The widespread use of the method of frictional surface welding in industry requires that the processing regime be worked out carefully. At the I. M. Gubkin Moscow Institute of the Petrochemical and Gas Industry, a set of experiments was carried out with the aim of optimizing the process regime in frictional surface welding. It was established that a minimum period for the surface welding process leads to a sharp increase in temperature in the zone of metal contact, up to the "flash" temperature, at which the temperature increase is of an "explosive" nature [1].

From metallographic studies of a bimetal consisting of steel 20 and BrAZh9-4 bronze,* produced by surface welding by friction with a rate of temperature increase in the metal contact zone of 30-40 deg/sec, it was shown that the microhardness of the transition zone of the bimetal was twice that of the steel base metal. Hence, with cyclic loading of such a bimetal, the transition layer, with greater hardness and brittleness, will serve as a concentrator of stresses, and ultimately as a source of premature loss of serviceability.

Thus, optimization of the processing regime in frictional surface welding must be directed toward maximizing the reliability of the bond between the metals. From an analysis of the operating conditions of a number of parts in oil and gas equipment that were subjected to bimetallization by frictional surface welding, it has been shown that one of the basic factors determining the life is the resistance to cyclic loads. Examples of such parts are shafts and bearings of submersible electric motors and centrifugal pumps, pins of the idler pulleys in OR-4 and OR-8 hoists, water pump shafts in KDM-46 and KDM-100 engines, and certain others.

The data of [2, 3], as well as our experimental data, point out the existence of a relationship between fatigue strength and the magnitude of the residual stresses. One of the most important processes in frictional surface welding is the heat treatment, as governed by the cooling regime, which determines the magnitude and nature of distribution of the residual stresses. The existing methods for experimental determination of residual stresses and fatigue strength limit are complex and time-consuming.

As shown by studies of the kinetics of breakdown of metal specimens in fatigue tests [2, 3], the main factor characterizing the ability of a specimen to resist cyclic loading is the degree of accumulation of residual deformations, which to a considerable extent determines the damping capacity and the magnitude of the damping decrement of free oscillations of the metal.

Considering that the character of the damping of free oscillations of metals will reflect most precisely any changes in their structural properties, we have proposed the use of an internal friction method to evaluate the influence of surface-welding process conditions on the reliability of the joints. This method will provide the needed information in the shortest possible time.

In order to perform the required experimental studies, we designed and built a special instrument— the RM-1 relaxation oscillator (Fig. 1). The instrument is intended for the measurement of internal friction, and also for conducting fatigue tests in torsion with massive commercial specimens (Fig. 2) 26 mm

*Steel 20 is a mild steel similar to 1020; BrAZh9-4 bronze is an aluminum bronze similar to B 30-54 No. 9A — Consultants Bureau.
The RM-1 relaxation oscillator (see Fig. 1) consists of a device for exciting oscillations in the specimen, with a set of radio-electronic components to register the vibrations. The oscillation exciting device is an inverted torsion pendulum, the torsion element of which is the specimen itself. The torsion pendulum oscillator is mounted on a heavy welded frame that is set on a separate concrete base.

The specimen is held in the grips, which are lock-wedge units that eliminate the possibility of slipping. For installing and replacing the specimens, the column supporting the specimen is lowered by means of a special hoist; here the crossbar that twists the specimens, made in the form of two tubular arms with ribs for rigidity, is fixed on the framework of the relaxation oscillator by support blocks. The specimen suspension system includes a counterweight to compensate the axial force.

The relaxation oscillator is equipped with a trisectional cylindrical furnace and a device for producing low temperatures, with temperature control blocks, so that the temperature dependence of internal friction can be measured over a range of temperature from −70 to +600°.

For "zero" correction of the specimen, the relaxation oscillator is provided with an optical system, which may also be used for visual counting of oscillations.

The initial oscillation amplitude is set by rotating the crossbar around the specimen axis by means of a pair of heavy-duty electromagnets with the power supplied either from line voltage (~220 V) through an autotransformer and heavy-duty rectifier for single-action loading of the specimen, or from a GZ-34 generator and TU-500 power amplifier for cyclic loading of the specimen.

The oscillations in the instrument are registered by two methods:

1) automatically (by means of an inductance pickup and a set of radio-electronic components) with strip-chart recording of the amplitude relationship in an EPP-09M potentiometer;

2) by strain gage, recording the damping vibrograms on the tape of an N-700 loop oscillograph.

In our studies, we recorded the oscillations by strain gages. The treatment and deciphering of the resulting vibrograms were carried out in accordance with a standard procedure [4].

Before test, the specimens were heat treated, using different cooling regimes – in air, in the furnace, and in water.

As shown by tests of these specimens for fatigue strength with cyclic loading by cantilever bending with rotation in a VU-3000 machine, their fatigue limit $\sigma_{\text{fatigue}} = 26 \text{ kg/mm}^2$ for the specimens heat-treated at 200°C.

For bimetallic specimens, the amplitude dependence of logarithmic damping decrement of free oscillations of specimens (steel 20 + BrAZh9-4), heat treated in different regimes ($\delta = \log_{10}$), $\tau = \text{tangential stress}$: 1) no heat treatment; 2) annealed at 950°C; 3) normalized; 4) quenched from 950°C in water.