AN AUTOMATIC BALANCE FOR MEASUREMENTS IN A VACUUM

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This paper deals with an automatic balance using an induction pickup and an automatic system of weight placement. The balance is intended to measure changes in material mass within a vacuum.

Remote-controlled measurement of mass loss in investigations into the processes of heat and mass transfer in the phase transitions and chemical conversions which occur under conditions of a vacuum is a particularly complex experimental problem [3]. The complexity of the problem lies in the need for continuous remote-controlled measurements of mass loss with high accuracy and reliability under the nonsteady conditions in which the processes take place.

The solution of this problem is sought through the development of various types of electronic attachments to an analytical balance.

Popov [1], in 1951, developed an improved balance system. The shortcoming of this system is its unsuitability for work in a vacuum and the comparatively low accuracy with which the system measures mass loss.

To measure the mass loss in a specimen under conditions of sublimation drying, in 1954 Verb [2] used a balance with tensometric sensors connected into a bridge measuring circuit. The shortcoming of this scheme lies in the fact that within the limits of elastic straining the change in the wire resistance in insignificant and commensurate with the change in resistance as a result of fluctuations in temperature, thus reducing measurement accuracy. In 1963, Karabanov employed his inductive remote-controlled balance to investigate the processes of heat and mass transfer in the presence of chemical conversions. The drawback of this balance involved the frequent adhesion of the plunger to the coil and the related difficulty of executing continuous and reliable measurements of the changing material mass.

Proceeding from the need to measure mass loss with an error on the order of 0.5%, we fabricated and operationally tested an automatic balance with an induction pickup and an automatic system of weight placement. The system was based on the ADV-200 analytical balance which covers the specified measurement range from 0 to 200 g. Figure 1 shows that portion of the automatic balance which is housed in a vacuum chamber. The balancing of the changing material mass is accomplished with a small pendulum couterweight 10. The remote-controlled transmission of the readings to a recording potentiometer is accomplished by the induction-pickup attachment. It is the design of this transducer and the manner of its attachment that represent the unique features of this balance. Coil 11 of the induction pickup with a rectangular inside orifice is attached to the balance in the position shown in Fig. 1. Plunger 12 is sickle-shaped. It is mounted on aluminum sector 13 whose shaft passes through the center of the plunger's inside orifice. This shaft is rigidly connected at its center to the middle of balance arm 14, and seated agate bearings 15 at its ends.

An induction pickup of this design makes it possible to avoid adhesion of the plunger to the coil and to define explicitly the plane of plunger motion within the coils, thus raising the reliability and speed of the measurements.

To raise accuracy and to improve the dynamic properties of the measurement circuit, we resorted to the principle of a balancing converter or feedback. The feedback includes the modulator and the mechanical system of the potentiometer indicator when we use a potentiometer in series production. Such a system raises measurement accuracy many times over and above that attainable in instruments without feedback [4].

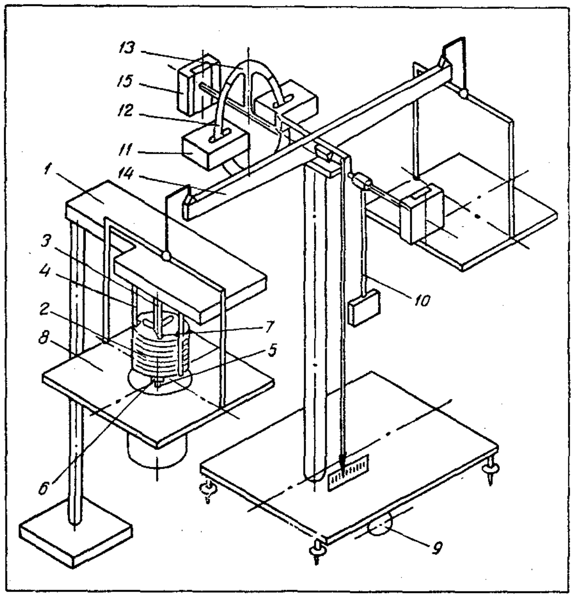

Fig. 1. Schematic presentation of part of automatic balance placed in vacuum chamber: 1) pitch selector; 2) weights; 3) steel axis; 4) generating lines; 5) steel holder; 6) arms of holder; 7) slits in weights; 8) balance dish; 9) catcher motor; 10) pendulum balance weights; 11) inductive coils; 12) probe plunger; 13) aluminum sector; 14) balance beam; 15) agate bearings.

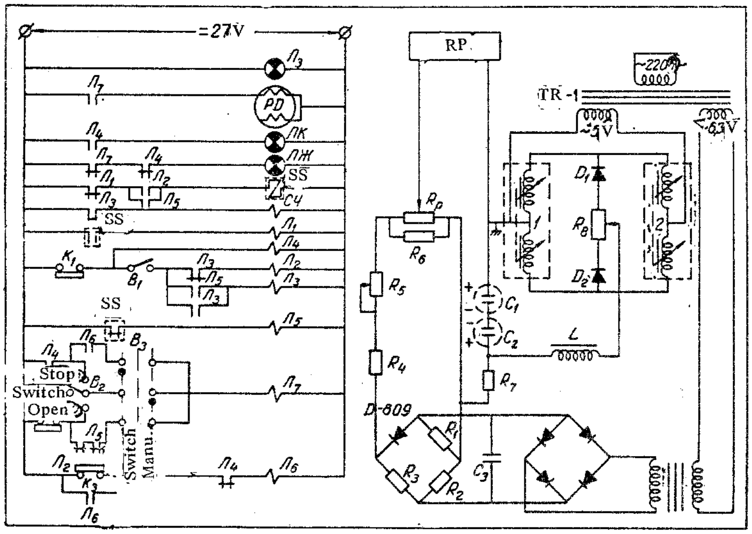

Fig. 2. Electfic circuits of automatic balance: measuring ciruit; b) system of weight placement.

The electrical circuit (Fig. 2) is made up of differential induction pickup 1 and controller 2, connected into a bridge circuit. An unbalance voltage is applied from one of the bridge arms through a rectifier and a capacitance-inductance filter to the recording potentiometer RP. The working current of the potentiometer, passing through slide wire R_p, is stabilized with diode D-809. The presence of a stabilizer virtually excludes any effect of voltage fluctuations within the circuit. Diodes D_1 and D_2 have to be thermostated to eliminate the effect of temperature fluctuations within the ambient medium on the potentiometer readings.

The shape of the plunger and that of the induction coils permits us to derive a linear relationship between the readings of the potentiometer and the changes in the mass of the load.

With the given electrical measurement circuit and the design of the balance we achieve a measurement accuracy of ± 0. 7% within the limits of the potentiometer scale.

To increase accuracy and to expand the measurement limits, we designed a system for the automatic placement of the weights.

The design for the induction pickup, as well as the measuring circuit, remain the same as before.

The mechanical weight-placement set-up is shown in Fig. 1. Vertical steel shaft 3 is attached at its upper end to the SS-17 step-by-step selector 1 mounted on a rack. Weights 2 can shift along guide rails 4 in the vertical direction and are restrained from such motion by means of steel holder 5 with three arms 6 set at an angle of 120° and mounted at the lower end of the vertical shaft. The weights, with three slits 7 set at angles of 120° to permit the passage of the holder at the instant that it lines up with the slits of the weights, are seated onto the vertical shaft each shifted through an angle of 180° relative to the other so that the angle between the slits in the bottom weight and the arms of the holder is 60°.

When the shaft of the step-by-step selector is turned through 60° (see Fig. 2a) the slits in the weight line up with the holder arms and the weight drops to the balance tray 8. On subsequent rotation of the shaft, the next weight drops, etc. The maximum power required by the step-by-step selector does not exceed 8 W. The weights are numbered, and their mass is determined with the required accuracy.

The operation of the automatic balance with an induction pickup and an automatic system of weight placement proceeds in the following manner.

The loss of the load mass is initially fixed by means of the recording potentiometer. As the needle of the potentiometer approaches the end of the dial terminal switch K_3 (Fig. 2) is actuated; this switch is mounted on the potentiometer. With a signal from the terminal switch, an electrical relay control circuit mounted on a separate console is switched on, and this circuit initially brings the balance to a stop by means of motor 9 mounted beneath the base of the balance; then the relay control circuit switches on the step-by-step selector turning the vertical shaft (which is attached to the selector) together with the holder through an angle of 60°, causing a weight to drop into the balance tray as a result and, finally, the relay control circuit removes the balance from the stop mechanism. The continued operation of the balance proceeds in cycles of this proceedure. Depending on the time involved in the process of material-mass loss, we can alter the weight of the pendulum couterweight so that the limits of the potentiometer scale vary from 1 to 10 g.

There must be a corresponding change in the mass of each of the dropped weights.

The number of dropped weights is determined with an electrical counter mounted on the console.

Consequently, at any given instant of time it is possible, quite quickly and accurately, to determine the mass loss of the load. The measurement accuracy in this case does not exceed ± 0. 7% of the limits of the potentiometer scale. The electrical relay control circuit for the placement of balance weights enables us to carry out the balance-stop and weight-placement operations both automatically and by remote control, i.e., manually, by means of switches. With the above-described automatic balance we were able to carry out numerous experiments in our investigation of heat and mass transfer in a vacuum.

The experiment showed that the automatic balance can ensure: 1) the attainment of a linear relationship between the readings of series-produced recording potentiometer and the changes in load mass; 2) the execution of measurements with high reliability, owing to the indicated design and the attachement of an induction pickup; 3) an increase in weighing accuracy, owing to stepwise changes in the limits of the potentiometer scale (placement of weights); 4) rather high speed and operational convenience, owing to the use of automated components.

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