Upgrade of the world's largest hoisting plant at the Kiruna iron ore mine

The mining company LKAB, based at Kiruna in northern Sweden, operates one of the world's most productive iron ore mines. 500 men work underground to produce 22 million tonnes of ore a year. Crucial to this productivity is the mine's efficient hoisting system, which makes use of equipment delivered by ABB at the beginning of the 1970s. Recently, LKAB awarded ABB a contract to install new hoisting equipment and to upgrade the existing hoists within six years to secure efficient operation for the mine for at least the next two decades. Five renovated hoists have meanwhile been handed over to LKAB, and are currently proving their worth in day-to-day operation.

LKAB, which has mined iron ore at Kiruna in northern Sweden for more than a century, is investing US$ 600 million in a programme to expand and upgrade its production plant as the company enters the next millenium. LKAB's operations focus on Kiirunavaara mountain **1**, from which it mines high-grade ore (magnetite) with an iron content of 55 to 70 percent. The amount of phosphorus in the ore varies, but is decreasing as the depth increases. To date, the Kiirunavaara mine has yielded approximately 800 million tonnes of iron ore.

The ore body, which has a length of about 4,000 m and an average thickness of 80 m, has been explored down to a depth of 2,000 m measured from the top of the mountain. It is estimated to hold at least another 1,800 million tonnes of ore.

The ore is extracted by means of sublevel caving. After blasting at the face, LHDs transport the ore to passes that open onto the main level below it. From there, automated trains transport the ore horizontally to the crushers. After being crushed, the ore is stored in crusher bins and then transported by conveyors to the hoisting plant, which carries it to the surface for further processing. The transport system is designed to keep the processing plant supplied with ore 24 hours a day.

The sixth main level is currently under construction at 1,045 m **2**, and will allow further production up until the year 2015.

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In parallel with the construction of the new main level, the company is also improving the capacity of the ore extraction process. For example, the sublevel heights are being increased from 12 m to approximately 30 m.

Efficient ore extraction

The crude ore is transported from the new main level to the surface in two stages, the first overcoming a height of 355 m and the second a height of 802 m. Four hoists are needed for the first stage and six for the second. All of the hoists, ie the nine existing ones plus the new one, are automated. Operation of the hoisting plant is monitored from an underground control room **3**.

Whereas in the past eight hoists were needed for the second stage, six hoists are now used **4**. Each of the hoists therefore has to perform more work (*Table 1*). This called for optimization of the hoisting cycle as well as state-of-the-art drives and controls, communication systems and diagnostics facilities. Besides shortening the hoisting cycle, the upgrade also targeted an improvement in plant availability through an increase in the mean time between failures (MTBF) and an improvement in the mean time to repair (MTTR).

The hoists are of the friction type **5**, the angle of contact between the rope and the pulley being 180°. Two of the headframe hoists and all of the subvertical hoists have double skips. The others have one skip and a counterweight which compensates for the tare weight and half the payload. Tail ropes hanging between the bottom sides of the skips as well as between the skips and the counterweights compensate for the weight of the head ropes. The design of the hoists ensures that the ratio of the rope force with a loaded skip to the rope force with an empty skip (or counterweight) never exceeds 1.50. The hoisting speed is

LKAB's iron ore mine at Kiruna in northern Sweden **1**

17 m/s, or 61 km/h. Soft starting and braking prevents slip between the ropes and the pulley.

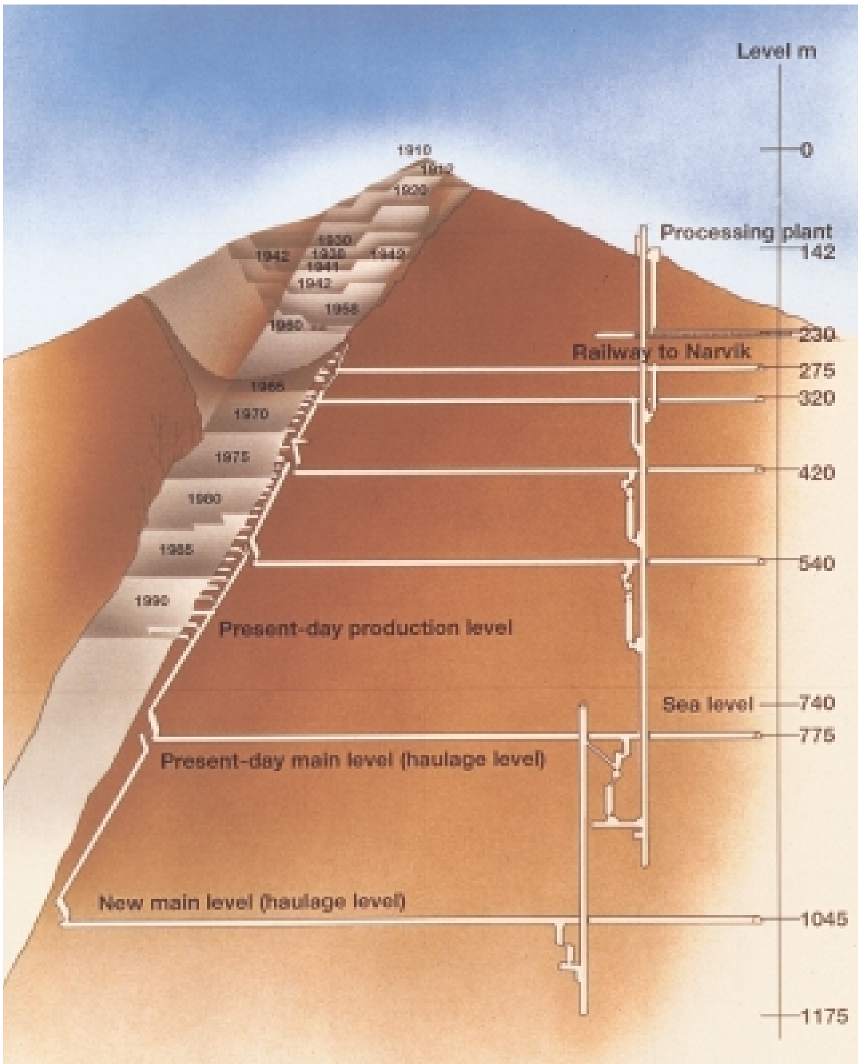
Upgrading of the existing hoists

The hoists are driven by DC motors **4** fed and controlled by thyristor converters.

The hoists that were installed in the early 1970s were equipped with relay controls for fully automatic operation. Analogue speed controllers, panel instruments, annunciator boards and switches have all contributed to the smooth operation of the mine in the intervening years.

To meet the need for increased production, reliability and availability, a comprehensive modernization programme was implemented. The work involved was carried out without interrupting production.

The hydraulic disc brakes for braking at standstill and in emergencies were completely overhauled. Among other things, newly developed transducers for continuous air-gap measurement and brake disc temperature sensors were installed. The new brake units are controlled such that braking takes place with constant retardation, independently of the load.



The Kiruna mine's haulage levels and hoisting shafts **2**

On average, the Kiruna mine is sunk a further 19 m every year. The new main level, at a depth of 1045 m, is the sixth main level to be worked since underground mining began in the 1960s. Earlier main levels are situated at 275 m, 320 m, 420 m and 540 m. The level currently being worked is at 775 m.

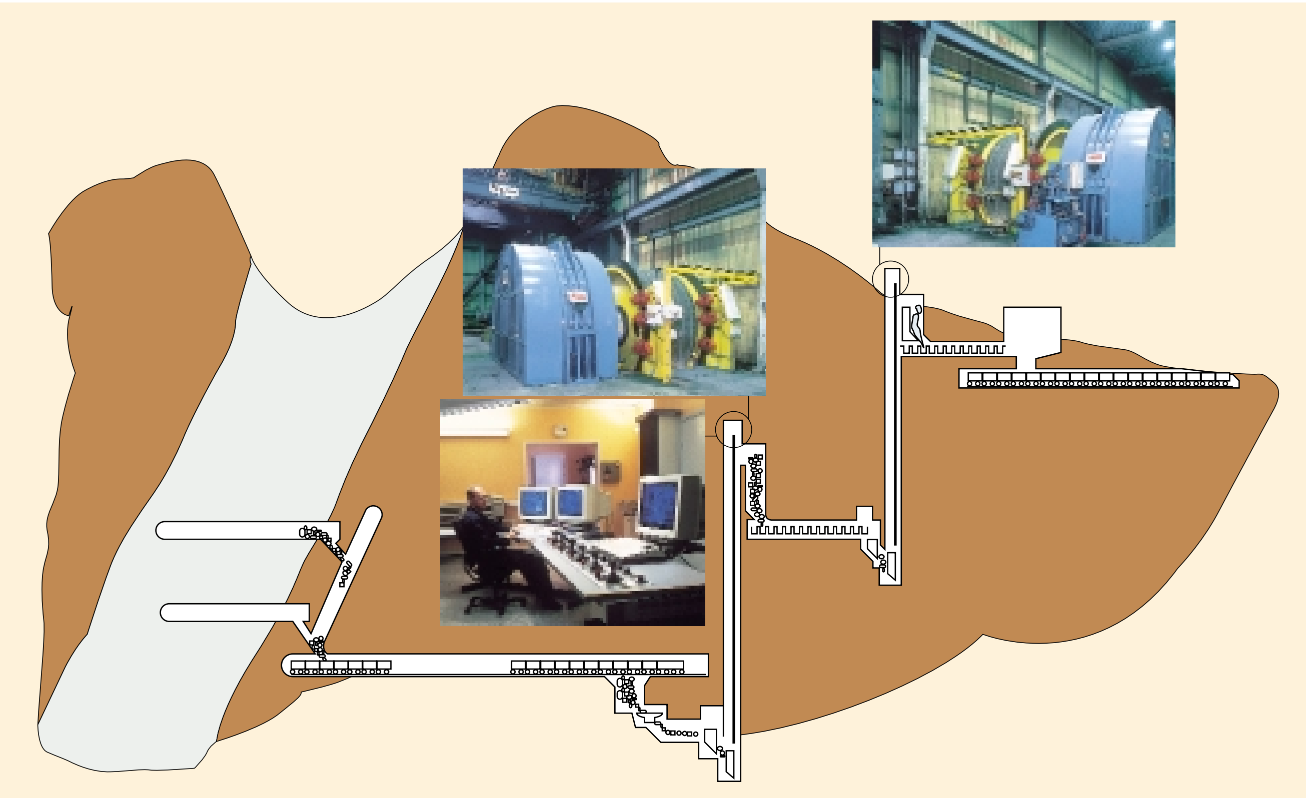
Table 1:
Technical data of the hoists

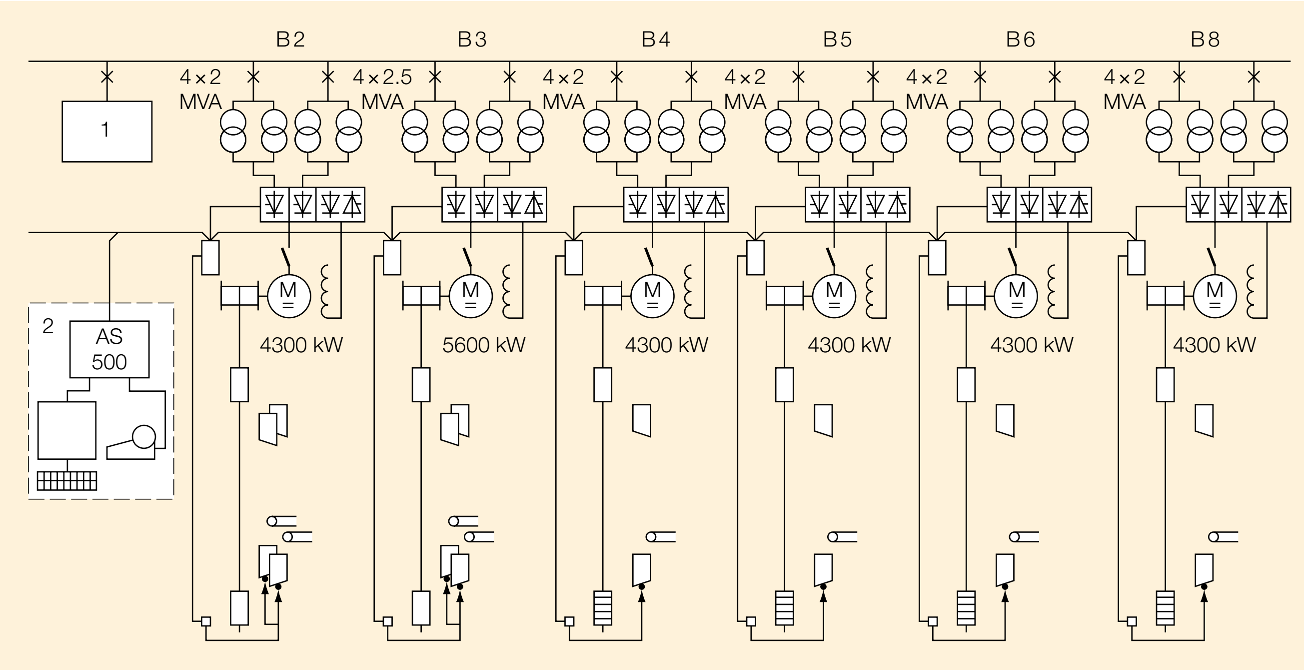
Technical data	Headframe		Subvertical hoist	
Hoist no.	B2, B3	B4, B5, B6, B8	B11, B13, B14	B12
No. of machines	2	4	3	1
Disc diameter	3.25 m	3.25 m	3.25 m	3.25 m
Hoist type	Double	Single	Double	Double
Useful load	24 t	40 t	24 t	24 t
Skip weight	25.1 t	32 t	37.4 t	37.4 t
Hoisting distance	802 m	802 m	355 m	355 m
Hoist speed	17 m/s	17 m/s	10 m/s	10 m/s
No. of main ropes	4	6	4	4
Rope diameter	40 mm	40 mm	40 mm	40 mm
Rope type	Triangular strand	Triangular strand	Triangular strand	Triangular strand
Motor rating	4,300 kW	4,300 kW	4,300 kW	5,600 kW
Hoist capacity	1,025 t/h	856 t/h	1,344 t/h	1,344 t/h

The hoist pulleys and shafts were examined for cracks by means of X-ray and ultrasonic equipment. The rotors and bearings of the drive motors had originally been shrunk onto a conical seat on the main shaft with the help of hydraulic oil injection. Thus, the rotors, pulleys and bearings could be easily dismantled using the same method.

The DC motors **4**, **5** were taken apart for checking, cleaning and re-impregnation in ABB workshops. Spark detectors fitted at the commutators allow the current to be quickly limited in the event of commutation failure **6**. New thyristor rectifiers with microprocessor-based controllers were installed for the power supply. These feature advanced monitoring and fault diagnostics functions as well as functions

Location of the two hoisting plants (one with six and one with four hoists) and the control room **3**





Circuit diagram for hoists B2 to B8 (second stage) **4**

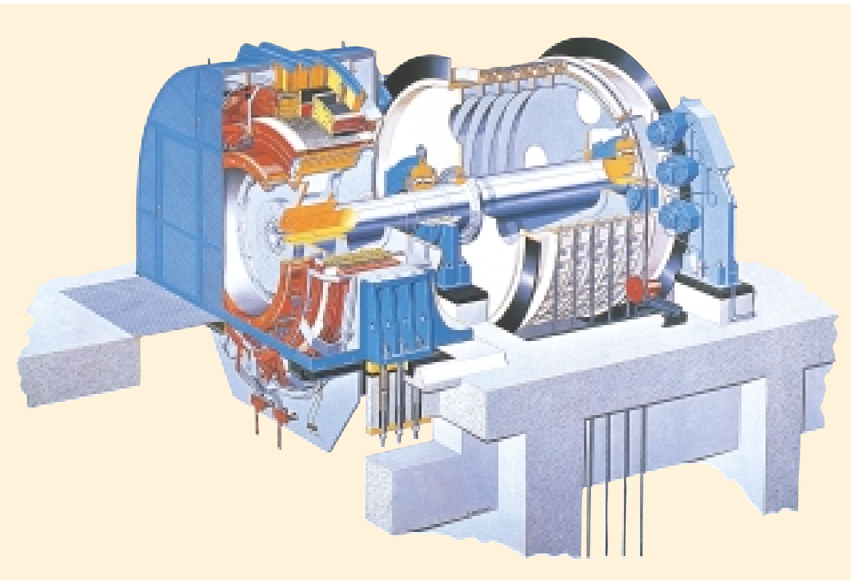
1 *PF correction equipment*
2 *Central control room*
AS *Advant station*
M *DC motors of hoists*

for the serial bus communication with the hoist control system.

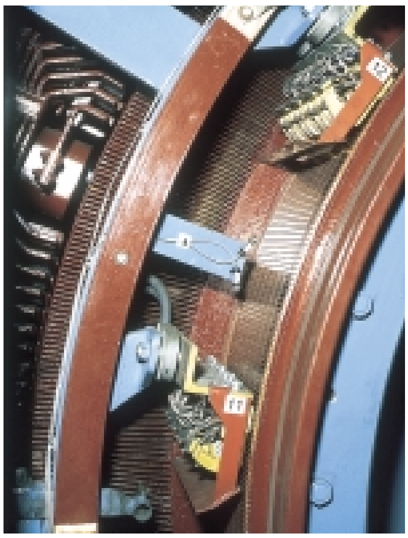
The main power circuits of the converters have far fewer components than the earlier converters, one modern power thyristor replacing the ten parallel-connected thyristors that were previously needed for each branch of the bridge.

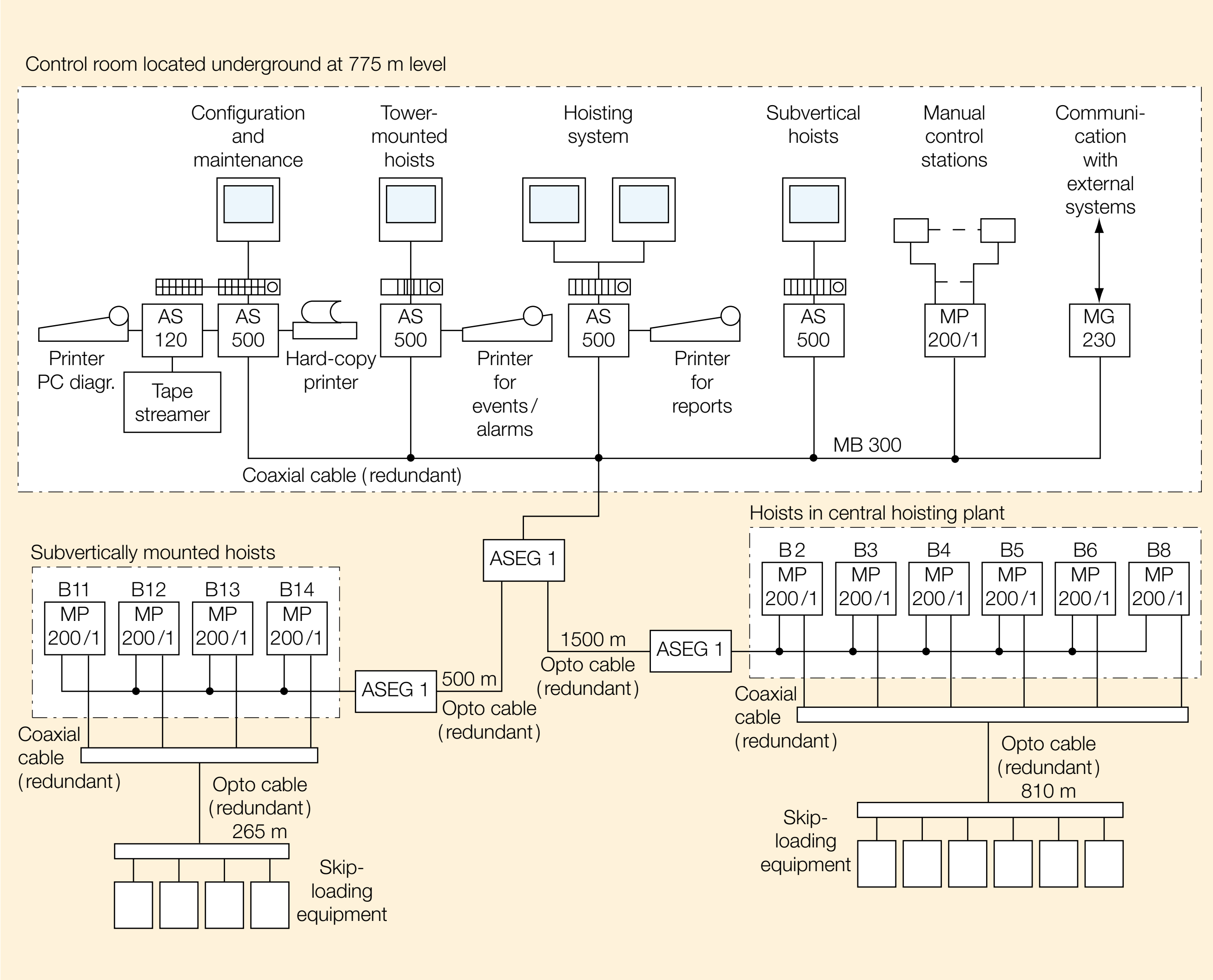
Computer-based Advant Station 500 operator stations are now the dominant feature of the hoist control system **7**. Four such stations were installed in all – one for monitoring and one for manual operation of each hoist group.

Friction hoist with DC motor and hydraulic disc brakes **5**



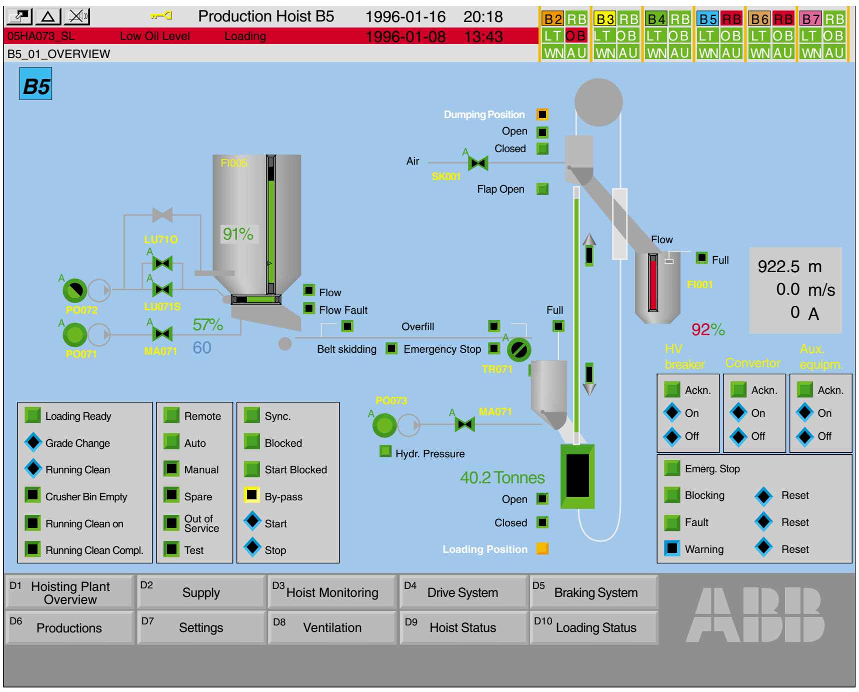
Spark detectors mounted in the DC motors check for commutation failure. **6**



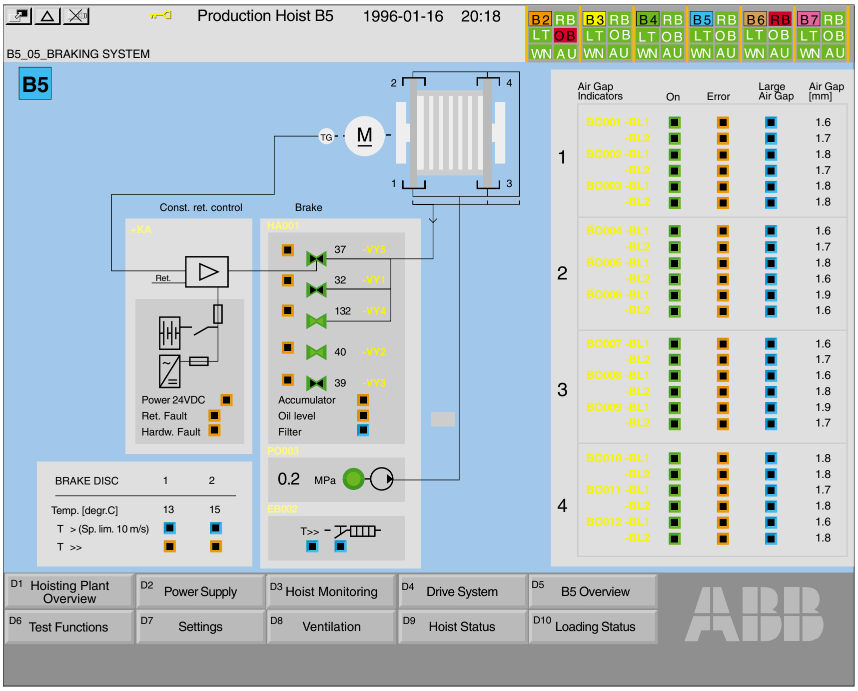


Block diagram of the systems for automatic and manual operation of hoists B2 to B8 and B11 to B14 **7**

AS	*Advant station*
MP	*MasterPiece*
MG	*MasterGate*
MB	*MasterBus*
ASEG	*Star connector*



Overview of operation of hoist B5 **8**



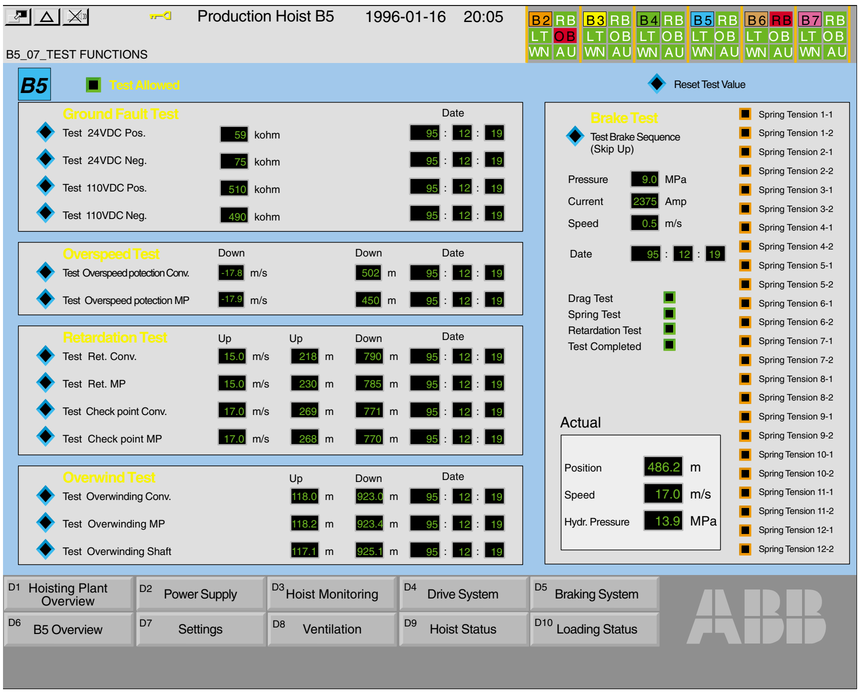
Overview of the brake system for hoist B5 **9**

The desk with the operator stations is installed in a control room at the 775-m level. The desk has been designed in accordance with ergonomic principles and can be raised or lowered electrically.

A desk with a limited number of controls is also provided for manual operation during maintenance work and inspections.

Besides the operating stations at the control desk, an Advant Station 120 engineering station was installed for programming and for fault location in the hoisting plant, plus an AS500 station for configuration and display building. Communication between the controls and the operator stations of the hoists is via fiber-optic links (also installed in redundant mode).

Test functions plus results of last test carried out on hoist B5 **10**



Automated ore transport

The transport of the ore from the crusher bins via the hoist skips to the receiving bins in the sorting plant is fully automatic. The skips are loaded from ore pockets equipped with weighing systems based on ABB Pressductors. The ore pockets are automatically refilled by conveyors bringing ore from the crusher bins.

As soon as an empty skip is in the right position at the weighing pocket, the ore is automatically dumped into the skip and the hoist is started, This transports the skip to an unloading station, where a door in the bottom of the skip opens automatically. The unloading operation is monitored by a motion detector. Afterwards, the hoist takes the skip back underground to pick up a new load. The loading and dumping times are monitored. If the normal time is exceeded, an alarm is activated, thereby ensuring that the operator in the control room can respond quickly to faults and disturbances.

The skip is positioned by a closed-loop position and speed controller implemented in the computer of the drive system. For safety reasons, the speed measurement and the calculation of the skip's position are monitored by the drive system computer and the hoist control computer with the help of separate pulse generators on the shaft of the hoisting machine. A difference between the two results in either case trips an emergency stop.

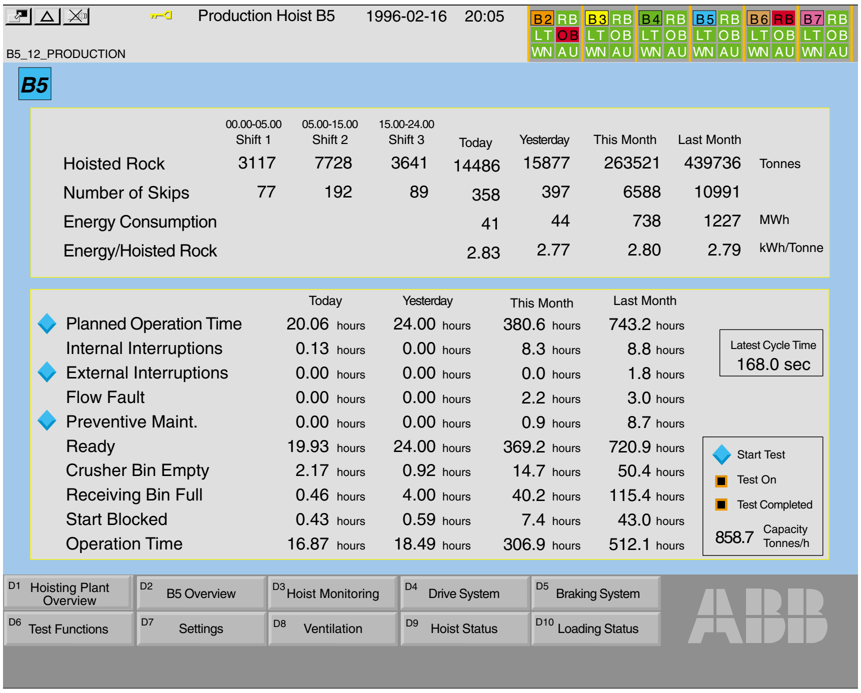
Position calculations based on pulse generators need to be reset often due to elongation of the head ropes and wear of the pulley friction liners. Hitherto, resetting has been carried out with the help of so-called synchronization points in the skip's retardation ranges. These were provided by skip proximity switches installed in the shaft. Since repairing defective switches mounted in wet shafts is a time-consuming business, the skip ropes were fitted with magnetic marks which can be detected by pickups located at the pulley.

Modern operations management and supervision

The hoists are controlled and monitored with the help of the Advant Station 500 operator stations **7**. Their operating statuses, etc, are displayed, with dynamic and steady-stage data added, on high-resolution colour monitors. Coloured graphic symbols represent the hoist components. The equipment parameters are displayed in green as long as they lie within defined limits; otherwise, they change to red. Special care was taken to make sure that the information provided by the control and monitoring systems is easy to access and readily understandable to the operating, maintenance and production staff.

Each of the hoists is represented by an overview and the specific hoist data, eg the actual hoist speed, power consumption, skip position, level of ore in the loading bins and skip, plus the current operating mode **8**.

Individual displays showing subsystems of the hoists (eg, the brake system **9**) can be selected with the help of function keys. This kind of dis-play may show, for example, the temperature of the brake disc. The air gap between the brake liner and the disc is displayed with a resolution of 0.1 mm. Adjustment of the airgap is possible with the equipment still in operation. Precision measurement and supervision allows the air gap to be made smaller than with monitoring systems based on conventional limit switches. This results not only in the brake responding faster but also in more braking effort and increased lifetime for the brake springs.



Hoist (B5) production report. Alarm messages and the last faults to occur (with time) as well as status information about all the hoists are given at the top of the screen. **11**

Statutory tests are carried out regularly to check all the main safety and monitoring functions. The results are stored and shown on a special display **10**.

The new control system automatically generates production statistics for each individual hoist and for the shaft winding installation as a whole. Planned and actual production times as well as any causes of production stops are shown **11**. This information is valuable for planning production and maintenance work.

More efficient control of the hoisting cycle allowed production to be increased by 12.5 percent soon after the first upgraded hoist began working. Also, all of the modernized hoists have demonstrated improved ease of maintenance and higher system availability.

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