GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

DEVELOPMENT OF 6000 HP DIESEL ELECTRIC LOCOMOTIVE

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DEVELOPMENT OF 6000 HP AC/AC DIESEL ELECTRIC LOCOMOTIVE

1. OBJECTIVE

Diesel traction is a very important mode of traction on Indian Railways. It came into being in the early 1960s when 2600 hp locomotives with DC-DC electric transmission were imported from American Locomotive Company, along with the transfer of technology arrangement to manufacture the locomotives at DLW, Varanasi. Various modifications and improvements have been made on this locomotive in the 1990s and have been upgraded to 3100 hp/3300hp.

Another era in diesel traction started in 1999, when 4000 hp diesel locomotives with AC-AC electric transmission, imported from the Electro Motive Division of General Motors, USA with a transfer of technology arrangement. Indigenous manufacture of these locomotives at DLW, Varanasi is under way.

On Indian Railways, scenario of freight and passenger movement will be undergoing a sea change in the near future. IR is contemplating to lay exclusive freight corridors for movement of heavy haul goods trains. It is also planned to upgrade speed of the passenger trains to 150 Kmph on existing tracks and 200 Kmph on proposed passenger corridors.

To meet the above requirements, hauling power of the diesel locomotive has to be improved further. Design and development of state of the art 6000 HP diesel electric locomotive is proposed to be taken up, with a view to achieve higher balancing speed on both freight and passenger trains, higher starting tractive effort, higher goods hauling capacity and higher passenger carrying capacity.

2.0 CAPABILITIES OF EXISTING LOCOMOTIVES

WDM2, WDG3A and WDG4 are the major freight locos on the diesel traction. WDM2 and WDG3A are DC-DC/AC-DC traction locos based on ALCO technology while WDG4 is AC-AC traction loco based on EMD technology. Axle load of these locos is generally limited by track standards and is limited to a maximum value of 21 tons on WDG4 locomotive.

Broad features of these freight locomotives, their starting capability and balancing speed with 58 BOXN trains are given below.

2.1 Features of existing freight locomotives

PARAMTETER	WDM2	WDG3A	WDG4
Axle load(t)	18.8	20.5	21
Weight (t)	112.8	123	126
Starting TE(t)	30.45	40.6	53
Starting capability (t)			
Level	7485	10050	13100
1 IN 150	2690	3690	4840
1 in 200	3195	4400	5760

1 in 500	4935	6660	8700
Balancing Speed			
58 BOXN	63	70	81
58 BOXN(CC+4+2)	60	67	79
58 BOXN(CC+8+2)	59	65	77
PARAMTETER	WDM2	WDG3A	WDG4
Axle load(t)	18.8	20.5	21

- Balancing speeds of 77 km/h and 76 km/h are achieved with WDG4 GM 4000HP loco working 58 BOXN on level with CC+4+2 and CC+8+2 loading. The speeds are achieved after 30 km & 30 minutes. Speeds achieved will be 61 km/h and 69 kmph after 10 minutes and 15 minutes respectively .
- Balancing speed will be around 50 km/h on 1 in 500 up gradient.
- With double headed WDG3A balancing speed achieved is around 91 km/h after 35km & 29 minutes on level for 58 BOXN (CC+8+2) and around 60 km/h on 1 in 500 up gradient. Speeds achieved will be 75 km/h and 83 kmph after 10 minutes and 15 minutes respectively.

2.3 Features of existing passenger locomotives

WDM2, WDP3A, WDM3D and WDP4 are the passenger locomotive on diesel traction. WDM2, WDP3A and WDM3D are based on DC-DC/AC-DC traction and WDP4 is based on AC-AC traction. Axle load of these locomotives is limited to 19.5t. Salient features of these locomotives and balancing speeds while working coaching trains are given below.

	WDM2	WDP3A	WDM3D	WDP4
Axle load(t)	18.8	19.5	19.5	19.5
Weight (t)	112.8	117	117	117
Speed Potential	120	140	120	160
Balancing Speed (Km/h)				
15 ICF+3ACII COACH	98	112	117	135
17 ICF+4ACII COACH	91	103	108	125
18 ICF+6ACII COACH	85	97	102	123

Time in minutes to achieve speed of 120 km/h

NO. OF COACHES	WDP3A	WDP4
15 ICF + 3 AC II COACH	-	4.7
17 ICF + 4 AC II COACH	-	5.7
18 ICF + 6 AC II COACH		-

- Balancing speed of 24 coach train with 6 AC coaches will be 123 kmph on level with WDP4 locomotives and time to achieve 120 kmph will be 17minutes
- Balancing speed of 18 EOG coach train will be 143 kmph with WDP4 locomotive

3.0 NEED FOR 6000 HP LOCMOTIVE

3.1 With the up gradation of tracks, it has become possible to increase axle load, adhesion and speed of operation. With WDM2 locomotives, which are not designed for sustaining high adhesion, starting loads are severely limited. With the introduction of WDG3A and WDG4 locos, starting loads could be improved substantially. These locos have axle loads of 20.5t/21t and horsepower of 3100hp/4000hp. It is planned to increase axle loads up to 25/30 t on the proposed freight corridor. On the existing routes, freight stock is being upgraded to the speed of 100 kmph.

To harness the benefits which should flow because of technological up gradation of track and other infrastructure, axle loads and hauling power of freight locos need to be improved further.

3.2 Railway Board has taken following decisions to increase carrying capacity of freight trains. With the increase of carrying capacity from CC to CC+8+2, the trailing load has increased from 4700 t to 5294 t.

- Railway Board has decided to enhance carrying capacity of wagon to CC+4+2 throughout IR round the year. This amounts to axle load of 21.82t.
- Loading up to CC+8+2 on identified iron ore routes has also been permitted as a pilot project. This amounts to axle load of 22.82t.
- Haulage of 58 BOXN with CC+4+2/CC+8+2 with trailing loads of 5062/5294t would require enhanced power and tractive effort.

3.3 For increasing throughput, freight trains have to be run at 100 km/h on existing routes, for which higher hp diesel locomotives are required. Speed of the freight train has to be increased from the current level of 75 kmph to 100 kmph and also speed of 100 kmph should be achieved in reasonable time and distance. For achieving a balancing speed of 100 kmph for 58 BOXN, 6000 HP locomotive is required.

3.4 No. of coaches on passenger carrying train has increased from the previous level of 17 to 21 on most of the mail express trains and to 24 coaches on some of the trains. No. of AC coaches on self generating trains has also gone up to 6 on many of the trains. Self-generating AC coach requires 60% additional traction power. Running of these trains at higher acceleration requires higher horsepower.

- With upgradation in infrastructure, 21 – 24 coach self-generating trains will have to run at 120 km/h and 18 EOG air-conditioned intercity trains will have to run at 150 km/h in the near future.
- For running of 24 coach (with 6 AC coaches) at 120 km/h at higher acceleration – within 8 minutes against 17 minutes with WDP4 - 6000 hp is required
- For running of 18 EOG ac coach at train at 150 km/h within 12 minutes 5500 hp required

3.5 Likely feature scenario

Apart from the above requirements of freight and passenger traffic, following major changes in traffic pattern are being envisaged by Rly Board.

- Exclusive freight corridor

- Double stack container movement
- Operating speed of freight trains up to 100 kmph
- Wagon axle load of 30 tons and gross load of 120 t
- 120 Wagon trains on freight corridors with trailing load of 14400 tons(120x120)
- Target for originating traffic is 700 mt during 2005-06 with incremental traffic of 50-60 mt every year. To achieve this, there is need to carry more per train at improved average speed

3.6 Power to Gross Load Ratio on Other Railway Systems

On Indian Railways, almost the entire track is of mixed traffic type. To increase the throughput speed difference between passenger and freight trains has to be kept as low as possible. This requires that the freight trains should be run at higher speed and also the locomotives working freight trains should have higher acceleration. Currently power to gross load ratio on Indian Railways is in the order of 0.65 to 0.85 against 1.1 in South Africa, 1.2 in Australia and 1.75 in Sweden. Desirable power to gross load ratio on Indian Railways should be in order of 1.1 to 1.5. At this power to grass load ratio, a CC+8+2 loaded BOXN train (5294 t) will require a locomotive of 6000 HP.

3.7 Single 6000 HP loco Vs. Multiple Operation

Working of the trains with 3WDG3A or 2WDG4 will involve almost twice the capital cost in comparison to single 6000 HP locomotive. Maintenance cost will also be twice in multiple operation against working with single loco. It is seen that 20% savings in energy can be obtained with single loco in comparison to multiple operation. In multiple operation, dead weight of around 120 tonnes is carried leading to higher cost and also around 200 HP is consumed by auxiliaries throughout the working. Also multiple is not energy efficient at lighter loads.

4.0 POTENTIAL OF 6000HP LOCO

The proposal for a high-horsepower 6000 hp locomotive, designated as WDG6/WDP6 is mooted in this background. Two variants of the loco are proposed one for freight operation (WDG6) and the other for passenger operation (WDP6). The proposed loco will have state of the art technology with features like microprocessor controls, advance emission standards, high fuel efficiency, radial bogies, AC/AC traction and on board diagnostics.

It is proposed to manufacture freight loco with 21 ton/25 ton/30 ton axle load and passenger loco with 19.5 ton axle load.

A preliminary comparison of performance of the proposed WDG6/WDP6 locomotives with the existing locomotives has been prepared, making an assumption for certain indices, like rolling resistance and locomotive weight etc., for 6000 hp locomotive. This comparison has been presented in the following tables.

30 ton axle load loco will produce attractive effort of 75.6 tons at 42% adhesion. This will increase starting capability of the loco on gradients substantially. A multiple of 25 ton axle load loco 6000 hp loco will have a total starting tractive effort of 126 tons and therefore can safely be used with the existing Centre buffer coupler.

4.1 Starting loads on level and gradient

Parameters		WDG3A (3100HP)	WDG4 (4000HP)	Proposed Locomotive		
				6000hp (21 t)	6000hp (25 t)	6000hp (30 t)
Max. Tractive Effort		40.6	53.0	53.0	63.0	75.6
LOAD (T)	Level	10050	13100	13100	15585	18700
	1:200	4400	5760	5760	6845	8210
	1:150	3690	4840	4840	5750	6900

4.2 Running of CC+4+2 carrying capacity rakes has been introduced as regular measure. On select routes CC+8+2 carrying capacity rakes are also being run. To start 58 B OXN rake of CC+4+2 and CC+8+2 carrying capacity, on 1 in 150 gradient, tractive effort requirement will be around 60 tons. A 21 ton axle load loco will not be able to produce tractive effort of this magnitude and axle load has to be increased to 25 tons and above.

Load (t)	Grade	TE reqd.	WDG3A (3100HP)	WDG4 (4000HP)	Proposed Locomotive		
					6000hp (21 t)	6000hp (25 t)	6000hp (30 t)
58 BOXN (4714 t)	1:200	43.8	N	Y	Y	Y	Y
	1:150	51.8	N	Y	Y	Y	Y
58 BOXN CC+4+2 (5062 t)	1:200	46.9	N	Y	Y	Y	Y
	1:150	55.6	N	N	N	Y	Y
58 BOXN CC+8+2 (5294 t)	1:200	49.0	N	Y	Y	Y	Y
	1:150	58.0	N	N	N	Y	Y

4.3 Time taken (min) to achieve 100 km/h on level

To haul 58 BOXN rake at 100 kmph, multiple of WDG4 locos and triplet of WDG3A locos is required. A single 6000 hp loco will be able to meet this requirement almost.

Trailing Load(t)	3XWDG3A (3X3100HP)	2XWDG4 (2X4000HP)	Proposed Loco		
			6000hp (21 t)	6000hp (25 t)	6000hp (30 t)
CC (4714t)	12.4	14. 4	20.4 (75 Km/h in 9 minutes)		

CC+4+2 (5026t)	14.3	17.2	97 Km/h - 23.2 (75 Km/h in 10 minutes)
CC+8+2 (5294t)	16.4	19.3	94 Km/h - 25.3 (75 Km/h in 11 minutes)
9600t	83 Km/h, T-29	81 Km/h, T - 30	70 Km/h, T - 30
14400 t	70 Km,/h, T–33.3	67 Km/h, T-34.5	57 Km/h- 37 MINUTES
14400t (Double head 6000 hp loco)			80 Km/h – 31 MINUTES 75 Km/h – 20 MINUTES

4.4 Performance with coaching trains

As can be seen from the following table, there is considerable improvement in acceleration and balancing speed of 6000 HP WDP6 locomotive in comparison to existing locomotive. WDP6 loco takes around 8 minutes to achieve balancing speed of 120 kmph while working 24 coach (18 II Class+6AC) train against 18 minutes with WDP4 locomotive.

4.4.1 Balancing speeds with coaching trains

Speed in kmph.

NO. OF COACHES	WDP3A	WDP4	WDP6 (6000HP)
15 ICF + 3 AC II COACH	112	135	153
17 ICF + 4 AC II COACH	103	125	145
18 ICF + 6 AC II COACH	97	123	138
18 EOG COACHES	123	143	155

4.4.2 Acceleration for coaching train

Tme in minutes to achieve speed of 120 km/h

NO. OF COACHES	**WDP3A**	**WDP4**	**WDP6 (6000HP)**
15 ICF + 3 AC II COACH	19	7.9	4.9
17 ICF + 4 AC II COACH	-	10.75	6.0
18 ICF + 6 AC II COACH	-	17.7	7.75
18 EOG COACHES	17	7.5	4.5

5.0 WORLD SCENARIO

Development of 6000 Hp locomotives has been started in early 90s by EMD and General Electrics, who are the major manufacturers of the diesel locomotives. EMD has produced SD90MAC locomotives with 16 cylinder 4 stroke H engine. So far EMD manufactured 66 of these locomotives and they are working on Union Pacific Railway and Canadian Pacific Railway. General Electric has manufactured GE 6000AC locomotives with 16 cylinder 4 stroke HDL engine. So far GE manufactured 205 of these locomotives and they are working on Union pacific and CSX in North America and BHP in Australia.

Both EMD and GE have recently upgraded their engines of these locomotives, to meet Tier 2 emission standards.

LSR ZIYANG Locomotive Works of China has recently developed 5630 HP locomotive type DF8BJ with indigenous electrics.

One of the major recent developments, which has given boost for 6000 HP loco technology is that China has placed an order for 600 numbers of 6000HP locomotives, 300 locos on EMD and 300 locos on General Electrics. These locomotives are scheduled to be delivered during 2007-2009.

The agreement was entered by EMD during September'2005 with Chinese Ministry of Railways and Dalian Locomotive Works. Similar agreement was entered by General Electrics with Chinese Ministry of Railways and Qishuyan Locomotive and Rolling Stock Works.

The locomotive will be capable of meeting EPA Tier 2 emission regulations, making them most environmentally friendly locomotives in the world. Some of the salient features of these locomotives are given below.

5.1 6000 HP AC/AC GE LOCMOTIVE

- GE AC6000 CW
- Weight : 187 tons
- Tractive effort: 90t
- Maximum speed: 120 kmph
- GE 7 HDL 16 Cylinder, Twin Turbo Charged Engine
- 6250 Hp Gross Diesel Engine
- Greater Fuel Efficiency
- CO-CO bogie
- Inverters: One Per Axle To Regulate AC Motors
- AC/AC traction
- Microprocessor based control system
- Open Architecture Type Controls. Will Allow Integration of Diagnostics, Loco Tracking, Positive Train Separation And Precision Train Control
- Currently used on Union Pacific, CSX in US and BHP in Australia.

5.2 6000 HP AC/AC EMD LOCMOTIVE

- EMD SD 90 MAC
- Weight 193 t
- Tractive effort : 91 t
- Maximum speed 120 kmph
- 6000 Hp Diesel Electric
- AC/AC traction
- Microprocessor based control system
- Co-CO Bogie
- Radial Steering Trucks
- Isolated Cab Mounted On Shock Absorbers to reduce Vibrations
- AC Traction Motors And Twin Inverters
- Safety Cabs
- 16 Cylinder Four Stroke H Series Engine
- Currently Used On Union Pacific And Canadian Pacific Railways

5.3 5630 HP AC/AC CSR ZIYANG LOCOMOTIVE

- Axle arrangement : Co-Co
- Axle load : 25t (or 23t)
- Max. speed : 120 km/h
- Starting tractive effort : 57 tons (axle load 25t)
  : 53 tons (axle load 23t)
- Continuous tractive effort : 410 kN
- Overall dimensions (LxWxH) : 22300x3304x4736 mm
- Model of diesel engine : 16V280ZJG
- Engine service output : 5630 hp

6.0 CONCLUSION AND DEVELOPMENT STRATEGY

6.1 Hauling power of existing locos is 3300 HP for WDG3A/WDM3D and 4000 HP for WDG4 locomotives. Upgradation is taking place on rolling stock and track. Higher axle load freight trains with increased carrying capacity are permitted by Railway Board. On Mail/Express trains no. of coaches has gone up to 24. No. of self generating AC coaches in a train has gone up to 6 on many coaching trains. It is decided to increase freight traffic level to 700 million tonnes during the current year and with incremental increase of around 60 million tonnes every year.

Improvement in infrastructure cannot be harnessed to the full potential unless matching motive power is available. To meet the above objectives, 6000 HP freight locomotives with the axle load of 25 tonnes/30 tonnes and passenger locomotive of 6000 HP with axle load of 19.5 tonnes are essential.

6.2 Developmental Strategy

As discussed above 6000 HP diesel locomotive are produced mainly in North America by General Motors and General Electrics. China has also recently developed 5630 HP diesel locomotive. In late 90s Indian Railways have acquired technology for manufacturing for 4000 HP state of the art diesel locomotive from General Motors. The

technology was successfully observed and indigenised to a large extent. Presently 4000 HP freight and passenger locomotives are on regular production at DLW.

6.3 Broad strategies for developing 6000 HP diesel locomotive are detailed below.

OPTION –I

It is possible to build new 6000 hp locomotive on existing 4000HP GM loco platform through TOT from General Motors. This will involve provision of new assemblies like diesel engine, traction converters auxiliary machines and controls. It may be possible to retain some of the existing items like basic design of under frame and super structure, bogies, air brake equipment etc.

OPTION-II

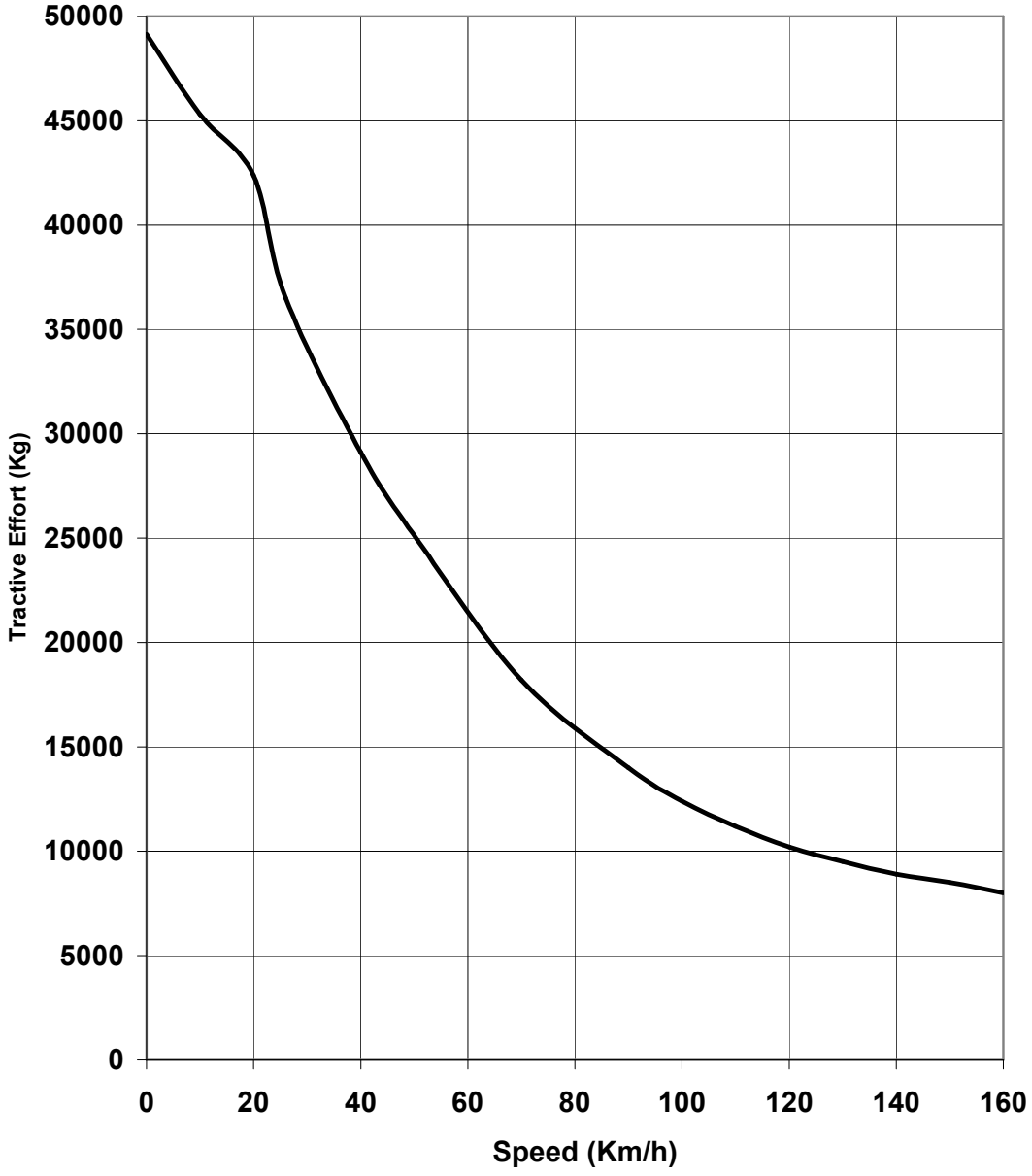
A new 6000HP locomotive can also be developed from scratch through technology transfer from the source identified through global tendering. Subsequently the 6000hp locomotive can be manufactured in India. This will be similar to the strategy adopted for development of 4000HP GM locomotive.

Annexure - 1

PERFORMANCE OF 6000 HP BG DIESEL ELECTRIC LOCOMOTIVE
(PASSENGER VERSION)
5500 HP INPUT TO TRACTION

Wheel Dia.(Half Worn) - 1055 mm, Gear Ratio - 18:65

Starting TE for 19.5 t axle load - 49140 Kg.,
Max. Speed - 160 Km/h



Annexure - 2

PERFORMANCE OF 6000 HP BG DIESEL ELECTRIC LOCOMOTIVE
(FREIGHT VERSION)
5500 HP INPUT TO TRACTION

Wheel Dia.(Half Worn) - 1055 mm, Gear Ratio - 18:74

Starting TE for 21 t axle load - 53000 Kg.,
Starting TE for 25 t axle load - 63000 Kg.,
Starting TE for 30 t axle load - 75600 Kg.,
Max. Speed - 120 Km/h