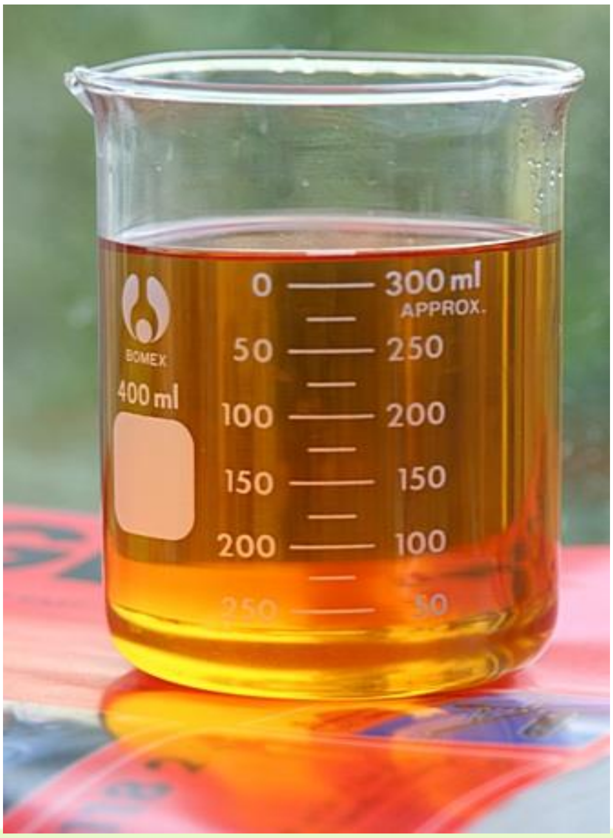
Lao
Institute for
Renewable
Energy

Biofuel Series



Technical Recommendations for the Establishment of a Sustainable Biodiesel Sector in Lao PDR

Report

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Vientiane

July 2013

Lao Institute for Renewable Energy

LIRE

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About us

LIRE is a non-profit organisation dedicated to the sustainable development of a self sufficient renewable energy sector in the Lao PDR. The institute offers agronomical, technological and socio-economic research services, and works to provide a free public resource of information and advice on the use of renewable energy technologies in Laos. LIRE strives to support the development of the country by exploring commercially viable means to establish renewable energy technologies in rural parts of the country, in areas without connection to the national grid and with little access to technical expertise.

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I. Establishment of National Standards based on available feedstock

- **Background**

Fuel quality plays an important role in order that the latest low emission vehicles and their emission control systems may function properly. Especially in Japan, USA and Europe, nearly same levels of stringent emission regulations are scheduled to be introduced, and it is a common recognition of vehicle manufacturers that the supply of globally harmonized clean fuels is essential to achieve the target of cleaner air quality and environment protections worldwide.

On the other hand, there are large varieties of fuels in many regions of the world, especially in the developing countries and districts. This situation is one of the obstacles to prevent quick introduction of the latest low emission vehicles, and it is strongly required **to improve fuel quality in the corresponded markets.**

In order to get an approval system of quality fuels in the market, the automotive industries from Japan, USA and Europe decided to cooperate together and published the 1st edition of "World Wide Fuel Charter" (WWFC) in 1998.After the several times of revision, the 4th edition published in 2006 is the latest version at the moment.

The WWFC Committee consists of 4 major automotive industry organizations of Japan Automobile Manufacturers Association (JAMA), Alliance of Automobile Manufacturers (AAM), Engine Manufacturers Association (EMA) and European Automobile Manufacturers Association (ACEA), and also associates members of other country national organizations from all over the world.

National organizations:

- Brazil (ANFAVEA)
- Canada (AIAMC, CVMA)
- China (CAAM)
- Europe (ACEA)
- India (SIAM)
- Indonesia (IAF)
- Japan (JAMA)
- Korea (KAMA)
- Malaysia (MAA)
- Mexico (AMIA)
- Philippines (CAMPI)
- South Africa (NAAMSA)
- Thailand (TAIA)
- USA (Alliance, AIAM, EMA)
- Vietnam (VAMA)

The uses of bio-components like ethanol and fatty acid methyl esters (FAME) in market fuels are increasing as from CO2 reduction and energy security points of view. There only existed national/regional standards and specifications for bio-components so far.
Their qualities were highly variable and not always fit for purpose. Bio-components can be inherently feedstock dependent (e.g. type and the nature of vegetable oils, their processing routes), and this represents additional challenges for the standardization activity. **On the other hands, as the automotive industry's activities are global, there also exists an increased need for international harmonization of market fuels including bio-components.** Indeed if these standards have been set up in close collaboration with car manufacturers present all around the world, it is to make sure that wherever the fuel is made it will not damage engines, and the car warrantee can still be used.

Thus establishing National Standards without involving the car manufacturers will bring a lot of issues and this is not recommended.

- **Based on established national or regional biodiesel standards**

The subject of this paper is focused on FAME (Fatty Acid Methyl Ester) as a biodiesel fuel. **Established national or regional biodiesel standards can serve as example to set up the Lao National Standards**. The table 1 compares some existing national and regional biodiesel standards, where we can see that the parameters remain pretty similar from a country to another, just some parameters might differs due to the use of different sources of feedstock. Biodiesel standards include twenty six main parameters to measure for assessing biodiesel quality.

Among the twenty six main parameters to measure for assessing biodiesel quality, ten parameters are measured according petro diesel standard methods and fifteen parameters are specific to biodiesel and measured according specific standardized methods. The parameters specific to biodiesel are the following:

- Ester content;
- Acid value;
- Oxidative stability;
- Iodine value;
- Methyl linolenate;
- Polyunsaturated FAME;
- Methanol content;
- Monoglyceride content;
- Diglyceride content;
- Triglyceride content;
- Free glycerol content;
- Total glycerol content;
- Sodium and potassium content;
- Calcium and magnesium content;
- Phosphorus content.

The parameters specific to biodiesel can also be divided into two classes, parameters related to biodiesel molecular structure and parameters related to biodiesel quality.

Comparison of existing biodiesel fuel standards

Items	Units	U.S.	EU	Australia	Japan	Rep. of Korea	Thailand	Vietnam
		ASTM D6751-07b	EN14214:2003		JIS K2390:2008	PPAFB Act	DOEB: 2009	TCVN 7717:2007
Ester content	mass%	-	96.5 min.	96.5 min.	96.5 min.	96.5 min.	96.5	96.5 min.
Density	kg/m3	-	860-900	860-900	860-900	860-900	860-900	860-900
Viscosity	mm2/s	1.9-6.0	3.50-5.00	3.5 - 5.0	3.50-5.00	1.9-5.0	3.5-5.0	1.90-6.00
Flashpoint	deg. C	93 min.	120 min.	120.0 min.	120 min.	120 min.	120 min	130 min.
Sulfur content	mass%	0.0015 max.	0.0010 max.	0.0010 max.	0.0010 max.	0.0010 max.	0.0010 max	0.05 max.
Distillation, T90	deg. C	360 max.	-	360 max.	-	-	-	360 max.
Carbon residue (100%) or Carbon residue (10%)	mass%	0.05 max. -	- 0.30 max.	- 0.30 max.	- 0.3 max.	- 0.10 max.	- 0.30 max.	0.050 max. -
Cetane number		47 min.	51.0 min.	51.0 min.	51.0 min.	-	51.0 min	47.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.02 max.	0.02 max.	0.01 max.	0.02 max	0.020 max.
Water content	mg/kg	0.05[vol%] max.	500 max.	0.050 [vol%] max.(1)	500 max.	500 max.	0.05[Wt%] max	0.05[vol%] max.
Total contamination	mg/kg	-	24 max.	24 max.	24 max.	24 max.	24 max.	-
Copper corrosion		No.3	Class-1	Class-1	Class-1	Class-1	Class-1	No.1
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.80 max.	0.50 max.	0.50 max.	0.50 max.	0.50 max.
Oxidation stability	hrs.	3 min.	6.0 min.	6 min.	(**)	6.0 min.	10.0 min.	6.0 min.
Iodine value		-	120 max.	-	120 max.	-	120 max.	120 max.
Methyl Linolenate	mass%	-	12.0 max.	-	12.0 max.	-	12.0 max.	-
Polyunsaturated FAME (more than 4 double bonds)	mass%	-	1 max.	-	N.D.	-	-	-
Methanol content	mass%	0.2 max. (*)	0.20 max.	0.20 max.	0.20 max.	0.20 max.	0.20 max.	-
Monoglyceride content	mass%	-	0.80 max.	-	0.80 max.	0.80 max.	0.80 max.	-
Diglyceride content	mass%	-	0.20 max.	-	0.20 max.	0.20 max.	0.20 max.	-
Triglyceride content	mass%	-	0.20 max.	-	0.20 max.	0.20 max.	0.20 max.	-
Free glycerol content	mass%	0.020 max.	0.02 max.	0.020 max.	0.02 max.	0.02 max.	0.02 max.	0.020 max.
Total glycerol content	mass%	0.240 max.	0.25 max.	0.250 max.	0.25 max.	0.24 max.	0.25 max.	0.240 max.
Na+K	mg/kg	5 max.	5.0 max.	5 max.	5.0 max.	5.0 max.	5.0 max.	5.0 max.
Ca+Mg	mg/kg	5 max.	5.0 max.	5 max.	5.0 max.	5.0 max.	5.0 max.	-
Phosphorous content	mg/kg	10 max.	10.0 max.	10 max.	10.0 max.	10.0 max.	10.0 max.	10.0 max.

(*) 130 deg.C of flashpoint is available instead of measuring methanol content (**) Meet diesel oil specification

- **Parameters related to biodiesel molecular structure**

Biodiesel is a mixture of fatty acid methyl (or ethyl) ester. These compounds are formed of long carbon chain linked to one methyl ester group. Carbon chain of fatty acid methyl esters can be saturated (carbons linked together by one molecular bond) or unsaturated (carbon are linked together by two or three molecular bond). Unsaturated carbon chain can contain one double (mono unsaturated chain) or more (poly unsaturated chain) up to six double bonding on the same carbon chain. The chemical stability of biodiesel during the storage depends on the fatty methyl ester molecular structure. Poly-unsaturated carbon chains are less stable than saturated carbon chain. Poly-unsaturated chains degrade quickly during the time in presence of oxygen and heat and produce by products that can plug fuel filter and cause combustion problems in the engine. In order to assess biodiesel stability the following parameters are measured:

- Oxidative stability;
- Iodine value;
- Methyl linolenate;
- Polyunsaturated FAME;

➢ **Oxidation stability**

Oxidation stability parameter is a measure of biodiesel sensitivity in presence of oxygen and heat. The oxygen can react with biodiesel double bond for producing gum that can clog engine fuel line and pump. Oxidation stability measures the induction time for biodiesel degradation. It depends on the number and the configuration of double bond of biodiesel carbon chains. Two or three double separated by one methylene group are more sensitive to oxygen. Oxidation stability depends on molecular structure and consequently it depends on oil or fat used for biodiesel processing. According to the table 1, oxidation stabilities of US, European and Thai standards are respectively, 3, 6 and 10 hours. Oxidation stability of 10 hours is only obtained with coconut and palm oil. For establishing national standard, one should take into account the kind of local oil species used for biodiesel production. An oxidation stability of 6 hours is quiet good for national standards. In case of low oxidation stability from local oil species it is possible to mix antioxidant with biodiesel for increasing oxidation stability.

➢ **Iodine value**

Iodine value measures the amount of double bonds contained in biodiesel carbon chains. Iodine value is expressed by quantity of iodine that reacts with double bonds contained in

100 grams of oil. Biodiesel produced from oil with high iodine value like linseed oil (iodine value ~170 − 203) is less stable than biodiesel produced from oil with low iodine value like palm oil (iodine value~50). European, Korean and Thai standards recommend a maximum iodine value of 120 grams per 100 grams of biodiesel. This maximum value can be retained for national standards.

- **Methyl linolenate**

Methyl linolenate is a fatty acid methyl ester with three contiguous double bonds adjacent to methylene group. This configuration is very sensitive to oxidation and many national and regional biodiesel standards recommend a maximum content of 12 % in biodiesel. Linolenate derivative are encountered in linseed oil in temperate countries and in candlenut oil (Aleurites moluccana). Eleostearate derivatives have also three contiguous double bonds adjacent to methylene group and are also very sensitive to oxidation. These compounds are encountered in Tung oil (Aleurite fordii). Aleurites are oils species growing in Asia and Pacific countries. For national standards one can recommend a maximum value of twelve % in biodiesel.

- **Polyunsaturated FAME**

Like methyl linolenate polyunsaturated FAME are very sensitive to oxidation. For national standards theirs percentage in biodiesel should not exceed 1%.

Parameters related to biodiesel quality

Besides parameters related to biodiesel molecular structure there are also parameters related to biodiesel quality like :

- Ester content;
- Acid value;
- Methanol content;
- Monoglyceride content;
- Diglyceride content;
- Triglyceride content;
- Free glycerol content;
- Total glycerol content;
- Sodium and potassium content;
- Calcium and magnesium content;
- Phosphorus content.

- **Ester content**

Ester content is expressed in percentage of Fatty acid methyl (or ethyl) ester and the minimum value for most of the standards is 96.5 %. This value should be retaining for national standards.

- **Acid value**

Acid value measures the amount of free fatty acid contained in biodiesel and it is expressed in milligrams of KOH per gram of biodiesel. Free fatty acids are detrimental to fuel system and engine because they induce corrosion or undergo oxidation. The maximum acid value for most of the standards is 0.5 milligrams of KOH per gram of biodiesel. This value should be retaining for national standards.

- **Methanol content**

Presence of methanol in biodiesel is due to un-efficient biodiesel washing. Quiet large amount of methanol decreases the flash point of biodiesel and increase the risk of explosion during biodiesel handling or t6ransportation. Most of standards recommend a maximum value of 0.2 %, this value should be considered for national standards.

- **Monoglyceride, diglyceride, triglyceride content**

Un-reacted mono, di and triglyceride may be oxidized or dissociate over time resulting if formation of free glycerol that can polymerize or oxidize and contribute to biodiesel instability. Maximum recommended percentages in biodiesel are 0.8 % for mono, and 0.2 % for di and triglycerides. These values should be retaining for national standards.

- **Free glycerol and total glycerol content**

Like mono, di and triglycerides, free glycerol contained in biodiesel should be under recommended values. Total glycerol is the summation of mono, di, triglycerides and free glycerol affected with specific coefficient for calculation. According standards free glycerol should be no more than 0.02 % and total glycerol should be no more than 0.24 %.

- **Sodium and potassium content**

Sodium and potassium come from the catalyst used for trans-esterification and the maximum total amount in biodiesel should not be more than 5 ppm. Higher amount can form sediment and cause injector failure.

➢ **Calcium and magnesium content**

Calcium and magnesium come from phospholipids contained in crude oil but also from water used for biodiesel washing. Like sodium and potassium they can form sediment and cause injector failure. The maximum total amount in biodiesel should not be more than 5 ppm.

➢ **Phosphorus content**

Like calcium and magnesium come from phospholipid. Phosphorus may cause severe damage because it can form abrasive scale in the combustion chamber. It can also poison the catalyst of exhaust pipe. The maximum total amount in biodiesel should not be more than 10 ppm.

- ## Conclusion

Feedstock or mix of feedstock that will be used in Lao PDR might be considered very carefully in order to establish national standards according to the selected crops. As we have seen above the main difference between a national standard to another is explained by the main source of Feedstock used.

Indeed if we have a look to one of the key parameters, Oxide Stability, its value goes from 3hours in the USA because using soybean while Thailand using 10hours due to the use of Palm Oil. Lao PDR should thus use an intermediary value, as in Europe, with an Oxide Stability of 6hours thus allowing the country to use a wider range of feedstock in order to ensure the national food security and an efficient land management strategy. The Oxide stability is just an example of the 15 parameters specific to Biodiesel that needs to be set up according to the nationally available energy crops.

Indeed International Standards of Biodiesel refers to 26 parameters which includes 11 specific to fossil diesel. These parameters will thus remain unchanged, which means that focus will be on the 15 specific parameters to Biodiesel.

II. Creation of a National Testing Facility

Due to the early stage of development of the Biofuel industry in Lao PDR, testing facility (quality control laboratory) still has to be implemented, in order to analyze biodiesel produced in Lao and certified its compliance towards selected standards.

Indeed for the moment producers of biodiesel in Lao are facing a lack of laboratories where standard analysis can be performed. The result is that samples have to be sent regularly to an external laboratory based in Thailand having for consequence to increase the cost of production and delay the marketing activities.

Only parameters specific to biodiesel have to be measured because the others parameters (cetane number, density, flash point, viscosity, etc.) can be measured at the laboratory of Lao State Fuel company.

• Definition of quality standards

Biodiesel is defined as the mono alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, for use in compression-ignition (diesel) engines. Before blending with diesel fuel biodiesel should match some specified quality standards. The quality standards required for pure biodiesel are gathered in a biodiesel specification. The required quality standards of biodiesel specification are listed in the table below.

➢ **Density (EN ISO 3675, EN ISO 12185)**

Biodiesel generally have higher densities than mineral diesel (EN 590 820-845 kg/m3 at 15°C). Density increases with a decrease in chain length and with unsaturation. This can impact on fuel consumption as fuel introduced into the combustion chamber is determined volumetrically.

➢ **Viscosity (EN ISO 3104, ISO 3105, D445)**

Viscosities of neat vegetable oils are many times higher which leads to serious problems in unmodified engines. The increase in viscosity results in poor atomization and incomplete combustion which leads to coking of injector tips. This results in engine power loss. Biodiesel still has higher viscosity than mineral diesel (3.50-5.00 mm2/s at 40°C vs 2.00-4.50 mm2/s). Viscosity decreases with unsaturation but increases markedly with contamination by mono, di or triglycerides.

- **Flash Point (ISO 3679, IP 523, IP 524, D93)**

Pure rapeseed methyl ester has a flash point value of up to 170°C. This method is therefore looking at residual components within the fuel that are combustible, especially methanol which is a particular hazard due to its invisible flame.

- **Distillation (T90 AET)**

Biodiesel is distilled at atmospheric pressure. At least 90 % of biodiesel should be distilled with a maximum temperature of 360 ^{o}C.

- **Carbon Residue (EN ISO 10370)**

The Carbon Residue is the material left after evaporation and pyrolysis of a sample fuel. This is a measure of the tendency to of a fuel to produce deposits on injector tips and the combustion chamber. For FAME samples it is an indication of the amount of glycerides, free fatty acids, soaps and catalyst residues remaining within the sample

- **Cetane Number (EN ISO 5165, D613)**

This serves as a measure of ignition quality. This is the most pronounced change from vegetable oil to the trans-esterified product. Fuels with low cetane numbers show an increase in emissions due to incomplete combustion. Palm Oil and Tallow derived biodiesels have the best cetane numbers.

- **Sulphated Ash (ISO 3987, D874)**

Ash describes the amount of inorganic contaminants, such as catalyst residues, remaining within the fuel. Ash is related to engine deposits on combustion.

- **Water Content (EN ISO 12937)**

As FAME is hygroscopic it can pick up water in storage and as such there can be problems meeting the specification. At around 1500 ppm the solubility limit is reached and the water bottoms out. Free water promotes biological growth and the reverse reaction turning biodiesel to free fatty acids.

- **Total Contamination (EN 12662)**

Total contamination is defined as the insoluble material retained after the filtration of a heated sample over a standardized 0.8m filter. FAME samples with high quantities of insoluble materials tend to cause fuel filter and injector blockages. High concentrations of soap stock are normally associated with high total contamination.

- **Copper Strip Corrosion (EN ISO 2160, D130)**

This is defined as the likelihood to cause corrosion to copper, zinc and bronze parts of an engine. A polished metallic strip is heated at 50°C for 3 hours, washed and compared to standards. Corrosion is likely to be caused by free acids or sulfur compounds. However FAME gives consistently good results in this area and is unlikely to fail due to the low sulfur content.

- **Oxidation Stability (EN 14112)**

The Oxidative stability specification is defined as a minimum Rancimat induction period of six hours. Essentially a fuel is heated at 110°C in a constant air stream and the formation of volatile organic acids is detected. This property relates to the overall storage stability of the fuel and the higher the degree of unsaturation (double bonds) within the FAME molecules gives a decrease is oxidative stability. This can be improved with the addition of antioxidant additives.

- **Acid Value (EN 14104, D664)**

Acid value is a measure of mineral acids and free fatty acids contained in a fuel sample. It is expressed in mg KOH required to neutralize 1g of FAME. High fuel acidity is linked with corrosion and engine deposits.

- **Iodine Value (EN 14111)**

Iodine number is a measure of total unsaturation (double bonds) within the FAME product. It is expressed as the grams Iodine required to react with 100g of FAME sample. High Iodine value is related to polymerization of fuels, leading to injector fouling. It is also linked to poor storage stability.

- **Ester Content (EN 14103)**

This is measured using gas chromatography and is restricted to esters falling within the C14-C24 range. It is ultimately a test for reaction conversion. Linolenic and polyunsaturated esters are controlled as they have been shown to display a disproportionately strong effect on oxidative stability.

- **Methanol Content (EN 14110)**

Methanol can be removed from FAME by washing or distillation. High methanol contents pose safety risks due to the very low flash point of methanol.

- **Glycerides (EN 14105, EN 14106, D6584)**

There is a limit on the mono, di, and triglycerides of no more than 0.80%, 0.20% and 0.20% respectively. Total glycerol is the sum of the bound and free glycerol and must not exceed 0.25%/ Failing to meet the spec implies low conversion to ester and deposit formation on injectors and valves.

- **Group I Metals**

Sodium and Potassium are limited to a combined 5ppm. These arise from the addition of catalyst, and result in high ash levels in the engine.

- **Group II Metals**

Calcium and Magnesium are limited to a combined 5ppm. These may arise from the addition of hard water in the washing process. Calcium and Magnesium soaps have been related to injector pump sticking.

- **Phosphorous Content (EN14107, D4951)**

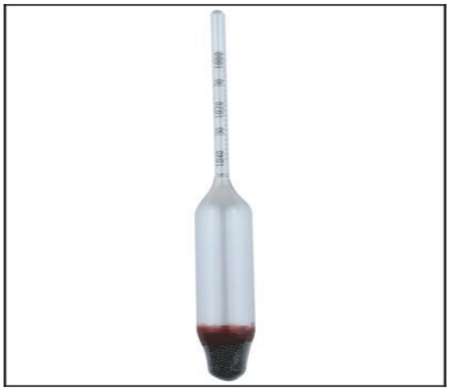
The phosphorous limit is approx 10 ppm and normally arises from phospholipids within the starting material or from addition of phosphoric acid in the production process. High phosphorus fuels are suspected of poisoning catalysts and increasing emissions.

- **Sulfur content (ASTM D 5453)**

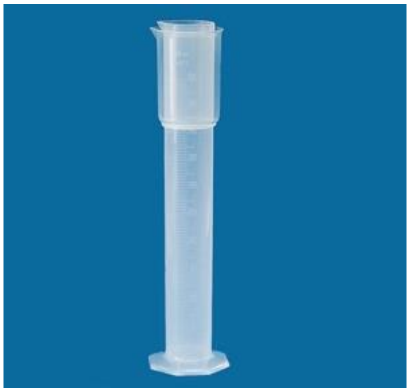
Limits: 0.05 % mass maximum
The measure is implemented by UV spectrophotometry

- **Equipment for assessing biodiesel quality**

➢ **Density (EN ISO 3675, EN ISO 12185)**



Densimeter



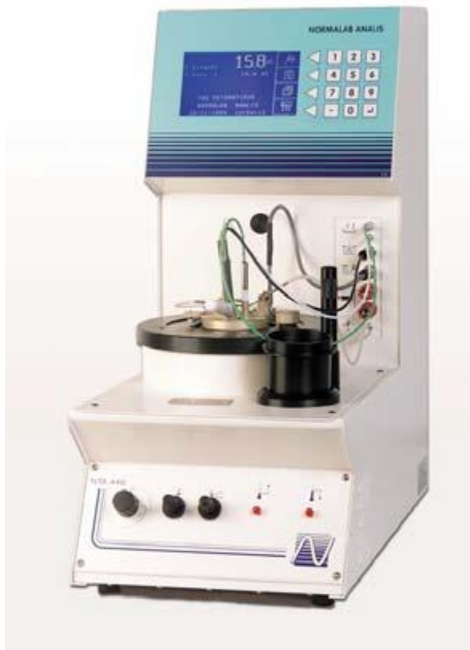
Cylinder for measuring

➢ **Viscosity (EN ISO 3104, ISO 3105, D445)**

Thermostated water bath

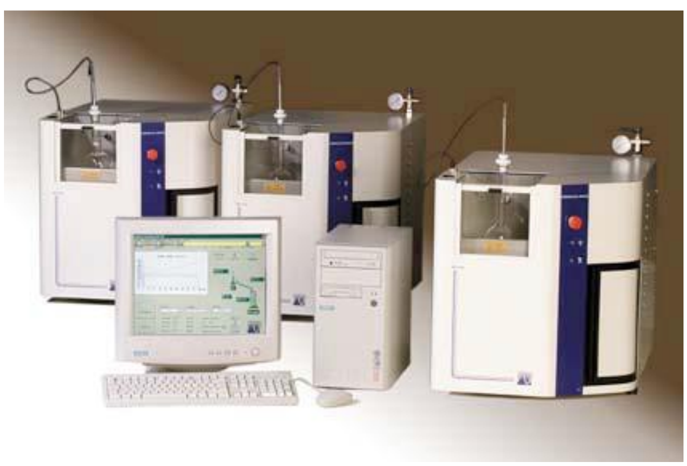
Viscosity tube

- **Flash Point (ISO 3679, IP 523, IP 524, D93)**



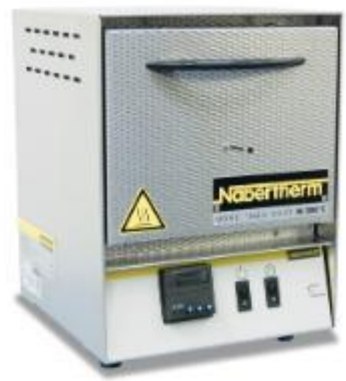
Flash point apparatus

- **Distillation (T90 AET)**



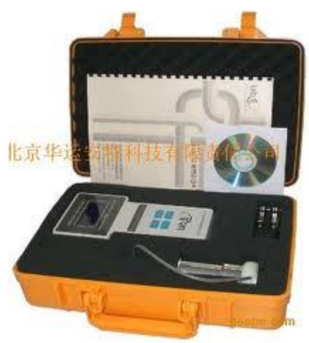
Distillation apparatus

➢ **Carbon Residue (EN ISO 10370), Sulphated Ash (ISO 3987, D874)**



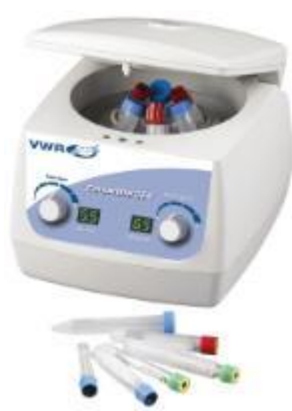
Muffle furnace

➢ **Cetane Number (EN ISO 5165, D613)**



Cetane number analyzer

➢ **Water & sediment Content (EN ISO 12937)**

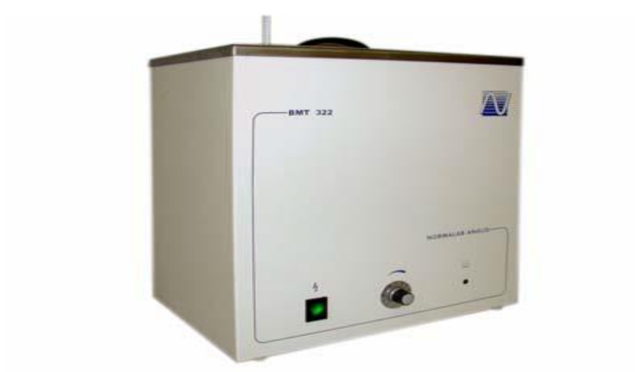


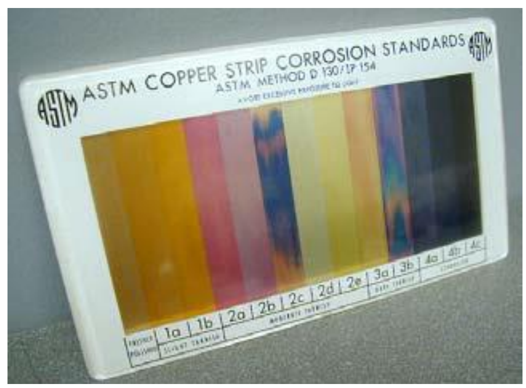
Centrifuge with tubes

- **Total Contamination (EN 12662)**

Filtration bank

- **Copper Strip Corrosion (EN ISO 2160, D130)**





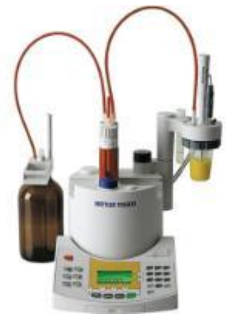
Copper strip corrosion apparatus

Copper strip corrosion chart

- **Oxidation Stability (EN 14112)**

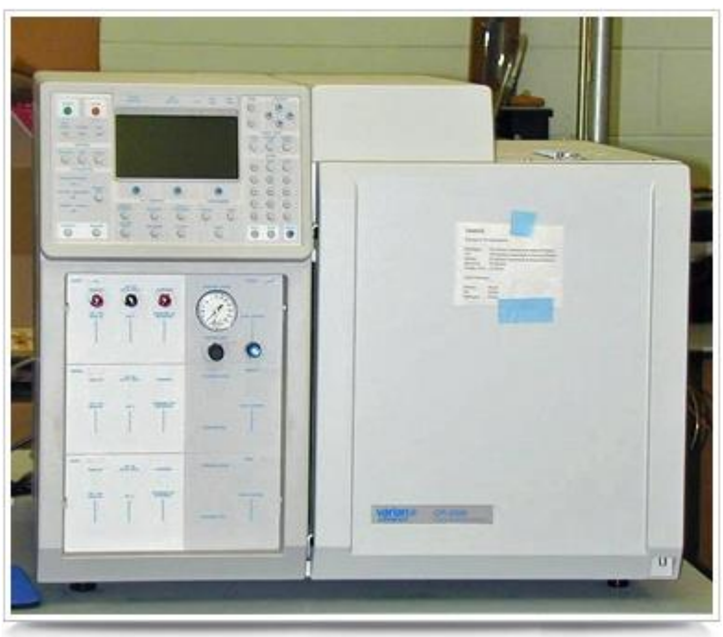
Rancimat

- **Acid Value (EN 14104, D664), Iodine Value (EN 14111)**



Tritration apparatus

- **Ester Content (EN 14103), Methanol Content (EN 14110), Glycerides (EN 14105, EN 14106, D6584)**



Gas chromatograph analyzer

- **Group I Metals, Group II Metals, Phosphorous Content (EN14107, D4951)**

ICP analyzer

- **Sulfur content (ASTM D 5453)**

UV-visible spectrophotometer

III. Equipment costs and specific operating costs of test facilities

The following table gives an indication of the equipment cost for the most important test methods. A prediction of the operating costs is not possible due to the special labor costs and the more or less optimal usage of reference materials. An orientation for the costs per analysis can give the price lists of international acting laboratories which are available on request. The operating costs depend remarkably from the throughput of analytics. From this position a concentration of the analytic work is desirable but on the other hand a minimum of independent labs is necessary to handle complaints and arbitrations.

Lab equipment costs and commercial prices for analytical work

Parameter	Method	Testing Equipment	Equipment cost in 1000 EUR	Commercial price per analysis in EUR
Ester content	EN 14103	GC-FID	30.0	40-60
Density at 15 ℃	EN ISO 12185	Density Meter (U-Tube)	2.0	10-20
Kinematic viscosity at 40 ℃	EN ISO 3104	Viscosimeter	3.0	20-40
Flashpoint	EN ISO 3679*	Pensky-Martens-Flashpoint-Tester	12.0	25-50
CFPP	EN 116	CFPP-Tester	24.0	35-70
Sulfur content	EN ISO 20884	RFA	70.0	45-90
Carbon residue CCR (from 10% distillation residue)	EN ISO 10370	Vacuum-Distillation + Conradson Tester	50.0 + 15.0	45-90
Cetane number	EN ISO 5165	Test Engine	120.0	120-200
Sulfated ash	ISO 3987	Muffle Furnace	1.50	15-30
Water content	EN ISO 12937	Karl-Fischer-Titrator	6.5	35-70
Total contamination	EN 12662	Suction Filter and Glass Ware	1.5	45-90
Corrosivity to copper	EN ISO 2160	Tempering Bath + Test Vessels	2.0	25-50
Oxidation stability	EN 14112	"Rancimat" test equipment	15.0	45-90
Acid number	EN 14104	Color Titration	0.5	30-60
Iodine number	EN 14111	Color Titration	0.5	30-60
Linolenic acid methyl ester content	EN 14103	GC-FID (same like ester content)	-	see ester content
Methanol content	EN 14110	GC-FID (same like ester content)	-	40-80
Free Glycerin, Monoglycerides, Diglycerides, Triglycerides, Total Glycerin	EN 14105	GC-FID	30.0	110-200
Phosphorus content	EN 14107	ICP-OES	70.0	45-90

Parameter	Method	Testing Equipment	Equipment cost in 1000 EUR	Commercial price per analysis in EUR
Metals I (Na, K)	EN 14108	AAS	30.0	40-80
Metals I (Na, K)	EN 14538	ICP-OES (same like P-content)	-	40-80
Metals II (Ca, Mg)	EN 14538[19]	ICP-OES (same like P-content)	-	40-80
Laboratory Balances	-	-	3.5	
Drying Cupboard	-	-	1.0	
Total			350.0 - 400.0	880-1680