THE FEDCHENKO CLOCK
by Myron Pleasure

IN the nineteen twenties and thirties, astronomers were intensely interested in pendulum clocks. The Shortt Free Pendulum had given them a tool which allowed for the first time the detection and measurement of irregularities in the rotation of the earth, and the scientific literature of the period contains many papers involving pendulum clocks, and attempts to improve on them. Had F. M. Fedchenko's isochronous pendulum clock appeared then, it should immediately have become world famous. So far as technology goes, there was no reason why the AChF-1 or the AChF-2 Fedchenko clocks could not have been made in 1920, or even earlier, when they might have caused a great sensation. In fact however, the AChF-1 clock was not announced until 1957, by which time quartz clocks were already superior. For this reason, Fedchenko's work seems to have been little noticed outside of Russia. The first published account of Fedchenko's clocks did not appear in western literature until 1970, when the October HOROLOGICAL JOURNAL gave a brief description, written by me. I am indebted to Dr George Feinstein, of Brooklyn, who first came across Fedchenko's work in the course of library research, and called it to my attention. Dr Feinstein has also translated some of Fedchenko's papers from their original Russian.

The Soviet scientific authorities did, however, become interested in this new clock, since the USSR was at that time still manufacturing its own version of the Shortt clock at the Etalon factory in Leningrad. Fedossov M. Fedchenko was transferred from his position at the Kharkov State Institute of Measures and Measuring Instruments to a new job in Moscow, at the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements. In Kharkov, Fedchenko's clocks had in 1955 hung on the wall of a simple basement room, no clock vault being available, and on the same wall, a storey higher, a motor and fan had added their intermittent vibrational disturbances. In spite of these handicaps, the AChF-1 succeeded in showing a stability to about 0.001 sec/day, which was twice as good as the Shortt clock, so Fedchenko was given the opportunity in Moscow to produce still better models.

In 1958 Fedchenko published a paper called "On the Isochronous Oscillation of a Pendulum". In this article, Fedchenko's straightforward methods of thinking are clearly evidenced, and he modestly discloses how he was led, in 1952, to propose his three-spring construction for an isochronous pendulum suspension because of his discovery, after many tests, that the isochronism reported by earlier experimenters could be repeated only when the bolts clamping the suspension springs were inadvertently left loose.

By 1956, Fedchenko's AChF-2 model clock had been completed; in it the gravity lever impulse to the pendulum was designed to be both quicker, and to vibrate the pendulum less. The temperature compensator, which in the AChF-1 had been in the rod, was shifted to a position under the bob. The bob was given a longitudinal open cut to expose the temperature compensator to the surrounding thin air, so as to achieve a quicker response time for the temperature compensation. Fedchenko's choice of copper for the bob material also shows attention to this requirement for quick thermal response response, since after silver, copper is the best heat conductor. A further unusual feature is the placing of the pendulum bob so as to rest on a fused quartz washer, so that its great thermal mass has no direct metallic contact with the invar rod or with its compensator. Despite these improvements, the AChF-2 clock still did not perform much better than the AChF-1, so Fedchenko proceeded to change the pendulum drive from the gravity lever to electromagnetic. This resulted in the present greatly improved AChF-3 clock which is shown in its steel cylinder housing in the photograph (Fig 1).

Figure 2 is a photograph showing the pendulum drive yoke which has two small pyramidal magnets facing one another. These are made of Magnico, a Russian alloy similar to Alnico V. The magnetic yoke assembly is attached to the pendulum below the bob, and the rectangular copper coils shown near it link the yoke when they are assembled. Two coils are wound in a single grooved form, which is held in a fixed position by a vertical invar bar whose upper end is fastened to the same bracket as is the pendulum. The two coils connect into the transistor circuit which is also visible in Fig 2.

Figure 3 shows a schematic diagram of the transistor circuitry. The pickup coil L1 has 2,000 turns of 30 micron (1.2 mill) wire, and the drive coil L2 has 1,900 turns of 50 micron (2.0 mill) wire.

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1See "Astronomical Clock AChF-1 With Isochronous Pendulum" by F. M. Fedchenko, in Astronomical Journal of the USSR Vol 1 (34) No. 4, 1957.

2This appeared in the 1958 Proceedings of the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements - "Measurement of Time". Edited by A. I. Konstantinov.

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3See HOROLOGICAL JOURNAL, October 1970, for drawings and explanations of the three-spring suspension. Note that in Fig 9 of that article, the dotted curve should not be shown passing through point B, since in general, it does not, and spring AC has no fastening at B.

4The photographs used as Fig 1 and 2 were provided by F. M. Fedchenko, to whom special thanks are due.
The pyramidal magnets create a sharply restricted transverse field which ensures that the transistor output pulse can occur only just as the pendulum is passing through its zero position. By choice of the yoke position, the transistor current pulse is made to occur in time with exact symmetry before and after the pendulum equilibrium position, so that the drive force will satisfy Airy's criterion for a zero escapement disturbance of the pendulum period. The transistor circuit itself is emitter coupled, using two germanium PNP types. The nominally 1200 ohm resistor is left external to the case, and can be adjusted to set the desired pendulum amplitude after evacuation of the enclosure. The power supply is at 1.4 volts, and the current drain is 0.2-0.3 milliamperes during the pulse, which lasts about 0.04 seconds, and occurs only for one direction of the pendulum motion. We can calculate from this an average continuous current of only about 5 microamperes, so that a single 2.5 A hour mercury cell supplies power for three years of operation.

In the design of the AChF-3 clock suspension, Fedchenko has given us an answer to the classical problem of circular error of the pendulum. This problem had been the object of 300 years of study by outstanding scientists, but Fedchenko’s is the first practical solution. Anyone studying this suspension must agree with the Russian academician, S. A. Kristianovich, who wrote, “F. M. Fedchenko’s isochronous suspension is technically extremely simple, but it is surprisingly ingenious and deep in concept.”

The suspension, however, is not the only important new solution to an old problem given us in the AChF-3 clock; the contactor is another. Users of pendulum clocks have long demanded some means of sharply defining the instant of each swing. The best solutions in the past have used cumbersome lamp and photocell devices, since the usual electromagnetic contactors would interfere with the pendulum’s motion. Figure 4 shows a drawing of the mechanical contactor devised by Fedchenko who wrote of it, “A light contact is fastened by thin springs 1 to the upper part of the suspension. When the pendulum moves to the right, the (contact) rod . . . is inclined to the angle of the pendulum; in displacement of the pendulum to the left . . . (the rod) rests on the contact stop . . . on the . . .


Fig 3. Transistor drive circuit AChF-3.

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contact coincidence, thus eliminating the possibility of harmful friction arising between the contact and the pin which deflects it. This kind of contact takes no energy from the pendulum, (apart from internal friction), since the energy expended by the pendulum in deflecting the contact returns to it in the reverse movement exactly as occurs in the suspension itself. The place of contact is closely adjusted to the equilibrium position of the pendulum, hence the contact cannot affect the period of the pendulum at all..."

To remain an honest critic, I must add to Fedchenko's statement here, and say that in my opinion the moving contact rod has a kinetic energy, some of which must be lost each time it falls to zero and hits its stop, although a part of the energy may still return to the pendulum via a distortion of its suspension spring. However, since the energy loss is small, and remains very constant, and since it occurs entirely at the instant of the pendulum's equilibrium position, clearly the pendulum's period should not be disturbed by the losses in this ingenious contact system.

In operation, it is claimed that variations in the clock pulses derived from this contact are only 10 to 15 microseconds, so that when these points are smoothed, actual times may be determined with much greater accuracy than this. Fedchenko has designed his own seconds-jumper slave dials for use in time indication. His remarkable contactor is a second important advance in clock technology for which engineer Fedchenko deserves to be honoured.

The AChF-3 clock is in mass production and is offered for export. The accuracy warranted for purchasers is that the RMS error of daily operation will not exceed 0.2 to 0.3 milliseconds. Previously published experimental curves did not show this clearly, and I wrote to Mr Fedchenko asking for some more recent data. He was kind enough to send me the curves shown in Fig 5, which were...
taken at the Pulkovo Astronomical Observatory near Leningrad. The smooth line for the year’s run of the AChF-3 clock is very satisfying. The Shortt Clock No. 50, which is also graphed, was listed by F. Hope-Jones in 1949\(^6\) as being at Pulkovo, and he, and Mr Shortt, might well have been proud to find their clock still at work in 1963.

Feodosii M. Fedchenko was, in 1962, awarded a large gold medal for his clock’s contribution to the Soviet economy, but he has not yet received any adequate recognition in the west for his pioneering work.