The service life of a glass furnace is determined by the operating time of its main components and especially by the condition of the furnace basin. The high temperature, flows of molten glass, aggressiveness of the environment, and a number of other factors lead to corrosion of the refractory blocks lining the basin during furnace operation. A timely check of the thickness of the furnace brickwork and appropriate preventive maintenance prolong the campaign and effect an appreciable economy.

At present there are no instruments for determining the condition of refractory materials in glass furnaces. The residual thickness of the block is determined by means of a metal hook inserted through the key course of the basin. However, this can be done only at a very limited number of accessible places. The key course has recently been eliminated on many glass furnaces in order to improve the heat insulation, which precludes the use of this method of checking.

There are a number of technical ways of solving this problem [1], for example, the use of various types of penetrating radiations and fields, including superhigh-frequency (SHF) radio waves, as an information source. The use of SHF radio waves has definite advantages which follow from the characteristics of SHF methods and equipment. The use of electromagnetic fields of this range meets such check requirements as contactlessness, localization, speed and accuracy of measurements, comparative compactness of equipment, and the possibility of conducting the check with a unilateral arrangement of the equipment relative to the object being measured. However, the end result is determined by how correctly the method was selected for solving a particular practical problem.

Fig. 1. Interaction of an electromagnetic beam with a flat dielectric layer.

The grades of refractories used in the brickwork of basins of glass furnaces can be referred to dielectrics with respect to their electromagnetic parameters in the SHF range. As a result of interaction with dielectrics, the SHF radio waves are partially reflected from the interfaces, partially refracted, propagating in a new direction, and undergo absorption and change of phase and polarization, thus enabling us to determine from the results of the interaction the characteristic properties of the medium and of the material itself and also the geometry and spatial arrangement of the investigated object. The use of the most advantageous interaction predetermines the method and apparatus for checking under industrial conditions.

An analysis of the problem stated with consideration of the requirements imposed on the checking process showed the expediency of using the laws of geometrical optics [2] as applied to radio waves of the SHF range. As a result, a geometrical method is proposed for checking the thickness of the lining, which in a spatial measurement is a flat layer transparent in the SHF range.

The essence of the method is as follows. In the case of an oblique incidence of a narrow light beam on an optically transparent layer of thickness h (Fig. 1), using the known law of refraction and having made...
simple calculations, we can express the thickness $h$ in terms of $a$, $n_2$, and $\theta_0$:

$$h = \frac{a}{\sin 2\theta_0} \sqrt{n_2^2 - \sin^2 \theta_0},$$

(1)

where $a$ is the shortest distance between the beams (rays) reflected from the front and back interface; $n_2$ is the refractive index of the layer material; $\theta_0$ is the angle of incidence of the beam of the layer being checked.

Information on the thickness is contained in the geometric parameter $a$, namely, in the distance between ray 1 reflected from the front surface of the layer and ray 2 reflected from the back surface of the layer. For the selected $\theta_0$ and constancy of $n_2$ we have a linear relation between the thickness $h$ and the quantity $a$, i.e.,

$$h = ka,$$

(2)

where $k$ is the proportionality factor.

Thus, the geometrical or ray method, while providing measurements of the absolute values of the thickness in a wide range of variations of $h$, does not depend on fluctuations of the signal amplitude, phase, or polarization and enables us to obtain data on thickness in the case of unilateral access to the object being checked.

The method is rather simple. In practice most nonmetallic media whose thickness must be determined are not transparent for visible optical radiation, but yet transmit and reflect radio waves in a certain frequency range where the formation of a beam with a narrow cross section is possible in principle but difficult in practice. It is known that the theoretical limit to which a beam of electromagnetic energy formed by any radiating antenna system can be narrowed is the wavelength. However, the selection of the wavelength of electromagnetic radiation in this case is limited by the transparency properties of the medium being checked.

Our calculations and experiments showed that with sufficiently small powers of the SHF sources (about $10^{-2}$ W) and sensitivity of the receiver-display devices of $10^{-9}$ W, we can check the thickness of refractory blocks within the following limits: up to 100 mm on an 8.6-mm wavelength; up to 190 mm on a 1.2-cm wavelength; and up to 500-600 mm on a 3.2-cm wavelength.

These data pertain to a check when the apparatus is located on one side of the refractory lining. In the case of an operating furnace the energy balance increases owing to the presence of a "refractory–molten glass" interface totally reflecting radio waves, since with an increase of the temperature of the glass its conductivity increases and upon reaching the melting point it becomes almost electrically conductive [3]. In the indicated range of wavelengths it is still possible to obtain quite directed electromagnetic beams with a small cross section. In the first approximation such a beam can be represented by three segments of a straight line to which the laws of refraction and reflection are applicable: a central ray coinciding with