ABB Hoisting Equipment for the Transalpine Gotthard Base Tunnel

By the year 2011 railway passengers will be able to travel by high-speed trains from Zurich to Milan in as little as 2 h 40 m and, later on, 2 h 10 m. This will be possible once construction of the new TransAlpine Railway Axis in Switzerland has been completed. The line will include three major tunnels, the Zimmerberg, Gotthard and Ceneri BaseTunnels.

Construction of the 57-km-long Gotthard Base Tunnel, which will be the world's longest railway tunnel, has commenced. Simultaneous heading operations are taking place from five points. Two sets of ABB mine hoist equipment have been installed at Sedrun, roughly in the middle of the tunnel route, for transporting excavated rock, tunnel and railway infrastructure material and people.

Hoisting systems

In May 1999 a consortium comprising Siemag Transplan GmbH and ABB was awarded a contract by AlpTransit Gotthard AG, a subsidiary of the Swiss Federal Railways (SFF), for the supply of a cage hoist and a service hoist.

Commercial operation of the two hoists (see Table 1) started at the end of 2002. ABB was responsible for the engineering and supply of all the electrical and control equipment, while Siemag Transplan built the mechanical parts of the two hoists. Once the tunnel construction has been completed, the service hoist will be retained for service and maintenance purposes.

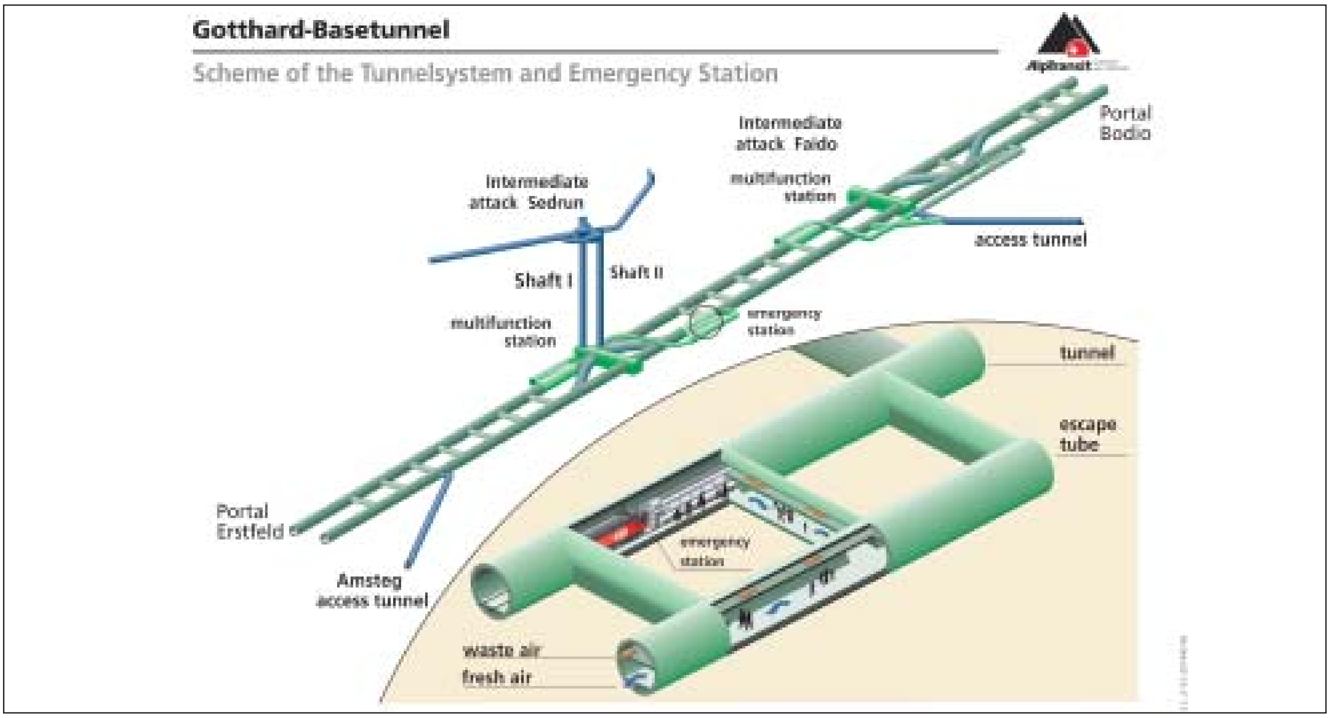
No decision has so far been made about the future of the cage (main) hoist.

Hoisting system parameters

The cage hoist is a 4-rope friction unit with a 4.8 m pulley, cage and counterweight with a capacity of 38.4 t. In addition to hoisting excavated rock, it is being used to transfer roof support and other material to the tunnelling level. The cage hoist's drive system consists of an ACS 6000 SD system with an AMZ 2000 KK16 synchronous motor. The service hoist is a drum unit with a 2 m drum and is driven by a 270 kW DC motor. With a capacity of 1.6 t, the drum hoist will be used mainly to transport people.

There is no headframe, because both mine hoists with their associated electrical and control equipment have been installed underground. Access to them from the ground site is via a horizontal 1 km tunnel.

Excavated rock material is removed from the headings by train. Some of this material is crushed and used for making concrete aggregate. The remainder is dumped into a loading station, at the bottom of the 800 m shaft. Here, the material is loaded into special cars, which are raised to the surface in the two-level cage at a speed of 16 m/s. At the top of the shaft the cars are dumped and the material is transported via the access tunnel to the ground site.



Plan of the Gotthard Base Tunnel system at Sedrun

In the foreground, the production hoist with a pulley diameter of 4.8 m and, in the background, the service hoist

Electrical equipment

Synchronous motor drive

ABB has been supplying electrical drive systems to the mining industry for over a century and consequently has comprehensive experience in this industry. The very earliest drive systems were based on 3-phase slip-ring motors with resistor banks that provided only limited speed control. Later, they were superseded by DC drives with Ward-Leonard control, which offered greatly improved speed control. Further improvements of variable-speed DC drives came with the introduction of thyristor converter technology. The development of power electronics, analogue and digital distributed control systems (DCS) and open control systems (OCS) led to the renaissance of variable-speed AC drive systems. From the 1980s AC drive systems with cycloconverters were more and more widely used for mine hoists.

The most recent AC drive system introduced by ABB is the ACS 6000 SD medium-voltage AC synchronous motor drive with direct torque control (DTC). It provides 4-quadrant operation and has an output frequency of 0-75 Hz at a voltage of 3,150 V and a current of 1,650 A.

ACS 6000 SD is used together with AC synchronous motors with outputs up to 27 MW. Besides mine hoists, typical applications are to be found in the pulp and paper, steel and chemical industries. The power circuit of the new drive system uses the IGCT (Integrated Gate Commutated Thyristor), a high-speed switching device. The IGCT is a redesigned GTO thyristor and represents a significant development in power semiconductor technology. ACS 6000 SD has six identical power phase modules with IGCT and diode power semiconductors.

Compared with cycloconverters, ACS 6000 SD has a number of advantages:

- No fuses or DC breakers are needed in the power circuit due to the high switching speed of the IGCT.
- Smaller footprint.
- Higher efficiency, ~98%.
- Both the drive system and the motor work on unity power factor.
- ACS 6000 SD does not consume any reactive power and therefore the transformer power rating will be only 50 per cent of that of a cycloconverter drive system.
- Low voltage fluctuations on the supply network, only 20 per cent of those of the cycloconverter. The mine hoist can consequently be connected to a weaker power supply system.
- ACS 6000 SD generates only a low level of harmonics and therefore does not normally require any filters. In principle, all harmonics below the 25th are eliminated.
- ACS 6000 SD has a response time that is up to ten times faster than that of a drive with a control system based on flux vector or PWM technology.

Hoist control desk

The 4,176 kW synchronous motor for the cage hoist

Another important feature of ACS 6000 SD is the use of Direct Torque Control (DTC). This is an optimum motor speed control method for AC drives with a very fast response to process changes.

Main features of DTC include:

- Control of both the speed and the torque of the motor.
- Stator flux and torque are the primary control variables.
- High starting torque and speed control at low speeds.
- High-speed digital signal processing using ASICS (Application Specific Integrated Circuits).
- Optical fibres for data transmission.

The first ACS 6000 SD drive system supplied by ABB for mine hoists has now been in operation since July 2001 at the Pyhäsalmi copper/zinc mine in Finland. Reliability and availability tests performed by ABB at the mine demonstrated that, for example, the total availability of the complete hoisting system was 99.7 per cent. Since the start-up of the cage hoist at Sedrun, reports show that it, too, has been performing very well.

The synchronous motor for the cage hoist at Sedrun is a 16-pole machine with a rating of 4,176 kW, 3,150 V, 0 - 8.4 Hz and a speed of 0 - 63 r/min. It is directly coupled to the mine hoist pulley without any gearbox. Both the motor and the converter have water cooling.

Hoist control system

The control systems of the two mine hoists at Sedrun are based on ABB's Control^{IT} and Operate^{IT} products. They provide powerful, user-friendly systems built up around the AC 110 process controller and a DC-based station for the HSI (Human-System Interface). With the help of Advant software, AdvaSoft, the hoist control systems optimize cycle times and production, thereby raising production and reducing maintenance. Operation of the cage hoist is fully automatic, while pushbutton control is used for the service hoist. During maintenance work, the cage hoist can be operated manually from the control desk in the underground control room. Safety functions are subject to semi-automatic testing.

Advant Hoist Monitor AHM 110

The electronic digital Advant Hoist Monitor AHM 110 is primarily intended to monitor and protect the mine hoists at Sedrun. It provides very accurate monitoring of the mine hoist parameters such as speed, acceleration, retardation, and conveyance position. AHM 110 initiates an emergency stop in the event of, for example, overwinding and overspeed. Operation of AHM 110 is completely independent of the hoist control system. A separate pulse generator that is driven directly by the hoist pulley/drum provides the speed and conveyance position information. AHM 110 has both analogue and digital inputs and outputs.

ACS 6000 SD drive for the cage hoist

Table 1. General data of the mine hoisting systems at Sedrun

	Cage hoist	Service hoist
Shaft diameter	9.0 m	9.0 m
Shaft depth	800 m	800 m
Net load	38.4 t	1.6 t
Design speed	16 m/s	4 m/s
Pulley/drum diameter	4.8 m	3 m
Drive system	ACS 6000 SD	DCS 600
Motor type	Synchronous	DC
Motor output	4,176 kW	270 kW
Motor voltage	3,150 V	410 V
Motor frequency	0 - 8.4 Hz	
Motor speed	0 – 63 r/min	1,085 r/min
Cooling	Water	Air

A display unit with digital keyboard is mounted on the front of the monitor to provide the operator interface. It is used to set the hoist parameters and present set and actual values. In addition, AHM 110 serves as a fault logger.

Multiple Check Point Hoist Monitor, PHM

The Sedrun mine hoists have been designed to comply with the German safety regulations (TAS), which are among the most stringent in the world. As a complement to the Advant Hoist Monitor, ABB has therefore included a specially developed Multiple Check Point Hoist Monitor (PHM). Based on switching relay technology, PHM includes a tachogenerator for measuring the hoist speed and 12 magnetic shaft limit switches, with six at the bottom of the shaft and six at the top. PHM provides both speed protection and point-based position monitoring.

General background

The introduction in 1981 of high-speed trains in Europe marked the beginning of a new era in passenger railway traffic. Over the past 20 years the European high-speed railway network has expanded rapidly. By 2005 it will have a total length of 6,000 km. This will result in a greater integration of national railway systems and increased cross-border traffic. Travel times on the existing St Gotthard line between Zurich and Milan today are 4 h 15 m for express trains and 3 h 40 m for high-speed trains.

Up until now, transalpine goods traffic in Switzerland has been predominantly by road. Between 1970 and 1998 goods traffic by road has increased by 1,150 percent. Goods traffic by rail, on the other hand, has grown by only 37 percent over the same period of time.

If the transport of goods by road continues to increase at the same rate, this will have a catastrophic impact on the quality of life and the environment.

The shortest transalpine route between, for example, Germany and Italy is via Switzerland. The existing St. Gotthard line built 120 years ago is quite simply unable to cope with this growth in rail traffic.

The Swiss government has been studying this development for a number of years, giving priority to the north-south axis. With a new TransAlpine Railway Axis it has been estimated that the annual freight traffic can be increased from 20 Mt today to 52 Mt.

When the AlpTransit line is completed, high-speed tilting passenger trains will run at a speed of 200-250 km/h, cutting the Zurich-Milan travel time to 2 h 40 m (stage 1) and, later, to 2 h 10 m (stage 2). In addition, rapid freight trains will be able to run at a speed of 160 km/h as against 100-120 km/h for traditional freight trains. With the new AlpTransit line it will also no longer be necessary for freight trains to stop to allow passenger trains to pass.

Four major projects involving a total investment of around CHF 30 billion have been planned. One of the goals is to integrate the Swiss railways into the European High-Speed Railway Network.

Another is to improve cross-border mobility, another to provide sound insulation along existing lines.

The AlpTransit Project and the Gotthard Base Tunnel

The AlpTransit line includes three major tunnels, the Zimmerberg Base Tunnel (20 km), the Gotthard Base Tunnel (57 km) and the Ceneri Base Tunnel (15 km). At its northern end, close to Zurich, the Gotthard Base Tunnel is linked to the Zimmerberg Base Tunnel. The southern end is connected, via the Ceneri Base Tunnel, to Lugano.

The Gotthard Base Tunnel will have a flat trajectory with a maximum height of 550 m above sea level, as against over 1,150 m above sea level of the existing St. Gotthard line. This will also reduce the length of the line by 40 km.

There will be two single-track lines in the twin-bore tunnel, which will greatly improve the safety by eliminating the risk of head-on collisions. Connecting evacuation galleries between the two lines will be located every 325 m along the tunnel.

To speed up the construction of the tunnel, the heading operations are taking place simultaneously from five points.

The different tunnel sections vary in length between 6.2 and 16.6 km. At the Sedrun intermediate heading, where the ABB mine hoists are installed, there is a vertical 800 m shaft. One of the two multi-function stations will be built here. This will accommodate parts of the tunnel ventilation equipment, track-crossover points and an emergency stop area. In addition, there is a 1 km horizontal access tunnel leading from the surface site to the top of the vertical shaft.

Two different tunnelling technologies are being used: tunnel boring machines (TBM) and rock blasting.

Loading station for the cage hoist at the bottom of the shaft

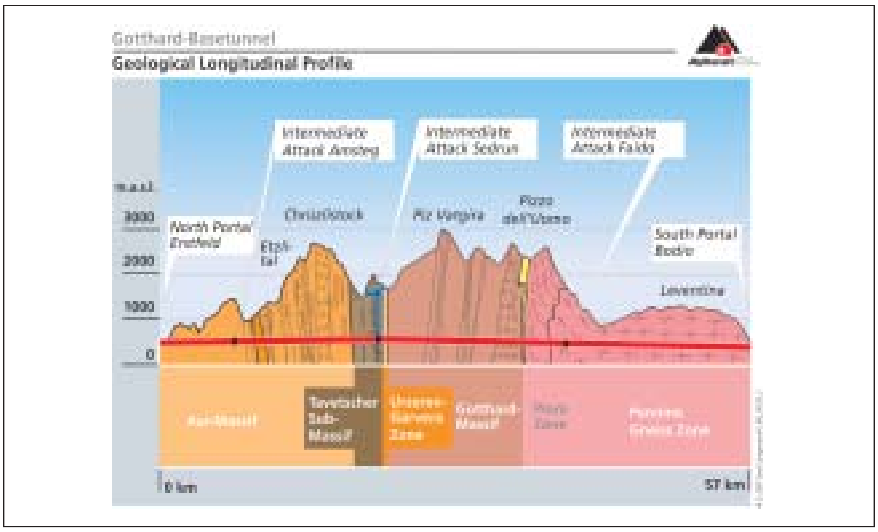
TBM technology is applied when the rock has a high quality. Rock blasting with drilling jumbos is applied when the rock quality is poor and geological faults are present. Around 30 people/shift are normally working at the headings, while the total number of people at Sedrun itself varies between 400 and 500.

An alignment accuracy of less than 1 cm will be achieved during the tunnelling. This is the result of advanced simulations in combination with the use of surveys, GPS technology and satellites.

24 million tonnes of excavated rock

The heading rate depends on the quality of the rock and consequently varies from as much as over 20 m/day to as little as 1 m/day. It is estimated that 24 Mt (13.3 million m^3) of rock material will be excavated. High-quality excavated rock material, after crushing, will be used to produce 5 Mt of concrete aggregate. Four special concrete plants, including an underground plant at Sedrun, have been constructed. The remaining material will be used as gravel sand, for making bricks, offered for sale for use in embankments, etc., while low-grade material will be deposited in different landfill sites.

Ventilation and cooling of the tunnel are essential to ensure good working conditions. The rock can have a temperature of as high as 45° C. In addition, the tunnelling machinery generates a considerable amount of heat. The ventilation system must also extract the gases arising from the blasting operations. Fresh air is drawn in through the portal or access tunnel and is blown to the headings via conduits. Fans are used to vent the exhaust air and gases via the portal/access tunnel.



Note: The background picture on the cover is from Erstfeld.

Table 2. Timetable for the Gotthard Base Tunnel Project

1947	First proposal for Gotthard Base Tunnel
1962	Start of project planning by Swiss Federal Railways
1992	Acceptance of proposal for new transalpine railway (Neat)
1996	Start of construction of access tunnel at Sedrun
1998	Start of sinking of 800 m shaft at Sedrun
1998	Call for tenders
1999	Start of civil engineering work
1999	The consortium receives order for two mine hoists
2002	Mine hoists enter into operation
2006	Start of railway infrastructure work
2011	Start of operation of Gotthard Base Tunnel

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