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GOVERNMENT OF INDIA
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Bio Diesel - The alternate fuel For Indian Railways

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1. INTRODUCTION

The diesel engines that power our locomotives are not just highly efficient power plants, they are also very versatile in the fuels they can use. Rudolf Diesel first conceived the engine that bears his name as running on powdered coal. A ruinous engine explosion taught him to value liquid fuels. He subsequently hit on the idea of using vegetable oil. The engine that he demonstrated at the World Exhibition in Paris in 1900 ran on oil extracted from peanuts. The world has now come a full circle – after nearly a century we are once again exploring alternatives and looking to nature's bounty for our fuels as Rudolf Diesel once did.

Alternative fuels are substantially non-petroleum and yield energy security and environmental benefits. The alternative fuel that we shall be discussing in this article is Biodiesel. Biodiesel blended with regular petroleum diesel fuel, as an alternate fuel for diesel engines, is currently attracting the attention of the Indian Railways. This attention stems from the fact that it is an alternative fuel, produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines with no major modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics.

Approximately two billion litres of diesel fuel are consumed annually by the 4,000 freight and passenger locomotives in the Indian railway fleet. The prime mover in all but a few of these locomotives is the medium-speed diesel engine, having power levels ranging up to 4000 horsepower. The expenditure of Indian Railways on diesel fuel is Rupees 4400 crores. Diesel fuel is approximately 18 percent of railways' total operating expenses. In view of the significance that diesel fuel has for the railways, alternate fuel sources and fuel management strategies are investigated regularly with the aim to reduce operating costs, enhance service performance, increase economic competitiveness and reduce the environmental impact.

This report addresses the applicability of biodiesel as a fuel for locomotives in India. A literature search was performed and the claims about biodiesel evaluated within the context of the Indian railway sector. An important caveat for consideration by the railway sector is that any alternate fuel must be widely available, yield energy security and to an extent should be price-competitive with petrodiesel.

When the consideration arises to try an alternate fuel, Railways have a checklist of factors to ask about. This report attempts to address all the implications of using biodiesel as an alternate fuel on the Indian Railways.

2. BIODIESEL PROPERTIES

2.1 DESCRIPTION

Biodiesel is a fuel manufactured from animal or vegetable fats that has physical properties very similar to petroleum diesel fuel. Biodiesel is manufactured by chemically reacting vegetable oil or animal fat, with methanol or ethanol in the presence of a catalyst to yield glycerin and biodiesel (chemically called methyl or ethyl esters).

Most biodiesel processing requires treating the fats with alcohol under high temperature and pressure. Some processes require considerable time and energy while other processes, just now approaching commercialization, take much less time and react at lower temperatures. The products from the manufacturing process are methyl esters (biodiesel) and glycerin. The glycerin must be separated from the biodiesel component because it is a thick butter-like component that will block fuel filters.

Advantages of Bio-diesel

Proponents of biodiesel as a substitute for diesel fuel (neat or in blends) point to its advantages:

- It can reduce our dependence on foreign petroleum

- Petroleum imports constitute a major foreign exchange outgo India, and will continue to rise as demand increases. Our transportation sector, with its great demand for gasoline and diesel fuel, relies almost exclusively on petroleum for energy. Biodiesel can be produced domestically from agricultural oils and from waste fats and oils. Because it can be used directly in diesel engines, biodiesel offers the immediate potential to reduce our demand for petroleum.

- It can leverage limited supplies of fossil fuel

  Regardless of whose perspective we choose to believe on the future of coal, oil, and natural gas, their supply is, ultimately, limited. Biodiesel can help us leverage our use of these fuels.

- It can help reduce greenhouse gas emissions

  The burning of fossil fuels during the past century has dramatically increased the levels of carbon dioxide (CO2) and other "greenhouse gases" that trap heat in our atmosphere. Their implications are hotly debated, but the levels of these gases have unquestionably risen at unprecedented rates in the context of geological time. To the extent that biodiesel is truly renewable, it could help reduce greenhouse gas emissions from the transportation sector.

- It can help reduce air pollution and related public health risks

- One of the U.S. Environmental Protection Agency's (EPA) primary objectives is to reduce public health risks associated with environmental pollution. Biodiesel can play a role in reducing emissions of many air pollutants, especially those targeted by EPA in urban areas. These include particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC), sulfur oxides (SOx), nitrogen oxides (NOx), and air toxics.

- It can benefit our domestic economy

- Spending on foreign imports of petroleum takes dollars away from our economy. Bio-diesel can help us shift this spending to domestically produced energy, and offers new energy-related markets to farmers.

2.2 AVAILABILITY IN INDIA

At present, no biodiesel is produced in India except for small quantities from pilot plant production.

M/s Indian Oil Corporation has set up a small pilot plant. Biodiesel can be produced in batches of approximately 200 liters per day. The product is produced to meet the ASTM D 6751 biodiesel fuel specification.

IOC R&D BIO- DIESEL PLANT (PILOT)

JATROPHA CURCAS PLANT

The preferable feedstocks being used are 'Jatropha curcas' and 'Karanjia' essentially because the oil generated from them is non-edible. Some details of Jatropha curcas plant which is estimated to be the main source of bio- diesel in India is given in **Annexure – I.**

Since India is essentially a net importer of edible vegetable oil therefore it is essential that only non-edible oil sources be used for developing biodiesel in India. Developmental biodiesel processing at this facility has been undertaken in association with scientists of various agricultural organizations in India.

Various studies indicate that the Indian bio-diesel production potential is 500-600 tons per year, using vegetable oil from the basic sources: Jatropha curcas & Karanjia. However, another projection is that, as the market demand increases, farmers could dedicate high yield land for biodiesel plants that could further enhance the production.

2.3 PHYSICAL PROPERTIES

Technically, the term "bio-diesel" refers to the fuel in its neat or pure state. This is designated as B100. For transportation applications, economics lead to blending the biodiesel with petrodiesel. For example, the most common blend is 20 percent biodiesel and 80 percent petrodiesel, which is referred to as B20.

2.3.1 Typical Properties

The physical properties of biodiesel are compared to petrodiesel in **Table 1.**

Table 1: Typical physical properties of Petrodiesel and Biodiesel

S. No.	Physical Characteristics	Petrodiesel as per IS 1460 : 2000	Biodiesel as per ASTM D 6751
1	Fuel Composition	Hydrocarbons	FAME*
2	Kinematic Viscosity @ 40 ^{0}C	2.0 to 5.0	1.9-6.0 mm^2/s
3	Cetane Number	48 Min.	47 min.
4	Sulfur, % mass	0.25 max.	0.05 max.
5	Cloud Point (^{0}C).	_	**
6	Pour Point (^{0}C) max	3^{0}C for winter & 15^{0}C for summer	
7	Flash Point (^{0}C)	35^{0}C min.	130.0 ^{0}C min.

* Biodiesel fuel typically contains up to 14 different types of fatty acids that are chemically transformed into fatty acids methyl esters (FAME).

** The cloud point of bio-diesel is generally higher than petrodiesel and should be taken into consideration when blending.

2.3.2 Specifications

The American Society for Testing and Materials (ASTM) published a specification for neat (100 percent) bio-diesel – ASTM D 6751 given in **Table -2**. The European specification for pure biodiesel is DIN 952. The specifications aim to ensure that biodiesel has the fuel properties for safe operation in a compression ignition (diesel) engine and to ensure that improper processing has not contaminated the fuel with products that will create engine damage. The standards are independent of any manufacturing process or feedstock.

Table 2: ASTM D 6751 Biodiesel Fuel (B100) Blend Stock for Distillate Fuels

S. No.	Property	Test Method	Limits
1	Flash Point, ºC	D 93	130.0 min
2	Water and Sediment, % vol	D 2709	0.050 max
3	Kinematic Viscosity, 40 ºC, mm²/sec	D 445	1.9 – 6.0
4	Sulfated Ash, % mass	D 874	0.020 max
5	Sulfur, % mass	D 5453	0.05 max
6	Copper Strip Corrosion	D 130	No. 3 max
7	Cetane Number	D 613	47 min
8	Cloud Point, ºC	D 2500	Report
9	Carbon Residue, 100% sample, %mass	D 4530	0.050 max
10	Acid Number, mg KOH/gm	D 664	0.80 max
11	Free Glycerin, % mass	D 6584	0.020 max
12	Total Glycerin, % mass	D 6584	0.240 max
13	Phosphorus content, % mass	D 4951	0.001 max
14	Distillation, 90 % recovered, ºC	D 1160	360 max

Specifications for biodiesel blends are under development. For example, ASTM has a provisional standard for a 20 percent biodiesel (PS 121), which is shown in **Table 3**.

Table 3: ASTM PS 121 Biodiesel B20 Biodiesel Blend

S. No.	Property	Test Method	Limits
1	Flash Point, ºC	D 93	100.0 min
2	Water and Sediment, % vol	D 2709	0.050 max
3	Kinematic Viscosity, 40 ºC, mm²/sec	D 445	1.9 – 6.0
4	Sulfated Ash, % mass	D 874	0.020 max
5	Sulfur, % mass	D 5453	0.0015 max
6	Copper Strip Corrosion	D 130	No. 3 max
7	Cetane Number	D 613	46 min
8	Cloud Point, ºC	D 2500	Report
9	Carbon Residue, 100% sample, %mass	D 4530	0.050 max
10	Carbon Residue, Ramsbottom, %mass	D 524	0.090 max
11	Acid Number, mg KOH/gm	D 664	0.80 max
12	Free Glycerin, % mass	D 6584	0.020 max
13	Total Glycerin, % mass	D 6584	0.240 max

2.4 TESTING IN RDSO TO ASCERTAIN PROPERTIES OF BIO-DIESEL

2.4.1 TESTING IN M & C Dte. (LAB)

The bio-diesel sample was tested as per IS 1460:2000 in M& C Dte. of RDSO. However this specification deals with testing of HSD oil which is the middle distillate of petroleum refining process. Since the bio-diesel is a mono alkyl ester of long chain fatty acids of vegetables oils and animals fats, its specification for India has been proposed by BIS. Since bio-diesel test method in BIS has yet not been mentioned and standards are yet to be ascertained, therefore the test was carried out as per IS 1460:2000.

As per the calorific value assessment done at M & C lab of R D S O, it was observed that the calorific value obtained for pure biodiesel was 10,777 as against 10,900 calories/ gm for petrodiesel. Tests results are given in **Annexure - II**.

2.4.2 TESTING IN ENGINE DEVELOPMENT DIRECTORATE

Tests were done at the Engine Development Directorate of RDSO on a 16 cylinder test bed. Results of the tests is RDSO are summarized in the **TABLE 4**:

Table 4: Test Result Of ED Dte For Different Blending Bio-diesel With Regular Diesel

	Regular Diesel	Bio Diesel Blends with Regular Diesel		
		5 %	10%	20%
Horsepower (HP)	3064	3070	3071	3068
SFC (gms/bhp-hr)	150.59	152.12	152.47	154.83
Firing pressure (psi)	1990	1940	1930	1895
Exhaust Gas Temp. in ºC	472	480	473	477

As can be seen from the results, the test engine was capable of obtaining full power output with biodiesel. Although this single test is the only data available with the Indian Railways at this time, it however suggests that biodiesel would not compromise horsepower requirements to any significant degree.

2.4.3 TRIAL RUN

In some tests with high-speed diesel engines in fleets such as buses, some operators have reported a loss of power with biodiesel blends. Upon investigation, however, it was found that fuel filters were becoming blocked with contaminants such as soot or glycerin. It is important, therefore, to separate biodiesel quality (contaminants) issues from biodiesel energy content as a reason for reports of power loss with biodiesel.

Indian Railways had also tried a 5% blend of biodiesel on a locomotive no. 14008 WDM_{2C} which was used to haul the prestigious Shatabdi express (2013) from New Delhi to Amritsar on 31st December, 2002. Before the run a new set of lube oil filters were installed on the locomotive.

No adverse effect was observed during the run in terms of haulage capacity etc. After the return trip, no unusual deposits were noticed on the filter surface. The fuel injection pumps and injector nozzles were also found in satisfactory condition and free of any gum or resinous deposits. The specific fuel consumption during the trip was 4.56 litres per 1000 GTKM. With addition of biodiesel in petrodiesel the Cetane value at different levels of blends varies from the normal cetane value of conventional petrodiesel and for this variations of Cetane value, the fuel cam profile will have to be modified to optimize the performance for this new blend. Indian Railways plan to undertake elaborate trials to further establish the efficacy of higher blends of biodiesel.

Loco Used To Haul Shatabdi Express
Using Bio-Diesel Blend As A Fuel

2.5 CRITICAL PROPERTIES

Several of the physical properties in Tables 2 and 3 are important for Indian railway operation are discussed.

2.5.1 Cloud Point

The cloud point is the temperature at which waxes first start to crystallize in diesel fuel. Cloud point is an indication of the lowest temperature at which diesel fuel can be used before wax crystals will block fuel filters. It predicts, therefore, the lowest temperature of the fuel for operability. Diesel fuel is defined to be above the cloud point for a specific locale.

Biodiesel has a higher cloud point than petrodiesel. The cloud point of neat biodiesel can be from -10°C to +20°C depending on the raw material source. When blended with petrodiesel at 20 percent (B20), the cloud point can be 3 to 5°C higher than petrodiesel. This introduces a higher degree of risk of fuel filter blockages with waxy components than with petrodiesel in winter.

The highest risk with any fuel is when a full load of fuel is introduced into a locomotive fuel tank and the locomotive immediately powers up to full power for heavy haul service. Any wax crystallization in the fuel would quickly block fuel filters.

It is yet to be determined whether B20 blends can perform in a satisfactory manner in locomotives under North Indian winter operations. Investigations in this regard will be required.

2.5.2 Energy Content

The energy content of neat biodiesel, measured as MJ/kg, is 1 to 10 percent less than petrodiesel, depending on raw material sources. A B20 blend would have a proportionate reduction in energy content. This suggests a 0.2 to 2.0 percent increase in fuel consumption based on energy content alone. Locomotive operating range, therefore, could be slightly less than with petrodiesel.

As per the calorific value assessment done at Research Designs & Standards Organization lab, it was observed that the calorific value obtained for pure biodiesel was 10777 as against 10900 calories/ gm for petrodiesel. Thus the energy content of biodiesel was only 1.13 % below that of petrodiesel.

2.5.3 Glycerin Content

Glycerin is a thick butter-like by-product of the production of biodiesel and must be removed at the manufacturing plant, before delivery. A small amount of glycerin contaminant would cause fuel filter blockage, particularly at the point of delivery. Fuel transfer filters would block quickly if glycerin were present in the biodiesel.

2.5.4 Stability

Stability is a broad term that describes the ability of fuel to withstand hot and cold temperatures, and to resist oxidation and water absorption. Biodiesel is possibly less stable than petrodiesel because of the nature of the methyl ester chemicals in biodiesel. The laboratory tests that predict stability are acid number and iodine number. The higher the numbers, the more susceptible the fuel is to stability problems. Different feedstocks have been found to have different laboratory test results. It is not known how these tests correlate to actual in-service locomotive biodiesel performance.

Long-term storage stability and thermal stability of biodiesel should be evaluated under Indian railway operations. Test programs to date indicate that both storage and thermal stability have not been a problem in truck and bus fleet demonstration projects; however, no experience has been gathered under Indian railway operation conditions where large wayside fuel storage tanks are common. This is a property that requires careful study.

2.5.5 Lubricity

Diesel fuel additive quantities of less than 1 percent have been used in regular diesel fuel. Lubricity of some low-sulfur (500 ppm) diesel fuel has been found to be a problem for some engine fuel pumps and injection equipment. Lubricity additives are now quite common in diesel fuel. Lubricity in Indian railway engines has so far not been identified as a problem. The lubricating components of the diesel fuels are believed to be the heavier hydrocarbons and polar fuel compounds. Diesel fuel pumps, without an

external lubrication system, rely on the lubricating properties of diesel fuel to ensure proper operation. Refining processes to remove diesel fuel sulfur tend to simultaneously reduce the components of the fuel which provide natural lubricity. As diesel fuel sulfur levels decrease, the risk of inadequate lubricity also increases. Inadequate lubricity can result in increased tailpipe emissions, excessive pump wear and, in some cases, catastrophic failures.

One of biodiesel's most promising future roles could be as a fuel additive. Tests have shown that blending biodiesel with petroleum based diesel fuel at just a 1% level could increase the lubricity of diesel fuel by upto 65%.

2.6 BIODIESEL BLENDS

Biodiesel can be used without engine modification in diesel engines at very low percentages (less than 1 percent) and up to neat (100 percent). The most common biodiesel blend is a 20 percent mixture of biodiesel in petrodiesel, commonly designated as B20. This has been chosen primarily for operational reasons. The cloud point of B20 raises the cloud point of petrodiesel from 3 to 5°C. In Europe, most regular diesel fuel contains 2 to 5 percent biodiesel.

2.7 FUEL CONSUMPTION

Fuel consumption is expected to increase slightly with biodiesel because of the lower energy content. The amount of increase would vary with service and blending ratio. The marginal increase in SFC (1.3 – 2.6 %) in the case of bio-diesel obtained during testing on the engine test bed can thus be explained on the basis of the lower energy content (ref 2.4.2).

COSTS

Costs of biodiesel are related to the source of the raw (feedstock) material. Production costs are expected to decrease when commercial-size plants come into production. At the present time in India, only small demonstration plants exist. Production costs have therefore not yet been optimized. The Indian Oil Corporation envisages biodiesel production costs to be competitive with petrodiesel for a commercial-size production plant that uses its oil derived from the Jatropha plant.

Cost estimates for a facility producing 1 ton of biodiesel per day :

Land required	1000 hectares
Seed yield	1500 tons
Oil yield	375 tons
Biodiesel yield	375 tons
Cost	
Seeds @ Rs. 4000/t	Rs. 60 lakhs
Processing cost @ Rs. 3000/t	Rs. 45 lakhs
Overheads @ 10 %	Rs. 10.5 lakhs
Total	Rs. 115.5 lakhs
Receipts	
Seed meal, 1125 tons @ Rs. 2000/t	Rs. 22.5 lakhs
Glycerine, 37.5 tons @Rs. 4000/t	Rs. 15.0 lakhs
NET COST (Cost minus Receipts)	Rs. 78 lakhs
Cost of Bio-diesel per kg = Rs. 20.00	
Estimated Cost of Bio-diesel per litre =	**Rs. 17.50**
Prevailing Price of HSD per liters =	**Rs. 22.00**

The above estimation done by M/s Indian Oil indicates that the cost of biodiesel may well be comparable or even lower than that of petrodiesel. However as per the global experience, the price of biodiesel is approximately 2-3 times the price of petrodiesel. The eventual price would of course depend on a number of economic factors but it is expected that taking into account the various potential benefits for the nation, the Indian government would provide the necessary support in terms of tax benefits etc.

3. BIODIESEL EXPERIENCE

Despite its cost, internationally biodiesel is a fast growing alternate fuel. It is being promoted for several reasons:

a) As a means of providing energy security for the country and reducing the reliance on imported petrodiesel

b) As a means for providing new market opportunities for farmers, Indian government, foresees biodiesel as a value added product that would increase farm revenues and provide significant employment to farmers.

Due to its current higher price globally, market acceptance of biodiesel has been the major obstacle to be overcome. Tax reduction or tax elimination has been a method used by governments to promote the use of biodiesel. Also, consistent biodiesel quality has been a concern in the past. This has been overcome by the development of biodiesel specifications that producers must meet. The next step will be to develop a specification for biodiesel blends, such as a B20, that would ensure the quality of the blended fuel.

3.1 USE IN HIGH-SPEED DIESEL ENGINES

In Canada, the BIOBUS project experience shows that the engines in its buses, Detroit Diesel 6V-71 and 6V-92 and Cummins 8.3 turbo, have been operating during the one – year trial at one of its seven garages with a minimum of problems. Rothsay produced the biodiesel in its pilot plant on an as required batch basis and splash blended the biodiesel with petrodiesel to provide to produce a B20. The biodiesel is added hot (35 ºC) to the truck containing petrodiesel, which could be at temperature as low as -15ºC in Montreal winters.

Sources report that at the start of the trial, bus filters were rapidly blocked with what appeared to be soot. The investigation into the problem indicated that the biodiesel blend was lifting soot off the walls of the bus fuel tank and depositing it on the bus fuel filters. Biodiesel has some detergent properties that account for this soot lifting. After this initial start-up difficulty the buses operated without operating problems during the one-year trial. Several incidences of glycerin contamination, causing truck delivery unloading filters to block, were reported.

There were also report of loss of power by drivers, however, it has been difficult to establish the reason for the reports. These are common even with buses operating with standard diesel fuels.

3.2 USE IN MEDIUM-SPEED DIESEL ENGINES

There is limited biodiesel experience with medium-speed diesel engines. The Tri-County Commuter Rail Authority (Tri-Rail), a passenger railway operating along the intercoastal waterway in Florida, US, used neat biodiesel for a three month period without any operating problems. The test was run on an F40PHL-2, 3,200 horsepower locomotive. Of interest to Tri-Rail was the enhanced biodegradation of biodiesel compared to petrodiesel. The intercoastal waterway would be sensitive to diesel fuel spills. The trial ended after three months and proved that this locomotive could run satisfactorily on biodiesel, if necessary. The higher cost of biodiesel makes its continued use prohibitive at this time.

In California, the Sierra Railroad is running on neat biodiesel. It is using locomotive engines to generate electrical power. The interest here is the lower GHG (green house gases) emissions of the overall biodiesel life cycle compared to petrodiesel.

As well, there are older models of medium-speed diesel engines in barge service undergoing biodiesel trials. The experience to date shows that there are no short-term operating problems when using biodiesel in medium-speed diesel engines.

3.3 INDIAN RAILWAYS EXPRIENCE

Indian Railway has successfully run Shatabdi express from New Delhi to Amritsar on 31st December 2002, as already mentioned in para 2.4.3. Further trials on mail express trains are proposed to be done to ascertain the field problems ,if any, with various blends of biodiesel.

4. EMISSIONS

4.1 POLLUTANTS

Most biodiesel emissions testing has been performed on high-speed diesel engines and has provided some indicators on what might be expected in medium-speed diesel engines.

Emissions reduction of Biodiesel w.r.t Petrodiesel are given in **TABLE – 5**.

Table 5 : Emissions Reduction of Biodiesel Relative to Petrodiesel

Pollutant	**B20**	**B100**
Unburned Hydrocarbons, %	-11.09	-56.3
Particulate Matter, %	-18.0	-55.4
NO_x , %	+1	+6
CO, %	-13	-43
$CO_{2,\%}$	-16	-78*

**The purported reductions in CO_2 of up to 78 percent are "life cycle" reductions. This means that if we consider the complete ecological cycle i.e. consumption of CO_2 by the plants that are grown to generate biodiesel and reduce this amount from the CO_2 generated as a result of combustion then we get an overall reduction of 78% as compared to petrodiesel. If we consider only the combustion side, the CO2 reduction appears to be minimal. This is because of the lower energy content and slightly higher fuel consumption of biodiesel. Reports show the emission CO_2 to be $^{+}/_{-}$ 1 percent of petrodiesel, depending on the engine.*

The Southwest Research Institute (SWRI) tested B20 biodiesel in a GM EMD GP-38 locomotive and found similar results to that found in high-speed diesel engines. NOx increased 5 to 6 percent; CO decreased by approximately 20 percent. PM did not decrease, but it was noted that, with this older two-stroke engine, PM is mostly lubricating oil derived.

Extrapolating the emissions profile from truck-size high-speed engines to medium-speed locomotive engines may not always be accurate. It is thus desirable that a systematic comparative testing program be commissioned to establish a sound database on emissions from Indian Railways locomotives. In particular, there is a need to perform testing on Indian Railways freight locomotives, such as the older model WDM_2 locomotives, to more closely align test data to the Indian Railway fleet.

5. ENGINE RELIABILITY

Locomotive sub-assembly manufacturers (viz. MICO for fuel injection pumps) issue performance warranties based on specific diesel fuel properties outlined in their diesel fuel specifications. Using diesel

fuel outside of these specified properties could reduce engine performance and reliability, and could void the warranties requiring the use of standard diesel fuel. To satisfy the locomotive sub-assembly manufacturers, that biodiesel blends would perform in their equipment without a negative impact on performance, the Indian railways would have to undertake extensive testing and evaluation.

Annexure –IV. outlines a proposed test program that would generate data to quantify the performance from the use of biodiesel blends.

Annexure – V, outline a proposed field trial program.

6. GOVERNMENT POLICY

Biodiesel appears to have all the attributes for successful public relations. It is envisaged that use of biodiesel by the Indian railways would result in accolades from the public. It is envisaged that use of biodiesel will generate a lot of employment opportunities, ensure security of energy supply by reducing dependence on imports and simultaneously give a much needed boost to the agricultural economy of the nation. Its environmental benefits are also expected to play a significant role in shaping government policy for adoption of this alternate fuel.

Indian Railways(IR) have taken a project with Indian Oil Corporation (IOC) and signed a Memorandum Of Understanding (MOU) for the use of petrol -diesel blended with biodiesel in appropriate proportion as a fuel for diesel locomotives for a period of 15 (fifteen) years from the effective date viz. 12th Feb, 2003.

The development phase shall be of eight years from the date of signing of MOU. In the MOU it was decided that IOC, R & D shall be developing a process for production of biodiesel from non-edible oils viz. “jatropha Carcus” and “karanjia”.

Bio diesel has almost no sulfur, no aromatics, has high cetane number, is rich in oxygen and has recently come into prominence because of its environmental benefits and also the fact that it is made from renewable resources, including non edible oils jatropha carcus and karanjia which can grow on waste land and provide abundant sources for production of biodiesel in India.

Indian Railway has offered 500 hectare of land to IOC for plantation of Jatropha Carcus for the intial growth potential assessment. IOC will develop the formulation of diesel containing various percentage of biodiesel and this will include selection of additives and their dosages. IOC will ensure that the diesel containing biodiesel supplied to railways meets all the specifications and will monitor the results of its usage. Initial testing of biodiesel with different levels of blending biodiesel oil has been done and now full scale testing trial’s to be conducted at Engine Development directorate’s test bed at RDSO. Subsequently field trial will be conducted at nominated diesel sheds as per Railway board’s order for checking the engine performance, wear, deposits on nozzles (injectors) &, fuel oil consumption during the trial.

Present Status of the project

IOC has already selected 81 hectares land for Jatropha carcus plantation at Surendra Nagar district and Chotila Than railway track in Gujrat under Rajkot division. IOC have floated the tenders for plantation. The tender was opened on 6 th October’03. The evaluation of tender is now in progress at IOC R & D, Faridabad.

The main points, which were signed between IOC R & D and Indian Railways for the project, are given **Annexure – III.**

7. CONCLUSIONS

The examination of the potential applicability of bio diesel as a fuel for locomotives in India has resulted in the following conclusions.

1. Technically, bio diesel can be used in medium-speed diesel engines. To date, limited testing and

usage on Alco locomotives has shown that bio diesel can be used without engine modification and can attain full operating power.

2. The use of bio diesel can reduce the amount of harmful emissions released from the fuel consumed by the Indian railways. The improvement would be directly proportional to the volume of petrodiesel displaced.
3. A blend of 20 percent biodiesel and 80 percent petrodiesel (B20) appears most compatible with Indian railway and climate conditions. A B20 blend equates to an overall annual railway market potential of 400 million litres of neat bio diesel.
4. In India, bio diesel is currently available in restricted quantities from pilot plants or by import. Feasibility studies are underway for commercial-size plants.
5. To gain railway acceptance, bio diesel blends would have to be price competitive with petrodiesel as well as consistent in quality and security of supply.
6. There is a need by railways for data on the performance and emissions resulting from bio diesel blends combusted in locomotives typical of those on Indian railways.
7. Commuter rail services and shunting operations would be suitable starting points to introduce bio diesel into the Indian railway sector.

8. RECOMMENDATIONS

The following recommendations stem from the findings and conclusions of the study.

The railway sector and associated agencies should actively monitor the various initiatives underway in India to promote, financially facilitate and realize the commercial supply of bio diesel, aimed at being a price-competitive & quality-consistent fuel that is a candidate for use in the medium-speed diesel engines in Indian railway locomotives.

Steps should be taken to obtain data so as to quantify the performance and emissions from the use of bio diesel blends in locomotives of the type in use on Indian railways via:

a) Full scale testing on the 16 cylinder laboratory medium-speed engine (such as exists at Engine Development Directorate according to test cycle prescribed)
b) Testing on a full fledged locomotive engine of the type in Indian railway service according to procedures specified.

Opportunities should be examined wherein biodiesel can be introduced into segments of the Indian railway. Feasibility studies should be commissioned to characterize the supply and usage aspects, quantify the expected environmental benefits and define the pricing formulae that could make bio diesel blends competitive with petrodiesel.

Globally, the strict emission laws and financial incentives for alternative fuel vehicles have provided the motivation for active research in alternate fuels. Though these environmental conditions do not exist in India, nevertheless it is best to be prepared for the future and actively work in this direction.

In India the fact that even today the bulk of petroleum crude oil is imported has compelled us to look for other options. Moreover growing environmental concerns have also directed attention on alternative energy sources for the transportation industry, including railways.

It is expected that the potential benefits of bio diesel will convince the policy makers to adapt this renewable fuel in a large way, which will pave the way for making our nation completely self reliant in energy sources in the future.

ANNEXURE –I

Jatropha Curcas Plant

Vegetable oils are categorized as edible and non-edible oils. Non-edible vegetable oils are used in the manufacture of lubricants, soaps, and other cosmetics. Though edible oils can be used in the place of non-edible oils, the latter cannot be a substitute for the former. Thus, shortage of edible oils may have implications for those industries which use non-edible oils. Augmenting the supply of non-edible oils will, therefore, release some quantity of edible oil in the market and ease the shortage of edible oils to some extent.

India had about 106 million hectares of agricultural, forest, and other lands classified as wastelands. While some categories of wastelands may not sustain vegetation, some others could be put under plantation without major investment. Some others would need initial investment before they are fit for use. Keeping this in view and the huge gap between the demand and supply of firewood which is increasing in spite of availability of other sources of energy, priority has been accorded in the national social forestry programme to cover wastelands and marginal farm lands with tree plantations. Jatropha curcas L. is one species which has been found suitable for such lands. The plant starts bearing fruits from the second year for about 30 years. It is hardy in nature and can survive in harsh soil and climatic conditions. It grows wild in some areas of Gujarat, Rajasthan, and Madhya Pradesh. It is also grown in boundaries of fields as live fence.

Keeping these characteristics of the plant in view, one agro-forestry federation in Maharashtra made efforts to propagate its cultivation among its members. Corporate giants such as Hindustan Lever and Godrej started organizing cultivation of the plant in Madhya Pradesh and Maharashtra respectively. It is in this background that the Core Group on Wastelands Development at the Indian Institute of Management, Ahmedabad took up this study of production and marketing of Jatropha seeds.

Objectives

The study has the following objectives:

- To examine the cultivational practices followed by Jatropha growers.
- To study the economic and management aspects of marketing and processing of Jatropha seeds.

Jatropha Crop

Jatropha (Jatropha curcas L) belongs to the family Euphorbiaceae. Carl van Linne was the first botanist who gave it this name in 1753. The name is derived from the medicinal users of the seed. (In Greek, Jatros means doctor and Jatropha means nutrition).

This plant originally belonged to South America and Africa from where it spread to other parts of the world. Jatropha curcas L. has more then 200 different names throughout the world. In India, the plant is known as follows (Vinayak Patil and Kanwarjit Singh, Oil Gloom to Oil Boom: Jatropha Curcas (Nashik: Agro-Forestry Federation, 1991), kp.2)

Assamese	:	Bongalihotra
Gujarati	:	Jamal Gota, Kala Eranda, Parsi Eranda, Ratan Jyot
Hindi	:	Bagh Eranda, Jangli Eranda, Safed Eranda
Kannada	:	Adalubraralu, Bettadaharalu, Karnocchi, Maraharalu
Malayalam	:	Kattavanakka, Kadalavanakk
Marathi	:	Mogali Eranda, Ranay Eranda, Vana Eranda, Chandra Jyot, Chandri
Oriya	:	Jahazigaba

Punjabi	:	Jamal Gota, Kala Eranda
Telugu	:	Nepalmu, Peddanepalamu, Adaviamidamu
Tamil	:	Kadalamanakku, Rattamanakku
Sanskrit	:	Kanana Eranda, Parvat Eranda

Being purgative and toxic no part of the plant or the oil cake is given to animals. Cattle, goats, and other animals do not eat this plant. Because of this property, Jatropha is planted on the boundaries of fields as live fence. It was not cultivated as a field crop till the late 80s when some efforts were made in Nashik to introduce it as a commercially viable economic activity on marginal farmlands. The corporate sector also took initiative to promote it among farmers.

Botanical Features

In his book Forest Flora of the Bombay Presidency, W.A. Talbot has described Jatropha curcas L. as a small evergreen, nearly glabrous tree or soft wooded shurb (3 to 4 meters high). It has along petioles, entire, 3 to 5 lobed or angled, orbicular, cordate, 10 to 15 cm long and yellowish green flowers in glabrous or pubescent cymes at the end of the branches (Ibid, p.2). The fruit is a capsule of 2.5 to 4 cm in diameter containing two to three seeds, each weighing about 0.6-0.7 g. The plant profusely flowers twice a year in November-December and May-June. It has a gestation period of three to five years and a long productive life span of 25-30 years. Irrigated plants remain green and set flowers and fruits almost throughout the year.

Climate and Soil

Jatropha flourishes well in arid and semi-arid areas. However, it thrives best in the high temperature range of 20 to 30 degree Celsius throughout the period. It is a sturdy plant and can withstand light frost. Its water requirement is low and can survive long periods of drought.

Jatropha can be grown on sandy, grave, stony, shallow, and even in calcareous soils. Because of its drought resistance capacity it is suitable as wind breaks/shelters to check shifting of sand dunes. It has a high degree of adaptability to a wide range of climatic conditions. It can be grown on wastelands including stony soil then it can even grow in the crevices of rocks.

ANNEXURE –II

TEST RESULTS (M & C DIRECTORATE)

S. No.	Tests	Specified Value of IS: 1460	Proposed BIS Standard	Observed Value
1	Visual examination	Free from grit, suspended matter and other visible impurities	-	Colour light yellow, free from grit and other visible matters
2	Density at 15 °C (kg/m^3)	820 - 860	870 -900	876
3	Cetane Number, min.	48	51	-
4	Distillation (i) 85 % volume recovery at °C,max.) (ii) 95% volume recovery at °C,max.)	350 370	- 360	350 355
5	Flash point, (min). °C	35	100	140
6	Ash% by mass(max.)	0.01	-	0.013
6A	Sulphated Ash% by mass(max.)	-	0.02	-
7	Cu strip corrosion test for 3 hrs. at 100 °C	Not worse than No. 1	-	Not worse than No. 1
7 A	Cu strip corrosion (3 hrs/50 °C) max.	-	1	-
8	Kinematic Viscosity at 40°C, cSt	2.0 to 5.0	3.5 to 5.0	4.7
9	Water content % by volume, max.	0.05	-	Negligible
9A	Water content mg/kg, max.	-	500	-
10	Pour point, max	3 °C	-	Below 3 °C
11	(i)Acidity inorganic (ii) Total Acidity, max (mg/ KOH/gm)	Nil 0.20	0.8	Nil 0.23

ANNEXURE –III

Description of MOU between Indian Railways and Indian Oil Corporation

1. In the project, IOC shall at its, own cost and initiative:

(i) Undertake through third parties cultivation of bio-crops on the land jointly identified by IR and IOC for the purpose.

(ii) Cause the oil seeds to be harvested from the bio-crops cultivated on the land and cause the oil to be extracted therefrom.

(iii) Cause the extracted oil to be esterified and under take the preparation/production of bio-diesel from the esterified oils.

(iv) IOC will develop the formulation of diesel containing various percentage of bio-diesel and this will include selection of additives and their dosages. IOC will ensure that the diesel containing bio- diesel supplied to Railways meets all the specifications and will monitor the results of its usage.

(v) Under take the blending of bio-diesel with petroleum diesel at different levels.

(vi) Arrange for supply of the blended diesel products to IR for testing of the different blends in its running locomotive engines.

1.2 For this project, IR shall lease about 500 hectare of land to IOC on a nominal lease charge of Rs. 1 per annum for a period of 15 years, which may be extended on mutual consent. A separate lease agreement would be entered in to, in this regard between Zonal Railway and IOC.

1.3(a) Once a optimum blend of blended diesel has been identified and a blended diesel product has been developed which can be satisfactorily used by IR as a fuel for its locomotive engines, the development phase of the project will be launched in which both parties shall jointly identify the measures required to jointly promote the cultivation of bio-crops to develop a cultivation base for the bio-corps necessary to produce bio-diesel or to obtain bio- diesel from any other source to enable IOC to make blended diesel of the quantity required to meet the requirement of IR of blended diesel as a fuel for its locomotive engines in the development phase. IOC will develop specialized additive packages, which can be used to make stable blended diesel and for this it will take in house projects. IOC will thus supply to IR a stable blended bio-diesel, which will meet all specifications for the transport fuel.

1.3(b) IOC and IR shall each take all steps and measures as are identified and agreed to be taken by each to create a necessary base for producing the identified blended diesel to the meet requirements of IR.

2.0 TESTING / TRIAL OF BIODIESEL

Testing of bio diesel supplied by IOC has already been done on RDSO test bed with satisfactory results. Supply of blended diesel oil to conduct field trials on locomotives by IR, will be done by IOC, on cost basis, without waiting for the supply through the project. IR on their part shall conduct expeditious field trials with bio diesel in different percentage of blending.

3.0 SUPPLIES OF BLENDED DIESEL

The supplies of blended diesel by IOC to IR shall be made at such point(s) of delivery and in such manner as is/are from time to time agreed to between IR and IOC in this behalf.

4.0 PRICE OF BLENDED DIESEL OIL

The supplies of blended diesel shall be at such price(s) as is/are from time to time agreed to between IR and IOC depending upon the cost of biodiesel to IOC, percentage of biodiesel in the

blended diesel product, price of diesel, blending and other costs, and costs of transportation and storage, and point of delivery.

5.0 EXCLUSIVITY

5.1 IR shall purchase the biodiesel from IOC made available from the project for 15 (fifteen) years.

5.2 Bearing in mind the investment of time, effort and money to be made by IOC in the project, IR undertakes that it shall work closely with IOC during the project.

5.3 For a period of 8 years from the date of signing of MOU or 6 years from the date of firs t supply of bio diesel through the project, whichever is earlier, IR undertakes to purchase bio-diesel exclusively from IOC.

5.4 In such cases where IOC is not able to meet the requirements, IR can source its supplies of bio diesel from elsewhere.

5.5 In situation of some party offering bio diesel to IR at cheaper rates, IR will direct the party to IOC for procurement of bio diesel and for supply of blended bio diesel to IR.

5.6 IOC undertakes, in turn, that it shall make available to IR on a priority basis its expertise and resources to develop a satisfactory blended diesel product for the locomotive engines of IR and to ensure the availability of required blended diesel necessary to meet fuel requirement of IR for the blended diesel product during the project period.

6.0 REVENUE MODEL

6.1 Each party shall bear its own cost of performing its obligations pursuant to or arising out of this memorandum.

6.2 Each party shall retain its own margins, revenues and advantages arising out of the performance of this MOU and there will not be any sharing of the same.

7.0 PROJECT MONITORING COMMITTEE

7.1 The parties shall within 30 days from the effective date of this Memorandum cause to be formed a monitoring committee to monitor and coordinate the activities to be performed and undertaken by the parties pursuant to this memorandum. The monitoring committee shall consist of 6 (six) members drawn from a suitable level of seniority within IR and IOC respectively in the relative disciplines involved in the implementation of this memorandum. 3 (three) members of the committee shall be appointed by IOC and 3 (three) members shall be appointed by IR.

7.2 Monitoring Committee shall:

(i) Periodicity identify in detail the various steps or actions to be taken by each of the party pursuant hereto and draw a time schedule for the implementation of such steps or actions.

(ii) Recommend the prices to be fixed for the supply of blended diesel by IOC to IR pursuant hereto.

(iii) Monitor and coordinate the efforts to IR and IOC in the implementation of this memorandum.

(iv) Take such other steps as shall or may be from time to time jointly assigned by the parties to the monitoring committee or as may be necessary for the implementation of the project.

7.3 (a) A quorum of at least 4 (four) members, of which at least 2 (two) shall be appointed by IR and at least 2 (two) shall be appointed by IOC shall constitute a quorum for the meeting of monitoring committee. The meeting shall however be attended by the appointed members of the quorum purpose.

(b) The monitoring committee shall meet as often as necessary and a meeting of the monitoring committee may be convened by notice of any member of the committee.

(c) All decisions of the monitoring committee shall be conveyed to IR and IOC.

(d) In addition, the monitoring committee shall each year submit a progress report to the management of IR and IOC reporting the progress achieved in the project since the last year.

8.0 CONFIDENTIALITY

8.1 The parties agree to hold in utmost secrecy and in the strictest confidence and trust the contents of this memorandum, any business details, trade secrets, confidential documents, software or any other information (in any form or medium, whether electronic, digital, magnetic or optic) provided or supplied to each other or which comes in their possession or custody prior to or pursuant to post this memorandum whether or not designated or marked as confidential or proprietary in nature (hereinafter referred to as " confidential information").

8.2 The parties accept that the obligation with respect to confidentiality shall apply to its Directors, Partners, Agents, Consultants, Employees and Officers as the case may be and each agrees not to use or permit its use or divulge or disclose such confidential information to any third party for any purpose other than for the purposes envisaged under this memorandum except with the prior written approval of the other party.

However, the obligation with respect to confidentiality shall cease when the confidential information;

8.2.1 enters the public domain otherwise than as a result of disclosure by either party.

8.2.2 Is required to be disclosed by virtue of government/court order(s)/direction(s), Statutes, Reserve Bank of India or by any other competent/regulatory/investigative authority etc. In such an event the party shall intimate the other party of such direction / order. Such intimation shall be accompanied by a copy of order / direction.

8.2.3 Is disclosed to its officers, employees, agents etc. for carrying out the intent of this memorandum.

8.3 The parties agree to return the confidential information in its possession within 7 days of demand or in the event of determination or termination of this memorandum within 3 days of determination or termination, as the case may be.

8.4 The obligation with respect to confidentiality and non-disclosure of confidential information shall survive the determination or termination of this memorandum.

9.0 EFFECTIVE DATE & TENURE

This memorandum shall be effective from the date of its signature by both the parties hereto and shall thereafter for the tenure of the project period.

ANNEXURE –IV

TEST SCHEME FOR FULL SCALE TESTING ON THE ENGINE TEST BED

SUBJECT : Bench marking Bio diesel versus High Speed Diesel in Medium Speed Diesel Engines as used by Indian Railways.

OBJECTIVE : ***To evaluate the impact of mixing of Bio Diesel (5%, 10 %, 15 %, and 20%) in HSD fuel oil on 16 Cylinder Alco Engine at Test Bed of Engine Development Directorate.***

Planned to be done (Complete Test Run of 5 hrs.)

LOAD & SPEED CONFIGURATION :

NOTCH	RPM	LOAD (N)
8th.	1050 ± 3	21600 ± 50
7th.	950 ± 3	19082 ± 50
6th.	850 ± 3	16018 ± 50
5th.	750 ± 3	13826 ± 50
4th.	650 ± 3	10616 ± 50
3rd.	550 ± 3	8138 ± 50
2nd.	450 ± 3	5471 ± 50
1st	350 ± 3	2984 ± 50
IDLE	350 ± 3	2131 ± 50

The test matrix envisages four bio diesel blends (5%, 10%, 15% and 20%) and each blend is to be tested for complete test of 5 hours at all the notches settings as shown in above table.

PREPARATION OF SAMPLE / MIXING OF OIL:

TEST (5 hrs. Run)	MIXTURE Of Bio Dsl. & HSD Oil	QUANTITES REQUIRED (Litre)		
		HSD OIL (Plain)	BIO DIESEL	TOTAL
Base Line	-	1200	-	1200
Test 1	5 %	1140	60	1200
Test 2	10%	1080	120	1200
Test 3	15%	1020	180	1200
Test 4	20%	960	240	1200
Base Line	-	1200	-	1200

ANNEXURE –V

PROPOSED FIELD TRIAL OUTLINE

Trial Scheme For Field Trials Of Bio Diesel (B20),
Alternate Fuel on WDM2 Diesel Locomotives

1. **Scope:**

1.1 The objective of the field evaluation is to examine the performance bio diesel blends in diesel engines of railroad locomotives of the Indian Railways in actual service with respect to wear, deposits, fuel oil consumption rates etc. During the trial preliminary testing indicates that specific fuel consumption would increase slightly with bio-diesel. The actual deterioration in SFC would be ascertained during the field trial. The trial shall also monitor the adverse effects of the fuel on filter clogging etc., if any. The other potential problems viz. cold starting in winter shall also be assessed during the field trial.

1.2 Field trials will be carried out on two sets of locomotives. The first set would be consisting of ten locomotives as trial locomotives and second set would be of ten locomotives to serve as control locomotives for comparison. The first set shall use B20 bio-diesel and second set shall use petrodiesel. The data for parameters indicated in the trial scheme will be collected for all the locomotives for evaluation of trial results.

1.3 The trial shall be conducted on conventional WDM2 locomotives based at nominated diesel shed in Indian Railways.

1.4 The duration of the trial is expected to be 18 /24 months (Yearly schedule). Trials shall, however, be terminated if the any abnormality observed on engine components, filters and in operation of locomotive.

1.5 As far as possible, trials shall commence on all the locomotives within a period of three month, so that effect of seasonal variations is kept to a minimum.

2. **General:**

2.1 Locomotives shall be painted in a different colour to indicate as a trial / control locomotive and also the stenciling on fuel tank with bold letters shall be done to indicate the brand of fuel in the fuel tank, to avoid wrong charging.

2.2 For these locomotives, periodical attention and other maintenance schedules shall be given by the homing diesel shed only to avoid wrong charging of a different brand of fuel oil at out stations.

3. **Selection of locomotives:**

3.1 The locomotive selected should preferably be those which have undergone a heavy repair schedule involving power assembly overhaul.

3.2 Trial and control locomotives should correspond to the same age group as far as possible.

3.3 The locomotive selected should not have the previous history of repeated leakages from fuel oil system.

3.4 The various components such as cylinder liners, pistons and pistons rings shall be new and from the same source of supply as far as possible for all sets of locomotives as detailed below:-

i) Liners shall be either DLW new/ reclaimed or GOC reclaimed. Liners of same origin only shall be used and not combinations.

ii) Piston rings shall be new and from the same source - selection shall be based on marking code adopted by DLW 10091774.

iii) Only barrel shaped a fuel efficient ring from the same manufacturer shall be used.

iv) Pistons (5 ring pack) shall be used of same make and design.

v) Fuel injection pumps and injectors shall be new and from the same source.

vi) Fuel filters shall be from same source.

3.5 As far as possible, trial and control locomotives shall be used on Mail/Express services enabling proper monitoring of the trial and ensuring use of appropriate fuel for charging.

3.6 Physico-chemical properties of biodiesel (B20) and petrodiesel are indicated in Annexure-V (a& b).

3.7 Adequate quantity of B20 biodiesel should be arranged so that trials can be undertaken for the specified period.

4. **Trial Scheme:**

Before commencement and on completion of trial, following shall be observed and recorded:

4.01 Any component change in the fuel oil system during trial shall be recorded. A special watch should be kept on the rubber components.

4.02 The fuel oil system shall be cleaned prior to start of the trial.

4.03 All components should be checked as per the prescribed schedules.

4.04 If low fuel pressure is experienced, problem should be noted with the remark.

4.05 If FIP is found to be excessive hot, the cause may be recorded along with the remedial action taken.

4.06 Fuel filters removed during trials may be kept for visual inspection by RDSO with proper indication.

4.07 The rubber components of the fuel oil system shall be removed after the trial and kept for RDSO's inspection with proper tags.

4.08 Physico - chemical properties of lube oil in used should be checked and ensured that they conform to the specification at every month. The behaviour of lube oil under the conditions of fuel dilution shall be an area of interest for the trial.

4.09 As far as possible, the engine smoke should be checked in every schedule.

4.10 Assessments of carbon deposits shall be made for piston, cylinder head and valves on completion of trials. Existing procedure should be adopted for rating the components wherever possible.

4.11 Timely intimation may be sent to RDSO and Indian Oil Corporation for deputing representatives to witness the commencement of trial and the final inspection.

4.12 The existing fuel oil in the tanks of the locomotives shall be brought down to 1000 lts. level before the new charge is filled in.

4.13 Complete record of the lube oil consumption, fuel oil consumption, kilometers earned, gross trailing load, period in service, type of service etc. shall be recorded and supplied to RDSO every month on a floppy in MS Excel.

4.14 The shed is requested to make the trip card data available on a floppy for detailed analysis by RDSO every month. In case locomotive comes to shed with missing trip card, the engine repair book would be used to reconstruct trip entries.

4.15 SFC in gm./ bhp. hr. shall be calculated at the time of commissioning the locomotive after yearly / 3 rd. yearly schedule and at half yearly schedule.

4.16 The period under repair, period for which locomotive is not in use, any special repairs etc., cases of any fuel pressure problems experienced, if any, shall be recorded in the shed for all locomotives.

5. **Fuel oil sampling and periodical testing:**

5.1 As soon as the engine is started and put on commission for trial, the first fuel /lube oil sample should be collected from the locomotive fuel/lube oil tank and sent to (M & C Laboratory) RDSO, Lucknow and oil company for analysis along with a fresh fuel sample collected from bio diesel supply/ diesel fuelling point.

5.2 During each monthly inspection, fuel/lube oil sample shall be sent to (M & C Laboratory) RDSO Lucknow and oil company for testing. Each time a sample is collected (not less than 500 ml.) for dispatch, it should be accompanied by detailed particulars in duplicate as per Annexure – V (c).

5.3 The fuel sample shall be tested in shed laboratory/ oil company/ RDSO as per the normal practice for condition monitoring. The laboratories shall carry out the following tests:

i) Kinematic viscosity at 40 ºC
ii) Acidity Inorganic
iii) Flash point COC
iv) Acidity, total mg of KOH/gm, max.
v) Ash percent by mass, max.
vi) Cetane number,min.
vii) Carbon residueon 10 percent residue, percent by mass, max.
viii) Distillation 85 percent volume recovery at ºC, max.
ix) Sediment, percent by mass,max
x) Water content, percent by volume, max.
xi) Total sediment, mg per 100 ml, max
xii) Total Sulphur percent by mass, max.

5.4 The oil sample shall be tested in shed laboratory/ oil company/ RDSO as per the normal practice for condition monitoring. The laboratories shall carry out the following tests :

i) (a) Kinematic viscosity at 40 deg.C and 100 deg.C.
(b) V.I.

ii) Flash point COC at shed and RDSO.

iii) TBN as per ASTM D-664 (B) at shed and RDSO, and as per ASTM D-2896 at IOC.

iv) pH value at shed and RDSO.

v) Insoluble- coagulated Hexane and Toluene as per ASTM D-893(B) at shed and RDSO.

vi) Spectrographic analysis for wear metals.
Cu, Pb, Fe, Cr, Na, Al, Si, Sn.

vii) Percentage of fuel dilution by gas liquid chromatograph, if necessary.

5.4 The lube oil change should be made strictly on condition basis only following the limits given in guide no.6. In case the oil is changed, two samples of oil, one of old oil and another new, from engine sump shall be dispatched to M & C laboratory, RDSO Lucknow and company.

5.5 Spectrographic analysis should be under taken every monthly and also at every lube oil filter change.

6. **Fuel filter :**

6.1 Fuel filters of approved sources shall be used for trial and control locomotives and shall be changed as per schedule.

7. **Load box testing:**

7.1 Load box testing shall be under taken on commencement and on completion of the trials and BSFC measurement shall be made for both trial and control locomotives.

(Note : Test method for BSFC as per RDSO report no.1416/88)

8. **Performance report :**

A brief monthly report indicating various data collected on the performance of trial and control locomotives shall be simultaneously sent to DG (MP), RDSO, Lucknow and IOC Ltd..

9. **Performance evaluation :**

9.1 On completion of trials, the performance shall be evaluated with respect to;

a) Specific fuel consumption in terms of bhp hr and 100-GTKm.
b) Condition of filters.
c) Condition of rubber components.
d) Complications due to fuel dilution of lube oil.

ANNEXURE – V (a)

PHYSIO - CHEMICAL PROPERTIES OF BIO-DIESEL (B 20)
AS PER ASTM D 6751

S.No.	Characteristics	Test Method	Control Specification
1	Appearence		
2	ASTM Colour		
3	Kinematic Viscosity @ 100 deg C,cSt		
4	Viscosity Index		
5	Pour Point,deg C		
6	Flash Point(COC),degC		
7	Total Base No,mg KOH/gm		
8	Elements Ca,% wt Zn,ppm Si,ppm		
9	Sulphated Ash,% wt.		
10	Foaming characteristics Tendency/ Stability, ml of foam, max Sequence I Sequence II Sequence III		
11	CCS at -10 deg C,cP		

ANNEXURE – V (b)

PHYSIO - CHEMICAL PROPERTIES OF PETRO DIESEL (HSD) AS PER IS 1460 –2000.

S.No.	Characteristics	Test Method	Control Specification
1	Appearence		
2	ASTM Colour		
3	Kinematic Viscosity @ 100 deg C,cSt		
4	Viscosity Index		
5	Pour Point,deg C		
6	Flash Point(COC),degC		
7	Total Base No,mg KOH/gm		
8	Elements Ca,% wt Zn,ppm Si,ppm		
9	Sulphated Ash,% wt.		
10	Foaming characteristics Tendency/ Stability, ml of foam, max Sequence I Sequence II Sequence III		
11	CCS at -10 deg C,cP		

ANNEXURE – V (c)

PARTICULARS OF SAMPLE

1. Brand of lube oil_____
2. Loco no._____
3. Date of sampling _____
4. Date, lube oil changed _____
5. Topping up of lube oil from last sample drawn_____ litres.