B&K Instruments, Inc.
Bruel & Kjaer Precision Instruments

application notes

B & K Field Balancing Set Working for the Power Engineer

DYNBAL and a pocket calculator speed up commissioning of Norwegian Hydro-electric Generator

Difficulties and delay are often experienced when commissioning hydro-electric plant because the initial unbalance of the rotating parts of the generating set proves tricky to eliminate by trial and error methods. The sheer size and mass of the generator rotor, together with the effects of the coupled turbine, make it important that field balancing be carried out — i.e., the complete set must be balanced in situ. Using suitable portable balancing instruments, such as the B & K Field Balancing Set Type 9500 (Fig.1), a task which might take weeks using conventional methods can be completed in a day or two. This was performed recently at one of the NEBB power stations in Norway.

The set to be balanced was a vertically-mounted 150-MW 200-tonne installation, with a Francis Turbine at the lower end of the shaft and a motor at the upper end (see Fig.2). The bearings were located at the top and bottom of the generator, and were separated by approximately 4 m (13 ft). The design speed for the set was 375 RPM. Provision was made for bolting on standard 10 kg weights for correcting unbalance in two planes through the rotor (Fig.3).

Unbalance in the rotor of a machine manifests itself as vibration, transmitted to the foundation via the bearings. The principle of the Portable Field Balancing Set developed by B & K is to measure the phase and magnitude of the vibration at each bearing, correlate it with the rotation of the shaft, and use this information to calculate the amount and position of the correction mass to be attached to the rotor in each correction plane.

The Balancing Set uses a pair of piezoelectric sensors to measure the vibration at the bearings. At the NEBB power station the sensors were mounted on magnets and positioned on the upper and lower bearing housings with their main axes of sensitivity horizontal, to measure radial vibrational motion (Fig.4). To provide a shaft rotation reference, a magnetic proximity probe was mounted adjacent to the main shaft on a bed of Plasticine. A high-permeability magnetic disc was taped to the shaft so as to activate the proximity probe once per revolution. The proximity probe and each of the two sensors were on different levels of the building, and long cables were needed to connect these monitoring devices to the Balancing Set.

To prevent any risk of damage to the generating set, the first stage of balancing was carried out at the reduced speed of 250 RPM. The set was run up, and the unbalance vibration velocity and phase were measured and recorded for each correction plane in turn. The set was then shut down, and trial weights

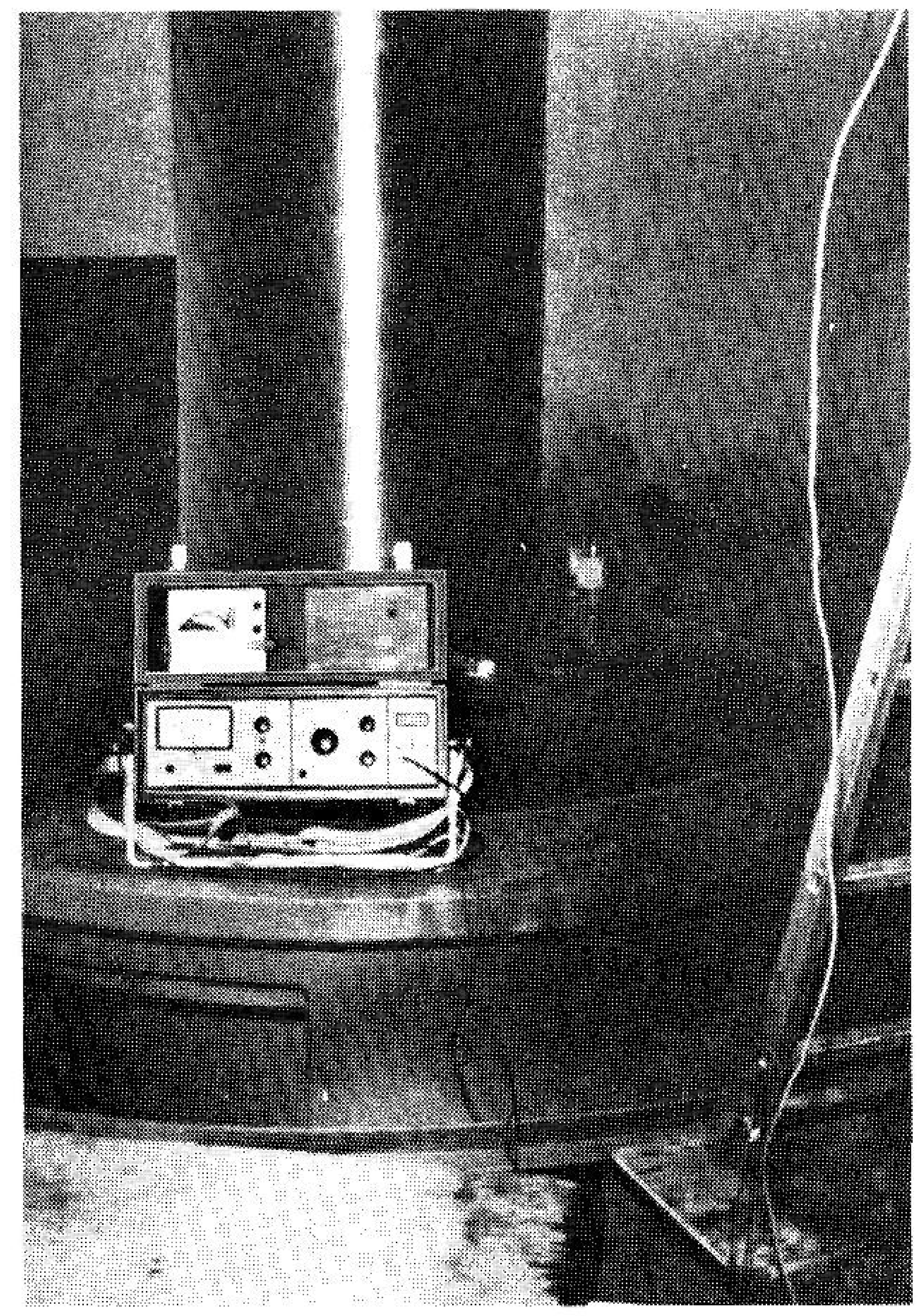

Fig.1. The B & K Portable Balanacing Set Type 9500, installed near the shaft of the generating set

added to each correction plane in turn, running the set up, measuring

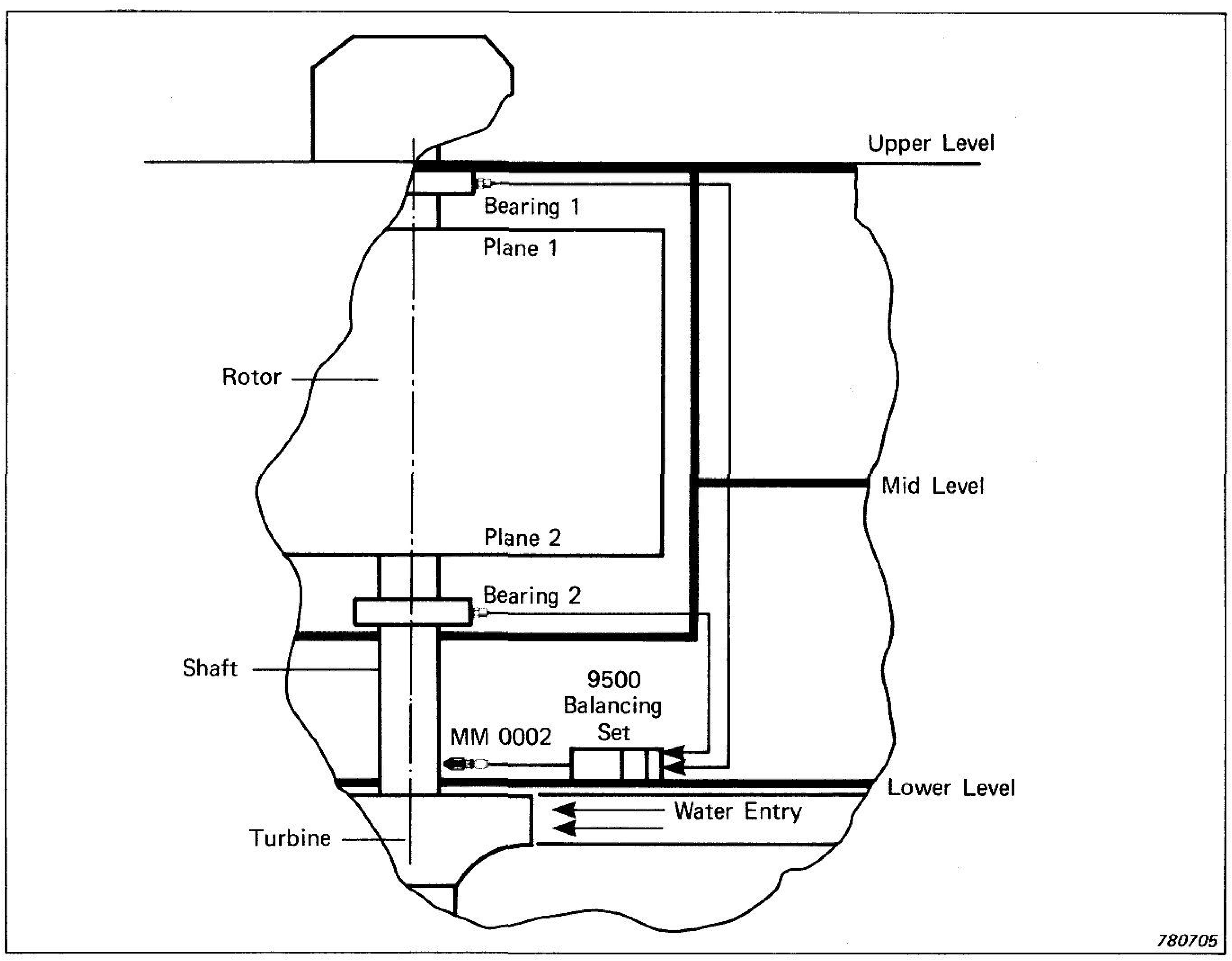

Fig.2. Cut-away drawing of the NEBB hydro-electric generating set, showing the relative positions of the equipment and the transducers used to perform the balancing operation

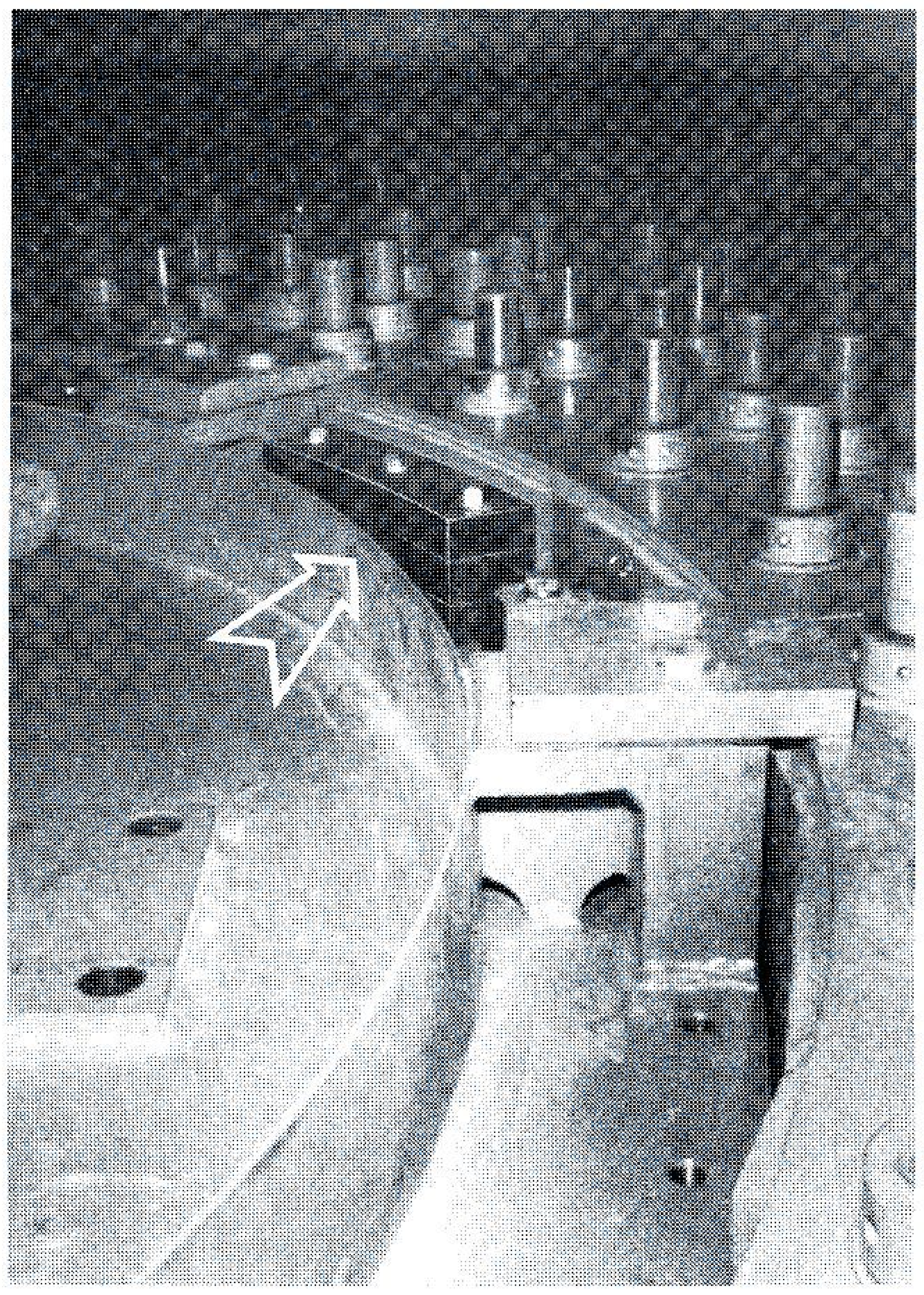

Fig.3. The top of the machine rotor, showing the unbalance correction weights in position for Plane 1

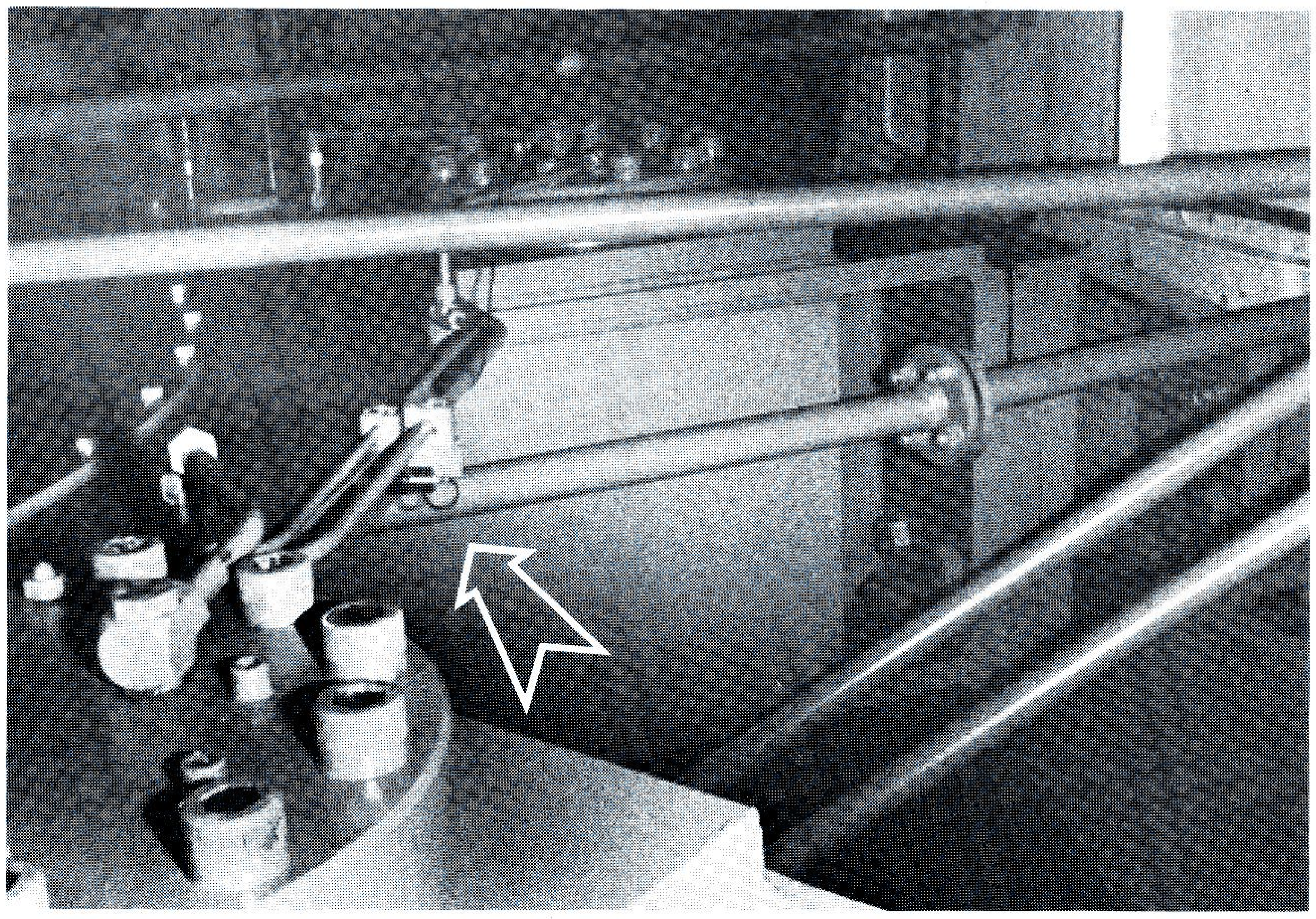

Fig.4. One of the sensors secured to a bearing housing

the effect, shutting down and removing the trial weight in each case. The initial measurement permitted approximate determination of the required correction mass, but not position. For this generating set 20 kg and 40 kg were used as trial weights.

The generating set was run up again, and the new values of phase and velocity were measured and recorded. These values made it possible to calculate the effect of a given correction mass at a given position in each plane; and thus calculate the actual masses and fixing positions needed to cancel out the unbalance measured during the first run.

All these calculations can be carried out on a programmable pocket calculator. B & K has a standard programme to calculate correction values, called DYNBAL. DYNBAL is accommodated on a single magnetic card for a Texas Instruments or Hewlett Packard calculator. The TI 59 was used to calculate that the required correction masses were 80 kg at the upper plane and 75 kg at the lower plane.

The calculated masses were added at the calculated positions, and the generating set run up again. Measurement showed a substantial reduction in unbalance — at the upper bearing, where the vibration had been more severe, the severity had been reduced from 0,45 mm s^{-1} RMS to 0,13 mm s^{-1} RMS.

It was now judged safe to run the set up to its design speed of 375 RPM. At this speed the sensors recorded as much vibration from other sources as from the unbalance components of the main rotor, so the narrow bandwidth of the filter incorporated in the Balancing Set was switched in, to filter out the most interfering vibrations.

The measurements of unbalance were taken at the higher speed, and then repeated with trial masses of 10 kg and 20 kg in the respective planes. A second calculation was made on the pocket calculator, and this called for correction masses of 32 kg and 22 kg in the upper and lower planes respectively. The generating set was shut down, some standard weights were divided to make up the total masses required, and the new correction made. When the set was run up again a considerable improvement was observed. The vibration severity at the upper bearing, which had been 0,53 mm s^{-1} at the higher speed, was now down to 0,18 mm s^{-1}, corresponding to approximately 5μm (0,2 thou) displacement. The permissible residual was 10μm. In fact the **overall** vibration level in the range 3-1000 Hz was now 0,8 mm s^{-1}, approximately four times higher than the component due to unbalance.

The B & K Portable Field Balancing Set enables the balancing operation to be performed under normal, as-installed conditions. The operation can be carried out quickly and systematically. This is a great advantage where high-cost capital equipment is being installed because it speeds up commissioning, minimises the risks of damage caused by initial unbalance, and cuts down charges for skilled labour. The Balancing Set incorporates a general-purpose vibration meter and a tunable filter as well as a phase meter so it is also useful for vibration monitoring, fault tracing, diagnostic checks, and on-condition maintenance of rotating machinery.

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