and commercial information were used as well as abstract logical approach to the generalization of research results and the formulation of conclusions made.

Results and discussion of research. Along with the temperature CCP ensuring proper microbiological state of the products, the posts for detection and removal of foreign inclusions are necessarily designated as CCP in HACCP systems, which is practical at the meat processing enterprises. Often, HACCP plans include checkpoints for metal or/and nonmetal detection in raw materials, intermediate masses, and finished product as CCP.

There are numerous types of foreign fragments detection appliances in food industry, operating on the base of different physical principles, among them: fluoroscopy (X-rays), ultrasound, radioactivity, optics, magnetism (both magnetostatic and variable magnetic force field). There are also a number of electrometric methods based on inductance, capacitance and electric

contact. Inductance appliances use industrial, sound and radio frequencies, electric contact detectors are of DC or AC operation [8].

Concerning CCP set at the different stages of meat processing, two technological operations are typical – reception of fresh or frozen meats and surveying prepared and ground meats before or during stuffing the sausage casings. These are important not only as food safety measures but also as guarding of meat grinders, mincers and cutters, namely their knives, and also adding longevity to sausage clippers. In the second case inserting detectors into the meat emulsion pipelines is practical [9, 10].

Figure 1 contains the scheme for the production of minced meat products with the corresponding metal detector [11]. In the layout of the CCP of the shop for the production of patties for burgers (Figure 2), at the end of the freezing tunnel, CCP5 is appointed at the post of a metal detector with an automatic device for removing ferromagnetic particles of 1.2 mm in size, non-ferromagnetic particles of 1.5 mm [11]. It should be noted that detection of metal fragments is the most technically developed operation. It is much more difficult to detect fragments of bones and nonmetallic materials. If the fragments of bones, sinews and cartilages are separated with sufficient probability by the use of desinewing wolves (meat mincers) and other appliances with the separation function (CCP4 in Figure 2), fluoroscopic detectors are required to detect other nonmetallic inclusions. The wide use of these devices was hampered by a high price, fluoroscopic detectors being then approximately 2.5 times more expensive than commercial metal detectors.

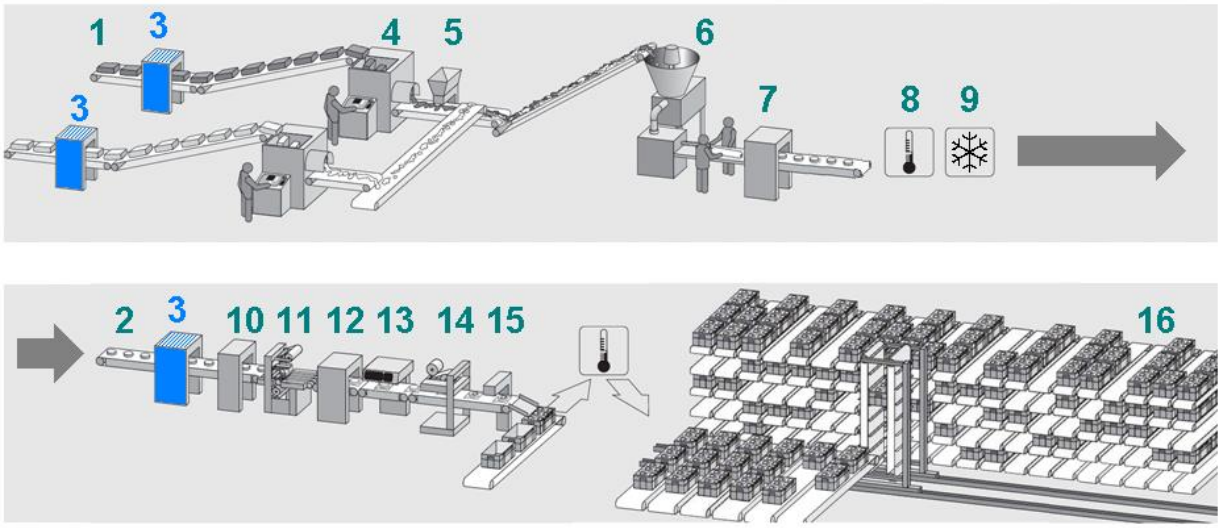

Fig. 1. Control of metal inclusions in the process of production of ground meat products: 1) feeding of frozen meat; 2) supply of fat; 3) metal detector; 4) grinding; 5) salting; 6) mixing; 7) forming; 8) cooling; 9) freezing; 10) optical control; 11) packaging; 12) packaging in film; 13) weighing; 14) labeling; 15) accounting; 16) storing [11]

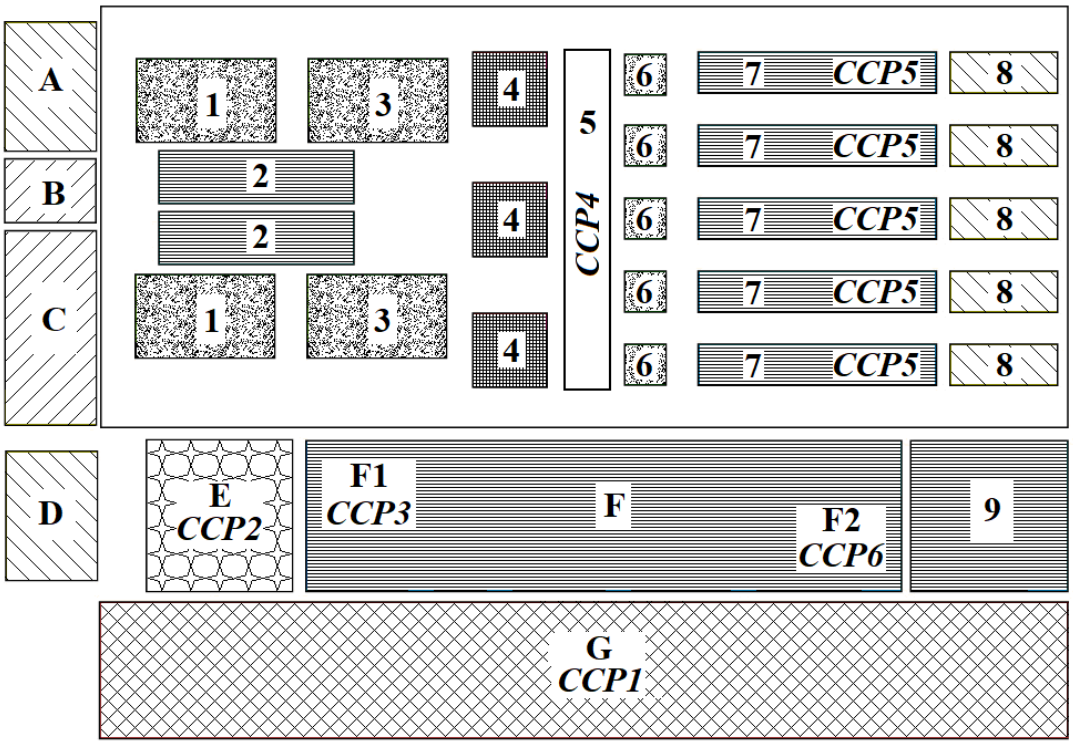

Fig. 2. CCP in a facility manufacturing frozen burger pattis. Processes:
1) grinding of raw materials; 2) grinding of frozen raw materials; 3) premixing; 4) mixing; 5) separation of bone remains; 6) forming; 7) freezing; 8) packing; 9) group packing. Premises: A) laboratory; B) washing; B) workshop; D) shower room; E) freezer; E1) frozen raw materials; E2) frozen products; G) ramp - acceptance of raw materials [12]

Detection and withdrawal of ferromagnetic inclusions from the stream can be carried out using permanent magnets, the effectiveness of these depending on their magnetic properties, the area of the working sector and the distance to the product flow, as well as temperature changes and the occurance of mechanical damages. HACCP plans necessarily provide for periodic verification of the effectiveness of permanent magnets, these shall be replaced in the case of a 10% or more declining of their magnetic force (adhesion). Electromagnetic metal detectors used at enterprises also need regular calibration, its performance depending on the signal strength, its nature, and also on the type of an object under inspection – especially at the packing post, where different products can be present. When the products being surveyed are transported by belt conveyors, the use of colored and antistatic conveyor belts that contain carbon or metal-based dyes both distorting the detector readings shall be avoided. These distortions are also likely to occur when the metal components of the conveyors, as well as the grounding elements, are not properly insulated.

Typical detectors of metal fragments (Figure 3), both ferromagnetic and non-ferromagnetic, are intended to work with materials such as fresh and frozen foods without packaging, as well as packaged products incl. those packed with metallized films. However, the latter packing material stipulates the necessity to use metal detectors adjusted specifically for the said type of packaging. A typical electrometric detector is provided with a metal casing in which an insulated coil is placed, and the opening designated for flowing a product is covered with plastic or other non-metallic material. The detection system, as a rule, consists of three coils: one generates a field that «illuminates» the particle, that is, it makes it possible to detect it, and two receiving signals indicate the presence of «illuminated» metal particles. In this case, the detection efficiency depends on the conductivity and magnetic properties of the objects being monitored. The voltage of the current on the receiving coils is very low (about 0.000001 V), and it is amplified in the processing module by a high-frequency amplifier, then the low frequency signal is modulated and digitized to inform about the presence of foreign objects and / or to instruct the actuator to remove a suspicious product from the stream.

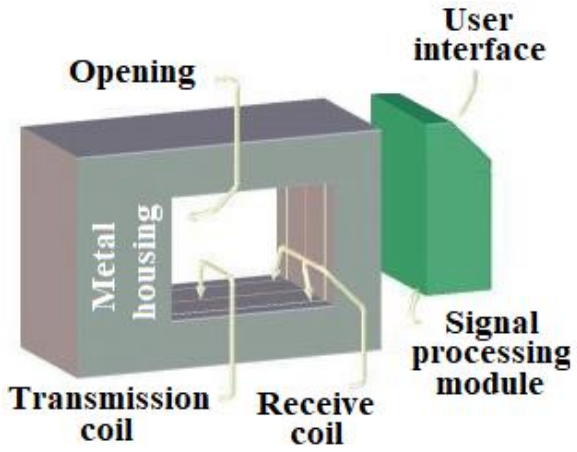

Fig. 3. Principal operation chart of a metal detector

Packing of foods with foils requires the use of detectors of a different design. In this case, a tunnel or portal is organized where all the ferromagnetic metal fragments are magnetized strong magnetic field. When passing through a group of coils, magnetized particles generate electric current that, after amplification in the detection unit, generates an output signal informing on the presence of foreign objects.

To remove defective units of production from the conveyor belt, various devices are used: straightforward pushers, pivoting pushers, air jets etc. The metal detection systems installed on the pipelines should be provided with an audible and visual indication of the operation of the withdrawing device. To ensure proper sensitivity, it is important to select detection units based on the properties and dimensions of the product and the packaging materials used. Metal detectors are not to be used at the highest threshold of their sensitivity, since operation in this mode will be unstable, and extraneous noise can cause false actuations. The data on typical sensitivity of detection units are summarized in Table 1.

Table 1

Sensitivity of metal detection units

Portal height	Dry product	Wet product	Wet product
	Ferromagnetic and nonferromagnetic	Ferromagnetic	Nonferromagnetic
No more than 50 mm	1.0 mm	1.5 mm	2.0 mm
No more than 125 mm	1.5 mm	2.0 mm	2.5 mm
No more than 200 mm	2.0 mm	2.5 mm	3.0 mm

In the best way the ferromagnetic fragments with strong magnetic properties and good conductivity are detected. It is simple enough to detect non-ferromagnetic fragments, since they have high conductivity. Often very poorly expressed magnetic properties and low conductivity are characteristic for stainless steel, its fragments are especially difficult to be detected in product containing a lot of water and salt, these being the substances that generate currents in the coils of the detector. That is why, for effective detection of fragments the sensitivity of a detector shall be 1.5 to 2.5 times greater than in the case of detecting fragments of carbon steels. The latter parameter is very dependent on the shape of the detected fragment and its position on the transport tape (Figure. 4). To minimize the negative consequences of the orientation effect, the detector shall be set to maximum sensitivity, or a device with two or three detection units shall be used (Figure 5). As a result, the probability of the fact that the orientation of the fragment would correspond to the position of at least one of the blocks increases significantly, and an extraneous object would be very likely to be successfully detected.

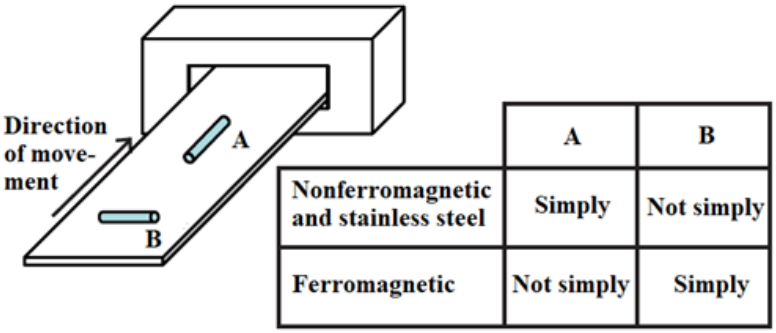

Fig. 4. Orientation effecting the efficiency of detection of metal fragments

Fig. 5. SAFELINE Profile metal detector with three detection units is intended to survey meat portions up to 25 kg. Manufacturer - Mettler-Toledo Safeline (UK)

Detectors based on the principle of X-ray techniques allow organizing a dynamic scan of the product at a conveyor belt speed of 90 m/min, which corresponds to 600 packs per 1 min, and foreign fragments are effectively detected in foil or sheet metal packages. Detectors of the type can detect bone fragments, are not so sensitive to the parameters of the environment and the controlled product, they are excellent at detecting fragments from such non-metals, but commonly met materials as glass, stone, bone, plastic, rubber, ceramics and etc. [13, 14].

On the other hand, X-ray detectors are ineffective in detecting fragments of low-density plastics, thin glass, low-density minerals, cardboard, paper, etc. The main components of the X-ray detector are an x-ray generator, a sensor for detecting inclusions, and a high-speed computer for data processing. While under the influence of high voltage, electrons hit the target, which creates an X-ray stream, which then focuses, passes through the product and enters the sensor. The sensor converts the signal and transmits it to the computer for processing. When passing through the product, X-rays lose some of the energy. If on their way there were a foreign inclusion, the density of which is greater than the product density, the energy loss would also be greater. The sensors are blocks of light detectors that accurately measure the energy of the radiation and convert it into an image in a gray scale. Fluoroscopic detectors are more universal and accurate than metal detectors, thus they are widely used in practice [15]. Some time ago the possibility to implement such appliances was constrained by their being extremely expensive as for the domestic meat processors. The situation has changed and today the appliances of the type become more frequent as important technical aids of HACCP plans for meat processing.

Conclusion. Developing and implementation of HACCP systems in the meat industry imply special CCP corresponding to physical hazards, such as structural elements of machines and mechanisms made of metal, glass, plastics, and other hard materials, since the fragments can pose a threat to the health and life of consumers in case of getting into the finished product, and, therewith, into the human body. Characteristic for meat processing factor of physical danger are also fragments of bone tissue formed as a result of the work of meat cutting equipment and met in ground meat products.

Thus, HACCP plans include checkpoints for metal or/and nonmetal detection in raw materials, intermediate masses, and finished product as CCP. Concerning CCP set at the different stages of meat processing, two technological operations are typical – reception of fresh or frozen meats and surveying prepared and ground meats before or during stuffing the sausage casings.

There are different methods of foreign fragments detection in food stuffs, based on different physical principles, among them: fluoroscopy (X-rays), ultrasound, radioactivity, optics, magnetism (both magnetostatic and variable magnetic force field). There are also a number of electrometric methods based on inductance, capacitance and electric contact.

Electrometric detection devices are the most practical as metal detectors but specific needs of meat processing cause the necessity to use detection appliances these being more universal and accurate than electrometric devices. The analysis made shows that for nonmetal inclusions, namely bone fragments, detection, fluoroscopic (X-ray) detectors are rational.

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