

By BRYAN MAHER



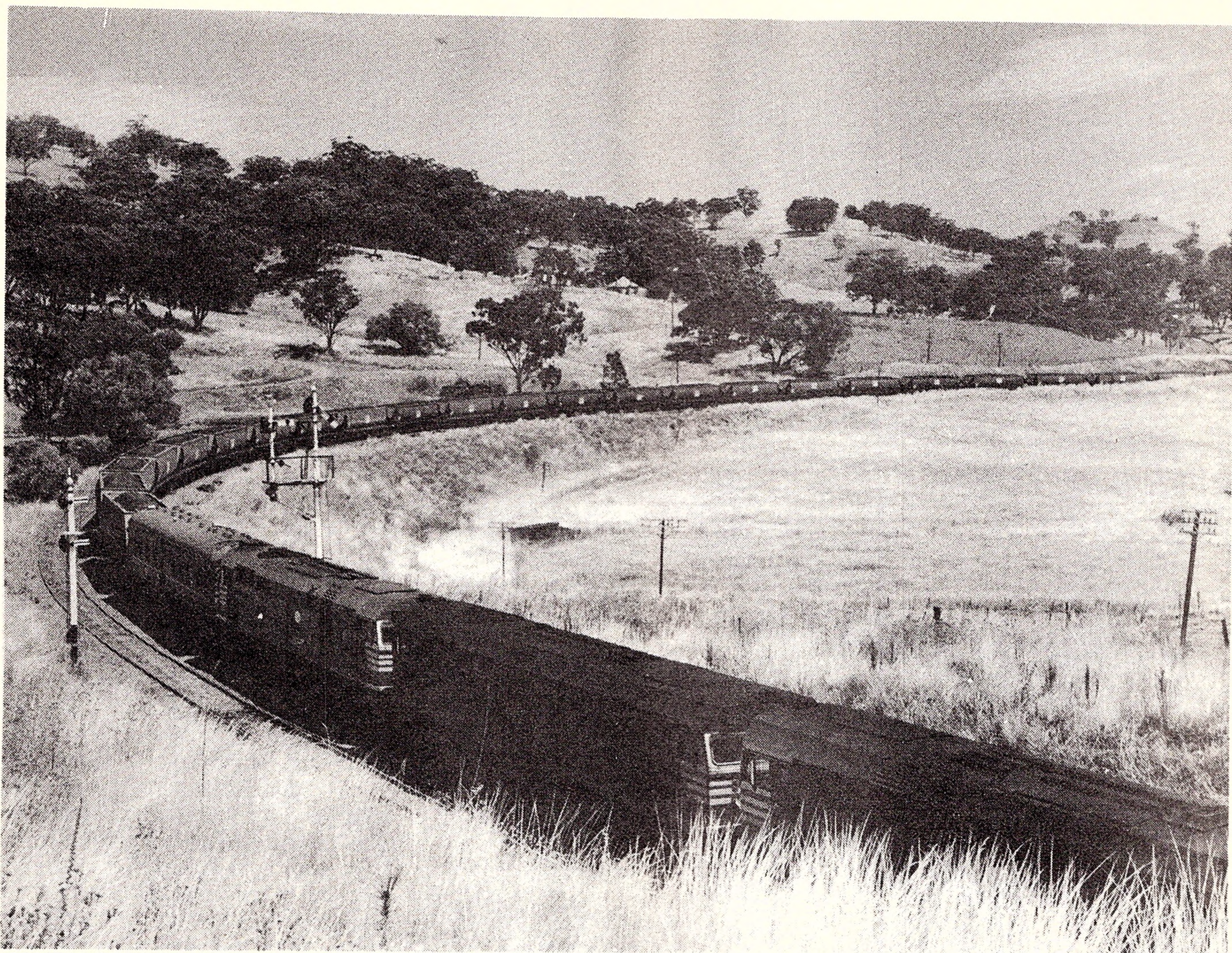
THE EVOLUTION OF ELECTRIC RAILWAYS

Diesel electric locomotives are perhaps the most common type of loco used throughout the world. They are used where the cost of supplying power makes electric locomotives economically unattractive.

While high power electric locomotives are clearly the most efficient means of land transport, transcending every competitor in tonnes moved per dollar running cost, they do depend on the prior installation of electric power supplies and overhead contact wires above all tracks.

Though the electric locomotive is cheaper than all other types, the

PT.13: A LOOK AT DIESEL ELECTRIC LOCOMOTIVES



CONTRAST IN SCENERY — in Canada, as in Australia, diesel-electric locomotives haul heavy freight trains over long distances. The view at left shows two powerful (2.24MW) SD-40 diesel-electric locomotives at work for the Canadian National Railroad. In the photo above, a heavy NSW-SRA coal train passes through a crossing loop on the run from coal mines in north-west NSW to Newcastle. It is hauled by four 442 diesel-electric locos, each rated at 1.49MW (2000hp).

overhead wiring, substations and associated feeder cables and power lines represent an investment of hundreds or even thousands of millions of dollars.

The costs associated with financial arrangements and loans of such magnitude must be weighed against alternative locomotive types.

In all other types of locomotive — diesel, diesel hydraulic, diesel electric or gas turbine electric — the complexity and capital cost of the locomotive itself is much higher than the comparatively simple electric locomotive.

It is not hard to see that the strongest case for the electric locomotive is where there is dense traffic over short to medium track length. So what should a railway

company or state authority do with their main and branch lines carrying fewer trains over thousands of kilometres? Many railways worldwide have chosen diesel electric locomotives for such service.

Diesel electric

Why diesel electric? Why not simply diesel, like an overgrown semi-trailer? The answer lies in the power of modern diesel electric locos which can be up to 4.92MW (6600hp). There is great difficulty in coupling such large power and torque from the engine to the driving wheels by mechanical drives.

The easiest and most successful power transfer method developed to date is electric transmission. This involves one or more large diesel engines within the locomotive

driving an electric generator. The electric power so generated is fed to electric traction motors which turn the loco driving wheels.

Many see a diesel electric locomotive as equivalent to an electric loco which carries its own power station around with it. This is a reasonable concept, for the diesel engine/generator set carried in modern large diesel electric locomotives is larger than the power station plant in some small country towns.

Naturally the price of diesel fuel vitally affects the choice between electric and diesel electric locos. It is not surprising then that low oil prices in the USA (compared to other countries) led to that country being the present front runner in diesel electric traction.



THE NSW-SRA 80-CLASS diesel-electric locomotive is rated at 1.492MW (2000hp), weighs 119 tonnes, and is capable of express speeds up to 130km/hr. The first unit was built by Comeng for the SRA in December 1978.

Some American railroads, such as the huge and successful Santa Fe Southern Pacific Corp Railroad, have never operated any electric locomotives. They changed over directly from steam motive power to diesel electric systems.

Electrical machinery

Early diesel electric locomotives used the most obvious design; ie, a diesel engine directly driving a large low speed multipole DC generator, generating up to about 500 volts DC at about 1200 amps. Usually the Co-Co wheel arrangement was used; ie two bogies, each with three driven axles. Six DC traction motors were used, three per bogie, each motor axle hung.

Traction motor control

Control of the motors in the early models, as illustrated in Fig.1, was by high current DC contactors with cast iron resistance banks switched in for starting. These resistance banks were progressively switched out as the train gathered speed.

To reduce the starting current load on the generator, it was common practice to switch all the traction motors in series for starting, then as speed built up, the motors might be switched into three pairs of two motors in series, or in some other cases simply all six motors directly in parallel across the generator.

Traction motors

Early designs invariably used DC series motors as this type provides

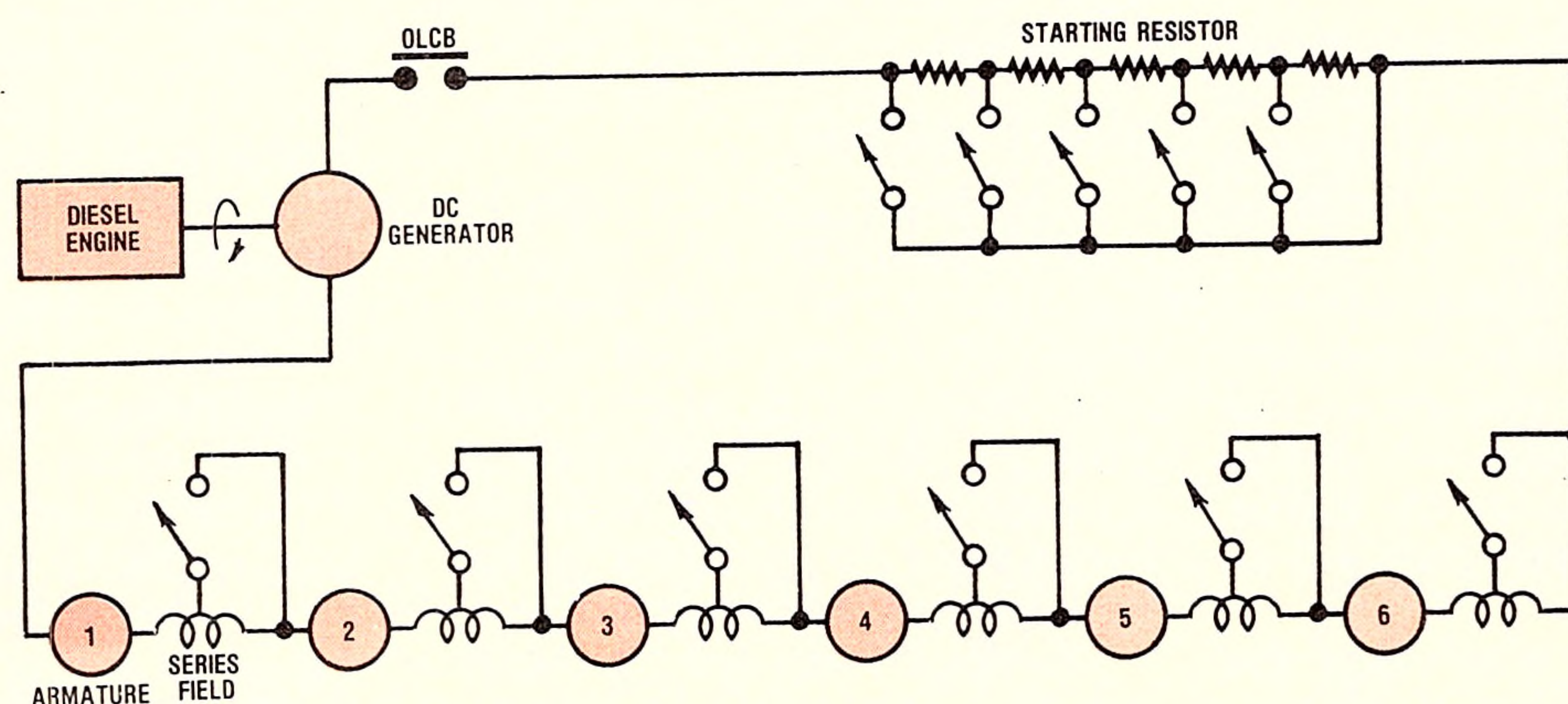


FIG.1(a): TO REDUCE THE STARTING CURRENT load on the generator, the traction motors are switched in series during starting. As the train gathers speed, the starting resistors are progressively switched out and the motors are switched in series-parallel combinations across the generator.

the greatest starting torque, hence maximum starting tractive effort. Usually 4-pole motors were employed despite the fact that a 6-pole motor of similar type is lighter for the same power. Because so much of the weight of the locomotive comes from the heavy diesel engine, DC generator and diesel fuel tanks, the traction motors are not such a large fraction of total loco weight.

As each diesel electric locomotive is (electrically speaking) a little world within itself, the designer can choose any voltage he deems optimum for the generator and traction motor system. Also the designer may choose between DC and AC systems. If AC is chosen, the frequency is also open to debate.

The most convenient voltage for DC generators and motors is somewhere between 200 and 600 volts. A 1.5 megawatt loco would involve a generator current of 1500 amps if a 1000V system were

adopted, or 3000 amps if a 500V system were chosen, or 6000 amps if a 250V system were used; the lower the voltage, the higher the current.

High voltage systems bring traction motor insulation difficulties from ingress of dirt, moisture and brake block dust, particularly iron dust from standard cast iron brake shoes. Furthermore, a higher voltage motor may have more voltage between segments on the commutator, and also wastes more space in the armature winding with extra thickness of insulation.

But the advantage of higher voltage lies in the lower current for the same power. This may result in less power loss in the circuit resistance and hence a slightly higher system efficiency.

The advantages of lower voltage systems lie in less insulation problems, less need for filtered clean air within the electrical machinery, and easier design of control contac-

tors. The higher currents usually do not lead to serious voltage drop problems as the length of motor cable runs is short and there is room for heavy copper busbar conductors in the main generator circuits.

Even when multiple locomotives are used, only low current control cables run between locos. The large traction current cables are confined within each locomotive.

For example, the early diesel electric locomotive class GR17 purchased by Canadian National Railroad from General Motors in 1956 was equipped with a 466 volt DC generator rated at 2800 amps continuous. This loco was of Bo-Bo type (two bogies, each with two driven axles) with four traction motors each rated at 466 volts, 700 amps, 326kW (437hp), giving a total power of 1.3MW (1750hp).

The traction motors were geared to the driving axles by a 15:62 ratio gear, giving a maximum speed of 104km/hour.

The diesel engine was a 16-cylinder 567-C type with 216mm bore and 254mm stroke (9.3 litres per cylinder) and was capable of running at 835RPM maximum rating. The complete locomotive with its 4200 litres of fuel oil weighed 112 tonnes.

Even the much later and more powerful General Motors SD-40 type locos of 1975, which develop 2.136MW (3000hp), use a DC generator rated at 508 volts, 4200 amps. Many American designs still tend towards the lower voltage, high current philosophy.

The General Motors model SD38-2, as exemplified by Canadian National's Co-Co class GF-620a of 1975, uses six traction motors each rated at 212 volts DC, 1050 amps, 223kW, giving a total power of 1.338MW (1794hp). The six traction motors are a DC series type, with each pair of motors permanently connected in series.

During starting, contactors switch all three pairs of motors in series, as shown in Fig.1(a). For higher speed, the motors are switched in series parallel as shown in Fig.1(b).

For yet higher speeds, the series fields have a tapping to allow of the field to be switched on

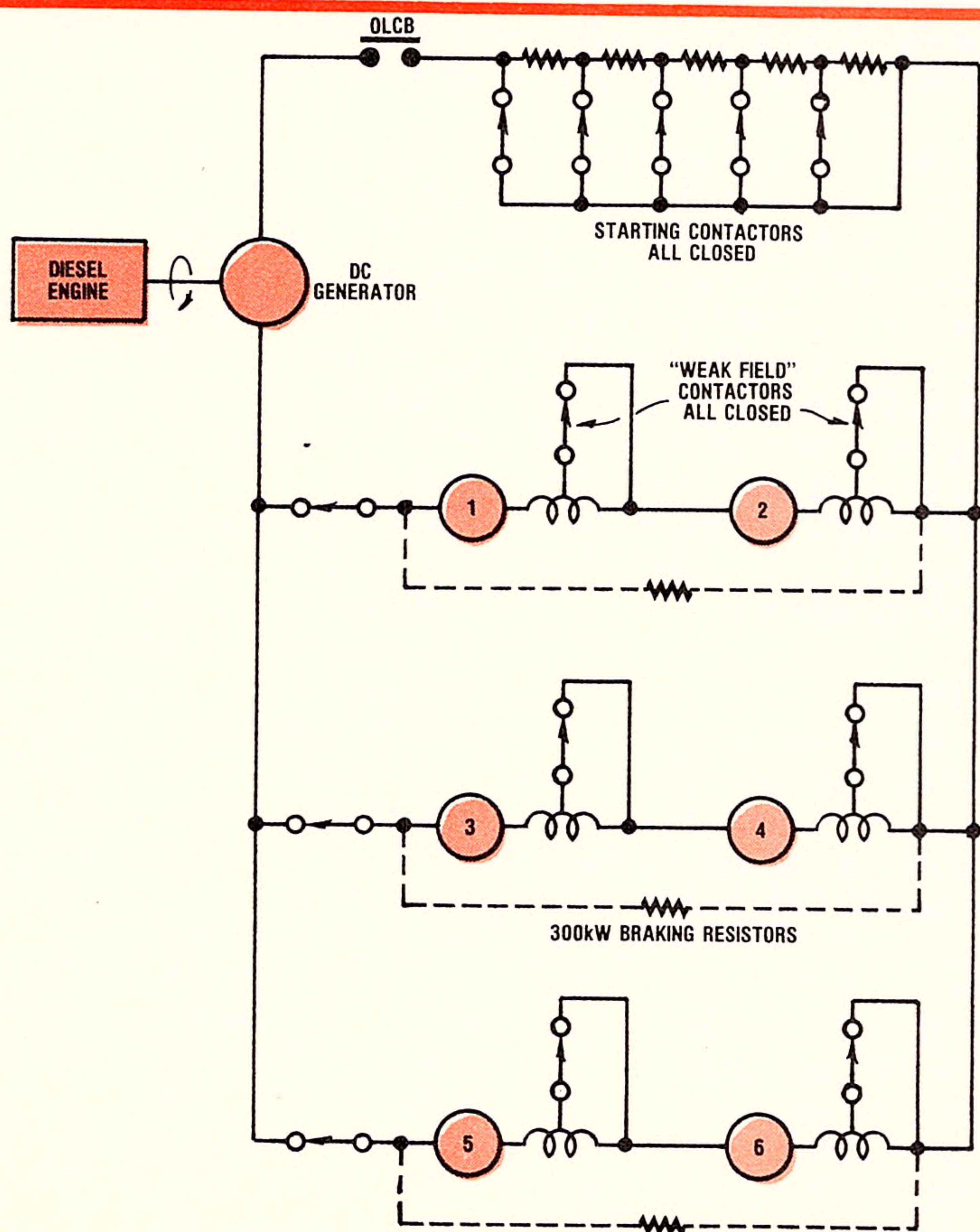


FIG.1(b): AT HIGH SPEEDS, the traction motors are switched in series-parallel across the generator and the starting and "weak-field" contactors closed. Dynamic braking is achieved by switching heavy-duty resistors (shown dotted) across the motor armatures.



AMTRAK'S P30CH DIESEL-ELECTRIC locomotives feature a big 13,700 litre fuel tank for medium and long-haul operation. These 6-axle Co-Co locomotives are rated at 2.24MW and are geared for a maximum speed of 165km/hr.

reduces the motor field strength and causes the armature to run faster.

Dynamic brakes

Most diesel electric locomotives use dynamic braking. This is achieved by disconnecting the armatures of the traction motors from the generator and then switching them each across a tapped heavy duty resistor. The field windings are separately excited by the diesel driven generator.

During deceleration, the train momentum drives the traction motors (which now act as DC generators), and the power generated is dissipated as heat in the braking resistor. This power loss causes considerable braking force to be applied to the locomotive.

In the current General Motors model SD38-2 locomotive, each of the three braking resistors is rated at 424 volts, 700 amps or almost 0.3MW of heating power per resistor. These resistors take the form of heavy cast iron grids which are cooled by large motor driven fans which draw outside air from

the sides of the loco and exhaust it from the top.

Strangely, not all diesel electric locos use dynamic brakes. One example was the 2.24MW (3000hp) GM model SD40 of 1971 weighing 176 tonnes and rated at 104km/h. It was not equipped with any form of electric brakes but did have the standard loco and train air brakes, the Westinghouse 26L Unitized air brake system being used.

Auxiliaries

As well as the main DC generator (or alternator in later models), diesel electric locomotives are equipped with an auxiliary 3-phase 60Hz alternator. This supplies the headlights, cab services and battery charger. The 3-phase supply also runs the air blowers which provide forced ventilation of the traction motors and the braking and control resistors.

These auxiliaries add up to a significant load — as much as 18kW in many locomotives. In some locos, the main diesel engine drives two auxiliary alternators, an air compressor and circulating water

pump, as well as the main DC traction generator.

The EMD model SD38-2 loco has one auxiliary alternator rated at 19kVA, rectified immediately to DC for auxiliary supply, and a second auxiliary alternator rated at 215 volts at 120Hz (at 900RPM engine speed).

The low compartment front of the cab of "hood" type locos houses a large lead acid battery for powering train control circuits, auxiliary air compressor, communications systems and essential lighting.

For operation in the cold mountain country of North America, the diesel fuel is preheated in a heat exchanger which is heated by the engine cooling water. Most locos in that continent are fitted with what looks like a bulldozer blade at the front. In the winter months these act as snow ploughs, a consideration Australian readers may not have had cause to ponder.

Early Australian diesel electrics

Since the 1950s Australian railways have made wide use of



AMERICAN MUSCLE — THREE NEW GP40 diesel-electric locomotives on their way to Conrail (USA) from the General Motors Electro-Motive Division. These 2.24MW (3000hp) Bo-Bo locomotives are used for general service.

diesel electric traction, starting with the imported 79 class of 1944 built by General Electric, USA.

From the 50s until the present many hundreds of diesel electric locos have been built by the Australian companies Comeng of Granville, Clyde Engineering and A. E. Goodwin Ltd. Further details of Australian diesel experience will be published in a later episode.

On the world scene many advanced engineering features including extra large powers up to 6MW (8000hp), high current solid state silicon rectifiers, and high current thyristors appear in the latest diesel electric locomotives. We'll talk about those in a later episode.

Acknowledgements

Thanks are due to NSW-SRA, VR, Canadian National, Comeng (Granville) and Amtrak for data, drawings and photographs. &



FOUR LOCOMOTIVES ARE used here on this NSW-SRA train to give a total power of 5.66MW. Leading is a 1.34MW 45 class locomotive weighing 112 tonnes. Next come two 1.49MW 442 class locomotives, each weighing 115 tonnes. The fourth locomotive is another 45 class.