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Guidance on Industry Standard for Diesel Engines

GIS 34-305

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GIS 34-305. This Guidance on Industry Standard (GIS) is based on parts of heritage documents from the merged BP companies as follows:

British Petroleum

GS 134-8 Requirements for the Protection of Diesel Engines Operating in Zone 2 Hazardous Areas.

Amoco

A RE-ENG-HS-G Rotating Equipment—Engines—High Speed Gas and Diesel—Guide.
A RE-ENG-HS-P Rotating Equipment—Engines—High Speed Gas and Diesel—
Procurement Specification.

Gulf of Mexico Deepwater (GOMDW)

1400-20-ME-SP-2050 High Speed Diesel and Gas Engines.

PTA

PTA RE-ENG-HS-G Rotating Equipment—Engines—High Speed Gas and Diesel—Guide.
PTA RE-ENG-HS-P Rotating Equipment—Engines—High Speed Gas and Diesel—
Procurement Specification.

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1. Scope

This GIS provides guidance on industry standard for the design, materials, fabrication, inspection, testing, documentation, and preparation for shipment of diesel engines.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BP

GIS 06-601	Guidance on Industry Standard for Painting.
GIS 14-011	Guidance on Industry Standard for Noise Control.
GIS 34-503	Guidance on Industry Standard for API 671 Special Purpose Couplings.

American Bureau of Shipping (ABS)

ABS Publication 6	Rules For Building and Classing Mobile Offshore Drilling Units (MODUs).
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American Gear Manufacturers Association (AGMA)

AGMA 9000-C90	Flexible Couplings, Potential Unbalance Classification.
AGMA 9002-A	Bores and Keyways for Flexible Couplings (Inch Series).

American Society of Mechanical Engineers (ASME)

ASME B31.3	Process Piping.
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British Standards Institute (BSI)

BSI BS 2050	Electrical resistance of conducting and anti-static products made from flexible polymeric material.
BSI BS EN 50014	Electrical apparatus for potentially explosive atmospheres – General requirements.

Diesel Engine Manufacturers Association (DEMA)

	Standard Practices for Low and Medium Speed Stationary Diesel and Gas Engines.
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International Electrotechnical Commission (IEC)

IEC 60079-4	Electrical apparatus for explosive gas atmospheres – Part 4: Method of test for ignition temperature.
IEC 60079-14	Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines).



The Engineering Equipment and Materials Users Association (EEMUA)

Publication No. 107 Recommendations for the Protection of Diesel Engines for use in Zone 2 Hazardous Areas.

National Fire Protection Association (NFPA)

NFPA 20 Installation of Centrifugal Fire Pumps.
NFPA 37 Installation and Use of Stationary Combustion Engines and Gas Turbines.

3. Symbols and abbreviations

For the purpose of this GIS, the following symbols and abbreviations apply:

bhp Brake horsepower.
BMEP Brake mean effective pressure.
LHV Low heating value.
TBN Total base number.

4. Technical requirements

- a. Technical requirements for separable high speed diesel engines (600 rpm or higher) are based on engine manufacturer standard design. This GIS provides additional requirements.
- b. Equipment noise levels shall comply with GIS 14-011.
- c. Design and mechanical construction of engines, accessories, and auxiliary system components shall have minimum of 16 000 hours of field operating service.
- d. Unless specified otherwise, engines shall be rated for continuous service, except for firewater pump and emergency generator drivers addressed in clause 11.
- e. Engines rated for continuous service shall be designed to operate in excess of 8 000 hr/yr with uninterrupted periods of 1 000 hr, minimum, excluding oil filters, air filters, and spark plugs.
- f. Current turnkey overhaul cost shall be provided as follows:
 1. Major and minor overhauls shall be included.
 2. Parts and labour shall be listed separately.

This GIS encourages standard package in which auxiliary systems (except main cooler) are engine mounted. Reliable and compatible auxiliary systems are usually provided by Vendor and are not specified in detail.

Continuous and intermittent performance classifications are commonly used by BP. The following are general criteria for each:

- *Continuous duty engines operate at least 8 000 hr/yr and operate for uninterrupted periods of 1 000 hours or more, excluding normal maintenance of oil filter, air filters, and spark plugs.*
- *Intermittent duty engines operate less than 1 500 hr/yr and operate at rated kW (bhp) for 4 hours in any 24 hour period, then operate at or below continuous kW (bhp) rating, excluding normal maintenance of oil filter, air filters, and spark plugs.*



5. Performance

5.1. Standard conditions and fuel heating values

The following standard conditions shall be used for engine rating:

- Standard conditions are 29°C (85°F) and barometric pressure of 0,9949 bar (29,38 in of mercury).
- Standard water vapour pressure is 0,0129 bar (0,38 in of mercury), which corresponds to 50% relative humidity and dry barometric pressure of 0,9820 bar (29,0 in of mercury) at sea level.
- Standard diesel fuel shall have LHV of 42 780 kJ/kg (18 390 Btu/lb).

Three sets of operating conditions for specifying and evaluating a diesel engine are:

- Standard conditions in accordance with this GIS.*
- Standard conditions as defined by Vendor.*
- Site conditions where engine will be installed.*

Paragraphs 5.1.a through 5.1.c specify operating conditions and require Vendor to calculate (horse)power for proposed engine for these conditions. This requirement establishes common base for engine (horse)power evaluation, whereas Vendor standard conditions vary and cannot be used to make meaningful comparisons.

Site conditions normally differ from BP specified standard conditions. Site conditions should be defined and entered on data sheet because they affect engine rated (horse)power.

Site conditions have significant effect on selection of engines and auxiliary systems. If selecting engines and air coolers, maximum ambient temperature should be highest temperature that is exceeded only 3% of the time. Critical concerns are rated ambient temperature and emission control.

5.2. Performance correction

5.2.1. Standard to site conditions

(Horse)power corrections for temperature and altitude from standard conditions to site conditions shall be as follows:

- For naturally aspirated engines, 2,5% for each 5,6°C (10°F) above 32°C (90°F) and 3,5% for each 300 m 1 000 ft in excess of 460 m 1 500 ft above sea level.
- For supercharged or turbocharged engines, Vendor standard correction for site temperature and barometric pressure shall apply.

Most Vendors do not guarantee site performance because of variance in conditions. However, they do guarantee test stand performance corrected to site conditions by agreed upon derating criteria. Typical (horse)power derating criteria for naturally aspirated engines are:

- Derate 2,5% for each 5,6°C above 32°C (10°F above 90°F).*
- Derate 3,5% for each 300 m (1 000 ft) of elevation above 460 m (1500 ft).*

Derate supercharged or turbocharged engines in accordance with Vendor criteria.

Values for ambient temperature and barometric pressure become less significant if intake air is compressed by supercharger or turbocharger because superchargers and turbochargers increase inlet air pressure and temperature. Net pressure and temperature increase depend on Vendor design. Therefore, (horse)power corrections for supercharged or turbocharged engines should be made by Vendor.



Superchargers or turbochargers increase air/fuel mixture density, which results in higher (horse)power rating for a given engine. Turbocharger efficiency decreases at low speeds. Therefore, supercharger designs should be chosen for applications with wide speed variations. Compared to naturally aspirated engine, turbocharging increases power output by 25% to 40%, with slight decrease in fuel consumption.

(Horse)power correction formulas may be found in the Diesel Engineering Handbook. Refer to Bibliography.

Allowable kW (bhp) should be 90% of rated kW (bhp) at standard conditions. This derating should be applied to all engines regardless of service. This derating allows for variations in test tolerances (typically $\pm 5\%$), site fuel quality, off design conditions, and normal wear. This is necessary because Vendor (horse)power rating does not consider test tolerances or site specific variations.

Operating an engine for extended periods above continuous rated speed increases wear and maintenance. Speed versus power limitations in this GIS are based on successful field operating experience that results in acceptable maintenance levels.

[EDS Note: Recommend moving all commentary following 5.2.1 to the GP.]

5.2.2. Diesel fuels

- a. If diesel fuel LHV is different from standard diesel fuel LHV, engine shall be rerated to adjust for difference.
- b. Diesel fuel limitations, such as sulphur content or cetane number, shall be stated in proposal.

Heating value: This GIS has standard LHV for diesel fuels. Vendor is required to use these values if calculating (horse)power at standard conditions. It is important to obtain and specify LHV (or range) for site fuel to ensure proper engine (horse)power rating and selection.

Proper fuel composition and combustion characteristics should be verified with intended suppliers. Number 2 diesel (ASTM D975) is normally acceptable to all engine suppliers. The following diesel fuel properties may cause field problems:

- *Cetane number: Engine startability and acceleration under load are sensitive to fuel cetane number. Minimum cetane number requirement for No. 2 diesel fuel is 40. Lower cetane numbers may be raised by blending fuels or by adding amyl nitrate.*
- *Sulphur content: Sulphur in fuel causes corrosive wear, lube oil deterioration, and deposit formations. Sulphur content of diesel fuel should not exceed 0,5% by weight. Engines that use high sulphur fuel require special lubricating oils with high alkalinity. Lube oil total base number (TBN) 10 is suitable for fuels with less than 0,5% sulphur. Refer to ASTM D1552 and ASTM D2896 for more details.*
- *Water and sediment: Water and sediment significantly affect fuel filter life and cause wear of fuel pumps and injection equipment. Total water and sediment content should not exceed 0,05% by volume.*
- *Pour point: Pour point significantly affects cold weather starting. Extremely cold conditions may require fuel heating or special fuel filters that are heated by jacket water. Fuel filter plugging is not a problem if fuel pour point is 5,6°C (10°F) below minimum engine installation temperature.*

[EDS Note: Recommend moving all above commentary to the GP.]



5.2.3. Emission controls

If emission control is specified, modifications necessary to meet these conditions shall be selected and shall include derating if converting from standard conditions to site conditions.

5.3. Utility evaluation

Utility evaluation shall be based on kJ/kW-h (Btu/bhp-hr) and rated shaft kW (bhp) at site conditions.

5.4. Performance criteria

- a. Performance shall be based on site fuel specifications and rated shaft kW (bhp) at site conditions.

Vendors have published performance curve for each engine configuration based on their standard conditions. Vendors have developed individual performance curve formats, and curve information may vary. The following information should be shown versus engine speed:

- Power (kW (bhp)).
- Fuel consumption (kJ/kW-h (Btu/hp-hr) or kg/kW-h (lb/hp-hr)).
- Torque (N-m (ft-lb)).
- Intake manifold pressure (bar (in-Hg)).
- Exhaust temperature (°C/°F).

Performance curve should be requested on inquiry documentation sheet. It is useful to hand plot fuel consumption and kW (bhp) (overrated speed range) for site conditions on each Vendor performance curve.

Testing is optional but required for certification or guarantee.

[EDS Note: Recommend moving commentary to the GP.]

- b. Guaranteed fuel use (kJ/kW-h (Btu/bhp-hr)) shall be certified for the following percents of engine rated shaft kW (bhp) at site conditions:
1. 50%.
 2. 75%.
 3. 100%.
- c. Performance map shall be submitted with proposal that includes:
1. Engine speed (rpm).
 2. Specific fuel consumption (kJ/kW-h (Btu/bhp-hr)).
 3. Output power (kW (bhp)).
 4. Torque (N-m (lb-ft)).
 5. Exhaust temperature (°C (°F)).
 6. Minimum turndown conditions recommended for continuous service.
 7. Brake mean effective pressure (BMEP) (kPa (psi)).

BMEP is used to compare engines because it is directly proportional to engine power and indicates how efficiently an engine is using piston displacement to perform work.

BMEP has an indirect relation to cylinder peak pressure and temperature. If Vendor offering is high, maintenance levels should be verified with other users having at least 2 years of field experience with same engine. High BMEP may result in higher



operating cost due to increased maintenance and reduced run time. High BMEP is more fuel efficient. With proper control system to prevent detonation, higher BMEP does not adversely affect maintenance or runtime.

5.5. Rating limitations

- a. Engines shall be rated for published power at 90% of maximum continuous speed. Continuous power rating shall include auxiliaries such as water pumps and cooling fans.
- b. Power at standard conditions shall be maximum shaft kW (bhp) that engine can produce under continuous service duty at rated speed, standard conditions, and fuel heating values in accordance with paragraph 5.1. Power for integral and external engine driven accessories shall be deducted from gross engine output.
- c. Allowable kW (bhp) shall be 90% of kW (bhp) at standard conditions.
- d. Rated kW (bhp) shall be engine site kW (bhp) rating that results after derating allowable kW (bhp) from standard conditions to site conditions.
- e. Run time of 97% shall be guaranteed for specified operating conditions.
- f. At standard conditions, engine used for mechanical drives shall comply with the following (horse)power and rpm limitations:

RPM range	Maximum kW (bhp)
1 800 to 1 500	187 (250)
1 500 to 1 200	300 (400)
1 200 to 1 000	600 (800)
1 000 to 900	900 (1 200)
900 and below	1 870 (2 500)

- g. At standard conditions, engines used for 50 (60) cycle generator drive shall comply with the following rpm limitations:
 1. Continuous duty, 1 000 (1 200) rpm maximum.
 2. Noncontinuous duty, 1 500 (1 800) rpm maximum.
- h. At standard conditions, BMEP as defined by DEMA standards shall not exceed values below:

Engine type	BMEP
Naturally aspirated	590 kPa (85 psi)
Two cycle supercharged	830 kPa (120 psi)
Two cycle turbocharged	1100 kPa (160 psi)
Four cycle turbocharged	1400 kPa (200 psi)

Four cycle engines are recommended for all continuous service applications for the following reasons:

- *Lower fuel consumption at reduced power (50% to 90% lower).*
- *More time for complete burning and expansion while using approximately 85% (versus 67%) of expansion stroke for useful work.*
- *Scavenging air required for two cycle engines reduces net (horse)power output and increases fuel consumption. Four cycle engine air requirements are approximately 50% to 70% of comparable two cycle engine air requirements.*
- *Two cycle engines have inlet and exhaust ports through their cylinder liners, which prevents even cooling throughout full stroke, causing reduced piston and ring life.*
- *Carbon deposits build up on exhaust ports of two cycle engines because of high heat concentration, causing reduced piston and ring life.*



Both naturally aspirated and turbocharged gas engine compression ratios typically vary from 7:1 to 10,5:1. Compression ratios above 8,5:1 may cause certain fuel gas mixtures to self ignite. Vendor should be questioned about self ignition potential of site gas fuel.

[EDS Note: Recommend putting this commentary in GP.]

6. Speed governing

6.1. Governor

- a. Engine governor shall be mechanical, mechanical/hydraulic, or electronic as follows:

1. Pneumatic governors shall be bellows type.
2. Minimum and maximum range setpoints and speed setpoint shall be manually adjustable.

Three categories of engine governors are:

- *Mechanical.*
- *Mechanical/hydraulic.*
- *Electronic (most commonly used).*

Isochronous governor is most common. It maintains constant engine speed within range regardless of engine load.

- b. Specified governor class shall meet the following percent of rated speed restrictions:

Governor class	A	B	C	D
Speed regulation	10,00%	6,00%	4,00%	0,50%
Speed variation	+0,75%	+0,50%	+0,25%	+0,25%
Maximum speed rise	13,00%	7,00%	7,00%	7,00%

1. Speed regulation is allowable speed change from rated speed setpoint if engine load is gradually reduced from rated power to zero.
 2. Speed variation is allowable speed fluctuation from rated speed setpoint at constant load with all other engine operating conditions remaining constant.
 3. Maximum speed rise is allowable momentary increase in speed if engine is producing rated power at rated speed and load is rapidly dropped to zero.
- c. Engines for 60 cycle generator drivers shall have electronic governor in accordance with ABS Publication 6 (MODU), Rule 4/3C2.17.1.

[EDS Question: Would it be helpful to add similar information for 50 cycles?]

This GIS defines several governor characteristics that are based on NEMA SM 23 definitions. Term "speed regulation" is equivalent to "speed droop".

Governors may be classified by degree of speed regulation, speed variation, and maximum speed rise. Recognised industrial standard for speed governors is NEMA SM 23. However, it is a steam turbine standard and creates confusion for engine suppliers. For this reason, this GIS defines four NEMA governor classes (A, B, C, and D) without reference to the NEMA standard.

[EDS Note: Recommend moving this commentary to the GP.]

6.2. Speed indication

- a. Tachometer shall have range from 0% to 115% (minimum) of rated speed.

