LOAD BOX TESTING,HP,SFC OF DIESEL LOCO.

Horse Power of Diesel Engine

- There are four different horsepower ratings on a Diesel electric locomotive-
  - Brake Horse Power/Rated Horse Power
  - Gross Engine Power/Gross HP
  - Input to Traction
  - Traction Output
  - Rail Horsepower
  - Draw bar HP

Brake Horse Power

- Brake horsepower is measured at the engine crankshaft and is a measure of the TOTAL horsepower available for conversion to electrical energy at the main generator plus the power required for driving accessory loads.

Gross Horse Power

- It is the engine BHP at standard conditions obtained after making corrections to the site engine out put for temperature ,altitude and specific gravity of fuel.
- GHP=BHPX Correction factor(As per site condition on basis of Ambient Temp, Altitude & Fuel sp.gravity.)

Input to Traction

- It is the mechanical power input to Traction Alternator
- Input to Traction = Gross Horse Power - Accessory loads/Auxiliary HP(AHP)

Traction output

- Traction output = Input to Traction x Generator Efficiency
  - In case of WDM2 locomotive, Approx 0.94 is considered as efficiency of the Main Generator.

Rail Horsepower

- Rail horsepower, the power delivered by the locomotive wheels at the rails,can be expressed by
  - Rail Horsepower = Traction out put x Transmission Efficiency
    - Traction efficiency depends on
      - Traction Motor
      - Pinion & Axle Gears.

Load Box Testing-Introduction

- Load box examination is carried out on diesel locomotives to determine the Generator/ Alternator output and gross engine power by simulating the actual working condition of the locomotive at rated output in static condition.

WHY, WHEN AND WHERE

- Why
  - To Check engine output.
  - Whether all systems functioning properly or not.
- When
  - After new manufacturing
  - Before and after major repairs
  - Before and after major schedule.
  - To diagnose any specific problem
- Where
  - In the shed or in the POH workshop.
  - Within the loco itself.

TYPES OF LOAD BOX

- Grid Resistance Load Box.
- Water Resistance Load Box.

Water load Box Vs Grid load Box

Water load box testing

- Load resistance can be varied at infinite stages.
- Load resistance can be changed during loaded condition.
- It can be conducted for a longer duration.
- it can not be shifted easily.

Grid load box testing

- Load Resistance can be changed only at limited stages.
- load resistance can be change only after stepped down to lower notch.
- Can not be conducted for longer duration.
- Can be shifted with lesser effort

Procedure of Load Box Test

- Preparation for starting loco.
- Pre-inspection
- Cranking, Starting & Checking
- Notch –up
- Pre-Load Test
- Preparation for Load box testing.
- Load box testing and Parameters

1.Preparation for starting loco.

- Water filling .
- Fuel filling .
- Supplement the engine with required supplements.
- Pre-lubrication

2.Pre-Inspection

- All 4 systems- Fuel Oil, Lube Oil, water Cooling & Air Systems.
- All auxiliaries and fittings driven by engine crankshaft.
- Recording of following parameter-
  - Fuel Orifice Test,Limit Drop: 0.8 to 1kg/cm2
  - Fuel Pump Vacuum,at load:35-50 cm, at No-Load: 65-80 cm
  - Fuel Oil Pump delivery: 14-15 liters/min.

3.Cranking,Starting & Checking

- Run the engine for a minute or two. During running observe un-usual sound or leakage.
- If OK, run the engine for 5 minutes, stop and measure the following parameter -
  - Lube Oil Pressure 3.5-5 Kg/cm2
  - Fuel Oil Pressure 3.8-4.0 Kg/cm2
  - All M/B Temperature and water temperature.
- If Ok,run the engine and measure Water temp,M/B temp after interval of 15min,30min,60min,2hrs,4hrs.
- After 4 hr take Compression and Firing pressure for all cylinders at idle.

4.Notch –Up

- Run the engine on idle at least for 4 hour or 6 to 8 hr, then start notching up to 8th .
- At every notch ,run the engine for 15 min & record the following data as given below-
  - Engine RPM,FOP,LOP,
- At 3rd ,6th & 8th notch, measure Cooling Water temp and all M/B temp.

5. Pre-Load Tests

- Record the following parameters before & after starting the engine .
  - OST: 1120-1160 RPM
  - TRD: At 65°C of water temp,TRD: 95 to 120 sec.
  - OPS(Picking and Dropping) –
    - 2.1 Kg/cm2 1.8 Kg/cm2 PG Governor
    - 2.8 Kg/cm2 1.3 Kg/cm2
  - R/ Fan RPM: 1200-1250 RPM
  - Cooling down time : Less than 6 Min.

6.Preparation & Load Box Testing

- Mechanical preparation
  - Fit Adopter,Pressure gauges ,Temp gauges ,Manometer etc in appropriate location for measuring of various mechanical parameters.
- Electrical preparation
    - Connect various cables, Tachometer, DC Ammeter, DC voltmeter etc in different location for measuring of various electrical parameters and toward execution of Load box testing.

7.Load Box Testing & Parameters

- Exhaust gas Temperature
- Compression pressure
- Booster air pressure
- Firing pressure
- Fuel rack travel
- Lube oil pressure
- Crank case vacuum
- TSC speed
- Exhaust gas appearance

Exhaust gas temp

- It causes excessive thermal loading of TSC components, Exhaust manifold, Pistons, Cylinder heads etc.
- In case of WDM2 with high efficient turbo , Exh.gas temp at Turbine inlet(Max)- 620'c and EGT is 490-510'c with 720 A turbo.
- High exhaust gas temperature is caused by –
  - Incomplete combustion of fuel/After burning of fuel.
  - Higher inlet air temperature.

Compression pressure

- Compression pressure is the pressure developed in the combustion chamber when the piston reaches at the Top dead center while moving the engine manually. Low compression pressure leads low HP.
- Low compression pressure is caused –
  - If excessive leakage either through piston rings or valves or from both. Range: 400-440 PSI at idle in WDM2.

Booster air pressure

- Causes of low booster pressure-
  - choking of intake filter,
  - defective TSC and
  - inefficient After cooler.
- High Booster pressure will lead to higher peak firing pressure in cylinder ie increase mechanical loading. it would also result in surging and damage the TSC.
- In case of WDM3A, Range -1.6 to 2.0 kg/cm2

Firing pressure

- Low firing pressure may be due to defective fuel injection system, improper valve timing and low booster air.
- High firing pressure may be caused due to higher booster pressure with high fuel oil supply. It leads to high Exh.gas temp resulting in excessive thermal and mechanical stresses on piston ,Cyl.heads and other components.

Fuel rack travel

- The function of the fuel rack is to control the supply of fuel to the engine in accordance to the throttle handle position and generator /alternator demand
- If the rack opening reading is less ,but sufficient horse power is developed ,it implies incorrect initial adjustment of the fuel rack linkage or fuel injection pump having higher delivery than specified. Fuel rack at full load on 8th notch: 30+1/-2 mm

Lube oil pressure

- Causes of lube oil pressure drop- Malfunctioning of Lube oil P/P,Low lub oil in sump tank, dirty lube oil strainer, leakage in the system, low viscosity of oil, wrong setting of Relief V/v or regulating V/V.
- Range of Lube oil pressure –
  - At header (at full speed): 5.3 to 6.0 Kg/cm2
  - At header (at idling speed -350 rpm & 80'c water temp):2.0 kg/cm2 (min)

Crank case vacuum

- Low crank case vacuum causes high lube oil consumption. In extreme cases, an explosion in the crank case my occur due to high positive pressure.
- Range: min crank case vacuum in inch of H2O- O.5 inch

TSC Speed

- Measurement of TSC speed is extremely important.
- Higher turbo RPM indicates lesser service margin and higher pressure ratios leading to the low reliability as such.
- Range of the speed
  - ABB-VTC-304-VG15 -24600RPM (Max)
  - Napier-NA-295IR -27000RPM ‘’
  - GE 7S1716 -20000RPM ‘’

Exhaust gas appearance

- Black smoke : This may be due to-
  - Defective fuel injection equipment.
  - Insufficient availability of air to the cylinder.
  - Defective power assembly(Excessive Blow bye)
- White smoke: it may be due to-
  - Water in the cylinder during combustion.
  - Insufficient fuel or misfiring IN cylinders.
  - White smoke can also appear during starter.
- Grayish blue smoke: this is due to burning of lube oil.

READINGS TAKEN IN ALL NOTCHES

Notch	Lube oil Pressure			Fuel oil Pressure	Booster Air pressure	Engine Speed RPM	Rack Position in mm	LCR position (Hy.Gov)	Excitation current (16V-64V)
	Eng	Com/ Exp							
1	2	3	4	5	6	7	8	9	10
Idle 1st 2nd 3rd 4th 5th 6th 7th 8th									

READINGS TAKEN IN 1ST & 8TH NOTCH

Notch	Auxiliary Voltage (72V)	Reference Voltage (24.5v)	AC Voltage between 3φ (35v-135V)related to Tacho.Gen.			Load Current	Load Voltage	Horse Power	Corrected HP	Water Temp
	11	12	13	14	15	16	17	18	19	20
Idle to 8th notch		(related to Gov. &Excitor)				I	V	V.I/ 700 (700= 746 x Gen η)	Cal HP/ a.b.c (a,b,c are correction factors)	

Notch	Colour of smoke	Current limit	Specific Fuel Consumption (gms / bhp.hr)	Efficiency	Crank case vacuum		Remarks
					Engine	Expr./ Comp	
	21	22	23	24	25	26	27
Idle to 8th notch							

READINGS TAKEN IN 8TH NOTCH

Cyl. No	Compression Pressure	Firing Pressure	Exhaust Gas Temp	Cyl. No	Compression Pressure	Firing Pressure	Exhaust Gas Temp
1R				1L			
2R				2L			
3R				3L			
4R				4L			
5R				5L			
6R				6L			
7R				7L			
8R				8L			

- **Turbo Supercharger**

  Take exhaust gas temp before and after TSC
- **Lube Oil Cooler**

  Take Lube Oil Temp Before and after lube Oil Cooler

  Take water inlet temperature
- **After Cooler**

  Take charge air temp before and after After Cooler

  Take water inlet temperature into A/ Cooler
- **L/Oil Filter Tank**

  Check Lube oil pressure before and after filter tank
- **Cooling Water pressure**

  Check pressure at pump outlet

Check pressure at the headers also

Loco No.16401/WDM2/PTRU/POH/RUNNING

Cranking Date	22/06/07
Load Box Date	25/06/07
Dispatch Date	26/06/07

Main Bearing Temperature After 5th Notch

Water Temperature	M/B Temperature								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
65°C	70	71	70	71	71	72	72	70	69

Load Box Parameters

Notch	Rack	FOP	LOP	CCV	BAP	RPM	TG (V)	TG (A)	LCR
1st	10	3.7	4.3	1.5	0	400	112	360	5:30
2nd	11	3.7	4.6	1.4	0	490	196	618	5:30
3rd	13	3.7	4.9	1.2	0	590	281	883	5:30
4th	15	3.6	5.0	1	0	690	362	1140	5:30
5th	19	3.5	5.1	.9	0.1	740	460	1420	5:30
6th	24	3.4	5.2	.8	0.4	800	586	1780	5:30
7th	27	3.3	5.3	.3	0.8	900	688	2050	5:30
8th	30.5	3.3	5.3	.7	1.4	1000	730	2160	3:00

Compression & firing pressure

Location	Compression	Firing	Location	Compression	Firing
1R	1050	1450	1L	900	1300
2R	1050	1250	2L	950	1250
3R	1050	1250	3L		1375
4R	1050	1550	4L	950	1400
5R	1000	1400	5L	1000	1450
6R	1050	1400	6L	1000	1450
7R	1050	1400	7L	1050	1475
8R	950	1350	8L	1000	1350

Calculations

- In put to Traction or Observed HP =

  = (V x I)/746*Alt.effeciency

  = (730 x2160)/746*0.94 = 2248.5

- BHP(2600)=

  = (Input to traction)/X.Y.Z +AHP

  (Here X,Y,Z are Correction factor (ie 0.98) for Altitude ,Fuel gravity & Temperature for standard condition)

  = 2248/0.98 +186

  = 2294+186=**2480 HP**

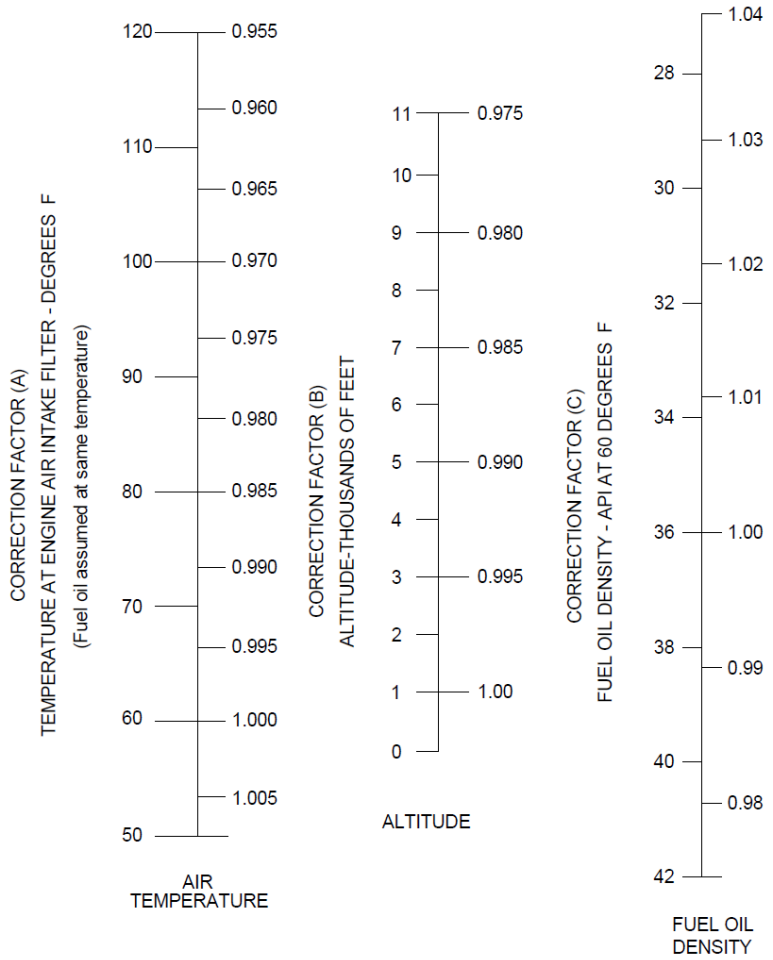
(Note: this data record are not standard. These are taken only for calculation & explanation)

Correction factor

MAINTANANCE INSTRUCTION No. MP.MI-10 (Rev-0.02)

ANNEXURE-A

CORRECTION CHART
ALCO 251 ENGINES WITH AFTER COOLER



Performance test report of WDM2

PERFORMANCE TEST OF DIFFERENT PARAMETERS OF 16 CYL. 251B 2600HP DIESEL LOCOMOTIVE

S.No.	PARAMETERS	UNIT	SPECIFIED
1	Initial rack (at engine shut down position)	mm	2.5 ± 0.25
2	Fuel rack at full load on 8th notch	mm	25 to 26 (with 17mm FIP and high efficiency turbo) 28.5 to 30 (with 15 mm FIP and ALCO turbo) (with max. rack differential of 1 mm between any two FIPs)
3	SFC maximum	gm/bhp/hr	154 ± 4 (with ABB &Napier turbo) 163 ± 2 (with ALCO turbo)
4	Engine RPM a) 8th notch b) Idle c) Overspeed trip	 RPM RPM RPM	 1000 400 (350 with low idle feature) 1145 ± 20
5	Turbocharger RPM a) ABB-VTC-304-V13 b) NAPIER –NA-295 c) ALCO/ Eliott-Phase I d) Hispano Suiza e) GE	RPM	 23400 max. 27000 max. 19000 max 25600 max 18000 max.
6	TURBO- RUN DOWN a) ALCO/ Eliott-Phase I b) NAPIER –NA-295IR	 Seconds Seconds	 90 (minimum.) 20 (minimum.)
7	Lube oil pressure a) At header (at full speed) b) At header (at idling speed-350 rpm)-80°C water temp. c) At header (at idling speed-400 rpm)-80°C water temp.	 Kg /cm² or psi Kg /cm² or psi Kg /cm² or psi	 5.3 to 6.0 or 75 to 85 2.0 or 28.5 minimum 2.2 or 31.3 minimum
8	Pressure each cylinder a) Compression at idle b) Differential (maximum) c) Peak firing pressure(ALCO turbo) d) Peak firing pressure (High eff. turbo) e) Differential in peak firing pressure	 Kg /cm² or psi Kg /cm² or psi psi psi Kg /cm² or psi	 28 .± 2.8 or 400 ± 40 3.0 or 40 1450 to 1600 1650 to1800 7.0 or 100(in any two cylinders.)
9	Air booster pressure a) ALCO 720A turbo b) High efficiency turbo	 Kg /cm² Kg /cm²	 1.1 to 1.5 1.6 to1.8
10	Crankcase Vacuum (min)	Inch of H_2O	0.5.
11	Exhaust gas temperature at turbine inlet (max) a) ALCO 720A turbo b)High efficiency turbo	 °C or °F °C or °F	 620 or 1148 525 or 977
12	Exhaust gas temperature at cylinder head a) Maximum • ALCO 720A turbo • High efficiency turbo Differential (maxi.)	 °C or °F °C or °F °C or °F	 550 or 1022 476 or 890 38 or 100

MATERIAL STANDARDS DIESEL LOCOMOTIVE WORKS VARANASI	NUMBER	01 P 7801C
	INDEX	TEST 16 CYL. 251 C ENGINE
PLANT TEST REQUIREMENTS & PROCEDURE LOCO DIESEL ENGINE ALONE, 16 CYL VEE 9x10 ½ - 251C 3100 HP FE	SHEET	7 OF 9
	DATE	Rev. 11-4-2005

PART 2

S.N	PARAMETERS	UNIT	SPECIFIED
PRESSURE:			
1.	L.O. PRESSURE		
	a) Pump Discharge	Kg cm^2/psi	8.8 to 9.5/125 to 135
	b) At header (at full speed)	Kg cm^2/psi	7.0 to 8.0/100 to 114
	c) At header (at idling speed)	Kg cm^2/psi	1.76/25 minimum
	d) Filter IN	Kg cm^2/psi	7.7 to 8.45/110 to 120
	e) Filter OUT	Kg cm^2/psi	7.0 to 7.7/100 to 110
	f) Turbo IN	Kg cm^2/psi	2.5 to 3.5/ 35 to 50 (Min. 35)
2.	GOVERNOR OIL PRESS. (With EDC Gov.)	Kg cm^2/psi	9.5 to 9.9/135-140
3.	FUEL OIL PRESSURE	Kg cm^2/psi	2.8 to 4 / 40 -57 (at full load)
4.	COOLING WATER PRESSURE AT PUMP DISCHARGE	Kg cm^2/psi	2-3 / 28-42
5.	PRESSURE EACH CYLINDER		
	a) Compression at idle	Kg cm^2/psi	24-25.5/340-360
	b) Differential (max.)	Kg cm^2/psi	3.0 / 40
	c) Firing pressure at 60 deg. F.	Kg cm^2/psi	114-125/1625-1775
	d) Differential in firing pressure	Kg cm^2/psi	7.0/100 psi (in any of the two cyl. heads)

MATERIAL STANDARDS DIESEL LOCOMOTIVE WORKS VARANASI	NUMBER	01 P 7801C
	INDEX	TEST 16 CYL. 251 C ENGINE
PLANT TEST REQUIREMENTS & PROCEDURE LOCO DIESEL ENGINE ALONE, 16 CYL VEE 9x10 ½ - 251C 3100 HP FE	SHEET	8 OF 9
	DATE	Rev. 11-4-2005

PART 2

S. No.	PARAMETERS	UNIT	SPECIFIED
6.	a) Super charged air booster pressure at 60 Deg F	As given	48" to 60" of Hg. 1.66kg/cm^2 to 2.07 kg/cm^2 R15
	b) Pressure Air manifold	As given	47"– 59" Hg. (Ref.) 25.5 psi to 29 psi (Ref.) 1.62kg/cm^2 to 2.0 kg/cm^2 (Ref.)
7.	Turbine Inlet Gas Pressure (Exhaust Gas pressure near turbine)	As given	35" to 40" of Hg 17 psi to 20 psi 1.2 kg/cm^2 to 1.4 kg/cm^2
8.	Turbo Suction Vacuum	mm of H20 inch of H20	500-550 mm 19.7 – 21.7 inch
9.	Crankcase Vacuum	Mm of H20 inch of H20	12.5-25mm 0.5 - 1 inch
TEMPERATURE			
1.	L.O. TEMPERATURE a) Inlet b) Outlet	 °C/°F °C/°F	 60 -82/140-180 77 – 88/170-190
2.	TURBOCHARGED (COMPRESSED) a) Temp. of Air inlet b) Temp. in Air manifold	 °C/°F °C/°F	 155-165 / 310-330 79 – 90/175-195
3.	Exhaust Manifold	°C/°F	455-477 at 15 °C/850- 890 at 60°F
4.	Exhaust Stack	°C/°F	300-355 at 15 °C/572-670 at 60°F
5.	Water In	°C/°F	60-80 / 140-175
6.	Water Out	°C/°F	71 – 85 / 160-185
7.	Exhaust Temp. each cylinder Max. Differential (Max.) Idling (Min.)	°C/°F °C/°F °C/°F °C/°F	390-451/735-845 476.00 / 890 38.00 / 100 99.00 / 210

S F C

Introduction

- In IR, Fuel Consumption of a diesel locomotive is expressed in two defined way –
  - SFC in term of gm/Hp.hr.
  - SFC in term of litre/1000GTKM.

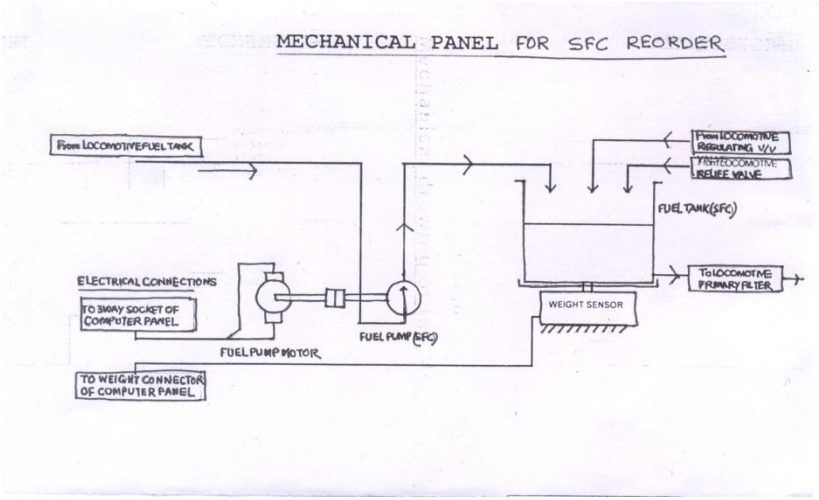
SFC in term of gm /Hp.hr

- Fuel consumption is measured in term of gm/(HP.hr) and calculated during Load box testing of loco.
- It is defined as the amount of fuel required to generate unit horse power per hour.
- It is calculated by using the given formula-
  - SFC= (Cons. of fuel in gmX3600)/BHP x time (sec)

Process of measurement in gm/HP.hr

- The Weight sensor fuel tank collect fuel.
- SFC fuel pump suck fuel from loco fuel tank and fill into Weight sensor fuel tank.
- Loco Booster Pump sucks fuel from Weight sensor fuel tank.
- The fuel consumed(10 kg) and respective time taken is recorded in seconds.

SFC recorder



SFC Calculation in gm/HP.Hr(WDM2/2600HP loco)

- Generator voltage : 568V volts
- Generator current : 2901 Amp
- Generator efficiency : 0.935(assumed 93.5%)
- Traction out put= (568 x 2901)/746 =2208.80HP
- Input to Traction=Traction output/Tr. efficiency
  =2208.80/0.935=2362.35HP
- BHP= Input to traction/xyz +AHP
  = 2362.35/0.98+186 = **2596HP.**
  - In WDM2,AHP=Power consumed by the Auxiliaries=186 HP
- SFC= **(10000 gms x 3600)/(88x 2596) = 157.58 gms/HP/Hr**

SFC in term of Litre/1000GTKM

- It is measured in term of Ltrs/1000GTKM when loco is doing service and hauling the train.
- SFC is the ratio between the fuel consumed and load hauled.
- It is calculated by using the given formula-
  SFC= (Fuel oil Consumption in Litres x1000)/(Load in tonnage xKM earned)

SFC CALCULATIONS in Litre /1000GTKM

- This method for calculation of SFC is adopted, when loco is in service and working in train.
- SFC= (Fuel oil Consumption in Litres x1000)/(Load in tonnage x KM earned)
- Example:
  - From "TRIP CARD",the following deta are collected .(This deta is for passenger train hauled by WDM2/2600HP loco)
  - KM earned : 232 KM (BGP to DNR)
  - Fuel oil consumption : 1050 Ltrs
  - Load on train(15 coaches) : 60x15+113=1013 tons
- SFC= (1050x1000)/(1013x232)=4.46 ltrs/1000GTKM.(Note:This value is not standard)

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
RAILWAY BOARD

No.2015/Fuel/289/3. New Delhi, Dated .10.2016.

The Chief Mechanical Engineers,
All Indian Railways.

Sub : Specific Fuel Consumption on Indian Railways.
Ref : Rly Bd's letter of even number, dated 05.05.99.

****

The specific fuel consumption (per 1000 GTKMs) for Apr'2015 - Mar'2016 as per "Monthly Evaluation Report" is as under:

Railway	BG	
	Passenger	Goods
CR	3.94	2.35
ER	3.68	2.22
ECR	3.55	1.91
ECOR	3.94	1.88
NR	3.43	1.83
NCR	3.95	1.97
NER	3.78	2.01
NFR	4.03	1.67
NWR	3.99	2.00
SR	4.02	2.02
SCR	3.01	1.68
SER	3.22	1.89
SECR	3.48	1.92
SWR	4.14	2.89
WR	3.26	2.03
WCR	3.46	1.87

All the credit and debit for Apr-June' 2016 should be raised as per these SFC figures.

(A.K. Misra)
Dir. Mech. Engg. (Tr.)
Railway Board

As a loco maintainer how can reduce excess fuel consumption?

- Ensure perfection of loco wheel profile.
- Avoid Brake binding in train .
- Set temperature for operation of R/fan.
- Compression pressure and Firing pressure must be check.
- Ensure SFC calculated during load box testing is within range.
- Ensure that Dynamic brake on loco is functioning properly.
- Use Dynamic brake to control the train .

Cont……

- Blow bye testing must be conducted in schedule .
- After cooler must be cleaned and tested in schedule.
- Properly overhauled and tested FI & FIP are only to be fitted.
- Pipes to be properly clamped to ensure no leakages.
- Ensure required booster pressure at different notch.

How to reduce excess fuel oil consumption?

- No of stoppage of train should be bare minimum (Commercial dept).
- Reduce number of caution order to minimum(Civil engg).
- Curved line impose speed restriction resultant in excess fuel oil consumption.(Civil engg)
- Avoid Signal failure and Poor visibility of signal.(Sig.& Tel dept).
- Minimize detention of train in yard.(commercial dept).
- Try to run the train on constant speed as possible as per instructions.(C&W).
- Try to avoid deceleration and acceleration of the train.(C&W)
- Idle running of engine and idle movement of loco must be avoided(Commercial)

Thanking You