Penstocks are critical components with the dams and the turbines in any hydro-electric project. Their correct behaviour are fundamental for human beings and environment safety.

Instrumentation is used to accurately quantify certain parameters of structural behavior and to monitor their rate of change. It is possible to observe stabilization movement, or, in the case of acceleration, to deduce the possibility of failure. Seismic events and landslides are the two main external factors that may have an impact on the life of a penstocks.

ROCTEST is proposing custom monitoring solutions based on fiber optic technology and traditional vibrating wire sensors to monitor penstocks when the structure has been subject to specific damages.

References
- Nendaz penstock, Grande Dixence – Switzerland
- Malgovert – France
- Eygliers - France
- Rosone - Italy
- S. Antonio HPP, Bolzano - Italy
Typically the penstocks are not monitored during the construction phase or during the service, the monitoring plays an important role only when the damages occur. That doesn’t mean that this critical element is not controlled during its life span but it means that SHM solutions are not typically used.

The main inspections and controls (destructive and not destructive) to which the penstocks are subjected are:
- System history (on-site inspection and visual test)
- Dimensional Test (DT)
- Penetrant Test with liquids (PT), Magnetoscopic Test (MT), Ultrasonic Test (UT), Radiographic Test (RT) for welds and other elements
- Lab Test on material taken
- Hydrostatic Test

**TYPES OF PENSTOCKS**

The penstocks can be classified by construction’s material:
- Steel
- Reinforced concrete / Pre-stressed reinforced concrete
- Cast iron
- HDPE (High-density polyethylene)
- Glass fiber reinforced plastic

or by construction types and laying method:
- Surface penstocks are laid exposed and are supported above ground by saddle supports or ring girders supports.
- In tunnel
- Embedded penstocks in large mass of dam
- Buried

**TYPES OF MEASUREMENT**

The types of measurement and instrument location must be adapted to the type of penstock as well as existing geological and environmental conditions.

The main parameters to be measured are:
- 3D movements between saddle and conduit
- Joints relative movement
- Conduit dimensional variations - convergence
- Stress in lining segments
- Ground settlement
- Global movement

So typically the sensors used are:
- Fiber optic and vibrating wire strain gauge
- Fiber optic deformation sensor
- Distributed strain sensing cable
- 3D joint-meter
- Others no-contact sensors

Nonetheless, these are general indications, each project is unique and requires a specific instrumentation selection.

**AUTOMATED DATA ACQUISITION AND PROCESSING**

The collection and analysis of large quantities of data, especially over long distances, requires centralized and automated measuring techniques. Results are more accurate and data can be processed more rapidly thus enabling efficient alarm systems to be implemented when predetermined thresholds are exceeded.

Smartec has supplied and installed over thousands automated data acquisition systems. These remote monitoring systems enable efficient data management from networks of several hundred instruments.
Penstocks - Application Note

SURFACE PENSTOCK

Objectives
- Ensure integrity of the penstock

Measured Parameters
- Deformation of the structural components
- Ground settlement
- Monitor the movements among saddles, joints and conduit

EMBEDDED PENSTOCK

Objectives
- Monitor the integrity of the penstock
- Ensure stability in lining segments

Measured Parameters
- Stress in the segments (interior installation)
- Deformation of the joints

BURIED PENSTOCK

Objectives
- Detect the leakages
- Ensure the stability of the penstock

Measured Parameters
- Ground settlement
- Deformation of the joints
- Stress / strain in the conduit
- Leak detection

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Penstocks - Application Note

PENSTOCKS INSTRUMENTATION & STRUCTURAL HEALTH MONITORING

About Roctest

Roctest is the leading developer, manufacturer and supplier of innovative sensing technologies based on vibrating wire and fiber optic sensors for geotechnical and structural instrumentation.

We are featuring a complete line of conventional sensor-based solutions ranging from the ultra-robust traditional vibrating wire technology to state-of-the-art fiber-optic technology used for the measurement and monitoring of geotechnical projects and structural health monitoring (SHM) of critical assets such as: dams, tunnels, mines, buildings, bridges, nuclear power plants and many other structures too numerous to list.

Roctest offers a wide range of pressuremeters, rock dilatometers, laboratory and in-situ testing equipment for soil and rock.

Application Notes Available

- Dam Safety and Monitoring Instrumentation
- Bridge Instrumentation and Rehabilitation Monitoring
- Dam Safety and Monitoring Instrumentation
- FO Leak Detection for Dams and Dikes
- FO Leak Detection for Gas & Toxic / Flammable Liquids
- Geotechnical and Structural Monitoring
- Historical Monuments Instrumentation
- Nuclear Power Plants Instrumentation
- Storage Facilities Instrumentation
- Mine Instrumentation
- Tunnel Instrumentation
- Cliff Instrumentation
- Penstocks