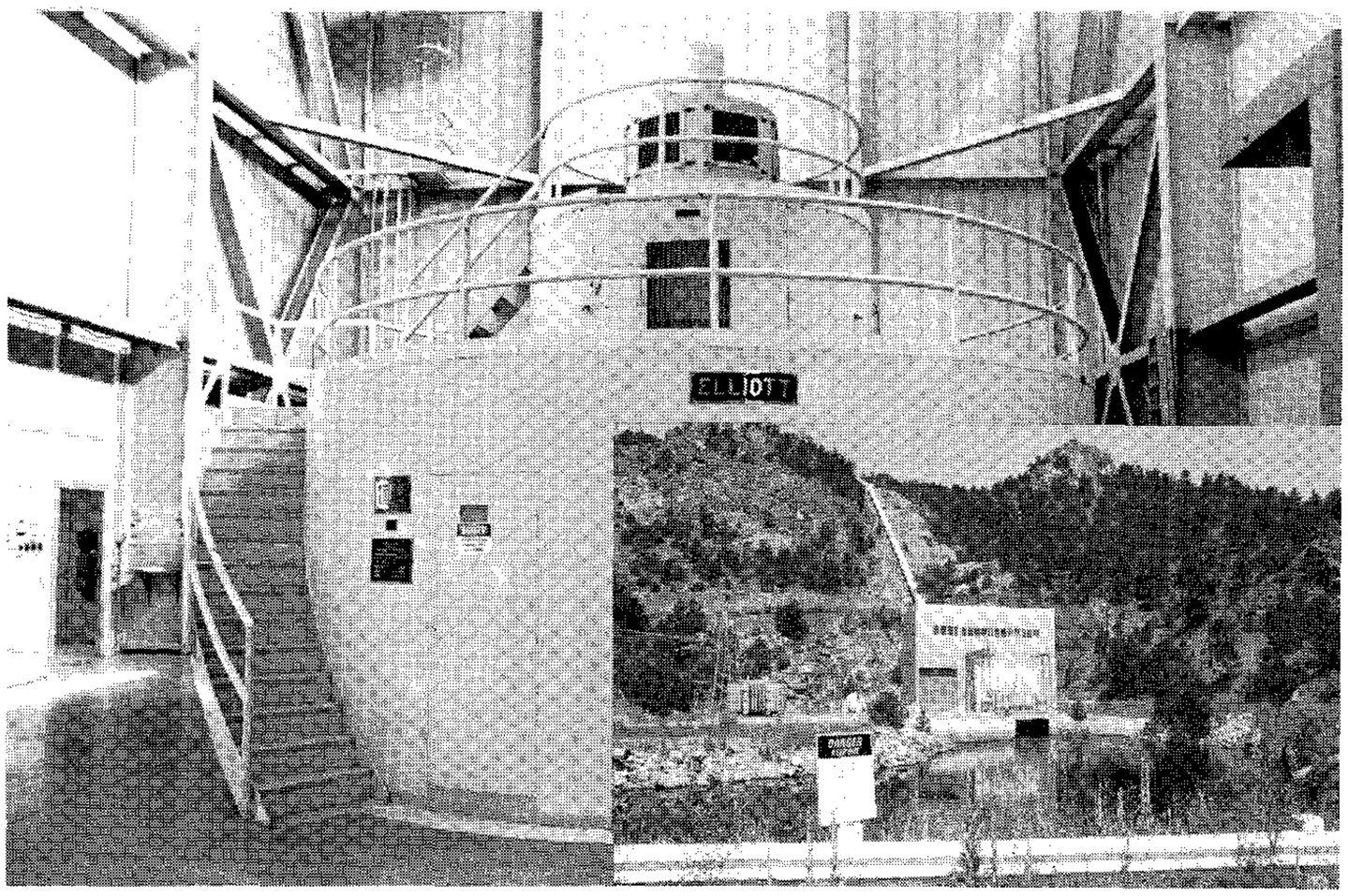
Application Notes

Permanent Vibration-monitoring on a Hydroelectric Generator Set

This Application Note describes a vibration-monitoring system in use at a North American hydroelectric power-generating station. The turbine and generator unit are permanently monitored using a 4-channel accelerometer based system. This system provides continuous surveillance of vibration levels, and can supply remote warnings and shut down the unit if problems arise.

Faults can develop quickly in a generator set of this kind sited remotely — hence the need for permanent condition-monitoring. Wear to the journal bearings and damage to the runner blades from corrosion or foreign particles in the water supply are the most likely problems.



The Pole-Hill 33 MW hydroelectric generating unit. The unit is located at a remote station in the Rocky Mountains, and permanent vibration-monitoring is essential to maintain a continuous check of machine condition

The Rationale of Permanent Condition-monitoring

The permanent condition-monitoring of hydroelectric power-generating units can be essential to protect these units against sudden failure. Fault development can occur very quickly, and many of these units are located in remote areas, making regular inspection difficult. A system that continuously checks machine condition, and can remotely indicate the onset of a fault and provide the possibility of automatic shutdown is therefore very necessary. This Application Note describes such a monitoring system in use at a North American hydroelectric generating station.

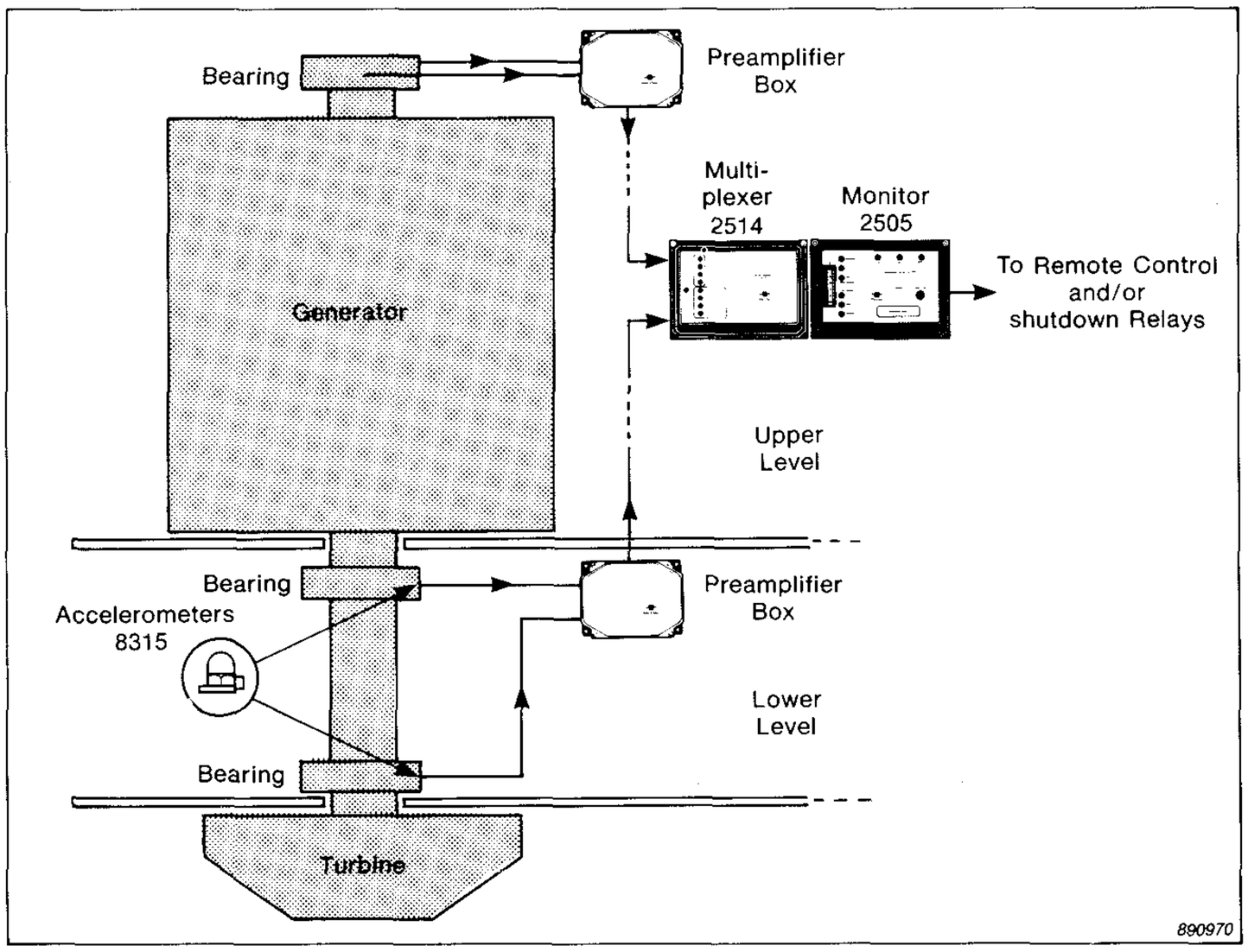


Fig. 1. Layout of the generator set showing the mounting position of the four accelerometers and monitoring instrumentation

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Pole-Hill Generating Station – The Rocky Mountains, Colorado, U.S.A.
The Bureau of Reclamation's Pole-Hill Generating Station was a prime candidate for a permanent monitoring system. The 33 MW generator is at an unmanned station, located at the foot of the Rocky Mountains someway from the central control station. The generator set had been prone to vibration problems and, in fact, one visit to the station revealed the set to be on the verge of a catastrophic breakdown. This prompted the decision to purchase a number of monitoring systems for the various generator sets in the region.

Monitoring the Generator Set

The monitoring system is shown in Fig. 1. To effectively monitor the condition of the generator set it was necessary to measure vibrations at each of the bearings, i.e. at the top of the generator, between the generator and turbine, and at the top of the turbine.

Vibration Measurement

Due to the nature of the installation, the vibration pickup had to be capable of long-term use in industrial environments. The Industrial Accelerometer Type 8315 chosen, is a robust, sealed accelerometer designed for permanent monitoring installations. It has a balanced isolated output for a low-noise signal. The accelerometer cable is a special double-shielded low-noise type to avoid noise interference and to provide mechanical protection.

Preamplifiers were used to provide transmission of the vibration signal to the control room via 150 metres of inexpensive signal-transmission cable. The preamplifiers are built into a special watertight junction box, and positioned close to the accelerometers.

Permanent Signal Monitoring

In the control room, the vibration signals are routed to a Multiplexer/Monitor system, shown in Fig. 2. Measurements are made cyclically, with each of the 4 channels being accessed automatically every few seconds to provide the surveillance of levels. The monitoring system, with its application defined filters and monitoring parameters, is well capable of detecting the rapid rises in vibration level that could be expected from the type of fault feared.

The Multiplexer Type 2514 automatically switches the input channels one at a time to the Monitor Type 2505, where the vibration levels are compared with preset vibration limits. If the vibration levels fall above or below the limits, a warning is given by an LED display, and built-in relays will trigger for connection to remote warning/shutdown devices.

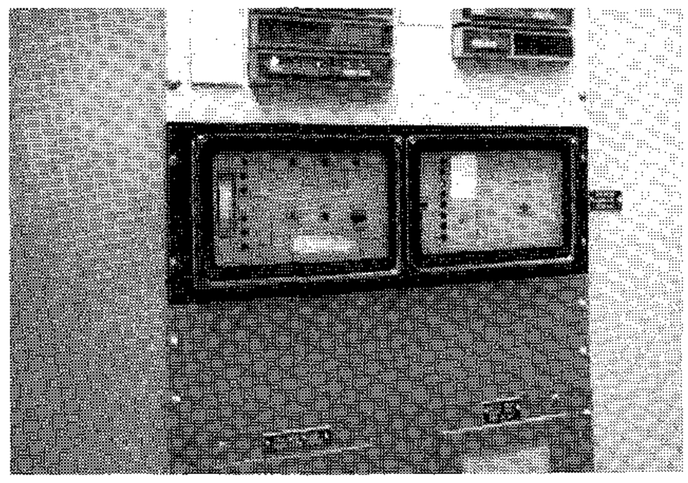

Fig. 2. The Multiplexer/Monitor system located in the local control room

What Type of Faults Can be Detected?

Unbalance and blade-damage could be expected to show up as vibration increases at the turbine's running speed and the blade-pass frequency. Therefore the monitoring system was set up to cover this frequency range.

To be certain that the right frequency range and the best vibration parameters to monitor were chosen, a vibration analyzer was first used to make a frequency analysis of the machine's vibration signal. Fig. 3 shows a frequency spectrum taken from the turbine bearing. The rotational speed of the turbine shaft is evident at 7,5 Hz (450 RPM), and the blade-pass fundamental at 97,5 Hz (the 13-bladed turbine gives a blade-pass fundamental frequency of $13 \times 7{,}5 = 97{,}5$ Hz). Oil whirl could be expected to show up at a little less than 1/2 the rotational speed. The frequency range chosen for monitoring, therefore, was 1 to 100 Hz with vibration velocity as the monitoring parameter.

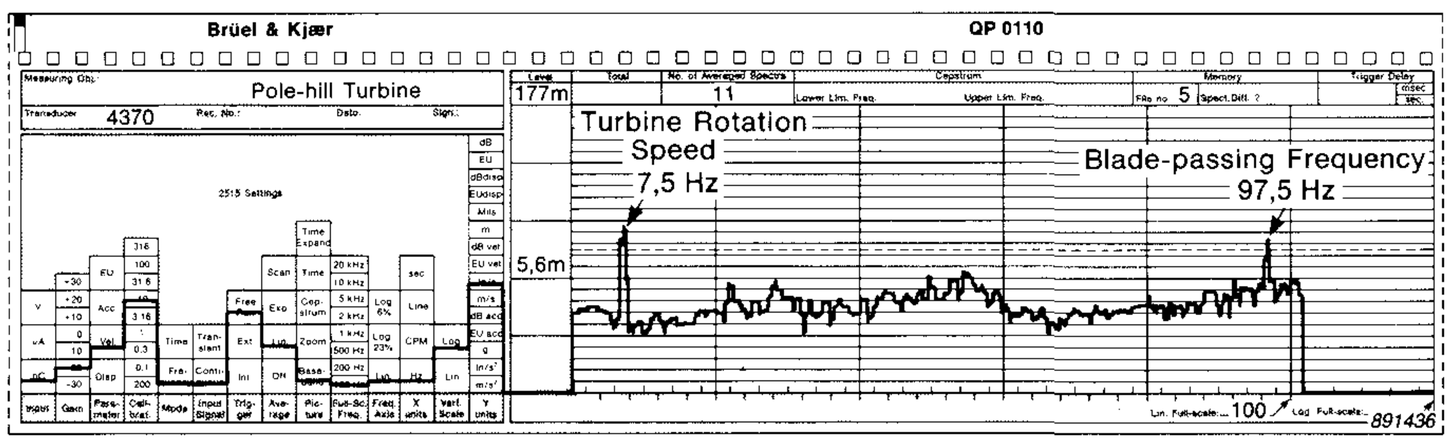

Fig. 3. A frequency spectrum recorded from the turbine bearing showing the rotational speed and blade-pass frequency

Operational Reliability

With expensive machinery like this hydroelectric generator operating at a remote station, the importance of the operational reliability of the monitoring system is paramount. Inaccurate readings and false warnings cannot be accepted. For this purpose the monitoring system is of sturdy mechanical design, capable of operating long-term in humid or dust-laden environments — environmental testing has been made to MIL standards.

The front-end ancilliaries of accelerometers, cables and preamplifier boxes are designed for "heavy" industrial use. The Monitor itself has a number of features to prevent false alarms: the alarms can be inhibited during machine startup; and vibration signals must exceed the limits for a preset time before a warning is given, to stop spurious signals from tripping the system.

Brüel & Kjær has over 20 years of experience with the permanent monitoring of hydroelectric power plants. Our monitoring systems have proven themselves more than capable of handling the task of long-term, remote, and reliable machine condition monitoring.

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