

## DAFTAR PUSTAKA

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**Lampiran 1 : Hasil Pengujian Massa Jenis Bahan bakar Solar Pertamina Dex dan Biosolar B30**

**Solar Pertamina DEX**

No.	Temperatur (°C)	Massa Jenis (kg/m <sup>3</sup> )			Rata-rata
		I	II	III	
1	27 °C	823	823	823	823
2	40 °C	811	809	813	811
3	50 °C	805	801	803	803
4	60 °C	797	795	799	797
5	70 °C	787	785	783	785

**Biodiesel B-30**

No.	Temperatur (°C)	Massa Jenis (kg/m <sup>3</sup> )			Rata-rata
		I	II	III	
1	27 °C	849	847	851	849
2	40 °C	829	825	831	828
3	50 °C	825	823	827	825
4	60 °C	819	823	823	822
5	70 °C	817	815	819	817

**Lampiran 2 : Hasil Pengujian Unjuk Kerja Mesin Diesel 6 Silinder tipe Deutz BF6M  
1013 EC dengan Bahan bakar Solar Pertamina Dex dan Biosolar B30**

**SOLAR PERTAMINA DEX**

Nomor	Temperatur Bahan Bakar (°C)	Beban Kontrol 30 kW			Beban Kontrol 50 kW			Beban Kontrol 70 kW			Beban Kontrol 80 kW		
		RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)	RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)	RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)	RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)
(1)	(2)	(3)	(4)	(6)	(7)	(8)	(10)	(11)	(12)	(14)	(15)	(16)	(18)
1	27 °C	1501	20	10.8	1503	20	17.6	1503	20	23.0	1501	20	26.7
2	40 °C	1503	20	10.7	1505	20	18.5	1501	20	23.0	1500	20	25.8
3	50 °C	1503	20	10.5	1501	20	17.7	1500	20	23.3	1497	20	24.8
4	60 °C	1501	20	11.3	1501	20	18.0	1498	20	23.1	1501	20	26.7
5	70 °C	1501	20	11.0	1497	20	18.6	1498	20	23.6	1501	20	27.3

**BIOSOLAR B30**

Nomor	Temperatur Bahan Bakar (°C)	Beban Kontrol 30 kW			Beban Kontrol 50 kW			Beban Kontrol 70 kW			Beban Kontrol 80 kW		
		RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)	RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)	RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)	RPM Actual (Rpm)	Waktu Ops Msn (menit)	Konsumsi BBM (liter)
(1)	(2)	(3)	(4)	(6)	(7)	(8)	(10)	(11)	(12)	(14)	(15)	(16)	(18)
1	27 °C	1500	20	11.3	1503	20	20.0	1503	20	24.5	1501	20	26.6
2	40 °C	1501	20	11.1	1505	20	20.1	1500	20	24.9	1498	20	27.3
3	50 °C	1503	20	11.3	1503	20	20.1	1500	20	26.3	1500	20	27.0
4	60 °C	1500	20	11.4	1501	20	20.1	1498	20	24.2	1503	20	25.5
5	70 °C	1501	20	11.4	1501	20	21.0	1500	20	24.5	1501	20	26.3

### Lampiran 3 : Perhitungan Torsi, BMEP, SFC dan Efisiensi Thermal

#### 1) Menghitung Torsi Mesin Diesel

Untuk menghitung nilai torsi pada mesin diesel dapat menggunakan rumus sebagai berikut:

$$Mt = \frac{60 \cdot Ne}{n} \text{ N.m}$$

dimana:         $Mt$     = Torsi (N.m)  
                   $Ne$     = Daya output generator (Watt) dibagi efisiensi generator  
                   $n$       = Putaran mesin (rpm), Engine Konstan 1.500 rpm

Karena daya efektif tersebut adalah output dari generator sehingga untuk memperoleh daya efektif engine maka  $Ne$  (daya efektif) dibagi dengan efisiensi generator ( $\cos \phi$ ) sebesar 0.98.

Maka dapat dihitung nilai torsi pada mesin diesel pada beban 30 kW sebagai berikut:

$$\begin{aligned} Mt &= \frac{60 \times Ne}{n} \\ &= \frac{60 \times \left(\frac{30.000}{0,98}\right) \text{ Watt}}{1.501 \text{ rpm}} \\ &= \frac{1.836.735 \text{ Watt}}{1.501 \text{ rpm}} \\ &= 1.224 \text{ N.m} \end{aligned}$$

#### 2) Menghitung BMEP Mesin Diesel

Untuk menghitung nilai BMEP pada mesin diesel dapat menggunakan rumus sebagai berikut:

$$BMEP = \frac{Ne \cdot Z \cdot 60}{A \cdot l \cdot n \cdot i} \text{ N/m}^2$$

dimana:         $Ne$     = Daya output generator (Watt) dibagi efisiensi generator  
                   $A$      = luas penampang piston (m<sup>2</sup>); 0,108 m

- l = panjang langkah piston (m); 0,130 m
- i = jumlah silinder; 6 Silinder
- n = putaran mesin diesel (rpm); Engine Konstan 1.500 rpm
- Z = 2 (mesin 4 langkah)

sehingga dapat dihitung nilai BMEP pada mesin diesel pada beban 30 kW sebagai berikut:

$$\begin{aligned}
 \text{BMEP} &= \frac{Ne \cdot Z \cdot 60}{A \cdot l \cdot n \cdot i} \text{ N/m}^2 \\
 &= \frac{(30.000/0,98) \text{ Watt} \times 2 \times 60}{0,108 \text{ m}^2 \times 0,13 \text{ m} \times 1.501 \text{ rpm} \times 6} \\
 &= 29.052 \text{ N/m}^2 \\
 &= 29,05 \text{ kPa}
 \end{aligned}$$

### 3) Menghitung *Specific Fuel Consumption* Mesin Diesel

Untuk menghitung nilai *Specific Fuel Consumption* pada mesin diesel dapat menggunakan rumus sebagai berikut:

$$SFC = \frac{\dot{m}_{bb}}{Ne} \text{ Kg/kW.jam}$$

dimana:  $\dot{m}_{bb} = \frac{m_{bb}}{s}$

$$m_{bb} = \rho_{bb} \cdot V$$

$$\dot{m}_{bb} = \text{mass flowrate bahan bakar/jam (Kg/jam)}$$

$$m_{bb} = \text{massa bahan bakar (Kg)}$$

$$s = \text{waktu (detik)}$$

$$\rho_{bb} = \text{Massa jenis bahan bakar (kg/m}^3\text{)}$$

$$V = \text{Volume konsumsi bahan bakar mesin (liter)}$$

Data hasil penelitian berupa Massa jenis bahan bakar (kg/m<sup>3</sup>), waktu (second) dan volume konsumsi bahan bakar mesin (liter), untuk itu diperlukan perhitungan *massa* bahan bakar/jam (Kg/jam) sebagai berikut:

$$\begin{aligned}
 m_{bb} &= \rho_{bb} \times V \\
 &= 842 \text{ kg/m}^3 \times 10,08 \text{ liter}
 \end{aligned}$$

$$\begin{aligned}
&= 9.094 \text{ kg/m}^3 \cdot \text{liter}; \text{ dimana } 1 \text{ m}^3 = 1.000 \text{ liter} \\
&= 6.094 \text{ kg/m}^3 \times 0,0001 \text{ m}^3 \\
&= 6,09 \text{ kg}
\end{aligned}$$

Selanjutnya perhitungan *mass flowrate* bahan bakar/jam (Kg/jam) sebagai berikut:

$$\begin{aligned}
\dot{m}_{bb} &= \frac{m_{bb}}{s} \\
&= \frac{9,09 \text{ kg}}{0,33 \text{ jam (20 menit)}} \\
&= 27,28 \text{ Kg/jam}
\end{aligned}$$

Sehingga nilai *Specific Fuel Consumption* pada mesin diesel pada beban 30 kW dapat dihitung sebagai berikut:

$$\begin{aligned}
SFC &= \frac{\dot{m}_{bb}}{Ne} \\
&= \frac{27,28 \text{ kg/jam}}{(30/0,98) \text{ kW} \div 0,33 \text{ jam}} \\
&= 0,297 \text{ kg/kW.jam}
\end{aligned}$$

#### 4) Menghitung Efisiensi Thermal Mesin Diesel

Untuk menghitung nilai Efisiensi Thermal pada mesin diesel dapat menggunakan rumus sebagai berikut:

$$\eta_{th} = \left( \frac{Ne}{(\dot{m}_{\text{bahan bakar}} \cdot Q_{\text{bahan bakar}})} \right) \times 100\%$$

dimana:  $\eta_{th}$  = Efisiensi Thermal  
 $Ne$  = Daya output generator (Watt) dibagi efisiensi generator  
 $\dot{m}_{\text{bahan bakar}}$  = *mass flowrate* bahan bakar/jam (Kg/jam)  
 $Q_{\text{bahan bakar}}$  = Nilai Kalor Bahan Bakar,  
Solar Pertamina DEX: 10.450 k.cal/kg;  
Biosolar B30: 10.340 k.cal/kg.

Sehingga Efisiensi Thermal pada mesin diesel dengan bahan bakar Solar Pertamina DEX dengan beban 30 kW dapat dihitung sebagai berikut:

$$\begin{aligned}\eta_{th} &= \left( \frac{Ne}{(\dot{m}_{\text{bahan bakar}} \cdot Q_{\text{bahan bakar}})} \right) \times 100\% \\ &= \left( \frac{(30.000/0,98) \text{ Watt}}{27,28 \frac{\text{kg}}{\text{jam}} \times 10.450 \text{ k.cal/kg}} \right) \times 100\% \\ &= 10,74\%\end{aligned}$$

## Lampiran 4 : Material Safety Data Sheet PT Pertamina (Persero) bahan bakar Solar Pertamina Dex

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### SAFETY DATA SHEET

#### 1. IDENTIFICATION

Product identifier	: Pertamina Dex
Other means of identification	: Solar 53, Automotive Diesel Fuel, High Speed Diesel Fuel, Gasoil, HSD atau Distillate Diesel Fuel.
Recommended use of the chemical and restrictions on use	: Designed for diesel-fueled engine with high rotation and some of middle rotation Not recommended for gasoline-fueled engine.
Manufacturer	: PT Pertamina (Persero) Jl. Medan Merdeka Timur No. 1A Jakarta Pusat ZIP Code 10110 Phone: 1500-000 Email: pcc@pertamina.com
Emergency phone number	: 1500-000

#### 2. HAZARD IDENTIFICATION

Classification	: Flammable liquid, category3 Aspiration hazards, category 1 Skin corrosion/irritation, category 2 Acute toxicity (inhalation), category 4 Carcinogenicity, category2 Specific target organ toxicity (STOT)-repeated exposure, category 2 Hazardous to the aquatic environment (long-term hazard), category 2
Signal word	: Warning
Hazard statement	: <u>Physical Hazard</u> H226 – Flammable liquid and vapor <u>Health Hazard</u> H304 – May be fatal if swallowed and enters airways H315 – Causes skin irritation H332 – Harmful if inhaled H351 –Suspected of causing cancer H373 –May cause damage to organs through prolonged or repeated exposure <u>Environmental Hazard</u> H411 – Toxic to aquatic life with long lasting effects
Precautionary statement	: <u>Prevention</u> P202 – Do not handle until all safety precautions have been read and understood P210 –Keep away from heat/sparks/open flames/hot surfaces. - No smoking. P233 –Keep container tightly closed. P240 –Ground/bond container and receiving equipment. P241 –Use explosion-proof electrical/ventilating/lighting/equipment.

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### SAFETY DATA SHEET

#### 5. FIRE-FIGHTING MEASURES

Specific hazards	
• Other explosion and fire hazards	: This product may be ignited if there is heat, fire sparks, or other ignition sources (static electricity, mechanic/electric tools, and other electronic devices). The product's vapor may cause explosion in the room, in confined space, outside the room, and even in disposal lines. This product may float on the water. It is heavier than air and may be accumulated in low area. If the product's container is not placed in cool area, the container can be broken because of heat or fire.
Flash point°C	: Min. 125.6°F atau 52°C
Flammability value	: LEL 1.3%, UEL 6.0%
Hazardous chemical composition	: Carbon monoxide (CO), smoke and uncompleted combustion product. Nitrogen oxide and sulphur are also maybe produced.
Special protective actions for fire fighters	
a. Carbon dioxide (CO <sub>2</sub> )	: Spray to the origin of fire in the same direction with the wind.
b. Dry chemical powder	: Spray to the origin of fire in the same direction with the wind.
c. Foam	: If the fire is in a container, spray the foam to inner wall of the container (not to the ignited liquid) in the same direction with the wind. If the fire occurs because spill, spray to the origin of fire in the same direction with wind until all the fire covered. Do not dispose the spill to the clean water source (drinking water).
Special protective equipment for fire-fighter	: If fire occurs in limited/indoor/closed area, fire fighter operator must wear <i>Self-Contained Breathing Apparatus</i> (SCBA).

#### 6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment, and emergency procedures	: The product spillage may cause condition that is easy to ignite and explode. Keep away all ignition sources and hot metal surfaces from the spillage (if possible). Use explosion proof electrical devices. Do not contact with product spillage. For huge spillage, isolate the area immediatelt and keep away any unconcerned people. Wear appropriate personal protective equipment, including respiratory protection.
Environmental precautions	: Stop the spillage/leakage if possible. Prevent oil spill goes into drainage, sewage system, and soil.



## Lampiran 5 : *Material Safety Data Sheet* PT Pertamina (Persero) bahan bakar Biosolar

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### SAFETY DATA SHEET

#### 5. FIRE-FIGHTING MEASURES

Specific hazards	
• Other explosion and fire hazards	: This material can be ignited by heat, sparks, flames, or other sources of ignition (e.g. static electricity, mechanical/electrical equipment, and other electronic equipment). May create vapor/air explosion hazard indoors, in confined spaces, outdoors, or in sewer. This product will float and can be reignited on surface water. Vapors are heavier than air and can accumulate in low areas. If container is not properly cooled, it can rupture in the heat of a fire.
Flash point°C	: 140 °F or 60°C
Flammability value	: LEL 1.3%, UEL 6.0%
Hazardous chemical composition	: Carbon monoxide (CO), smoke and other products of incomplete combustion. Oxides of nitrogen and sulfur may also be formed.
Special protective actions for fire fighters	
a. Carbon dioxide (CO <sub>2</sub> )	: Spray to the origin of fire in the same direction with the wind.
b. Dry chemical powder	: Spray to the origin of fire in the same direction with the wind.
c. Foam	: If the fire is in a container, spray the foam to inner wall of the container (not to the ignited liquid) in the same direction with the wind. If the fire occurs because spill, spray to the origin of fire in the same direction with wind.
Special protective equipment for fire-fighter	: If fire occurs in limited/indoor/closed area, fire fighter operator must wear <i>Self-Contained Breathing Apparatus</i> (SCBA).

#### 6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment, and emergency procedures	: Spill of liquid product will create a fire hazard and may form an explosive atmosphere. Keep all sources of ignition and hot metal surfaces away from spill/release (if safe to do so). The use of explosion-proof electrical equipment is recommended. Stay upwind and away from spill/release. Avoid direct contact with material. For huge spill, isolate immediate hazard area and keep unauthorized personnel out. Wear appropriate protective equipment, including respiratory protection.
Environmental precautions	: Stop spill/release (if it can be done safely). Prevent spilled material from entering sewers, storm drains, or seepage into the ground. Use foam on spills to minimize vapor generation.

### SAFETY DATA SHEET

#### 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

• Respiratory protection	: Wear respiratory protection if concentration in air excess the cut-off value.
• Hygiene practices	: Implement good personal hygiene

#### 9. PHYSICAL AND CHEMICAL PROPERTIES AND SAFETY CHARACTERISTICS

Characteristic	Test Result
Organoleptic (physical appearance, color, etc)	: Liquid, clear, and bright
Odor	: Diesel
Odor threshold	: No data available
pH	: No data available
Melting/freezing point	: Cannot be applied
Boiling point/boiling range	: 150 - 365 °C
Flammability	: Flammable liquid
Flash point	: 60 °C
Evaporation rate	: No data available
Lower/upperflammability limit and explosion limit	: LEL 1.3%; UEL 6.0%
Vapor pressure	: No data available
Vapor density	: No data available
Relative density	: No data available
Solubility	
• Water solubility	: Not soluble
• Other solubility	: No data available
Partition coefficient (n-octanol/water)	: No data available
Auto-ignition temperature	: 260 °C
Decomposition temperature	: No data available
Viscosity	: 2.0 - 5.0 mm <sup>2</sup> /sec(at 40°C)

#### 10. STABILITY AND REACTIVITY

Reactivity	: Not chemically reactive.
Chemical stability	: Stable under normal condition.
Posibility of hazardous reactions	: No hazardous reactions if handled and stored according to the requirements.
Conditions to avoid	: Heat, fire sparks, flame, or condition that induce electrostatic charges. Prevent vapor accumulation.
Incompatible materials	: Halogen, strong acid, base dan strong oxidizer.
Hazardous decomposition products	: Carbon monoxide (CO).

#### 11. TOXICOLOGICAL INFORMATION

Comprehensive toxicological/health information	
• Acute toxicity	: Acute toxicological study shows that no acute effect