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LINK

A New DMU Generation

ELF EMU Description

A Spanish Miscellany

Kiruna Locomotives, Part 1

New Turkish High Speed Lines

Modernised Carriages For HKX

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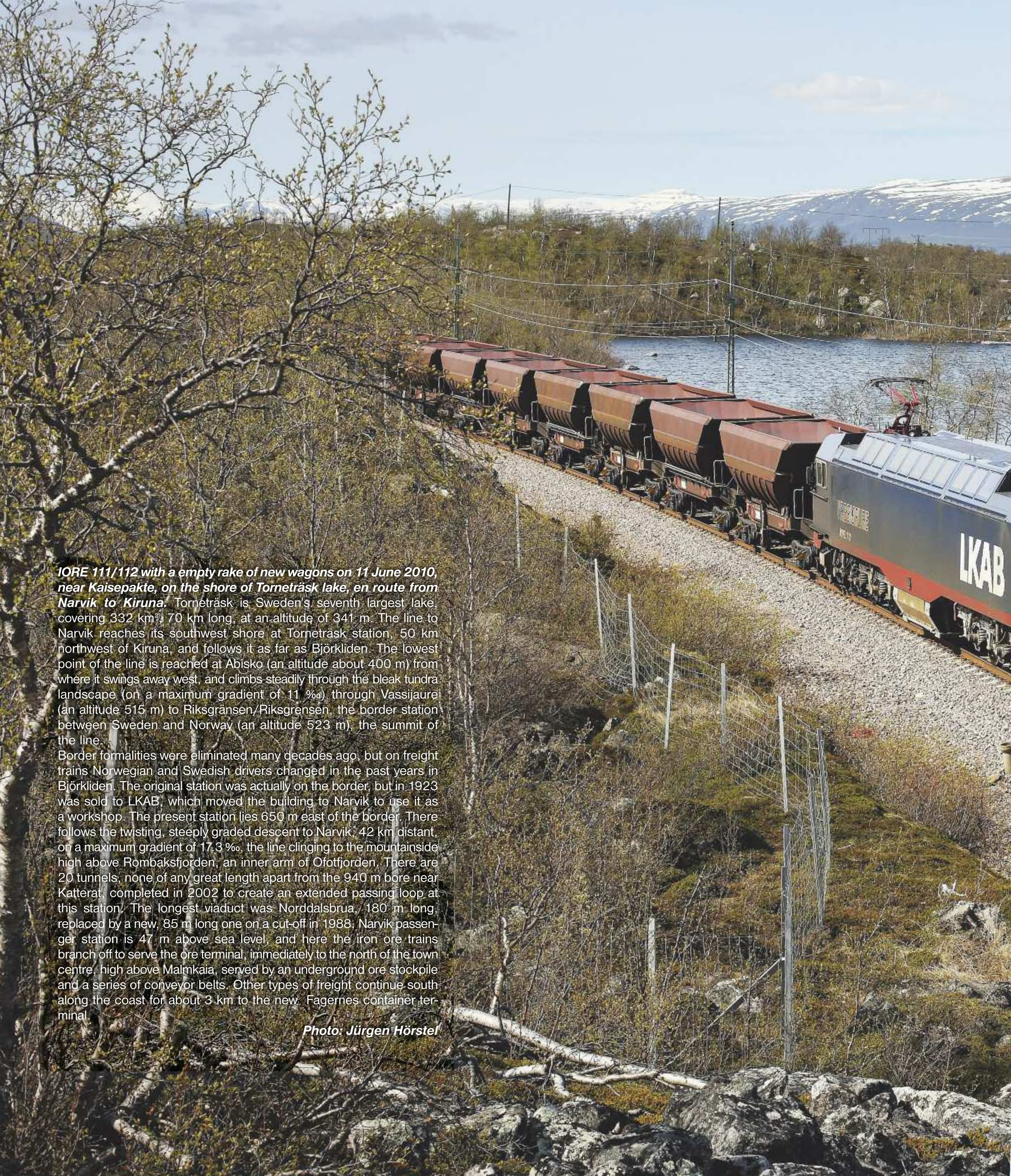
Kiruna Electric Locomotives

In 1997 the Swedish iron ore mining company LKAB decided to acquire a fleet of powerful new electric locomotives to replace the ageing Classes Dm3 and El 15 which hauled its heavy trains originating from the mines near Kiruna and Gällivare to the ports of Luleå on the Gulf of Bothnia and Narvik in Norway. With the railway being upgraded to raise the maximum permitted axle-load from 25 to 30 tonnes, plans were also drawn up for a new wagon fleet, to increase train capacity.



IORE 111/112 with a empty rake of new wagons on 11 June 2010, near Kaisepakte, on the shore of Torneträsk lake, en route from Narvik to Kiruna. Torneträsk is Sweden's seventh largest lake, covering 332 km^2, 70 km long, at an altitude of 341 m. The line to Narvik reaches its southwest shore at Torneträsk station, 50 km northwest of Kiruna, and follows it as far as Björkliden. The lowest point of the line is reached at Abisko (an altitude about 400 m) from where it swings away west, and climbs steadily through the bleak tundra landscape (on a maximum gradient of 11 ‰) through Vassijaure (an altitude 515 m) to Riksgränsen/Riksgrensen, the border station between Sweden and Norway (an altitude 523 m), the summit of the line.
Border formalities were eliminated many decades ago, but on freight trains Norwegian and Swedish drivers changed in the past years in Björkliden. The original station was actually on the border, but in 1923 was sold to LKAB, which moved the building to Narvik to use it as a workshop. The present station lies 650 m east of the border. There follows the twisting, steeply graded descent to Narvik, 42 km distant, on a maximum gradient of 17.3 ‰, the line clinging to the mountainside high above Rombaksfjorden, an inner arm of Ofotfjorden. There are 20 tunnels, none of any great length apart from the 940 m bore near Katterat, completed in 2002 to create an extended passing loop at this station. The longest viaduct was Norddalsbrua, 180 m long, replaced by a new, 85 m long one on a cut-off in 1988. Narvik passenger station is 47 m above sea level, and here the iron ore trains branch off to serve the ore terminal, immediately to the north of the town centre, high above Malmkaia, served by an underground ore stockpile and a series of conveyor belts. Other types of freight continue south along the coast for about 3 km to the new Fagernes container terminal.

Photo: Jürgen Hörstel

LKAB's History

LKAB stands for Luossavaara-Kiirunavaara Aktiebolag. The company is owned by the Swedish Government, and has its head offices in Luleå. It was founded, as a private enterprise, in **1890**, and its first mining activities involved exploitation of an iron ore opencast on the inhospitable tundra plateau roughly a third of the way from Narvik to Luleå, at an altitude of around 500 m, where the village of Kiruna was founded when mining activities started, to accommodate workers.

In **1907** LKAB absorbed Aktiebolaget Gällivare Malmfält, which in 1884 had been granted a concession to exploit iron ore reserves at Malmberget (which literally translates as „Ore Mountain"), near Gällivare, 100 km southeast of Kiruna. That same year the state bought a small stake in the mining concern, expanding this over the years until 1957, when it bought the company out, acquiring the remaining 4 % of the shares in 1976. Meanwhile, in 1964 LKAB opened a new mine near Svappavaara, about 50 km east of Kiruna, together with a branch line from the latter town.

Falling sales during the late **1970s** led to closure of this mine in 1983, though iron ore pellets are still produced in the factory here, whilst there are other ore enrichment centres in Kiruna and Malmberget, too. 1974 was the year when the mines recorded their all-time maximum output - 30.9 million tonnes. There then followed a general drop in output as the world market for iron ore went into temporary decline, though production has stabilised since the turn of the millennium at around 25 million tonnes per annum. Kiruna is still the home of the world's largest underground iron ore mine, and this incredible working accounts for around 67 % of all LKAB's output.

Nowadays the ore is extracted from a vast warren of underground galleries, extending to a depth of around 1,045 m, and this lowest level has its own railway system with trains, hauled by driverless locomotives, loading to around 500 t each. A new working level, at a depth of 1,365 m, is to be created, and this too will have its own rail system. Moreover, only around a third of the body of ore has so far been extracted. In 2010 a new mine in Svappavaara was opened and one of the mines which had been closed here in the early 1980s is planned to be reopened. Over the coming years it is planned to raise annual output to around 37 million tonnes.


Photo: LKAB

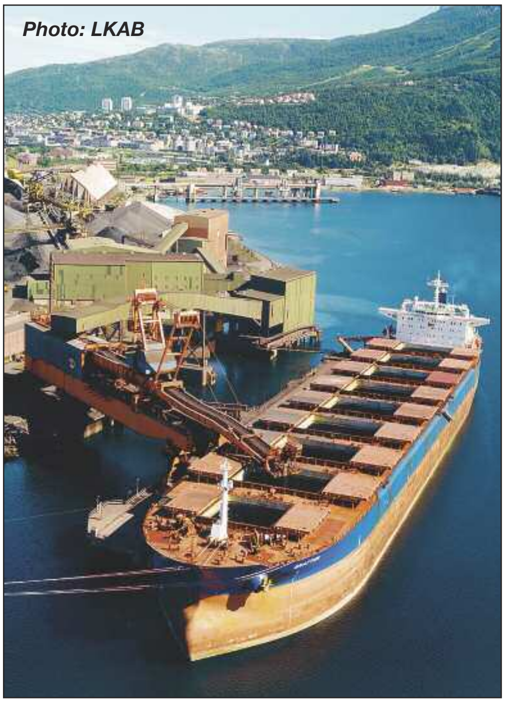


Photo: LKAB

An aerial view looking south over the town of Kiruna, the railway station (centre foreground) and the opencast part of the iron ore mine. The right-hand photo shows Malmkaia, the ore terminal in Narvik (town centre in background), which can accommodate vessels with a loading capacity of up to 350,000 t, and which is ice-free throughout the year.

The Malmbana/Ofotbana

474 km in length, excluding the LKAB branch to Svappavaara, this railway links Narvik with Luleå via Kiruna and Gällivare. It owes its Swedish name to the fact that it serves the LKAB iron ore mining districts, whilst its Norwegian name reflects the fact that Narvik lies at the head of fjord Ofotfjorden. Construction in Sweden, by the London-registered Swedish & Norwegian Railway Company, began in **1884**, with the 36 km linking Luleå with Boden (the junction with the main line to Stockholm and the south) inaugurated in 1886, and Gällivare, 168 km from Boden, being reached the following year. The first iron ore train ran on 12 March 1888.

However, soon afterwards a major problem was discovered - the spring thaw caused trackbed subsidence, and such was the scale of the damage that it was not until 23 March 1892 that the trains started running again. In **1889** the railway company went bankrupt, and the line was acquired by the State for 8 million SEK - half the construction cost. The 100 km from Gällivare to Kiruna were inaugurated in autumn 1899.

Luleå is ice-bound in winter, so the mining companies naturally looked west to the fishing village of Narvik, whose port is free of ice throughout the year. Construction of the Ofotbana, again under the auspices of the London-registered Swedish & Norwegian Railway Company, began on 3 July **1885**, Narvik was renamed Victoriahavn (only temporarily) the following year, and by the time the company went bankrupt in 1889, 20 km of trackbed within Norway had been completed. There then followed negotiations between LKAB and the Norwegian Government, which eventually agreed to finance completion of the line, work resuming in autumn 1898. Tracklaying was completed on 14 November 1902 and King Oscar II performed the formal inauguration on 14 July 1903. The Swedish infrastructure was owned by state operator Statens Järnväger (SJ), and that in Norway by the latter's counterpart, Norges Statsbaner (NSB). Although the Ofotbana was well and truly isolated from the rest of the Norwegian rail network, NSB nevertheless supplied the motive power here.

The whole line was initially worked using a fleet of steam locomotives, but these struggled with the loaded ore trains on the steep ascent between Torneträsk lake and the Norwegian border at Riksgransen. To improve operation, in 1910 SJ started planning the 15 kV 15 Hz **electrification** of the section of line between Kiruna and Riksgränsen. This was completed in 1915, but its prolongation by NSB to Narvik was not formally inaugurated until 10 June 1923, at which time the frequency was adjusted to 16 2/3 Hz. The same year the catenary was extended east to Gällivare, Boden and Luleå. It is interesting to note that this was one of the very first railway electrifications in Europe to be realised under a turnkey contract. Moreover, the work had to be done under very difficult climatic conditions.

The first 15 **electric locomotives** were built for SJ by Siemens, these being intended for freight duties and designated Class Oa, rated at 1,200 kW and with a 1'C+C'1 axle arrangement. Two more, built by ASEA, were designated Class Pa, had a 2' B 2' axle arrangement, were rated at 665 kW, and were used for passenger services. In 1922 SJ acquired a batch of Class Oe electrics, rated at 2,060 kW, to enable an increase in trailing loads on the short but stiff westbound climb between Abisko and Vassijaure. NSB in turn ordered from Thune i Hamar, Siemens and AEG a batch of ten Class El 3 two-section articulated locomotives, rated at 2,133 kW. By the 1930s


Photo: Jürgen Hörstel


Photo: Jürgen Hörstel

In January 2006 work started on a new ore discharge facility, SILA, at the site of the shunting yard for ore trains in the actual terminal. There are 11 underground silos for ore, and one for additives. They have a diameter of 40 m and a depth of 60 m, and the discharge hall is 600 m long, the track running on a bridge above the silos. Between 1.3 and 1.5 million tonnes of ore can be stored. Conveyors run from the silos to the screening plant and quays. The left-hand photo, taken on 1 September 2006, shows excavation in progress, while by 17 September 2009 (right) the work was nearing completion, with the excavations filled in and track laid through the unloading hall with hot-water shower for de-icing to facilitate unloading, on the right.

Photo: LKAB

MTAB/MTAS took over from SJ and NSB a batch of around 900 type Uad and Uadp ore wagons, some 600 from SJ and 300 from NSB. These were as an intermediate solution supplemented later by 110 type Uadk wagons, which like the earlier ones, can carry a payload of 80 t. However, LKAB decided to invest in a completely new fleet of vehicles each capable of carrying 100 t of ore. The first 70 of these type UNO wagons were ordered in 1998 from a South African manufacturer (Transwerk), but afterwards LKAB relied on the Malmö-based company Kockums Industrier to supply the remainder, called Fanoo wagons.
The underframes and running gear are built in Malmö (see R 5/09, pp. 68 - 70), while Kiruna Wagon, acting as sub-supplier, builds the bodies and the hopper unloading system, and realises the final stages of assembly. The framework contract worth 800 million SEK (at that time around 77 million EUR) specified 760 such vehicles, and the last of these were outshopped in autumn 2010. Then, on 3 May 2010, encouraged by the economic revival and the expansion of mining activities in northern Sweden, LKAB ordered 74 more, worth around 10.5 million EUR, and these will be delivered by summer 2011. ***Here is the first 100-tonne payload Fanoo wagon after assembly at Kiruna Wagon's works on 4 October 2005.***

104 under construction at Kassel on 18 October 2001. On the right is ALP4602, destined for NJT. It was quite a coincidence that while the first batch of IOREs was under construction, so was the first batch of ALP46s, while construction of the second batch of IOREs coincided with that of the ALP46As and the start of work on the batch of electro-diesel ALP45DPs (see R 6/10, pp. 52 - 58).

Photo: Jaromír Pernička

the standard iron ore train consisted of 45 wagons, each with a payload of 35 t of ore. Colour light signalling was installed, and the single track route, with its numerous multi-track passing loops, had a capacity of over 12 million tonnes per annum.

In 1953 NSB's El 3s were transformed into three-section locomotives by the expedient of joining one section to a two-section machine, while the El 4s were simply coupled permanently in pairs, to create six-section leviathans. They were thus compatible in terms of hauling capability with SJ's Class **Dm** electrics, for which in all 97 sections were built by ASEA between 1953 and 1971. These originally had a 1'D+D1' axle arrangement. Three such locomotives were ordered with an additional booster section designated Dm3, giving them a 1'D+D+D1' configuration and increasing their power rating from 3,680 to 5,520 kW. In 1960 the last 15 two-section Class Dm 1200s, with more powerful traction motors rated at 4,800 kW, were acquired. A sixteenth Dm 1200 was acquired, this one already provided with a booster section, giving it a power rating of 7,200 kW. Subsequently the 15 two-section Dm 1200s were also given boosters, thus increasing their power rating to 7,200 kW. These Dm3s could haul trains with a weight of 5,200 t. Unofficially all the three-section locomotives are called Dm3, though only the central section has this designation on its number plate.

NSB in turn acquired six similar single-cab sections from Motala Verkstad in 1954, and two more sections were delivered in 1957 from Nohab, thus creating a fleet of four two-section Class **El 12** locomotives in all. Three were subsequently rebuilt as three-section locomotives. Unlike in the case of the Swedish rebuilds, the centre sections of the El 12s still had cabs. In 1967 six single-section Co'Co' Class **El 15** locomotives were ordered from ASEA, these being rated at 5,400 kW. The maximum weight of iron ore trains hauled by a pair of these Norwegian electrics was also 5,200 t - the same as for the three-section Dm3s.

The deterioration of the iron ore market in the early 1980s prompted LKAB to negotiate with both SJ and NSB to improve efficiency and to reduce transport costs. To retain its level of **competitiveness** in the world market for iron ore, LKAB had to make its transport system more efficient, on a par with those serving Australian, Brazilian and Canadian mines. Some progress was achieved during this decade, but it transpired that both state operators were still making large operational surpluses, with few benefits accruing to the mining concern. In December 1991 LKAB announced that it wanted to assume responsibility for ore train operation, and this was agreed to in April the following year by the Swedish rail infrastructure manager, Banverket.

Both SJ and NSB subsequently announced plans for a joint venture to run the ore trains, and on 8 June 1995 **Malmtrafik** (MTAB in Sweden, MTAS in Norway, reflecting language differences) was created as LKAB's rail transport subsidiary, and with shareholding participation by both SJ and NSB (24.5 % each). In autumn 1996, with MTAB owning the fleets of Dm, Dm3 and El 15 locomotives, Malmtrafik became the first open access railfreight operator in Europe to run international trains. With LKAB, like SJ and NSB, being state-owned, this was not quite the equivalent of a true private railfreight operation, though! The same year NSB hived off its infrastructure management activities to Jernbaneverket.

Both Jernbaneverket and the 2010 successor to Banverket, Trafikverket, which is also responsible for road, sea and air transport issues in Sweden, are committed to maintaining and developing the Luleå to Narvik rail corridor according to LKAB's requirements, and a major advance came in 2007 when the **axle-load** limit was raised from 25 to 30 t, following a request from LKAB dating from 1998. During upgrading of the line the trackbed foundation was strengthened and bridges were reinforced or rebuilt to accommodate the heavier axle-load, and the passing loops were extended in length to 790 m

Photo: Tomáš Kuchta

Following the electrification of the Ofotbana in 1923, NSB relied on Class El 3 and El 4 locomotives, similar to those used by SJ. By the 1960s these were reaching the end of their useful lives, so in 1967 NSB ordered a batch of six Class El 15 single-section Co'Co' locomotives from ASEA, rated at 5,400 kW, based on the design of CFL's type 060-EA. Both these latter types were built under ASEA licence by Electroputere in Romania. The operator originally thought about having them built as single-cab locomotives, but in the end opted for a cab at each end, so that they could also be used singly on passenger trains if required. In pairs the El 15s offered the same tractive effort as a three-section SJ Class Dm3. Although they were much more powerful than the latter, and incorporated more modern technology, their tractive characteristics were not as good as those of the Dm3s. ***The El 15s were given the numbers from 15 2191 to 15 2196. Here we see El 15 2195 and 2192 at Narvik in August 1999, with Dm3 1215/1246/1216 in the background.*** Once most of the IOREs of the first batch had been delivered, the El 15s were sold in 2004 to Hector Rail, having hauled their last iron ore trains between Kiruna and Narvik on 30 November 2003.

IORE 119 en route to Kiruna, at Freden/Leine on the Göttingen - Hannover line on 21 October 2009. Hauling this unusual train is DB's 155 033, built by LEW of Hennigsdorf (now Bombardier) for Deutsche Reichsbahn in the late 1970s. This locomotive has an hourly rating of 5,400 kW and a top speed of 125 km/h. 119, on its own, also has a similar power rating and a Co'Co' axle arrangement, and operates off 15 kV AC, but otherwise these two machines of quite different generations have very little in common. Since each of the IORE's bogies weighs around 30 t, these were replaced by lighter ones to keep the axle-load to around 20 t, and to comply with the DB Netz infrastructure limits. The first wagon is carrying the IORE's snowploughs and around 30 t of ballast including the traction transformer's protective structures.

to enable the crossing of longer trains (740 m).

IORE Advent

In February 1995, when negotiations with LKAB had reached deadlock, SJ and NSB announced that they were going to issue an invitation to tender for a new batch of electric locomotives. The creation of Malmtrafik enabled all three parties concerned to develop this project, which culminated on 12 September 1998 in the signing of a **contract** with Adtranz and the latter's Kassel, Oerlikon, Winterthur, Siegen and Hennigsdorf subsidiaries for a batch of nine new machines. The following year LKAB bought up the Malmtrafik shares owned by SJ and NSB.

At that time Adtranz offered a family of locomotives brand-named **Octeon**, to which belong DB's Class 145s, and the machines for the Narvik to Luleå line were based on this, duly adapted

On 26 January 2010 Klas Wahlberg (president of Bombardier Transportation AB) officially handed over 119 + 120 to LKAB/MTAB, which was represented by the company's Head of Logistics, Goran Heikkilä.

for service under conditions of heavy snow and extremely low temperatures.

I-ORE (standing for Iron Ore) was used as a working name in LKAB's invitation to tender, but by the time the project really got under way the name chosen for the locomotives was simply IORE, without the hyphen. They are two-section locomotives, with a Co'Co'+ Co'Co' axle arrangement, and each section bears its own number. 101 + 102 were assembled at Adtranz's Kassel factory, work starting in March 2000, and were delivered to Kiruna in August that year, being subjected to intensive testing before batch production started up. Testing on lines in Germany was not possible on account of the 30-tonne axle-load. The locomotive was commissioned in December that year, driver and maintenance staff training was realised, and it entered commercial service on 7 March 2001.

In May 2001 Bombardier acquired Adtranz, and took over responsibility for the IORE order, the type subsequently being designated **TRAXX H80 AC** when in September 2003 the TRAXX family was created. „H" signifies „Heavy" (freight), 80 is the maximum service speed, and AC refers to the voltage supply type. The remainder of the batch were delivered between 2002 and 2004 (details in the table on p. 41). Three were deployed on Gällivare to Luleå trains, the remainder on services linking Kiruna with Narvik (the „Southern" and „Northern Loops", respectively). Since 2006 Bombardier's Service Division has provided spare part supply for the locomotives.

A 52 million EUR contract for **four more IOREs** was signed on 13 August 2007. The price per locomotive was somewhat greater than for the initial batch - over the period since 1998 material and labour costs had risen, and with such a small batch economies of scale were not really possible. For operational and authorisation reasons, efforts were made to maintain the same design specifications for both series of locomotives, although naturally in the later batch minor modifications were

With snow having already fallen, 119 nears Kiruna on 24 October 2009, headed by Green Cargo's Rc2 1138.

incorporated, reflecting technological advances realised since the first IOREs were built, and also feedback from LKAB concerning operating experiences with these.

Over the intervening years **new design and safety standards** had come into force, too, and these required consideration. Perhaps the most difficult task for Bombardier was sourcing the appropriate electrical and electronic components, since these were now in relatively short supply. Fortunately, only a few were no longer available on the

Principal Technical Data

Track Gauge	1,435 mm
Operating Ambient Temperature Range	+30 to -40 °C
Axle Arrangement	Co'Co' + Co'Co'
Power Supply Voltage	15 kV 16.7 Hz
Maximum Speed	80 km/h
Continuous Power	2 x 5,400 kW
Starting Tractive Effort	2 x 600 kN
Boosting Starting Tractive Effort	2 x 700 kN
EDB Power At Wheel Rim	2 x 5,400 kW
Maximum Recuperative Braking Force	750 kN
Length Over Couplings	2 x 22,905 mm
Distance Between Bogie Centres (Within Each Locomotive Section)	12,890 mm
Bogie Wheelbase	1,920 + 1,920 mm
Bodyshell Width	2,950 mm
Max. Height Over Rail Top	4,465 mm
Wheel Diameter (New)	1,250 mm
Minimum Curve Radius Negotiable	90 m
Axle-Load	30 t
Weight In Working Order	2 x 180 t

market. Moreover, the design and engineering teams were faced with the not inconsiderable challenge of converting all the locomotive diagrams and documentation into the latest computerised formats.

The final assembly of 119 + 120 began at Kassel in July 2009, with 119 being outshopped on 20 October 2009 and dispatched to Kiruna, arriving just three days later. 120 departed on 13 November that year, reaching its new home on the 17th of the month. The **last fitting-out** procedures were realised at Kiruna, involving the replacement of the special bogies used for transport purposes by ordinary ones, the installation of ballast in the machinery room and around the transformer to bring the axle-load up to 30 t, and the mounting of certain exterior fittings, such as grab-rails, mirrors and snowploughs. Then followed testing and commissioning, and 119 + 120 entered service in January 2010. The last of the batch, 126, departed from Kassel on 13 August 2010, to be paired up with 125.

After all the IOREs have entered service the remaining Dm3s will be withdrawn, and it will be possible to lengthen all freight **trains** from 52 to 68 wagons, each with a 100 t payload, raising the total load from 5,200 to 8,160 t (payload is increased from 4,160 to 6,800 t) and increasing train length from 470 to 740 m. The maximum permitted speed of loaded trains has also been lifted from 50 to 60 km/h. As a result, line capacity has been increased from 28 to 33 million tonnes per annum, whilst the number of services per day has dropped, thus freeing up line capacity for both LKAB and other operators, both freight and passenger. The annual number of ore trains from the mines to the ports is being reduced from around 7,000 to 4,000, and this will result for LKAB in a cost reduction per tonne km of nearly 50 %.

IORE Anatomy

The following sections describe the IOREs of the first batch, although differences incorporated in the machines of the second batch are also noted. The two sections of each locomotive are identical, so descriptions and dimensions refer in general to just one of these.

Bodyshell And Underframe

Each section has a cab at one end and a close-coupled bellows gangway at the other, allowing locomotive crews access from one section to the other. The inner ends also have tail lights and an automatic coupling, with sockets and cables for electric circuit connections between the two sections being concealed from the elements within the gangway. Under normal circumstances the two sections are always coupled together, and although they can theoretically run independently, they are usually only separated for maintenance.

The IORE is designed for tension and compression drawbar forces of up to 2,700 kN. Initially the locomotives were ordered with Type F Association of American Railroads (AAR) **couplings**. However, because of delays in the delivery of the new wagons, they initially had to haul the older stock, fitted with Russian-style type SA3 couplings. 101 + 102 were indeed fitted with AAR F couplings, but all subsequent members of the fleet from 103 + 104 onwards had SA3 couplings at their front ends and AAR F couplings at their inner ends. Another reason for the subsequent replacement of all AAR F couplings was their lack of robustness compared with the SA3s.

At the front end of each section of the IORE there is a pair of auxiliary buffers, designed by Adtranz/Bombardier. These are retracted when the locomotive is hauling iron ore wagons, but can be extended if the IORE has to be coupled to vehicles with a UIC-type screw coupling and buffers. This may happen only in an emergency and is limited up to a maximum trailing load of about 1,000 t.

As with other Kassel-built TRAXXes, the bodyshells for the IOREs were produced at Bombardier's Wrocław works. The **bodyshell** is made of S355 NL steel, the structure being welded and ensuring that design impact strength is maintained even at temperatures as low as -50 °C. Although the standard technical specifications are for an ambient temperature range of between +30 and -40 °C, in the winter of 1999/2000 temperatures as low as -54 °C were recorded, and these caused breaks in the rails, with chipping of rails sometimes occurring between two adjacent sleepers! Services had to be suspended for several days while repairs were effected.

The bodyshell is structured to withstand an end-on compressive force of up to 3,500 kN. The cab windscreens are capable of withstanding an impact which conforms with the UIC test scenario standards. As in the rest of Scandinavia, a common problem on lines through isolated rural areas is the presence of reindeer and elk on the track. Each year in the past LKAB recorded around 1,000 (!) collisions with reindeer, though a mere 50 with elk. Such incidents cause damage to locomotive air pipes and equipment mounted below the underframe. These incidents are usually terminal in nature for the poor lumbering beast that has been impacted. To protect trains and wildlife and to reduce the number of incidents, most stretches of line are now being fenced.

The designers of the IORE were not too concerned about **weight** savings - in fact, quite the opposite, since to bring the axle-load up to 30 t it was necessary to install ballast. The bodyshell is thus extremely robust, with sidewall panels which are 16 mm thick, compared with just 3 mm on an ordinary European TRAXX. The plates used for the main frame are even more massive, the front end plates here being 50 mm thick.

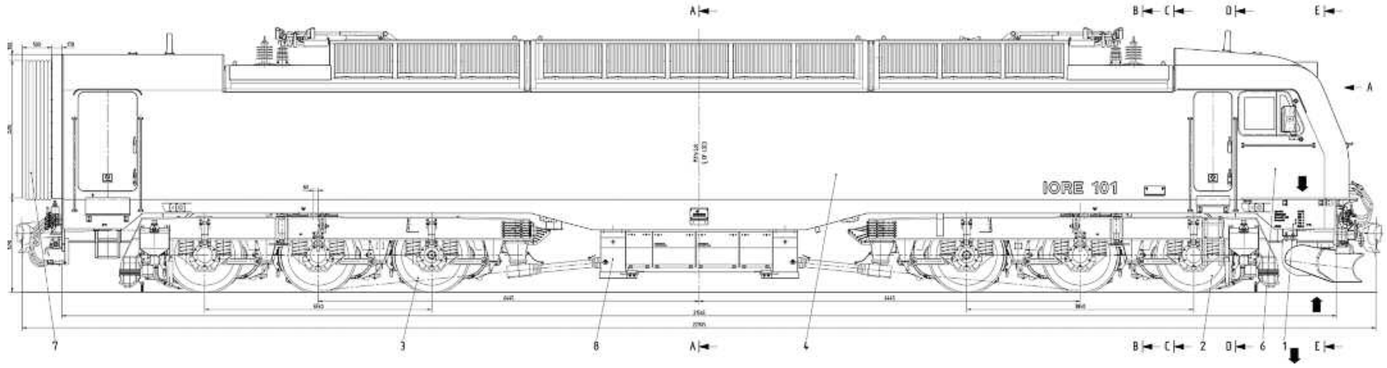
The traction transformer, suspended beneath the centre of the main frame, is protected at both ends by a massive steel structure weighing around 6 t. Further **ballast**, in the form of sets of steel plates weighing around 6 t each, is installed in the machinery room, above each secondary suspension system. Since LKAB initially requested the possibility of being able to vary the axle-load from 25 to 30 t, sections 101 and 102 were put in service with a 30 t axle-load, while the majority of the first batch locomotives operated for several years with an axle-load of 25 t, but these were all later ballasted up to 30 t. The

Just completed, 119 + 120 stands next to 111 + 112 on 26 January 2010 at Kiruna depot. On 119 are clearly visible the covers of the traction transformer and the massive protection beams on the bogies, which both serve to minimise underframe damage should a broken rail cause a derailment.

Delivery Dates Of IORE Locomotives

Manufacturer	Production Number	Built	Operator's Number
Adtranz	33829	2000	IORE 101
Adtranz	33830	2000	IORE 102
Bombardier	33899	2001	IORE 103
Bombardier	33900	2001	IORE 104
Bombardier	33901	2001	IORE 105
Bombardier	33902	2001	IORE 106
Bombardier	33903	2002	IORE 107
Bombardier	33904	2002	IORE 108
Bombardier	33905	2002	IORE 109
Bombardier	33906	2002	IORE 110
Bombardier	33907	2002	IORE 111
Bombardier	33908	2002	IORE 112
Bombardier	33909	2003	IORE 113
Bombardier	33910	2003	IORE 114
Bombardier	33911	2004	IORE 115
Bombardier	33912	2004	IORE 116
Bombardier	33913	2004	IORE 117
Bombardier	33914	2004	IORE 118
Bombardier	34845	2009	IORE 119
Bombardier	34846	2009	IORE 120
Bombardier	34847	2010	IORE 121
Bombardier	34848	2010	IORE 122
Bombardier	34849	2010	IORE 123
Bombardier	34850	2010	IORE 124
Bombardier	34851	2010	IORE 125
Bombardier	34852	2010	IORE 126

Side view of an IORE locomotive.



second batch of IORE locomotives started service ballasted to a 30 t axle-load.

Points for attaching tackle to lift the locomotive are situated on the main frame at both ends of the vehicle and adjacent to the secondary suspension system. Underneath the cab ends, below the front plates, are rugged, arrow-shaped snowploughs, their shape designed to eject the snow from the track. The lower edge of the plough is situated at a minimum height of 165 mm above rail top, even though it is wide enough to clear a broad path so that snow does not foul the bogies.

The **roof** hatches can be removed to access the machine room, while the sidewalls and underframe form an integrated unit. The roof consists of three removable steel sections, screwed into position on the sidewalls. The front and rear sections house the pantographs. It is on the roof hatches that the FSA filters for drawing in air are situated, and behind the latter are fine filter mats, which are exchanged every six months. The equalising chambers of all three hatches are linked by bellows. Out of this common chamber air is sucked by two traction motor blowers and two cooling towers. FSA 60/66 impurity separators (supplied by SGW Werder, Germany), which operate mechanically, are fitted. These are no-maintenance devices, working on the principle of centrifugal force, which is reflected in their name, Fliehkraft-Sedimentations-Abscheider (Centrifugal Sediment Separator). The numbers stand for profile/installation depth.

There is only one small air intake on the bodyshell side, and one above it in the roof hatch, situated to the rear of the cab, on the left-hand side in the direction of travel. They are the intakes for the air conditioning unit, the lower one of these being for its condenser, whilst the upper one is for the intake of fresh air, which is treated and ducted to the cab.

Cabs

The spacious cabs, soundproofed and air conditioned, are designed for the maximum possible comfort for the occupants on long journeys in harsh climatic conditions. The driving console is arranged for a left-hand driving position and for one-man operation. The 5 kW air conditioning unit is situated in the machinery room, behind the cab's bulkhead. Heating in the cab is also provided by floor heating (2 x 2,000 W) and three heaters below the side windows, 600 W each. The driver's seat has air suspension, and a heated base, while under the console is an adjustable footrest. A refrigerator, hot plate and a public radio with CD player are also provided.

As is standard practice in Sweden there is a foot-operated **vigilance device**, though as an alternative this is supplemented by a portable console with a button, linked by wire to the driving console, so that the driver can walk around in the cab while the train is on the move. The flat windscreens are heated and fitted with electrically powered sun blinds, which are essential at such high latitudes, when for much of the day the sun is at a very low angle. The rear-view mirrors are heated, too, and are adjusted electrically from inside the cab. The headlights are arranged in a triangle, and in each lamp unit there are two lights. The apex lamp unit also houses the red tail light.

Five **lighting combinations** are possible for various purposes:

- 1st position - low beam filaments of all three halogen headlights on the front section illuminated, together with the red tail light on the rear section. This combination is used in stations or when meeting other trains (or cars on adjacent routes) in order not to dazzle drivers.
- 2nd position - half beams on the two lower headlights on the front section, using the xenon lights, and low beam filament of the halogen light on the apex headlight, together with the red tail light on the rear section.
- 3rd position - all three xenon lights on full beam on the front section, plus the red tail light on the rear section. This is used in normal running on the line.
- 4th position - the two lower headlights on the front section illuminated using the low beam filament of the halogen light, the apex light switched off, and the same combination of headlights on the rear section, together with the red tail light. This combination is required when shunting is in progress.
- 5th position - the headlights, on full beam using the halogen filament, flash three times in succession at a frequency of 0.5 Hz. This indicates an emergency.

The sockets for wiring enabling operation in **multiple** (two two-section IOREs) are situated between the lower pair of headlights, each incorporating two contacts for WTB and two contacts for the Life Signal (the Life Line is an additional electric link when the two IOREs running in multiple, which activates the emergency brake and which is independent on WTB and computer systems). One of the sockets is red with additional contacts for the 110 V DC supply, and the other is green with four more contacts for the electropneumatic brake. It is technically feasible for up to three two-section IOREs to run in multiple, controlled from just one cab, but in practice this does not happen. Hand- and foot-rails are fitted around the cab sides and front, enabling staff to move safely when carrying out routine servicing and maintenance here.

Access to the cab is via a 650 mm wide, 1,675 mm high **door** on the right-hand side only looking ahead. Each section of the locomotive can be also accessed by a 1,000 x 1,675 mm door at the inner end, on the right-hand sidewall in the direction of travel. This door is wider so that depot staff can enter and leave easily when carrying out maintenance work and handling with batteries. The door in the rear bulkhead of the cab is 650 mm wide and 1,900 mm high, and accesses a corridor running through the machinery space on the centreline of the locomotive all the way through to the rear, where a door of identical dimensions accesses the gangway connection between the two sections.

The left-hand sliding side window in the cab is designed as emergency exit, and can thus be completely removed for this purpose. In each section, at the rear end of the machinery room, there is a **lavatory**, an essential item

An IORE bogie, showing the massive derailment protection beam, photographed at Kassel on 11 May 2000 following delivery from the works at Siegen. Note the steel pipes and tubes on the outside of the bogie frames in the right-hand photo.

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Photo: ABB

ABB's traction transformer for the IOREs has an aluminium housing. Its design power is 7,162 kVA, and it comprises four traction windings, two filters, one auxiliary reactor and two secondary harmonics filter reactors. It weighs 14 t and has losses of 260 kW. It was developed jointly by ABB and Bombardier's Oerlikon works in Switzerland.

given the remote nature of the route the IOREs are used on, and the severe weather conditions experienced in winter. The toilets in the first batch of IOREs were of a dry type, on account of the risk of water freezing in winter, but a Norwegian Cinderella dry toilet with electric waste burning system is installed in the locomotives of the second batch (exhaust being situated near gangway on the bodyshell's inner end), and the original ones on the first batch are now being replaced by these.

Another winter hazard on the Kiruna to Narvik line is avalanches, which can occasionally bring down the overhead wire and cause power cuts. When these happen, drivers are expected to remain with their trains. Each cab is thus provided with a 5.5 kW reserve fuel **oil heating**, which is quite a unique feature on an electric locomotive! The independent heating aggregate is situated adjacent to the rear bulkhead of the cab, in the machinery room, on the opposite side of the centre corridor to the air conditioning unit, and is fed from a 10-litre fuel tank, whose filling aperture is situated beside the heater behind a door accessed from the corridor. Each heater can run for up to 15 hours between refuelling, and the diesel aggregates installed in the second batch of IOREs are fully compatible with those provided in the first batch.

Bogies

The three-axle Flexifloat bogies were designed by Bombardier's bogie division and built by Siegen works, the bogie frames being welded at Bombardier's Mátranovák works in Hungary. These heavy bogies, designed specifically for the IOREs, have four cross-beams, while the outer leading one is a massive derailment protection girder, which helps to reduce the risk of damage should a derailment caused by a broken rail occur. Guide beams are fitted underneath these girders, so that should the bogie derail, it is held in more or less a straight line, and does not slew at an angle to the rails.

Nowadays these bogies are designated *FLEXX*Power 120, and their frame rigidity complies with the UIC 615 norm. Each bogie supports the bodyshell on two pairs of secondary Flexicoil springs, while the primary suspension consists of short helicoidal springs. The wheelsets are guided laterally by the latter springs, while the longitudinal forces are transmitted by horizontal links. The traction and braking forces between the bogie and the bodyshell are transferred by means of an inclined traction rod. Hydraulic dampers deaden the vertical and transverse movements both of the bogie and of the bodyshell.

The **wheels** are of monobloc design, and at Siegen plant they were pressed onto a forged axles (which were supplied by Bonatrans, Bohumín in the Czech Republic). The wheelsets can be exchanged without the bogies being dismantled. The housings for the bearings are metal castings, and their covers are adapted to accommodate earth return brushes. The wheel rpm sensors are however installed on the traction motors to avoid the risk of frequent damage by snow and ice. The axle-boxes incorporate pre-lubricated and sealed SKF cylindrical roller bearing units. The leading wheelset of the front bogie has flange lubrication jets, with automatic control of the air valve of the lubrication dispenser. There are two heated sandboxes, one on each side of the leading end of each bogie, and each with a capacity of 30 litres of sand. Heated tubes from the sandboxes eject sand onto the rails in front of the leading wheels of the first bogie in the direction of travel. The volume of sand dispensed is controlled by the driver.

The asynchronous, squirrel-cage **traction motors** are type 6-FRA 7072 D manufactured at Bombardier's Hennigsdorf works, and have a nominal power rating of 918 kW. They are nose-suspended, of welded construction, and frameless. The cooling air is delivered from the chamber in the centre section of the roof and once used is exhausted downwards onto the track from the traction motors. The single-stage axle-mounted gearboxes are also produced by Bombardier, their wheels incorporating oblique gearing (4°), the gear ratio being 1 : 6.2666. This is set for the optimum tractive force at a maximum speed of 60 km/h with a rake of loaded wagons and 70 km/h with a rake of empty ones. In the IORE's second batch the traction motors of the same design, but produced by TSA of Wiener Neudorf, were installed.

Traction Equipment

Given the harsh natural conditions under which the IOREs would be operating, the design engineers strove to minimise the quantity of roof-mounted electrical equipment. This consists solely of the two pantographs, the two surge arresters and the grommets to the inside. The main switch and the earthing switch are located within the machinery room, as are the pantograph disconnecting switches. The two pantographs are Schunk WBL88 models, with a skid width of 1,800 mm. A device is fitted to ensure that the pantograph can be lowered rapidly should the carbon current collection strip break.

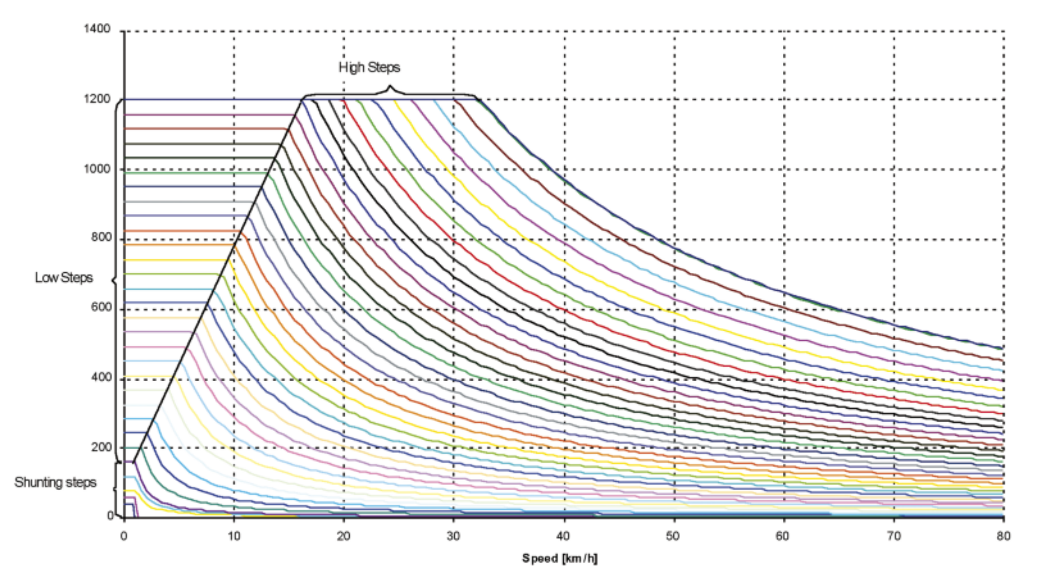
In each section there is a high voltage filter (**HVF**), necessary to avoid disturbing the ageing Swedish Automatic Train Control system (ATC-2), which is used in Norway too. The locomotive's ATC equipment communicates with that at the lineside using electronic telegrams.

The 15 kV AC 16.7 Hz power supply passes from pantographs through the main switch to the type LOT 7165 traction **transformer**, housed in an aluminium tank and produced by ABB Switzerland. The transformer is located between the bogies, has an output of up to 7,162 kVA and has four secondary traction windings. Two of them feed with a maximum 1,350 V single-phase voltage one Camilla traction converter of type UW2423-2810. The traction converters change the single-phase voltage into a three-phase, pulse-modulated one with a maximum of 2,180 V for the traction motors.

The **traction converter**, which has an output of 2,700 kW, comprises two four-quadrant rectifiers, an intermediate DC circuit operating at 2,800 V and a three-phase traction inverter. This supplies a voltage of variable frequency and current for the traction motors. Three of the latter always function in parallel, in group control mode, and thus each section of the locomotive has two motor groups. In the traction converters of all IOREs, water-cooled GTO thyristors were used. If one of the four motor groups of the two-section locomotive fail, then it can still haul a 8,200 t rake of loaded wagons, and even stop and start without any difficulty on the steep section of the Kiruna - Narvik line.

The fifth secondary transformer winding powers the **auxiliaries**. There is one three-phase auxiliary converter in each section, which creates a 3 x 400 V network and which incorporates IGBT modules in both batches of locomotives. The cooling requirements of the IORE vary significantly according to the time of year and weather conditions, hence under „average“ conditions the three outputs from the auxiliary converters are used as follows:

- the first output creates a variable voltage of between 40 and 400 V with a frequency of between 5 and 50 Hz for powering the motors of the fans for the cooling of the traction motors,
- the second output creates a variable



Traction characteristic of an IORE locomotive.

The driving console of an IORE from the first batch. On the left of the driving position is the automatic train brake control lever, which is via independent bus connections (WTB) wired to the brake electronic. On the right is the combined power and electrodynamic brake (EDB) control, which has six positions. Zero is in the centre, the first position forward is S/1 („S“ stands for „Stay“) and is used when coupling up to a rake of wagons. The second position forward is „+“, for step up. The power rises in progressive steps for as long as the lever is held in this position. If the driver then returns it to position S/1, the step last engaged remains active. If the driver moves the lever backwards beyond the 0 position, he engages the EDB, which has „S“ and „-“ positions. If the driver then pushes the lever as far back as possible, it reaches the emergency (NB) position, but the latter can only be engaged if he applies force to the lever - it is protected by a powerful spring so that it is not possible to engage it unintentionally. The emergency brake applies the maximum braking effort of 750 kN. Should the main control lever suffer a failure, the driver can select the same steps using the shunting switch, situated under the left-hand window.
On the far left of the horizontal panel is the lever for the two-tone warning horn. The left-hand sloping panel houses the direction of travel selector, the buttons and indicators for pantograph operation, the parking brake, the compressor etc., the key switch to activate control electronics, and the secured pushbutton to deactivate the driver's breath alcohol level checker (which is installed on the second batch IOREs so far). The red button applies the emergency brake. Above these is the train data input panel, and at the top of this panel is the shunting radio. All other basic operating data - speed, overhead wire voltage, traction and braking current, power being applied, air pressure levels in the main air reservoir and in the brake cylinders, and suchlike are positioned on the central sloping panel in the set of indicators.
On the left of the central panel is the GSM-R train radio display (a new type is installed on the second batch IOREs, since the original model was no longer available). On the right of the central panel there is a public radio with CD player. Towards the top of this fascia is the white rectangular horizontal display panel of the Swedish ATP system. On the right-hand sloping panel are switches for operating the windscreen heating and wipers, sanders, exterior and interior lighting, clock and suchlike. There is also an INC-50 PIXY display for diagnostic and other operational data. On the far right of the console is the yellow wired control handset of the vigilance device to enable the driver to walk around in the cab. The adjustable folding footrests for the driver underneath the console are visible on the left and right.

voltage of between 40 and 400 V with a frequency of between 5 and 50 Hz for powering the motors of the fans for the cooling of the traction transformer and the traction converters,
- the third output, with a fixed voltage of 400 V and a fixed frequency of 50 Hz, supplies the motors of the compressor, the motors of the transformer oil and cooling liquid pumps, the cab air condition, heating and windscreen heating, the pre-heating units of the traction converters and compressor, the charger for the 110 V battery, and finally the motor of the machinery room overpressure fan.

Each section has a 110 Ah NiCd **battery**, which fullfills the requirement for operation without charging over a period of two hours. The battery, which is housed near the rear entrance door to facilitate access, has 80 cells arranged in two-level plugs, and after they have been unlocked, it can be removed from the locomotive using a fork-lift truck.

The **cooling** towers for both the traction transformer and traction converters were supplied by Behr Industrietechnik, Stuttgart. The main transformer is cooled by a mineral oil, while both the traction and auxiliary converters are cooled by water with glycol anti-freeze added, which withstands temperatures as low as -50 °C. As in the case of all TRAXX locomotives, all these components are modular in design, so that they can be assembled and tested prior to installation.

One additional difference between the two batches of IOREs concerns the electrical equipment. In the more recent locomotives Silicon **cables** manufactured by K. M. Cables & Conductors are used since the original GKW-Arctic type, produced by Huber + Suhner, is no longer available. Basically all the modifications incorporated in the second batch were designed with a view to their future incorporation in the first batch if required, without causing operational or maintenance difficulties. This was the most difficult aspect regarding building the second batch after nearly a decade had elapsed since the first - great efforts were necessary to acquire components suitable for use in temperatures as low as of -40 °C and which were, as far as possible, identical to those used in the earlier machine. Matters were complicated even more by the fact that in the second IORE batch an even smaller number of locomotives than in the first was involved.

Braking Systems

The principal braking system is electrodynamic, recuperative. The Knorr KE-GP automatic brake is electro-pneumatically controlled. The train pipe pressure is defined by the brake control and adjusted by an analogue converter. The direct-acting brake is controlled electrically. It is also possible to realise a rapid air discharge from the train pipe simply by opening the emergency brake valve, one of which is situated in each cab. When the driver applies the train brake, the locomotive brakes using the EDB for as long as the catenary can accept the recuperated energy.

Disc brakes are not fitted because the IORE locomotives are designed for a low maximum speed and because a **tread brake** would also be necessary for conditioning of the wheel surface. Only mechanical friction brake shoes are fitted, and each wheel has its own brake shoe unit. Air for activating the mechanical braking is supplied by steel pipes which are mounted on the outside of the bogie frames. If the EDB is functioning, the pneumatic brake in each section is deactivated once speed rises above 5 km/h, provided that the EDB force is sufficient. One of each of the pneumatic cylinders on each wheelset is equipped with a spring-applied parking brake, and the latter is activated from the driving console.

Compressed air creation and treatment takes place in a pneumatic distributor, and the compressed air of 10 bar is supplied by a Knorr SL 40 screw compressor (one in each section) delivering around 2,800 l/min. The two main compressed air reservoirs in each section of the locomotive each have a capacity of 800 litres and are situated in the rear part of the machinery room. In extreme winter conditions heat from the compressor cooling system is fed into the machinery space, while in summer, when temperatures in Lapland can reach remarkable heights, the heat is blown out via an aperture situated at the base of the bodyshell. The machinery room has no other heating, while all components there are designed to work under exterior temperatures as low as -40 °C. The auxiliary converter can start up at once under such a low temperature, and only the cooling liquid in the traction converter has to be „pre-heated“ a bit, to at least -27 °C before it becomes operational.

Another essential piece of pneumatic equipment is a powerful air dryer, on account of the wintertime change from relatively mild, humid air on the coast to cold, dry air up on the tundra plateau, which inevitably causes condensation.

Control Systems

Bombardier's MITRAC control system is installed. Although unusual in the modern era dominated by three-phase locomotives with continuously graduated power control, the IOREs have **stepped controls** for acceleration and braking: the master controller has 41 positions for power applications and 30 for the electrodynamic brake. The console instrumentation enables the driver to see these positions simultaneously for both sections of the locomotive. When starting off, positions 1 to 30 are used for speeds up to 16 km/h, when a maximum tractive force of 1,200 kN is achieved. Then positions 31 to 41 apply, thence up to 32 km/h, each step with a maximum tractive force of 1,200 kN (of course the lower steps can be used also for speeds higher than 16 km/h, but with lower tractive effort than the higher steps - see diagram on p. 44). At that stage the tractive effort (hyperbolic output) starts to fall, to around 500 kN at 80 km/h.

With a rake of empty wagons the effort of the electrodynamic brake is regulated in 10 steps up to 250 kN, whereas with a fully loaded train the driver simply presses a button to obtain the maximum effort of 750 kN, the 30th step on the master controller for the EDB.

Sound **reasoning** lies behind the choice of this type of control system, based on an assessment of LKAB's many years of experience in handling heavy trains. The drivers can evaluate their driving style better when they are aware exactly which power and braking steps are the most suitable for each stretch of line. This is invaluable on a line with numerous curves and frequent changes of gradient, since the 740 m long rakes of wagons and locomotive are rarely all on a homogenous stretch of track simultaneously.

Certain functions are used for **specific** operating conditions, namely:

- using the Boost button the starting tractive effort can be increased to 1,400 kN. This is achieved by increasing the power limit for a short time.
- During shunting (steps 1 to 5) or when the IORE, which weighs 360 t in working order, is being carefully reversed onto a rake of wagons, there is a maximum speed of just 1.2 km/h possible, with the tractive effort falling to zero.
- at iron ore loading and unloading facilities a very sensitive speed regulator can be employed, and train speed can be regulated very precisely, in steps of just 0.1 m/s (a mere 360 m/h). This is achieved by a push button selecting the step to internal speed control in „creeping“ mode, reliant on low voltage and mainly low frequency, the essential factors in the speed control of three-phase AC motors.
- technically it is possible to run with just one section of the locomotive activated. The driver is able to select which section is inactive. This is also useful at loading and unloading facilities, where the section closest to the wagons can be shut down, to prevent the air intakes from sucking in dust and dirt. Running with one section is also useful on the approaches to the unloading terminals at Narvik and Luleå, while the ore is defrosting following the run over the mountains.

When running with the rear section of the locomotive chosen as the active one, the leading section has to be switched into **„driving trailer“** mode so that all necessary functions - cab and windscreen heating, air conditioning and the battery charger - remain active and are powered from the 3 x 400 V AC supply. For this purpose a power connection is installed in the gangway between both sections, and this has to be activated.

The IORE incorporates a stand-by regime, in which it can be parked with the pantographs raised, to power the auxiliary functions. Moreover, the depot 3 x 400 V 50 Hz power supply can be plugged in to activate the cab and windscreen heating, air conditioning, battery charger and 220 V sockets. **Remote control** is possible - note in the photos the open boxes housing emergency buttons situated just above the sandboxes on all four corners of each section of the locomotive. This function is currently only prepared for future use at the ore loading and unloading terminals, however its future extension to cover operation over the whole length of the line is not anticipated. Preparations have also been made for the future installation of on-board ETCS equipment.

Photo: Christoph Grimm

On 5 February 2011 119 + 120, en route from Koskullskulle to Luleå, pass through Gällivare, where InfraNord 0001R locomotive, hauling the special train „Kalmar Veteranståg“ is waiting. The latter brought tourists to Kiruna (for the Ice Hotel in Jukkasjärvi) and to Gällivare (for the traditional Jokkmokk winter market).

Moreover, LKAB has for a couple of years been working together with Transrail of Sundbyberg, Sweden, on the development of an eco-driving system for the iron ore trains. A **CATO** (Computer Aided Train Operation) system is to be installed, this being partly financed by Banverket (nowadays Trafikverket), and partly by LKAB. In summer 2010 CATO was installed on 108 + 116 and at Boden Traffic Control Centre (TCC), the latter supplying the locomotives with data such as the timings at passing loops up ahead. The on-board computer system then calculates the optimum speed profile so that the train reaches each loop at precisely the right time, but without consuming excessive energy, the driver being provided with the necessary advice on how to achieve this. Tests indicate that the iron ore trains can reach the passing loops with a variation of within ±15 seconds of the scheduled time, and generate energy savings in the order of 20 %.

108 and 116 have their own driver Man-Machine Interfaces in their cabs showing the advice supplied by CATO. Since only these two sections are equipped with this device, when the section operating with CATO is leading, it becomes the master, while the rear one is the slave, merely running in multiple via the normal control system. Only the leading locomotive has CATO active (in any case, CATO is not connected to the locomotive control, it only gives advice to the driver). The CATO installation on the Malmbana is the type known as Level 3, which means that the traffic control setting of target points for CATO-fitted locomotive operation is based on the running of all trains on the line, and not only on those equipped with the device. CATO is now being phased in, and by summer 2011 it will be installed on two more IOREs. However no definitive arrangement has yet been reached for the equipping of other members of the fleet.

The Bombardier teams building the IOREs were called upon to undertake a detailed evaluation of the electromagnetic **compatibility** and disturbances set up in relation to the ATP and overhead wire power supply. Also the influence of the electromagnetic field on train crews should be kept as low as possible. These unique requirements, research for which indicated that the IOREs more than complied with the limits established by EU norms, nevertheless required a number of further design modifications, such as the re-laying of cables and power socket within the cabs.

We will continue our study of the IOREs in R 3/11, describing the movement of the machines from Kassel to Kiruna, looking at their servicing and maintenance routines and assessing the experience gained so far from their operation.

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Photos, unless cited, and diagrams: Bombardier Transportation

Artist's impression: LKAB

LKAB is now preparing to exploit the ore seams at Level 1365, and has ordered from Schalke ten remote controlled Bo'Bo' electric locomotives to move the iron ore along a T-shaped 1,435 mm gauge network from the workings to the hoists which carry the mineral to the surface. In the second part of our Kiruna feature we will take also a closer look at the underground rail networks in this huge mine.