



## **PRODUCT MANUAL of TRANSFORMER OIL**

## Brief Introduction

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Sinopec Lubricant Co.,Ltd. is the largest high-tier lubricant manufacturer and marketer in China with a production capacity of over 1.46million tons of packaged lubricants per year. With 5 regional sales center across China, sales subsidiaries all over the world, 11 lube oil & grease blending and manufacturing branches domestic and 1 branch company in Singapore, as well as two independent R&D Centers in Beijing and Shanghai, It integrates the function of lubricant manufacturing, research, storage, transportation, sales and service.

Equipped with world-class automatic blending and packaging production line, Sinopec Lubricant Co.,Ltd. provide over 2000 kinds of lube oils and greases in all 21 categories including engine oil, crankcase oil, industrial gear oil, hydraulic oil, greases, anti-coolant, brake fluid, metal working fluid, marine oil and additives, etc., which are widely used in the fields of aviation, space flight, automobile, machinery, metallurgy, mining, petrochemical engineering, power industry, etc. As one of China Aviation Partners, Sinopec Lubricant Co., Ltd. is devoted to providing lubrication service for Shenzhou series manned space craft and "Chang'e" series lunar probe satellite, making great contributions to the development of China aviation and space aerospace craft.

With high-quality raw material and high-tech formulations evaluated by strict engine and bench tests, SINOPEC products fully meet the requirements of special specification standards of ISO, API, DIN, JASO, etc. With stable product quality,



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the company has completed ISO16949 and HSE management system certification. R&D institutes in Beijing, Shanghai and Chongqing all have ISO/IEC 17025 laboratory accreditation certificates, and can undertake application research projects of both national and ministerial level, independently formulate various lubricant products to meet special market requirements.

In the process of development, Sinopec Lubricant Co., Ltd. has gradually nurtured its unique brand culture and strategy on international development. Insisting in building a high-tech, high-quality, international brand image, Sinopec lubricants have entered into more than 50 countries and regions such as Southeast Asia, Oceania, America, Africa, etc. Service network of marine oil have been set up in Singapore, UAE, the United States, South Africa and ready to expand to Europe and America. In July 2013, Singapore Lubricants production base was Officially put into operation. In 2013, the brand value of "SINOPEC Lubricant" boosted 3.79 billion us dollars, ranked 52nd in China's most valuable brand list in 2013 and 1st in Asian lubricant Industry.

Sinopec Lubricant Co., Ltd. has actively participated in international competition and made efforts in seeking long-term cooperation relationship with relative industries to achieve mutual development.



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## SINOPEC Transformer Oil

### Foreword

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- Transformer oil is one of the basic materials used in power transmission system, and mainly for insulation, cooling and heat dispersion of oil-filled electrical equipment, such as transformer, reactor, mutual inductor and switch, etc.
- A main function of transformer oil is to provide good electrical insulation performance. Through strict linkage control in manufacturing, transporting and using of transformer oil, the oil provides extremely low conductivity and high breakdown voltage, thus reducing power loss of electrical equipment. Electrical equipment will generate plenty of heat during power transmission and transformation process, so the transformer oil is required to provide good heat-transmission capability. Through hot and cold convection and circulating reflux, transformer oil with proper viscosity and low pour point can send heat out in time to avoid over temperature of electrical equipment like transformer. In addition, transformer is mainly composed of copper wire, iron core and non-conductive cellulose etc. To ensure a long service life of transformer, transformer oil must provide good antioxidant capacity.
- SINOPEC transformer oil I-0 (No.10) of Sinopec Lubricant Co., Ltd has a production history over 50 years, and transformer oil I-10 (No.25) and I-40 (No.45) are also the mature product with a production history over 20 years.



## Property Requirements of Transformer Oil

All specifications of transformer oil have index requirements on physical, electrical and chemical property, and main property requirements are as follows:

### 1. Appearance

Clear and transparent, without suspended solid or deposit at bottom, the color usually is water white or straw yellow.

### 2. Density

Density of oil has close relation with its compositions. As to transformer oil, the density shall be controlled low enough to effectively prevent floating ice in oil under cold climate which will consequently affect insulation property of oil.

### 3. Kinematic viscosity

Besides effect of insulation, transformer oil also provides effect of cooling and heat dispersion. As to transformer oil, proper high-temperature viscosity can ensure ideal effect of cooling and heat dispersion of transformer oil during long time service, while proper low-temperature viscosity can ensure working safety of lowest cold start of transformer.

### 4. Pour point

Pour point can reflect low temperature performance of transformer oil, from which low temperature environment for oil can be estimated.

### 5. Flash point

Flash point is a safety index of transformer oil during storage and use. Especially for supervision and control of transformer oil in service, flash point is an indispensable item. Descending of flash point indicates volatile combustible materials have been generated from oil. Such low molecular hydrocarbon is often generated during heating crack of transformer oil under high temperature, which is resulted from local overheating fault of electrical equipment. Therefore, from flash point, it can be observed whether electrical equipment have local overheating fault. For oil newly filled in equipment and after repair, checking flash point can discover whether there is light distillate mixed or not, thus ensuring operation safety of equipment.

### 6. Water content

Water content is a main factor affecting insulation property of transformer and aging of oil. Increasing of water content in transformer oil and insulation materials will directly result in decreasing of insulation property and aging of oil, which affects operation reliability and service life of equipment. To strictly supervise water content is a test item necessary for ensuring operation safety of equipment. However, care shall be taken to water absorptivity of transformer oil. Therefore, users shall implement vacuum dehydration treatment on transformer oil before filling it in equipment by requirements of guide for maintenance and supervision of transformer oil in service.

### 7. Interfacial tension

Interfacial tension refers to tension formed by interface between oil and water. Main functional groups of carboxylic acid, alcohol and ester and other active materials in oil belong to hydrophilic polar group, whose orientated arrangement on the two intersectant interfaces will change molecular arrangement status on the interface, thus reducing interfacial tension. The larger the interface tension value is, the less the hydrophilic polar materials in oil will be. To measure interfacial

tension of transformer oil in service is an indirect and effective method for checking whether there is soluble polar impurities in oil resulted from aging. At initial aging phase of oil, the change of interfacial tension is slightly faster. The change speed will slightly reduce till medium-term aging phase, while oil sludge generated increases obviously. Therefore, measurement of interfacial tension also can reliably judge oil sludge generating trend of oil in service.

### 8. Breakdown voltage

Breakdown voltage is a very important index to check electric stress limit resistance of transformer oil, can be used to judge water content in transformer oil and pollution extent of other suspended solid, and check drying and filtering level of oil before filling it in equipment. Decreasing of breakdown voltage of oil in service is a signal for working danger of transformer. To avoid affecting water content and impurities in oil by transportation or other factors, users must remeasure transformer oil after filtering (dehydration) or other treatment before using.

### 9. Dielectric dissipation factor

Dielectric dissipation factor refers to power loss resulted from oil electrolytic polarization and conductance under electric field. Pure hydrocarbon is non-polar compound, which never or occasionally translocate under electric field, so no power loss will be generated. However, impurities in oil, such as gummy matter and acid polar materials will translocate with change of power line direction under electric field, which consumes part of power for transforming into heat. Therefore, such impurities not only consume power, but also increase temperature and reduce working capacity of transformer, thus accelerating aging and deterioration of transformer oil. For transformer oil in service, dielectric dissipation factor can send signal earlier than other indexes. From the value of dielectric dissipation factor, deterioration and pollution extent of oil can be judged. Generally, fresh oil has less impurities and polar components etc. so dielectric dissipation factor is less. However, when oil deteriorates or mixes with other impurities, as increasing of polar materials or impurities content in oil, dielectric dissipation factor will increase too. Therefore, dielectric dissipation factor is of vital importance for quality supervision of oil in service.

### 10. Oxidation stability

Affected by oxidation catalysis of iron core, copper core and other metals and high oil temperature in service, transformer oil will age and form acid materials, and low molecular water-soluble acid will corrupt solid insulation materials greatly. In addition, transformer oil will generate oil sludge after severe oxidation. The oil sludge separated will deposit on surface of iron core and coil, which results in bad thermal conductivity and high temperature rise of solid insulating layer as well as aging and cracking of solid insulation materials, thus greatly threatening long time operation of transformer. Transformer oil with good oxidation stability can not only reduce the cost of repair and oil changing, but also benefit long operation of transformer. Therefore, oxidation stability is an important index of transformer oil.



### Product Standard and Quality Performance of SINOPEC Transformer Oil

The SINOPEC transformer oil is blended with highly refined mineral type base oil and well-chosen anti-oxidizer. Without PCB, it is suitable for insulation and cooling for transformer, oil immersed switch and other similar electrical insulation device. According to its low temperature performance, the product can be divided into four grades including I-0(No.10), I-10(No.25), I-30(No.40), I-40(No.45). Wherein, I-0(No.10), I-10(No.25) and I-40(No.45) conform to GB 2536-2011 national standard, and also satisfy quality requirements of IEC60296:2003 standard. Transformer oil I-30(No.40) is manufactured by Sinopec Lubricant Co., Ltd according to company's product standard which with reference to IEC 60296:2003 standard.

#### ◆ Performance and characteristic, technical specification and applications of SINOPEC transformer oil

##### Features and benefits

- Outstanding electrical insulation property, effectively preventing occurrence of discharge in electric field
- Excellent oxidation stability, effectively preventing formation of acidic material and sludge
- Good heat conductivity, ensuring effective cooling of transformer core and coiling

##### Technical specification

- The product meets the following specifications:  
GB 2536-2011  
IEC60296:2003

##### Recommended applications

- As insulating and cooling medium for transformer of 330kV or below as well as electrical equipment with similar requirements





## Typical Properties

Typical properties of SINOPEC transformer oil I-0(No.10) (IEC 60296:2003)			
Items	Limits	Typical data	Test method
<b>1. Function</b>			
Pour Point, °C	≧ -10	-12	GB/T 3535 or ISO 3016 or ASTM D97
Viscosity (40°C), mm <sup>2</sup> /s	≧ 12	11.38	GB/T 265 or ISO 3104 or ASTM D445
Viscosity (0°C), mm <sup>2</sup> /s	≧ 1800	68.96	GB/T 265 or ISO 3104 or ASTM D445
Water content (mg/kg)	≧ 40	24.0	GB/T 7600 or IEC 60814 or ASTM D1533
Breakdown voltage (2.5mm), kV			
No treated	≧ 30	49	GB/T 507 or IEC 60156
Treated	≧ 70	-	
Density (20°C), kg/m <sup>3</sup>	≧ 895	846.8	GB/T 1884 or ISO 3675 or ASTM D1298
Dielectric Dissipation Factor (90°C)	≧ 0.005	0.0018	GB/T 5654 or IEC 60247
<b>2. Refining, stability</b>			
Appearance	Bright and clear	Bright and clear	Visual
Acidity, mgKOH/g	≧ 0.01	0.005	IEC 62021-1
Interfacial Tension (mN/m)	≧ 40	49.13	GB/T 6541 or ISO 6295
Total sulfur content (m/m), %	No general requirement	0.027	SH/T 0689 or ISO 14596
Corrosive sulfur	Not corrosive	Not corrosive	DIN51353 ASTM 1275 B
Antioxidant additives, %	0.08~0.40	0.346	SH/T 0792 or ASTM D2668
2-Furfural content (mg/g)	≧ 0.1	< 0.01	IEC 61198
<b>3. Performance</b>			
Oxidation stability (120°C, 500hrs) Total acidity, mgKOH/g	≧ 1.2	0.0445	IEC 61125 (method C)
Sludge, %	≧ 0.8	0.0044	
DDF at 90°C	≧ 0.5	0.007	GB/T 5654 or IEC 60247
Gassing (μ L/min)	No general requirement	9.5	GB/T 11142 or ASTM D2300 or IEC 60628A
<b>4. Health, safety and environment</b>			
Flash point(COC), °C	≧ 135	168	GB/T 261 or ISO 2719
PCA content, %	≧ 3	< 3	BS2000 Part 346
PCB content, %	No detectable	No detectable	IEC 61619

## Typical Properties

Typical properties of SINOPEC transformer oil I-10(No.25) (IEC 60296:2003)			
Items	Limits	Typical data	Test method
<b>1. Function</b>			
Pour Point, °C	≥ -20	-30	GB/T 3535 or ISO 3016 or ASTM D97
Viscosity (40°C), mm <sup>2</sup> /s	≥ 12	8.976	GB/T 265 or ISO 3104 or ASTM D445
Viscosity (-10°C), mm <sup>2</sup> /s	≥ 1800	98.26	GB/T 265 or ISO 3104 or ASTM D445
Water content (mg/kg)	≥ 40	23.0	GB/T 7600 or IEC 60814 or ASTM D1533
Breakdown voltage (2.5mm), kV No treated Treated	≤ 30 ≤ 70	54.2 -	GB/T 507 or IEC 60156
Density (20°C), kg/m <sup>3</sup>	≥ 895	847.6	GB/T 1884 or ISO 3675 or ASTM D1298
Dielectric Dissipation Factor (90°C)	≥ 0.005	0.0002	GB/T 5654 or IEC 60247
<b>2. Refining, stability</b>			
Appearance	Bright and clear	Bright and clear	Visual
Acidity, mgKOH/g	≥ 0.01	0.007	IEC 62021-1
Interfacial Tension (mN/m)	≤ 40	46.7	GB/T 6541 or ISO 6295
Total sulfur content (m/m), %	No general requirement	0.0058	SH/T 0689 or ISO 14596
Corrosive sulfur	Not corrosive	Not corrosive	DIN51353 ASTM 1275 B
Antioxidant additives, %	0.08~0.40	0.35	SH/T 0792 or ASTM D2668
2-Furfural content (mg/g)	≥ 0.1	<0.01	IEC 61198
<b>3. Performance</b>			
Oxidation stability (120°C, 500hrs) Total acidity, mgKOH/g	≥ 1.2	0.0822	IEC 61125 (method C)
Sludge, %	≥ 0.8	0.0075	
DDF at 90°C	≥ 0.5	0.0015	GB/T 5654 or IEC 60247
Gassing (μ L/min)	No general requirement	20.1	GB/T 11142 or ASTM D2300 or IEC 60628A
<b>4. Health, safety and environment</b>			
Flash point(COC), °C	≤ 135	156	GB/T 261 or ISO 2719
PCA content, %	≥ 3	<3	BS2000 Part 346
PCB content, %	No detectable	No detectable	IEC 61619

## Typical Properties

Typical properties of SINOPEC transformer oil I-30(No.40) (IEC 60296:2003)			
Items	Limits	Typical data	Test method
<b>1. Function</b>			
Pour Point, °C	≥ -40	-51	GB/T 3535 or ISO 3016 or ASTM D97
Viscosity (40 °C), mm <sup>2</sup> /s	≥ 12	8.712	GB/T 265 or ISO 3104 or ASTM D445
Viscosity (-30 °C), mm <sup>2</sup> /s	≥ 1800	423.4	GB/T 265 or ISO 3104 or ASTM D445
Water content (mg/kg)	≥ 40	27	GB/T 7600 or IEC 60814 or ASTM D1533
Breakdown voltage (untreated), kV	≥ 30	55.4	GB/T 507 or IEC 60156
Density (20 °C), kg/m <sup>3</sup>	≥ 895	829.8	GB/T 1884 or ISO 3675 or ASTM D1298
Dielectric Dissipation Factor (90 °C)	≥ 0.005	0.0003	GB/T 5654 or IEC 60247
<b>2. Refining, stability</b>			
Appearance	Bright and clear	Bright and clear	Visual
Acidity, mgKOH/g	≥ 0.01	0.007	IEC 62021-1
Interfacial Tension (mN/m)	≥ 40	47.1	GB/T 6541 or ISO 6295
Total sulfur content (mass fraction), %	No general requirements	0.0087	SH/T 0689 or ISO 14596
Corrosive sulfur	Not corrosive	Not corrosive	DIN51353 ASTM 1275 B
Antioxidant additive (mass fraction), %	0.08 ~ 0.40	0.36	SH/T 0792 or ASTM D2668
2-Furfural content (mg/g)	≥ 0.1	< 0.1	IEC 61198
<b>3. Performance</b>			
Oxidation stability (120 °C, 500hrs) Total acidity, mgKOH/g	≥ 1.2	0.0822	IEC 61125 (method C)
Sludge (mass fraction), %	≥ 0.8	0.0075	
DDF at 90 °C	≥ 0.5	0.0015	GB/T 5654 or IEC 60247
Gassing (μ L/min)	No general requirement	20.1	GB/T 11142 or ASTM D2300 or IEC 60628A
<b>4. Health, safety and environment</b>			
Flash point(COC), °C	≥ 135	162	GB/T 261 or ISO 2719
PCA content (mass fraction), %	≥ 3	1.96	BS2000 Part 346
PCB content (mass fraction), %	No detectable	No detectable	IEC 61619



## Typical Properties

Typical properties of SINOPEC transformer oil I-40(No.45) (IEC 60296:2003)			
Items	Limits	Typical data	Test method
<b>1. Function</b>			
Pour Point, °C	≧ -40	-54	GB/T 3535 or ISO 3016 or ASTM D97
Viscosity (40°C), mm <sup>2</sup> /s	≧ 12	9.425	GB/T 265 or ISO 3104 or ASTM D445
Viscosity (-40°C), mm <sup>2</sup> /s	≧ 1800	609.7	GB/T 265 or ISO 3104 or ASTM D445
Water content (mg/kg)	≧ 40	15.0	GB/T 7600 or IEC 60814 or ASTM D1533
Breakdown voltage (2.5mm), kV			
No treated	≧ 30	55.7	GB/T 507 or IEC 60156
Treated	≧ 70	-	
Density (20°C), kg/m <sup>3</sup>	≧ 895	848.2	GB/T 1884 or ISO 3675 or ASTM D1298
Dielectric Dissipation Factor (90°C)	≧ 005	0.0004	GB/T 5654 or IEC 60247
<b>2. Refining, stability</b>			
Appearance	Bright and clear	Bright and clear	Visual
Acidity, mgKOH/g	≧ 0.01	0.008	IEC 62021-1
Interfacial Tension (mN/m)	≧ 40	44.6	GB/T 6541 or ISO 6295
Total sulfur content (m/m), %	No general requirement	0.0048	SH/T 0689 or ISO 14596
Corrosive sulfur	Not corrosive	Not corrosive	DIN51353 ASTM 1275 B
Antioxidant additives, %	0.08~0.40	0.36	SH/T 0792 or ASTM D2668
2-Furfural content (mg/g)	≧ 0.1	< 0.01	IEC 61198
<b>3. Performance</b>			
Oxidation stability (120°C, 500hrs) Total acidity, mgKOH/g	≧ 1.2	0.0478	IEC 61125 (method C)
Sludge, %	≧ 0.8	0.0036	
DDF at 90°C	≧ 0.5	0.0082	GB/T 5654 or IEC 60247
Gassing (μ L/min)	No general requirement	20	GB/T 11142 or ASTM D2300 or IEC 60628A
<b>4. Health, safety and environment</b>			
Flash point(COC), °C	≧ 135	153	GB/T 261 or ISO 2719
PCA content, %	≧ 3	< 3	BS2000 Part 346
PCB content, %	No detectable	No detectable	IEC 61619



## OEM Certificates of SINOPEC Transformer Oil

### ABB certificate

SINOPEC transformer oil I-10(No.25) and I-40(No.45) have gained technology certificates from ABB Company (Sweden ABB AB diagnosis and service department of power transformer).

SINOPEC transformer oil I-40(No.45) meets the requirements on high grade inhibited oil HI-A listed in the ABB materials specification 1ZBA117001-1. SINOPEC transformer oil I-10(No.25) meets the requirements on high grade inhibited oil HI-B listed in the ABB materials specification 1ZBA117001-1.

### ABB Power Technology Products

### Report

He Xiao-Ying Lucricant Company SINOPEC Corporation Shanghai, China		Document Number SETFO 2009-103	No of Pages 4
Prepared Ylva Persson 2009-05-18		Title Tests on Sinopec insulating oils SINOPEC No. 10, 25 and 45.	No of Attached Pages 0
Approved Lena Melzer 2009-05-20	Resp Dept PPTR/AD		Reg./Class no. 11713

#### Summary

The tested sample of SINOPEC No. 45 meets the requirements on high grade inhibited insulation oil HI-A listed in the ABB material specification 1ZBA 117001-1.

The tested sample of SINOPEC No. 25 meets the requirements on high grade inhibited insulating oil HI-B.

The tested sample of SINOPEC No. 10 fails to meet ABB requirements for low temperature properties.

**Siemens certificate**

SINOPEC transformer oil I-10(No.25) and I-40(No.45) have gained technology certificates from Siemens Company. SINOPEC transformer oil I-10(No.25) and I-40(No.45) can be used for all application cases described in TUN 901293 (Edition 2007) of Siemens.

SIEMENS

Technical Report

Department	Place	Pages-Annex	Date
ET TR TLM P4	Nbg K	1/3	22.04.2010
Handled by	Phone	Countersignature	Ref.
Mrs. Bergner	2493	Mrs. Hühlein	TLMD 176/10

Distribution

Sinopec	T PN SP 125	T TI	
PTD MVT	T PN E	T PN PU	T PN TA
ET TR TLM P4			

Actioned

Testing of the inhibited Transformer oils N25 and N45 ,  
supplier Lubricant Company Sinopec Corp., China

Summary

*The inhibited Transformer oils N25 and N45 from supplier Lubricant Company Sinopec Corp., China fulfil the requirements in the delivery state and for the oxidation stability high grade after ageing according to the IEC 60296 .*

*The inhibited Transformer oils N25 and N45 from supplier Lubricant Company Sinopec Corp., China can be used for all application cases described in TUN 901293 (Edition 2007).*

*The inhibited oils N25 and N45 contain Benzotriazol as an additive, which is allowed according IEC 60686.*







## Property Advantages of SINOPEC Transformer Oil

For no dewaxing procedure or pour point depressant, it is an accepted economic and effective method to prepare transformer oil from naphthenic base oil in nearly a century. As advancement of oil refining technology and knowledge on transformer oil, it is recognized that refining depth of base oil and compatibility with additive is essential for property of transformer oil. Quality of transformer oil is dependant on specifications of transformer oil product. Throughout the transformer oil specifications worldwide, no specification specifies raw oil for producing transformer oil. The reason is that basic compositions of mineral oil are mixtures of various hydrocarbons, which occupy more than 95% of mineral oil, and others are non-hydrocarbon materials containing S, N and O. Through refining process of oil, most non-hydrocarbon, polycyclic and condensed hydrocarbon component can be removed. Hydrocarbon component are poor conductor for electricity, providing good insulation property and small loss of medium. Variety of hydrocarbon structure (such as alkane, naphthenic hydrocarbon and aromatic hydrocarbon) makes same distillation of transformer oil with completely different specific gravity, viscosity, pour point and flash point etc.

At present, proper hydrogenation process for producing good transformer oil has been adopted internationally. Under certain temperature, pressure and with catalyst, hydrogenation process makes chemical reaction between hydrogen and hydrocarbon, which provides hydrogenation transformer oil with advantages, such as low viscosity, high flash point, low pour point and oxidation stability etc., and further improved electrical property. Each large transformer oil manufacturer in China also adopts different extent of hydrogenation process to improve quality of transformer oil. At present, SINOPEC transformer oil is also produced from hydrogenation-isomerization dewaxing base oil with outstanding property, which has further improved quality of transformer oil.

### Compositions:

For transformer oil after hydrogenation, the total naphthenic hydrocarbon content is almost the same as naphthenic base transformer oil.

Comparison of compositions in naphthenic hydrocarbon of transformer oil (measured by gas chromatograph-mass spectrometer)

Items	Hydrogenated transformer oil I-10(No.25)	Naphthenic base transformer oil I-10(No.25)	Hydrogenated transformer oil I-40(No.45)	Naphthenic base transformer oil I-40(No.45)
Total naphthenic hydrocarbon, %	80.2	84.4	79.9	82.3

### Density:

Operating under extremely low temperature or temporary stopping in winter, transformer shall be able to prevent floating ice in oil to the most extent. The floating ice won't affect operation of transformer. However, when temperature rises, the floating ice will become liquid water after melting. If the water flows to electrode zone, it will obviously reduce breakdown voltage to cause discharge danger. Under 0℃ and one atmospheric pressure, density of pure ice is 917kg/m<sup>3</sup>, which actually will change among range of 880kg/m<sup>3</sup>~920kg/m<sup>3</sup>. The larger density difference between transformer oil and floating ices, the easier control the appearance of floating. Generally, density of transformer oil shall be no more than 895kg/m<sup>3</sup> under 20℃. With higher carbon and hydrogen ratio in alkane of naphthenic hydrocarbon chain, so density of naphthenic base transformer oil is slightly higher. However, SINOPEC transformer oil manufactured on the basis of hydrogenation maintains the advantage of low density, which ensures use safety under low temperature.

### Viscosity:

Because transformer oil is used for heat transmission rather than lubrication, the transformer oil with lower viscosity is better while ensuring flash point and other safety indexes. The lower the viscosity, the better fluidity of oil for heat transmission. In addition, transformer oil should also provide lower low-temperature viscosity, which ensures transformer oil can be normally activated after stopping in cold winter. SINOPEC transformer oil provides proper high-temperature viscosity and good low-temperature viscosity benefiting heat transmission and low-temperature startup.

### Pour point:

N-alkanes can be isomerized through hydrogenation-isomerization dewaxing process, thus reducing wax content in oil greatly. Therefore, hydrogenated transformer oil has broken through bottleneck of poor property under low temperature, and provides low pour point satisfying the demands on low-temperature use of transformer oil.

### Flash point:

With reasonable control of raw materials and manufacturing process of base oil, SINOPEC transformer oil provides obviously higher flash point than that of other transformer oil, which certainly brings safety guarantee to transformer operating with electricity.

### Electrical property:

For new transformer oil, electrical properties, such as breakdown voltage, dielectric dissipation factor and interfacial tension etc. mainly depend on refining extent of oil during production procedure. With high depth of refining, water and impurities contained in transformer oil may be fewer so that the electrical property will be better. Therefore, different transformer oil with similar refining extent has little differences in electrical property. Base oil after hydrogenation is highly refined, which has little sulfur, nitrogen, metal and other impurities, soluble or suspensible water. Therefore, SINOPEC transformer oil manufactured by hydrogenated base oil provides high breakdown voltage and dielectric dissipation factor, thus ensuring use safety of transformer oil.

### Oxidation stability:

Sinopec Lubricant Co., Ltd provides the unique bench for evaluating oxidation property of transformer oil in China. The bench simulates actual operation conditions of transformer oil using in equipment, and the test result can properly reacts anti-oxxygenic property of transformer oil in service, which well corresponds to actual use life of transformer oil. The bench has provided joint test for various transformer oil manufacturers and users in China for many years. Through bench test and data accumulation for many years, the result indicates that SINOPEC transformer oil manufactured by proper hydrogenation provides obvious advantages on oxidation stability, which means that hydrogenated transformer oil has a longer use life.

Sample no	Result of bench test, hours	Test time
Paraffin base solvent refining 1	2388	1997
Paraffin base solvent refining 2	2815	1997
Paraffin base solvent refining 3	2610	1997
Paraffin base solvent refining 4	2390	1997
Paraffin base solvent refining 5	2537	1997
Paraffin base solvent refining 6	2224	1999
Naphthenic base 1	1013	1998
Naphthenic base 2	1056	1990
Naphthenic base 3	1507	1999
Naphthenic base 4	1203	1999
SINOPEC hydrogenated transformer oil No.1	3548	2007
SINOPEC hydrogenated transformer oil No.2	> 5000	2007

### Conclusion:

SINOPEC transformer oil manufactured by hydrogenated base oil not only maintains good electrical property and other quality advantages of solvent refining transformer oil, but also eliminates pour point difference with naphthenic base transformer oil, and provides more advantages than naphthenic base oil on density, flash point and oxidation stability etc.



## Accepting, Refilling and Changing of Transformer Oil

At different phases from fresh oil leaving factory to oil-filled transformer, transformer oil has different meanings mainly divided into three phases as follows:

- Fresh oil: Unused oil, which is fresh, has not contacted with materials and structural materials of electrical equipment, and whose product quality reaches GB 2536-2011 or SH 0040-2007 standard.
- Unused oil: fresh oil directly or through filling equipment filled in equipment before operation (energizing).
- Oil in service: transformer oil filled in equipment which has been put into operation. For transformer oil at the above three phases, GB/T 14542-2005 Guide for maintenance and supervision of transformer oil in service (which is reference to IEC60422-2005 Supervision and maintenance guide for mineral insulating oil in electrical equipment) provides corresponding standards on quality and supervision.

### 1. Inspection of transformer oil before accepting and filling in equipment

- Accepting of fresh oil:  
For transformer oil leaving factory, transformer oil manufacturers shall inspect by GB 2536-2011 (which is reference to IEC60296-2003) or SH 0040-2007 (which is reference to ASTM D3487-2006), and users shall accept by GB 2536-2011 or SH 0040-2007 standard.
- Inspection of fresh oil before and after filling in equipment (unused transformer oil):  
before filling in transformer, fresh oil must be vacuum filtered and purified to reach index requirements in GB/T 14542-2005 Inspection of fresh oil after purification. Oil filled in transformer must implement hot oil circulation by stipulated requirements, and reach index requirements in GB/T 14542-2005 quality inspection of oil after hot oil circulation, and satisfy related standard requirements before energizing to operate.

Inspection of fresh oil after purification

Items	Voltage level of equipment, kV		
	500 or above	330~220	≤110
Breakdown voltage, kV	≥60	≥55	≥45
Water content (mg/kg)	≤10	≤15	≤20
Dielectric dissipation factor (90℃)	≤0.002	≤0.005	≤0.005

Quality inspection of oil after hot oil circulation

Items	Voltage level of equipment, kV		
	500 or above	330~220	≤110
Breakdown voltage, kV	≥60	≥50	≥40
Water content (mg/kg)	≤10	≤15	≤20
Gas content (Volume fraction), %	≤1	—	—
Dielectric dissipation factor (90℃)	≤0.005	≤0.005	≤0.005

■ Supervision of transformer oil in service:

After filling transformer oil in new transformer, because impurities (such as organic polar materials, solid particle impurities and fiber etc.) may be solved while oil is contacting solid insulation materials and structural materials etc., which results in oil temperature rise and quality deterioration after energizing, the quality of transformer oil in service and unused transformer oil has great difference. Therefore, transformer oil in service shall be inspected by regulation of quality criteria, inspection items and frequencies of transformer oil in service in GB/T 14542-2005.

Quality criteria, inspection items and frequencies of transformer oil in service					
Items	Voltage level of equipment, kV	GB/T 7595-2000 standard	Recommended indexes and frequency		Test method
Appearance	Each voltage level	Clear and bright	Clear and bright	Once a year	Visual
Water-soluble acid (PH)	Each voltage level	≥4.2	≥4.2	Once a year or when necessary	GB/T 7598
Acidity, mgKOH/g	Each voltage level	≤0.1	≤0.1	Once a year	GB/T 264
Flash point (COC), °C	Each voltage level	No less than 10°C of original measured value of fresh oil	No less than 10°C of original measured value of fresh oil	When necessary	GB/T 261
Water content (mg/kg)	330~500 or above	≤15	≤20	At least once a year	GB/T 7600
	220	≤25	≤30		
	110 or below	≤35	≤40		
Interfacial tension (25°C), (mN/m)	Each voltage level	≥19	≥19	At least once a year	GB/T 6541
Dielectric dissipation factor (90°C)	500 or above	≤0.020	≤0.020	Once a year	GB/T 5654
	≤330	≤0.040	≤0.040		
Breakdown voltage (2.5mm), kV	500 or above	≥50	≥50	Once a year	GB/T 507
	330	≥45	≥45		
	220	≥35	≥40		
	66~110	≥35	≥30		
	35 or below	≥30		At least once every three year	DL/T 429.9
Volume resistivity (90°C), (Ω.m)	500 or above	≥1 × 10 <sup>10</sup>	≥1 × 10 <sup>10</sup>	Once a year or when necessary	GB/T 5654 or DL/T 421
	≤330	≥5 × 10 <sup>9</sup>	≥5 × 10 <sup>9</sup>		
Gas content (volume fraction), %	330~500	≤3	≤3	Once a year or when necessary	DL/T 423 or DL/T 703
	220	—	Report		
Sludge and deposit (mass fraction), %	Each voltage level	<0.02	<0.02	When necessary	See annex A

Use process of transformer can be monitored effectively based on change of the above indexes.

When one index of oil obviously becomes worse, strengthen analysis and recommend to adopt relative measures stipulated in GB 14542-2005. If rapid fluctuation of oil quality is resulted from antioxidant consumption in oil that antioxidant needs to be added, it is recommended to add by relative regulations in GB 14542-2005 and under the guidance of transformer oil manufacturer.

Extreme limit indexes of transformer oil in service (GB 14542-2005)		
Items	Extreme limit	
Appearance	Non transparent, with visible impurities or oil sludge deposit	
Color	Dark color	
Water content (mg/kg)	330kV~500kV	> 20
	220kV	> 30
	110kV or below	> 40
Acidity, mgKOH/g	> 0.1	
Water-soluble acid (PH)	PH < 4.2	
Breakdown voltage, kV	500kV	< 50
	330kV equipment	< 45
	220kV equipment	< 40
	66kV~110kV	< 35
	30kV or below equipment	< 30
Dielectric dissipation factor (90℃)	500kV or above equipment	> 0.02
	≤330kV or below equipment	> 0.04
Interfacial tension (mN/m)	< 19	
Volume resistivity 90℃, (Ω.m)	500kV or above equipment	< 1 × 10 <sup>10</sup>
	≤330kV or below equipment	< 5 × 10 <sup>9</sup>
Sludge and deposit	> 0.02%	
Flash point (COC), ℃	Less than 10℃ or above of original value of fresh oil	
Total gas content in oil (volume fraction), %	330kV~500kV or above equipment > 3	

## 2. Oil refilling and changing

For long time operation of oil-filled transformer, oil refilling and changing are necessary. However, GB/T 14542-2005 Guide for maintenance and supervision of transformer oil in service must be followed, key points are as follows:

- 1) For electrical equipment need to be refilled with oil, unused transformer oil conforming to relative fresh oil standard shall be prior selection. Refilling oil should better be oil with same oil base, grade and additive. Each property index of refilled oil shall be no less than that of oil in equipment. When amount of the fresh oil to be refilled is low, such as less than 5%, generally no problem will appear; while when amount of the fresh oil to be refilled is high, oil separation test shall be made before refilling. When ensuring no oil sludge separated, acidity and dielectric dissipation factor is no more than that of oil in equipment, oil can be refilled.
- 2) In principle, transformer oil come from different base oil should not be mixed to use. Under special conditions, for different grades of fresh oil need to be mixed for use, whether the local requirements can be satisfied depends on actual freezing point of mixed oil, and then oil-mixing test shall be carried out by DL/T 429.6 method. In addition, mixed oil sample shall be better than the worst single oil sample.
- 3) If different grades of fresh or used oil need to be mixed with oil in service, the freezing point of mixed oil shall be measured, and aging test shall be made by DL/T 429.6 method to measure acidity and dielectric dissipation factor of aged oil sample. Observe oil sludge separated, and use oil without deposit. When mixed sample obtained is better than original oil in service, the oil can be mixed to use.
- 4) In principle, imported oil or oil with unknown place of origin or manufacturer can not be mixed with different grades of oil in service. If necessary to mix, aging test on the oil to be mixed and mixed oil shall be made by DL/T 429.6 method to measure acidity, dielectric dissipation factor and observe sludge deposit in advance. If there is no sludge separated and quality of mixed oil is better than original oil in service, the oil can be mixed. If the oil to be mixed is fresh oil, the quality of mixed oil shall be better than the worst kind of oil, and whether the local requirements can be satisfied depends on actual freezing point of mixed oil.
- 5) Before oil-mixing test, mixing ratio of oil sample shall be the same as actual ratio. When mixing ratio can not be decided, mix by mass ratio of 1:1 for testing.
  - Attentions on oil changing: similar to oil refilling requirements, but the transformer oil shall be discharged as possible to avoid quality degradation of fresh oil.
  - Criteria for changing of transformer oil: transformer oil has different requirements on service quality in transformers with different voltage levels, so it shall be monitored by Quality Limit Value of Oil in Service (GB/T 14542-2005) stipulated by Power Industry. Change oil if such limit is exceeded.





## Management of Transformer Oil

Transformer oil is a liquid isolation material for electrical appliance with special requirements. One particularity of transformer oil is that the entry of exterior micro impurities (such as water, dust, fiber and surface active substance) will obviously change electrical isolation capability of oil, such as drop of breakdown voltage, rise of dielectric dissipation factor etc. Therefore, special measures shall be adopted in the processes of manufacturing, transporting and storing etc. The other particularity of transformer oil is that it will contact surfaces of various solid insulation materials and other members after refilling in transformer, so compatibility among transformer oil components and various solid solution materials (such as varnish, paper sheet, rubber, paint and adhesive etc.) also has important effect on electrical insulation property of oil. For this reason, all transformer oil manufacturers shall ensure transformer oil can't solve with all materials used in transformer, otherwise quality of oil will become worse. In addition, voltage resistance and dielectric dissipation factor of transformer oil will be affected by cleanness and dryness of solid insulation materials, micro moisture absorption and discharging among oil and solid insulation materials and dust etc.

Therefore, management of transformer oil not only refers to transformer oil manufacturer, but also extends through the whole process in selling and using. To ensure quality and good service of transformer oil, all vessels, tanks, pipeline, pumps, samplers and sample bottles etc. used during manufacturing, transporting, storing, loading and unloading processes of transformer oil shall satisfy the requirements of "special, dry and clean".





## Questions and Answers

### 1. What properties transformer oil provides?

Main properties of transformer oil include three aspects: firstly, good insulation property, namely, dielectric strength (or breakdown voltage) is high and dielectric dissipation factor is low. High dielectric strength ensures conductor can be insulated well and prevent jump spark between electrodes under voltage effect in using common insulating oil. dielectric dissipation factor can greatly reduce energy loss resulted from polarity reversal of AC current. Secondly, good heat transmission property and fluidity, namely, oil provides proper viscosity and low freezing point (pour point), which ensures transformer and coil be cooled effectively, and switches, breakers, pumps, regulators and load-tap converter members etc. act flexibly. In addition, the outstanding oxidation stability can greatly reduce oil sludge and acid materials which are generated during storage and service and will deteriorate electrical property and cooling capacity and reduce its use life.

### 2. Where does the water in transformer oil come from? What's the existence form?

During package transportation and storage management of transformer oil, water may be resulted from improper treatment. In addition, petroleum products are water absorptive, which can absorb and solve some water from atmosphere or in contacting water. Both compositions of transformer oil and the temperature environment located will affect its water absorptivity. For oil with different chemical compositions, the water absorptivity difference can reach tens of mg/kg. The more aromatic hydrocarbon content in oil means moisture absorptivity of oil is higher. Furthermore, some polar molecule in oil also can increase moisture absorptivity of oil. Generally speaking, water solubility of oil under 20 °C approximately is 40mg/kg, and water content of transformer oil can be reduced to 10mg/kg or about by industrial dehydration equipment. In addition, moisture absorptivity of oil takes linear increment with air relative humidity and oil temperature. For example, when relative humidity of oil sample is 40% under 60 °C, water content in oil is 80 mg/kg; while when relative humidity is 80%, water content in oil will reach 200mg/kg.

Water in transformer oil exists in three forms:

Suspended state: water is suspended in oil in the form of water droplet.

Floating state: water is distributed in oil in the form of extremely small water droplet.

Soluble state: water is solved in oil.

### 3. What bad effects that water brings to electrical property of transformer oil?

Water will bring great damage to electrical, physical and chemical properties of transformer oil. Firstly, water will reduce breakdown voltage of oil. According to relative experience data, when water content in oil is 0.01%, breakdown voltage of oil approximately is 15kV; while water content in oil increases to 0.03%, breakdown voltage of oil will reduce to about 6kV. In addition, water also affects loss factor of medium greatly. As increasing of water content in oil, loss factor of medium will increase. When water content in oil is 0.02%, loss factor of medium is  $1 \times 10^{-2}$ ; when water content in oil increases in 5 times (i.e., up to 0.10%), dielectric dissipation factor will increase to  $2.1 \times 10^{-2}$ . In addition, water also can accelerate corrosion of organic acid on copper, iron, and other metals, of which the polar materials like saponifiable matter will increase dielectric dissipation factor and moisture absorptivity, and catalyze oxidation of oil. It is generally believed that aging speed of wet oil is 2times~4times faster than that of dry oil. Therefore, much attention has been paid to water in transformer oil for a long time. Users must filter and dehydrate oil repeatedly till all electrical properties acceptable, and then fill it in electrical equipment.

### 4. What effects that water in transformer oil brings to mutual inductor?

#### How to remove water?

If transformer oil in mutual inducer contains supersaturated water, breakdown voltage will be generated during operation of equipment, which will affect normal operation, and even generate powerful electric arc to make porcelain shell explode, thus causing personal injury. Therefore, attention must be paid to transporting, storing and keeping process for preventing from water.

If there is water in oil barrel, measures shall be taken to remove water. Firstly, method shall be taken to deposit water at the bottom of barrel, and then pump oil in upper layer. However, it is inevitable that oil still contains some water, so oil shall not be used till water content in oil reaches the limit range allowed in relative quality standards after repeated filtering and absorbing by drier etc.

### 5. What's the meaning of measuring pH value of transformer oil in service?

PH value is mainly for indicating index of water-soluble acid in transformer oil. Generally, unused (fresh) transformer oil contains little acid materials, so the acid value is low that pH value is among 5~7. According to analysis on field investigation of transformer oil in China, simulation test and result of aging test in laboratory, when acid value of transformer oil in service is more than 0.1mgKOH/g and pH value is equal or less than 4.0, the probability of oil sludge separated in transformer oil will increase; when acid value of transformer oil in service is less than 0.1mgKOH/g and pH value is more than 4.0, the transformer oil generally can ensure good and reliable working of transformer; when acid value is up to 0.2mgKOH/g or above or pH value is less than 3.8, deterioration of oil quality will be obvious that much oil sludge will be generated. Therefore, it's stipulated that pH value of oil in service shall be more than 4.2 in relative standards.

### 6. Why does electrical property of oil in service deteriorate?

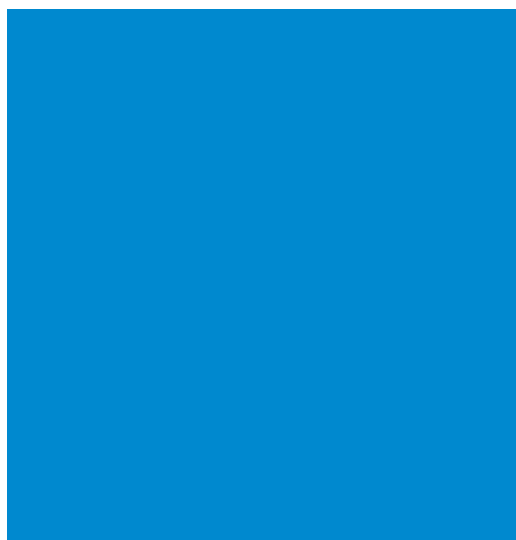
#### What remedy measures can be adopted?

For transformer oil in service, breakdown voltage and dielectric dissipation factor are usually used to indicate electrical property or insulating capacity. Even though there is little water or impurities, breakdown voltage of oil will also be affected obviously and reduced. In addition, suspended solid, such as scrap, fiber, dust and carbon black of metal filter screen will also bring bad effect on breakdown voltage. When transformer oil becomes aging and deteriorates to generate acid materials or oil sludge, or water or impurities is mixed with oil, dielectric dissipation factor will increase. Meanwhile, when load and unload oil, if improper oil delivery hose or plastic tube is used, oil will melt with the materials that results in oil deteriorating. The consequent phenomenon will be dielectric dissipation factor increasing abruptly, sometimes even up to 0.1 or more.

When oil with deteriorated quality and descended electrical property can not satisfy property index requirements of oil in service, the oil can be regenerated. The used method is to treat oil with hargil, and then add antioxidant to make its properties reach requirements of fresh oil.







## 7. Why to control density of transformer oil (or relative density) ?

Density (or relative density) has relation with compositions and water content of oil. To some extent, controlling density of transformer oil is equal to control water content of oil. For transformers used in cold areas, it's especially meaningful for preventing floating ice during temporary stopping in winter. If there is too much water in transformer oil, ice crystal will adhere on electrode under low temperature and melt when temperature rises to increase conductivity, thus resulting in discharging danger. Therefore, density of transformer oil generally shall be no more than  $895\text{kg/m}^3$  under  $20^\circ\text{C}$ .

## 8. What's the meaning to monitor flash point of "transformer oil in service" ?

Flash point is a safety index during storing and using process of insulating oil. Especially for supervision and control of transformer oil in service, flash point is an indispensable item. Descending of flash point indicates volatile combustible materials have been generated from oil. Such low molecular hydrocarbon is often generated during heating crack of transformer oil under high temperature, which is resulted from local overheating fault of electrical equipment. Therefore, from flash point, it can be observed whether electrical equipment have local overheating fault. For oil newly filled in equipment and after repair, checking flash point can discover whether there is light distillate mixed. Extremely low flash point will result in fire, even explosion of electrical equipment. Therefore, all fresh oil standards on transformer oil in each country provide strict flash point control index. Generally, CC flash point shall be no less than  $135^\circ\text{C}\sim 140^\circ\text{C}$ . Flash point of "oil in service" is also controlled strictly. Compared with the previous measured value, descending value of the next measured flash point shall be no more than  $5^\circ\text{C}$ .

## 9. What's the meaning to measure acid value of transformer oil for using transformer oil?

Acid value of transformer oil means there is acid materials in oil, namely, the total organic and inorganic acid. Fresh transformer oil contains little acid materials that the acid value is rather small. However, during long time storage, especially filling in electrical equipment and putting into operation, the oil will become aging in necessary contact with oxygen in air. During primary oxidation, low molecular organic acid is generated, and further oxidation will generate high molecular organic acid and acid products. If the above acid materials are generated in insulating oil, conductivity will be increased, while insulation property will be reduced, and even corrosion on metal will occur. Under high working temperature ( $80^\circ\text{C}$  or above), solid fiber insulation materials will become aging, which will reduce use life of equipment.

According to GB 2536-2011 standard, acid value of unused transformer oil generally shall be less than 0.03mgKOH/g; while that of oil in service shall be no more than 0.1mgKOH/g. As continuous increasing requirements of users, foreign related standards, such as IEC60296:2003, have suggested higher quality requirements on unused transformer oil, shall be no more than 0.01mgKOH/g.

## 10. What indicates when interfacial tension of transformer oil changes?

Interfacial tension refers to tension generated between insulating oil and immiscible water. Interfacial tension of unused transformer oil generally can reach 40mN/m~50mN/m. Oxidation and oil sludge etc. generated from aging and deteriorating of used oil will affect interfacial tension. Aged oil will generate various organic acid (-COOH), alcohol (-OH) and other polar materials, which reduce interfacial tension of oil gradually. Generally, the minimum limit value of interfacial tension of oil in service shall be 19mN/m.

### Annex

Oil-mixing test result of SINOPEC transformer oil I-10(No.25) and naphthenic base transformer oil I-10(No.25) (Aging measurement of open cup for oil in service DL 429.6-91)					
S/N	Proportion		Acid value of oil after test mgKOH/g	Appearance after diluting by petroleum ether	Appearance of oil after test
	SINOPEC transformer oil I-10(No.25)	Naphthenic base transformer oil I-10(No.25)			
1	10	-	0.002	No deposit	White, transparent no deposit
2	9	1	0.003	No deposit	White, transparent no deposit
3	5	5	0.003	No deposit	White, transparent no deposit
4	1	9	0.003	No deposit	White, transparent no deposit
5	-	10	0.004	No deposit	White, transparent no deposit

Conclusion of oil-mixing test: after test, appearance of oil sample is transparent and without deposit, indicating the two kinds of oil can be mixed for using.

