UNLINED PRESSURE CONDUITS - used in hydropower plants

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RockMass as

An unlined pressure conduit is a tunnel or shaft, which is not lined to withstand internal water pressures. As most rock have a very low permeability, water migrates into or out of a tunnel depending on the relation between natural ground water pressure and the pressure in the tunnel. Lining for rock support purpose is applied as necessary in sections having poor stability; average length of such linings very seldom exceeds 5% of total tunnel length. Possible pervious zones encountered during tunnelling are sealed by cement grouting to reduce possible loss of water.
The following conditions are important for a successful solution:
– Low permeability of the rock material.
– Low permeability or conductivity of the joints and fractures.
– Virgin stress sufficiently high to prevent development of fractures or jacking along existing joints.
– Physically and chemically stable rock masses.

The early Norwegian hydropower plants were designed with a horizontal headrace tunnel and a penstock on the surface as shown in Figure 1. Unlined water tunnels and shafts with pressures of any significance came into use in Norway at the end of World War I in 1919. After the first four shafts were built, no unlined pressure conduits were constructed until the mid fifties. From then on, a number of shafts with steadily increasing pressure on unlined rock have been constructed (Figure 1). Starting in the seventies, the shafts were often replaced by inclined pressure tunnels supplied with unlined air cushion chambers in rock. The common layouts of shafts and tunnels are shown in Figure 1. The choice of the actual layout is dependent upon topography, access and the need for secondary intakes. The application of air cushion surge chambers for the unlined pressure tunnels is a further development in the hydropower design and construction.

The design principles used for the first shafts are not known. In the fifties, several simple overburden criteria were developed, having the common goal that the water pressure should be less than the minimum principal rock stress. The assumption was that this stress was the vertical stress (or a stress component with some angle to the vertical), depending on surface slope or shaft inclination. The design was done long before reliable stress measurement techniques were developed and accepted. Hence, the design had to be based on theoretical considerations and certain assumptions.

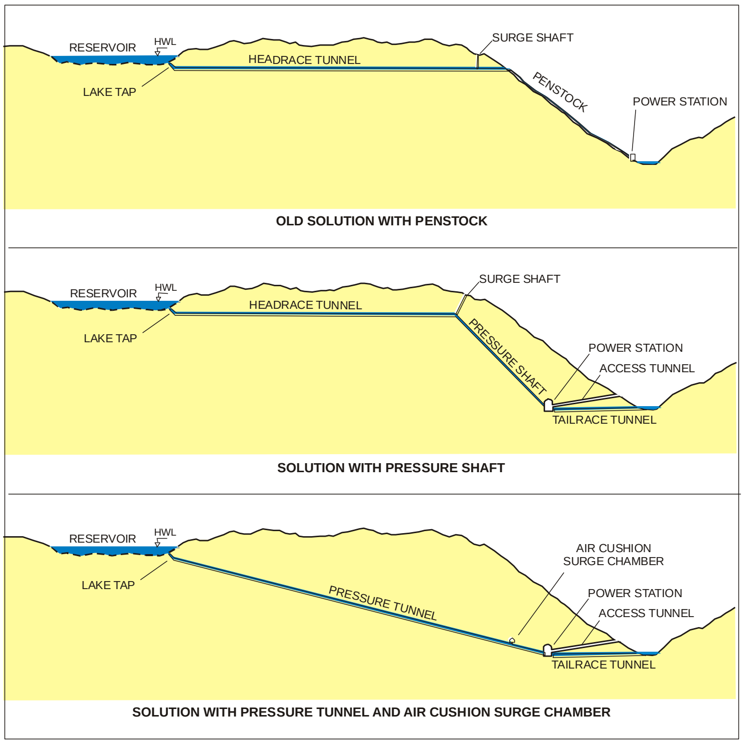

FIGURE 1. DEVELOPMENT IN DESIGN OF UNLINED PRESSURE CONDUITS

Later, in the seventies, a finite element model was developed and complimented by design charts. One limitation of these charts was that they are based on occurrence of high horizontal stresses (which is common in Scandinavia).

In the 1990s, powerful numerical analyses for computers were developed and refined. After these new and more precise design tools came into use, problems with failures seem largely to have been overcome. The increasingly common practise of checking the design values by in situ stress measurements (of increasing better quality) has contributed to the successful construction and operation of a number of high head conduits and air cushion surge chambers in the late seventies.

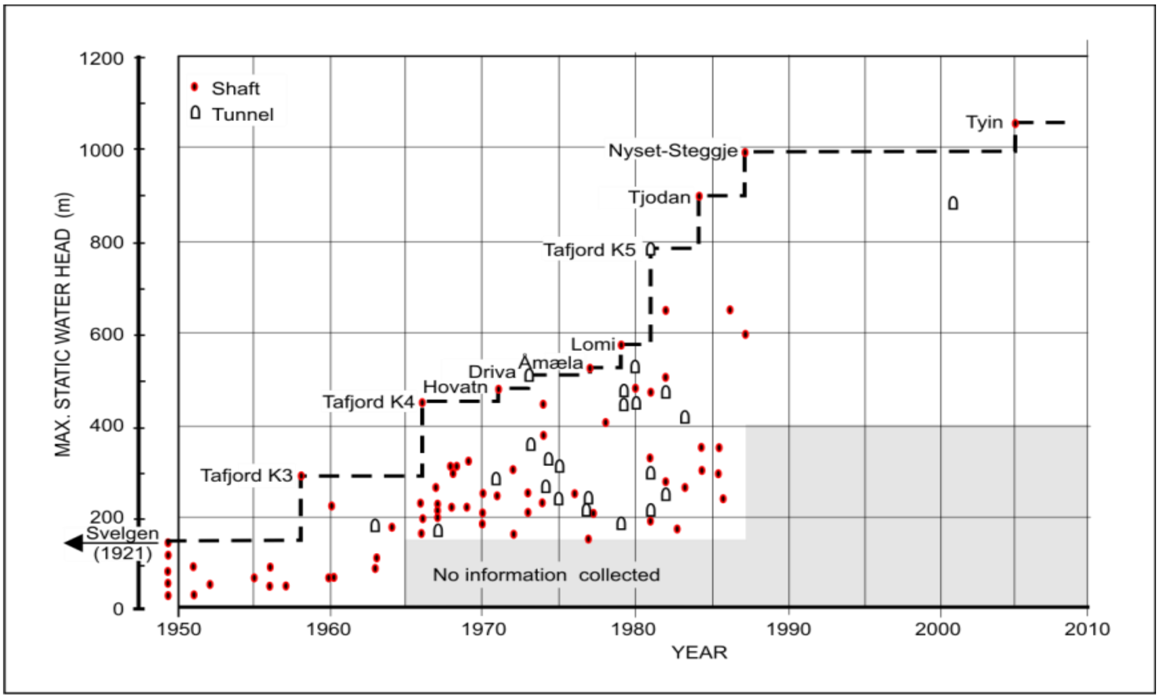

FIGURE 2. THE DEVELOPMENT OF UNLINED PRESSURE CONDUITS IN NORWAY

The main benefits using pressure shaft tunnel or pressure tunnel are:
- No expensive lining (except of the last 20 – 50m steel lining).
- Reduced number of construction adits.
- Shorter tunnel system.
- In addition, for pressure tunnels: shorter or no expensive shaft construction.

These features result in significant reduction in construction costs and often also shorter construction time for the hydropower plant.

The highest static head on unlined rock today is 1050m for the Tyin power plant (see Figure 2), constructed in 2004. The total length of unlined pressure conduits in Norway is not known exactly, but is estimated to exceed 2000 km.