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|--|------|---|---------------------------------------|---|--|--|------------------------|
| TD-106- 1 | Form |  | PRODUCT STANDARD HYDERABAD | | GT54720 Rev No. 01 PAGE 01 of 19 | | |
| COPYRIGHT AND CONFIDENTIAL The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company. | | <p align="center">HYDROCARBON BASED LUBRICATING OIL SPECIFICATION FOR BHEL HEAVY DUTY GAS TURBINES (GE Ref : GEK 28143A, GEK 32568F, GEK 101941A)</p> <p>1. <u>GENERAL</u></p> <p>This specification contains information intended to help the lubricant supplier to select the proper grade and quality of lubricating oil for the turbine application. For phosphate ester fire resistant lubricants refer to GEK 28136, "Phosphate Ester Based, Fire-Resistant Recommendations for Gas Turbines".</p> <p>These recommendations apply to BHEL's Heavy Duty Gas Turbines only. In particular, Tables 1 and 3 of these recommendations applies to certain gas turbines that utilize a load gear to reduce the turbine shaft speed prior driving the generator. With the exception of the added requirements pertaining to the load gear, Table 3 is similar to Table 2. For lubrication recommendations for equipment other than BHEL, refer to the instructions provided by the manufacturer of that equipment.</p> <p>The successful operation of the gas turbine and it's driven equipment is vitally dependent upon the lubrication system. Therefore, it is necessary that all factors contributing to correct lubrication be present and that the entire system be maintained in good order.</p> <p>The life of the apparatus depends upon a continuous supply of lubricant of proper quality, temperature, and pressure.</p> <p>This being the case, the life and quality of the lubricant is of prime importance to the user. Experience has shown that certain fluid monitoring and condition maintenance is required. Hence, the following recommendations are made.</p> <p>2. <u>REQUIRED PHYSICAL PROPERTIES</u></p> <p>The lubricating oil intended for this service is a rust and oxidation inhibiting petroleum lubricating oil or synthetic hydrocarbon with greater high temperature oxidation stability and load stage capability than conventional lubricating oils. Operating experience has shown the antioxidant of the di-tertiary butyl-paracresol (DBPC) type is not adequate for this service. The inhibitors must be of the non-volatile type.</p> <p>A listing of required properties of new oil is shown in Tables 1 to 3. Included with this listing is the ASTM test method and the recommended value. The supplier should refer to these methods for details of the tests. The oil is an International</p> | | | | | |
| | | Rev. Doc. | None | Revisions : Refer to record of revisions | Prepared : AV  | Approved : BSN  | Date : 15.03.12 |



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Standards Organization Viscosity Grade 32 (ISO VG 32) oil. The properties listed are rather typical of turbine lubricating oils except for the oxidation test requirements and load stage capability. Note that the values shown in Tables 1 to 3 are only recommended values.

The value obtained in the test of the treated oil should be not less than 85% of that obtained for the untreated.

When applying a new lubricating oil, it is recommended that laboratory test comparisons be made with known successful oils.

Briefing about Turbine Oil Grade VG 32:

- a. Compliance with national standards: (latest Publications including amendments)
 - i) IS1012 : Turbine Lubrication Oils
 - ii) BS 489 : Turbine Oils
- b. The use of viscosity index improver additives is prohibited. The additives used shall be wholly soluble in the oils and shall be uniformly distributed throughout at all temperatures above the specified pour point and upto 120 Deg C. When cooled to 6Deg C below its Pour Point for 4 hours, the oil shall regain its homogeneity and shall show no evidence of separation when brought to the ambient temperature in an undisturbed condition.
- c. PROPERTIES: When tested in accordance with the relevant parts of IS: 1448, the test sample shall show the following properties:
 - i) Kinematic Viscosity at 40 deg C: 29 to 35 Centi Stokes.
 - ii) Flash point(Cleveland open cup): 190 Deg C
 - iii) Total Acid Number: 0.10 mg of KOH/g Oil, maximum.



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VAR - 01 (Refer table 1 for required properties)
MATL CODE : GT9754720010

Note: All the Test Certificates for the test methods mentioned in the table below, to be furnished by the vendor at the time of technical scrutiny.

Table 1 : Required properties of lubricating oil with antiwear additives (for new oil) for GTs with bearing ambients below 260°C (i.e. for MS 1002, MS3002, MS5001, MS5002, MS6001 GTs) (Ref: GEK 28143A)

| ASTM Test Method No. | Property | Units | Recommended Value |
|----------------------|--|---------------------------------|--------------------------|
| D 88 | Viscosity at 100° F | Saybolt Universal Seconds (SUS) | 140 (min.) 170 (max.) |
| D 88 | Viscosity at 210° F | Saybolt Universal Seconds (SUS) | 43 (min.) |
| D 97 | Pour Point | ° F | 20 (max.) |
| D 92 | Flash Point | ° F | 330 (min.) |
| D 92 | Fire Point | ° F | 370 |
| D 974 | Neutralization Number or Total Acid Number (TAN) | mg KOH/g | 1.60 (max.) |
| D665 | Rust Preventing Characteristics | --- | Pass |
| D943 | Oxidation Characteristics | Hours to TAN of 2.0 | 1000 (min.) |
| DIN 51354 | FZG Gear Rig Test Failure Load stage | | 6 (min.) |

RECOMMENDED GRADES OF LUBRICATING OIL FOR MS 1002, MS3002, MS5001, MS5002, MS6001 GAS TURBINES (i.e. Meeting requirements of Table 1):

HINDUSTAN PETROLEUM CORPORATION LTD.: TURBINOL XT 32

130/1, Sarojini Devi Road
Sebastian Street
P.B. No. 5, Secunderabad-500 003
Ph: (040) 7704203
Fax: (040) 7700974



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45-A, Sarojini Devi Road
P.B.No.1511
Secunderabad-500 003
Ph: (040) 7705611
Fax: (040) 7701350

INDIAN OIL CORPORATION LIMITED : SERVOPRIME 32T

3-6-436 to 438, II Floor
Naspur House, Himayatnagar
Hyderabad-500 029
Ph: (040)7663263
Fax: (040)7663308

SHELL INDIA MARKETS PVT LTD : SHELL TURBO OIL T 32

2nd Floor,4A, RMZ Millenia Business Park, 143
Dr MGR Road, Kandanchavadi, Perungudi, CHENNAI - 600 096.
Telefax :+914443450000

CASTROL INDIA LIMITED : PERFECTO AWT32

Industrial Division
401,402, Sumer Kendra
Pandurang Budhkar Marg, Worli, Mumbai-400018
Ph: (022) 4910761/0181 Extn 219, Fax: (022) 4910192

EXXON MOBIL : MOBIL DTE 832

ExxonMobil Lubricants Pvt Ltd
3rd Floor, Tower A, Signature Towers
South City-I, NH 8, Gurgaon - 122001
Ph: (0124) 4951300, Fax: (0124) 4217069



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**IDIMETSU/SAVITA CHEMICALS LIMITED : DAPHNE SUPER
TURBINE FLUID AW32**

Lubricants Division
74, Maker Chambers VI
Nariman Point, Mumbai - 400 021
Ph: (022) 2027452, Fax: (022) 2833968

**PETROMIN LUBRICATING OIL COMPANY : PETROMIN TURBINE OIL
OIL T-32**

Dammam
Kingdom of Saudi Arabia

BP MIDDLE EAST LIMITED : 1. ENERGOL THB 32
or
2. ENERGOL TH-HT 32

P.O. Box : 92
Mina Al Fahal Muscat
Sultanate of Oman
Code : 118
Telephone : (00968) 561801
Fax : (00968) 561283

ESSO PETROLEUM INDIA PRIVATE LTD.: Teresso GT EP 32

**Mafatlal house, 3 rd floor,
Backbay Reclamation,
MUMBAI-400 020
Telephone: (022) 2882618, 2882619
Fax : (022) 2882620, 2850963**

TOTALFINAELF INDIA LTD.:

1.Preslia 32
or
2.Preslia GT 32

No.10, 1-B, Taas Mahal, 1st floor,
Montieth Road , Egmore
CHENNAI-600 008
Telephone No. (044) 28412823 / 2790
Fax : (044) 28412790

CHEVRONTXACO CORPORATION : REGAL R&O ISOSYN32

Chevron Texaco Corporation
Sultanate of Oman

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VAR - 02 (Refer table 2 for required properties)
MATL CODE : GT9754720029

Note: All the Test Certificates for the test methods mentioned in the table below, to be furnished by the vendor at the time of technical scrutiny.

Table 2 : Required properties of lubricating oil (for new oil) for GTs with bearing ambients above or equal to 260°C (i.e. for Fr 9E & 9FA GTs) (Ref: GEK 32568F)

| ASTM Test Method No. | Property | Recommended Value |
|-----------------------|---|---|
| D -287 | Gravity(° API) | 29-33.5 |
| D -1500 | Color | 2.0 (max) |
| D -97 | Pour Point (° F/° C) | +10/-12(max.) |
| D-445 | Viscosity @ 40°C (centistokes) | 28.8-35.2 |
| D- 974 | Neutralization No. or Total Acid Number (TAN) (mg KOH / g) | 0.20 (max.) |
| D -665 | Rust prevention - B | Pass |
| D-92 | Flash point (COC) (°F/°C) | 420/215 (min.) |
| D-130 | Copper corrosion | 1B (max.) |
| D-524 (or equivalent) | Carbon residue ramsbottom | 0.10% (max.) (or equivalent) |
| D-892 | Foam Seq I Seq II Seq III | 50/0 (max.) 50/0 (max.) 50/0 (max.) |
| D-943 | Turbine oil oxidation test (hrs.) | 3,000 (min.) |
| D-2272 | Oxidation stability by Rotating Bomb (miniutes) | 500 (min.) |
| D-2272 | Oxidation Stability by Rotating Bomb (modified) | 85% (min.) of time in unmodified test |
| D-3427 | Air Release | 5 (max.) |
| D-2270 | Viscosity Index (VI) | 95 (min.) |



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RECOMMENDED GRADES OF LUBRICATING OIL FOR Fr 9E and 9FA GAS TURBINES (i.e. Meeting requirements of Table 2)

CASTROL INDIA LIMITED

PERFECTO HPT 32

Industrial Division
401,402, Sumer Kendra
Pandurang Budhkar Marg
Worli, Mumbai-400018
Ph: (022) 4910761/0181 Extn 219
Fax: (022) 4910192

INDIAN OIL CORPORATION LIMITED

SERVOPRIME 32 LL

or

SERVOPRIME 32

3-6-436 to 438, II Floor
Naspur House, Himayatnagar
Hyderabad-500 029
Ph: (040) 7663263
Fax: (040) 7663308

BHARAT PETROLEUM CORPORATION LIMITED :BHARAT TURBOL 32

45-A, Sarojini Devi Road
P.B.No.1511
Secunderabad-500 003
Ph: (040) 7705611
Fax: (040) 7701350

HINDUSTAN PETROLEUM CORPORATION LIMITED :TURBINOL XT 32

Or TURBINOL 32

130/1, Sarojini Devi Road
Sebastian Street
P.B. No. 5, Secunderabad-500 003
Ph: (040) 7704203
Fax: (040) 7700974

SHELL INDIA MARKETS PVT LTD


SHELL TURBO T 32

or

SHELL TURBO CC 32

India

2nd Floor,4A, RMZ Millenia Business Park, 143
Dr MGR Road, Kandanchavadi, Perungudi, CHENNAI - 600 096.
Telefax :+914443450000

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Middle East (Shell Oman Marketing Co SAOG)
 P.B.No. 38
 Mina Al Fahal
 Postal code 116,
 Sultanate of Oman
 Ph: (00968) 570100
 Fax: (00968) 24570429

ESSO PETROLEUM INDIA PRIVATE LTD.: **Teresso GT 32**
 Mafatlal house, 3 rd floor,
 Backbay Reclamation,
 MUMBAI-400 020
 Telephone: (022) 2882618, 2882619
 Fax : (022) 2882620, 2850963

EXXON MOBIL : **MOBIL DTE 832**
 ExxonMobil Lubricants Pvt Ltd
 3rd Floor, Tower A, Signature Towers
 South City-I, NH 8, Gurgaon - 122001
 Ph: (0124) 4951300, Fax: (0124) 4217069

TOTALFINAELF INDIA LTD.:
1.Preslia 32
or
2.Preslia GT 32

 No.10, 1-B, Taas Mahal, 1st floor,
 Montieth Road , Egmore
 CHENNAI-600 008
 Telephone No. (044) 28412823 / 2790
 Fax : (044) 28412790

CHEVRONTEXACO CORPORATION : **REGAL R&O ISOSYN32**
 Chevron Texaco Corporation
 Sultanate of Oman





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VAR - 03 (Refer table 3 for required properties)

MATL CODE : GT9754720037

Note: All the Test Certificates for the test methods mentioned in the table below, to be furnished by the vendor at the time of technical scrutiny.

Table 3 : Required properties of lubricating oil with antiwear additives (for new oil) for GTs with bearing ambients above or equal to 260°C (i.e. for 6FA GTs) (Ref: GEK 101941A)

| ASTM Test Method No. | Property | Recommended Value |
|-----------------------|---|---|
| D -287 | Gravity(° API) | 29-33.5 |
| D -1500 | Color | 2.0 (max) |
| D -97 | Pour Point (° F/° C) | +10/-12(max.) |
| D-445 | Viscosity @ 40°C (centistokes) | 28.8-35.2 |
| D- 974 | Neutralization No. or Total Acid Number (TAN) (mg KOH / g) | 0.20 (max.) |
| D -665 | Rust prevention - B | Pass |
| D-92 | Flash point (COC) (°F/°C) | 420/215 (min.) |
| D-130 | Copper corrosion | 1B (max.) |
| D-524 (or equivalent) | Carbon residue ramsbottom | 0.10% (max.) (or equivalent) |
| D-892 | Foam Seq I Seq II Seq III | 50/0 (max.) 50/0 (max.) 50/0 (max.) |
| D-943 | Turbine oil oxidation test (hrs.) | 3,000 (min.) |
| D-2272 | Oxidation stability by Rotating Bomb (miniutes) | 500 (min.) |
| D-2272 | Oxidation Stability by Rotating Bomb (modified) | 85% (min.) of time in unmodified test |
| D-3427 | Air Release | 5 (max.) |
| D-2270 | Viscosity Index (VI) | 95 (min.) |
| DIN 51354 | FZG Gear Rig Test Failure Load Stage | 8 (min.) |
| D-4951 | Atomic Emission Spectroscopy | Zinc content<5 ppm |



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RECOMMENDED GRADES OF LUBRICATING OIL FOR Fr 6FA GAS TURBINES (i.e. Meeting requirements of Table 3):

HINDUSTAN PETROLEUM CORPORATION LTD.: TURBINOL XT 32

130/1, Sarojini Devi Road
Sebastian Street
P.B. No. 5, Secunderabad-500 003
Ph: (040) 7704203
Fax: (040) 7700974

BHARAT PETROLEUM CORPORATION LTD. :BHARAT TURBOL EP 32

45-A, Sarojini Devi Road
P.B.No.1511
Secunderabad-500 003
Ph: (040) 7705611
Fax: (040) 7701350


INDIAN OIL CORPORATION LIMITED : 1. SERVOPRIME 32LL Or 2. SERVOPRIME 32 Or 3. SERVOPRIME 32G

3-6-436 to 438, II Floor
Nasipur House, Himayatnagar
Hyderabad-500 029
Ph: (040)7663263
Fax: (040)7663308

CASTROL INDIA LIMITED : PERFECTO HPT 32

Industrial Division
401,402, Sumer Kendra
Pandurang Budhkar Marg
Worli, Mumbai-400018
Ph: (022) 4910761/0181 Extn 219
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ESSO PETROLEUM INDIA PRIVATE LTD.:

Teresso GT EP 32

Mafatlal house, 3 rd floor,
Backbay Reclamation,
MUMBAI-400 020
Telephone: (022) 2882618, 2882619
Fax : (022) 2882620, 2850963

TOTALFINAELF INDIA LTD.:

**1.Preslia 32
or
2.Preslia GT 32**

No.10, 1-B, Taas Mahal, 1st floor,
Montieth Road , Egmore
CHENNAI-600 008
Telephone No. (044) 28412823 / 2790
Fax : (044) 28412790

SHELL INDIA MARKETS PVT LTD :

Shell Turbo CC 32

India


2nd Floor,4A, RMZ Millenia Business Park, 143
Dr MGR Road, Kandanchavadi, Perungudi, CHENNAI - 600 096.
Telefax :+914443450000

Middle East


Shell Markets (Middle East) Ltd.
Dubai ,UAE

Shell Oman Marketing Co SAOG
P.B.No. 38
Mina Al Fahal
Postal code 116,
Sultanate of Oman
Ph: (00968) 570100
Fax: (00968) 24570429

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3. OPERATING TEMPERATURES

Lubricating oil is exposed to a range of temperatures as it is circulated through the gas turbine. For reliable circulation of oil before starting, the oil temperature should be 70°F(21°C) to obtain the appropriate viscosity.

The normal bearing inlet oil temperature is 130°F (54°C), However, because of customer requirements or because of ambient conditions and/or coolant temperatures, the actual operating conditions may be different.

The lubricating system cooling equipment is designed to maintain the nominal 130°F (54°C) bearing inlet oil temperature when raw water is available for cooling. However , when radiator systems are involved, the sizing is such that for the maximum recorded ambient temperature at the site, the bearing header temperature may be 160°F (71°C). The minimum recommended oil inlet temperature is 90°F(32°C). The gas turbine bearings are designed to operate satisfactorily at this these inlet oil temperatures. With radiator systems, the nominal 130°F (54°C) bearing header will be maintained for a high percentage of the operating time. In special cases, other design header temperatures are used as dictated by the load devices.

Operating bearing temperature rises are discussed in appropriate sections of the service manual. Typically, the lubricant temperature rise from inlet to drain is in the 25°F to 60°F (14°C to 33°C) range. If a reduction gear is involved, this temperature rise may be 60°F(33°C).

Some gas turbines have bearings that are in an ambient of high temperature. This ambient and the sealing air may be over 500°F(260°C). The bearing housing is sealed with labyrinths and airflow such that the bearing drain spaces are at approximately atmospheric pressure. A portion of the lubricating fluid will be mixed with a small quantity of hot air and will wash metal surfaces between the bearing housing ambient and the oil drain temperature.

The lubricant temperature in the tank will be 25°F to 40°F (14°C to 22°C) above the bearing header. Thus, the bulk temperature will be 155°F to 200°F (68°C to 93°C) during operation.



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4. RESPONSIBILITY OF OIL VENDOR

- i) It is generally recognized that turbine lubricating fluid should be a petroleum derivative or synthetic hydrocarbon free from water, sediment, inorganic acids, or any material which, in the service specified, would be injurious to the oil or the equipment. There should be no tendency toward permanent emulsification or rapid oxidation with the formation of sludge.

The responsibility of supplying the proper oil for the lubricating system to meet this instruction rests with the oil vendor and the turbine operator. The oil vendor is expected to make recommendations to the turbine operator concerning compatibility with the VSI oil and operational sampling and testing. Further, he is expected to cooperate with the manufacturer and the operator by providing the support necessary to ensure satisfactory performance of the lubricant, such as examination of oil samples and recommendations for corrective action, if required.

- ii) Oil shall be sent to site by the vendor properly packed in drums of capacity 200 liters each. Drums shall be leak proof.

QUANTITY : (These quantities are indicative only)

The indicative quantities for first fill of various gas turbine models are shown on the following table. Oil supplier shall supply quantity indicated in the purchase order.

| GT MODEL | QUANTITY, Litres |
|---------------------|------------------|
| MS 1002 | 3150 |
| MS 3002 | 7560 |
| MS 5001 | 7560 |
| MS 5002 | 8517 |
| MS 6001 Single Base | 7560 |
| MS 6001 Split Base | 11500 |
| MS 6001 FA | 23470 |
| MS 9001 E | 15120 |
| MS 9001 FA | 27900 |



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5. APPENDIX A - TEST METHOD

A. Discussion of Test Method

For detailed information concerning the various test methods, please refer to the parent published documents. The discussions below will help explain these various tests properties.

1. Viscosity

The viscosity of a fluid is its resistance to flow. Viscosity is commonly reported in stokes which has the units of cm²/sec. Centistokes (one hundredth of one stoke) are most commonly used for convenience. The viscosity in centistokes is also called the kinematic viscosity. The absolute or dynamic viscosity is expressed in poise (more commonly centipoise). It is the kinematic viscosity in stokes (or centistokes) at a given temperature multiplied by the density of the fluid at this temperature expressed in g/cm³.

The viscosity in centistokes is determined per ASTM D-445, "Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)". The viscosity is calculated from the time required for a fixed volume of fluid at a given temperature to flow through a calibrated glass capillary instrument using gravity flow. Centistoke viscosities can be converted to Saybolt and vice versa using the tables and formulas given in ASTM 2161 "Conversion of Kinematic Viscosity to Saybolt Universal Seconds".

2. Pour Point

The pour point is the lowest temperature at which a fluid is observed to flow. It is reported in increments of 5°F(3°C) and is determined as the temperature at which fluid, contained in a tube with an inside diameter of 30 to 33.5 mm, will not flow within five seconds of rotating the tube 90 degrees from the vertical to the horizontal position.

The pour point is reported more as a matter of information. Of practical concern in the design of lubrication systems is the viscosity at which the lubricant fluid becomes too viscous to be pumped. For BHEL gas turbines, the viscosity should be less than 173 centistokes for proper circulation of the fluid before starting.



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3.Total Acid Number

The total acid number is the milligrams of potassium hydroxide (KOH) required to neutralize the acidic constituents in a gram of sample. It is determined per ASTM D-974, "Neutralization Number by Color Indicator Titration. "The total acid number (TAN) is sometimes called the Neutralization Number (NN) or Neut Number and also the Acid Number (AN).

4.Flash and Fire Point

Flash and Fire Points are determined per ASTM D-92, "Flash and Fire Point by Cleveland Open Cup." Flash Point is the temperature at which the fluid contained in a test cup and heated at a constant rate will flash but not burn when a flame is passed over the cup.


Fire point is the temperature at which the fluid contained in a test cup and heated at a constant rate will burn for at least 5 seconds when a flame is passed over the cup.

Flash and Fire Points are an indirect measure of both the volatility of the fluid and the flammability of these volatiles. Since there are more accurate ways of determining these, as an example: distillation to determine volatiles, this test is mainly of value as a quality control test.

5.Autogenous Ignition Temperature

The Autogenous Ignition temperature of a fluid is the temperature of a fluid at which it will ignite due to heat alone, that is, without a flame or other ignition source being used. It is determined per ASTM D-2155, "Autoignition Temperature of Liquid Petroleum Products." It consists of injecting a small amount of fluid into a 200 milliliter flask at elevated temperature. The lowest temperature at which a fire occurs within 5 minutes of injecting the fluid is reported.

The autogenous ignition temperature (AIT) is sometimes called spontaneous ignition temperature (SIT). This test does not necessarily indicate ignition temperature in a "hardware" situation.

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| TD-106-1 Rev No.5 | Form No. |  | <p style="text-align: center;">PRODUCT STANDARD</p> <p style="text-align: center;">HYDERABAD</p> | <p style="text-align: right;">GT54720</p> <hr/> <p style="text-align: right;">REV No. 01</p> <hr/> <p style="text-align: right;">Page 17 of 19</p> |
| <p style="writing-mode: vertical-rl; transform: rotate(180deg);"> COPY RIGHT AND CONFIDENTIAL The information on this document is property of BHARAT HEAVY ELECTRICALS LIMITED It must not be used directly or indirectly in any way detrimental to the interest of the company. </p> | | <p>6.Oxidation Tests</p> <p>The ASTM D-943, "Oxidation Characteristics of Inhibited Steam-Turbine Oils" is the traditional oxidation test for turbine oils. In this test, a sample of oil is placed in a container of water along with pieces of steel and copper wire that have been coiled together. The container is maintained at a temperature of 203°F(95°C) and oxygen is passed through it. The test measures the time in hours for the acidity to reach 2.0 mg KOH per gram of sample.</p> <p>This test is used primarily to determine the life of the oxidation inhibitor and does not necessarily indicate the stability of the base oil.</p> <p>The ASTM D-2272, "Oxidation Stability of Steam-Turbine Oils by Rotating Bomb" is an oxygen absorption test. The test oil, water, and copper catalyst coil, contained in a covered glass container, are placed in a bomb equipped with a pressure gauge. The bomb is charged with oxygen to a pressure of 90 psi (620kPa), placed in a constant temperature oil bath set at 302°F(150°C), and rotated axially at 100 rpm at an angle of 30 degrees from the horizontal. The time for the test oil to react with a given volume of oxygen is measured, with completion of the time being indicated by a specific drop in pressure. This test is normally used for quality control of particular new oil formulation.</p> <p>Recent work shows it to be an excellent in -service monitoring test. Some studies show it to be a good indicator of performance.</p> <p>7.Foaming Tendency</p> <p>The ASTM method specifies three sequences of bubbling air through oil. First, it is done at 75°F (24°C); second, it is done with a new sample of oil at 200°F(93°C); and third, the oil from the second sequence is used but operated at 75°F(24°C).</p> <p>8.Rust Prevention</p> <p>The rust prevention characteristics of the lubricant are determined per ASTM D-665. A mixture of 300 ml of lubricant and 30 ml of distilled water (Procedure A) is stirred while held at a temperature of 140°F(160°C). A carbon steel rod conforming to ASTM specification A 108, is immersed in the oil for a period of 24 hours then examined for rust.</p> | | |



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9. Air Release


ASTM Test Method D-3427 describes the method for determining air release properties of petroleum oils. Compressed air is blown through oil heated to a specified temperature. The length of time required for the air entrained in the oil to reduce to 0.2% is recorded as the air release time. Air release provides a measure of the oil's performance in hydraulic systems because entrained air lead to sponginess.

10. Viscosity Index (VI)

Viscosity Index (VI) is an arbitrary number used to characterize the variation of kinematic viscosity with temperature. A higher VI indicates a smaller decrease in kinematic viscosity with increasing temperature.

11. FZG Gear Rig Test

This test measures the wear of two test gears that are bathed in a heated sample of the oil to be tested. The gears are weighed and then mounted on the ends of two parallel shafts such that the teeth mesh. One shaft is loaded and a motor drives the shafts for 15 minutes. The gear assembly is then dismantled and the gears are weighed. The test is terminated when there is a 10 mg weight loss recorded between the stages.

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| | | Rev.No | <u>Date</u> | Revision Details | Revised | Approved |
| | | 00 | 15.03.12 | FIRST MADE | AV <i>P. Deepthi</i> | BSN <i>BSN</i> |
| | | 01 | 24.01.18 | Recommended grades of lube oil are made part of the main specification. | Deepthi | VSH |
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