Mr.D-Varnish[32]

Best Practice OpEx Contest 2022

7 Feb 2022

Organize
Plant Inspection Division

Organize
Innovation Institute

ฝ่ายวิจัยผลิตภัณฑ์ปิโตรเลียมและยานยนต์ (วผว.)

กลุ่มวิจัยหล่อลื่นอุตสาหกรรมและผลิตภัณฑ์พิเศษ
ฝ่ายวิจัยผลิตภัณฑ์ปิโตรเลียมและยานยนต์
สถาบันนวัตกรรม

นายสุนทร ปรีดาพิทักษ์กุล
ผู้จัดการ

นายปองพล ทวีมา
นักวิจัย

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นักวิจัย

Organize
PTT OR

MR. ALONGKOT EIANLENG

Lubricant Product Development Division Manager

MR. NUTTAVUT WALAIKANOK

Analyst
(Lubricant Industrial Products)

MR. SATHAPORN CHUNHAKITIYANON

Lubricants Technical Services Division Manager

MR. JITTICHAI JUNTARATIN

MR. PUNNAWIT KIJSANAYOTHIN

Engineer
(All in Service)

MR. ITSARANUWAT AUNYINDEE

MISS SAROCHA RUNGRUSSAMEE

Engineer
(Product Monitoring)

ptt Lubricants SOLUTIONS

PID FAILURE IS NOT AN OPTION

Problem
Example History Case



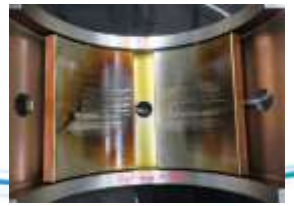
VOITH RFC TA5 GSP3 2018

- Found many varnish in all mechanical part
- Take long time to cleaning especially working oil cooler
- Make TA time delay 3 days from plan loss 105 MB!



Main LO OCS3 Package 2018

- Found bearing gearbox temp. high problem
- Operation can’t increase compressor load

Main LO SGC A&B TA3 GSP6 2018/2021

- Found temp. bearing swing high but can’t detect varnish by MPC
- Found varnish in bearing pad during TA

Timeline
From Practice to Best Practice

2013

MPC Varnish Monitoring

Implement ASTM D7843 standard to measure and monitoring Varnish

2015

Varnish Removal Unit

Implement with Mechanical Maintenance Team to used off-line filtration unit to filtrate the Varnish in oil tank, can remove Varnish only in tank but can't remove Varnish that stick in part and take long time circulate and high cost.

2018

New PTT M46

R&D with Innovation Institute & OR for New oil Group III, result Varnish better than original oil

2019

QSA Varnish Monitoring

Verify & develop new Varnish Monitoring technique for detect case that MPC can't, but result not effective, MPC still better.

2021

New PAG Oil

R&D with Innovation Institute & OR for New oil Group V to Solve at Root Cause of Varnish

GSP KM Portal

From KM to Best Practice

01

Varnish in Lube Oil Power turbine (Varnish Removal Unit)

Best Practice

02

Modify LO Sampling Point VOITH Gearbox (Oil Monitoring)

Best Practice

New Improvement to Best Practice

What is Varnish?

Nearly 10 years ago, GE reported that approximately one in three large industrial gas turbines showed signs of oil varnishing.

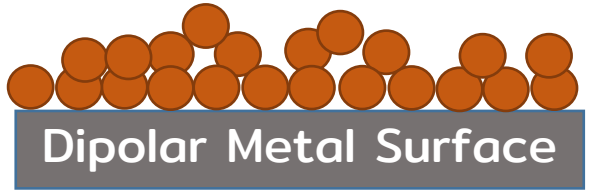
Lubricant varnish generally is defined as a thin, hard, lustrous, oil-insoluble deposit composed primarily of organic residue. It is most readily defined by color intensity and is not easily removed by wiping.

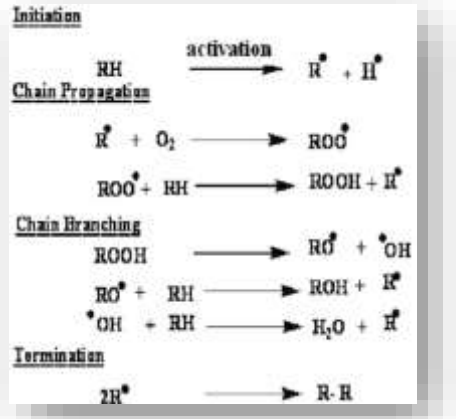
By Peter Dufresne Jr, Matthew G Hobbs, and **Glen MacInnis,** EPT

COMBINED CYCLE JOURNAL, Fourth Quarter 2013

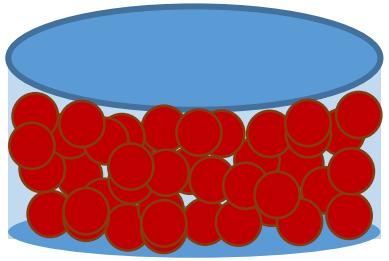
New Improvement to Best Practice

Cause, Type, Cycle of Varnish



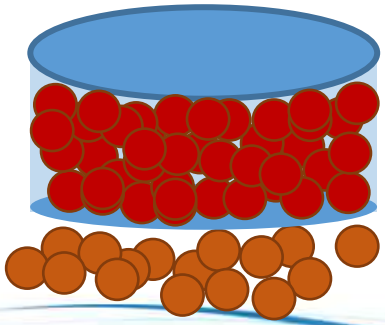


Oxidation Mechanism



Can used Varnish Removal Unit at this stage

Polar Oxidation By-Products [R-R, Dimers], Soluble Soft Contaminants

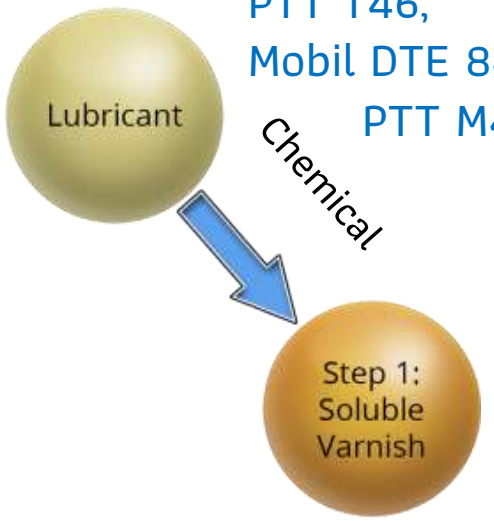


Can Monitoring Varnish at this stage by MPC or QSA

Polar Oxidation By-Products [R-R, Dimers], Insoluble Soft Contaminants, less than 1 micron

New Improvement to Best Practice

Solve Varnish at Root Cause



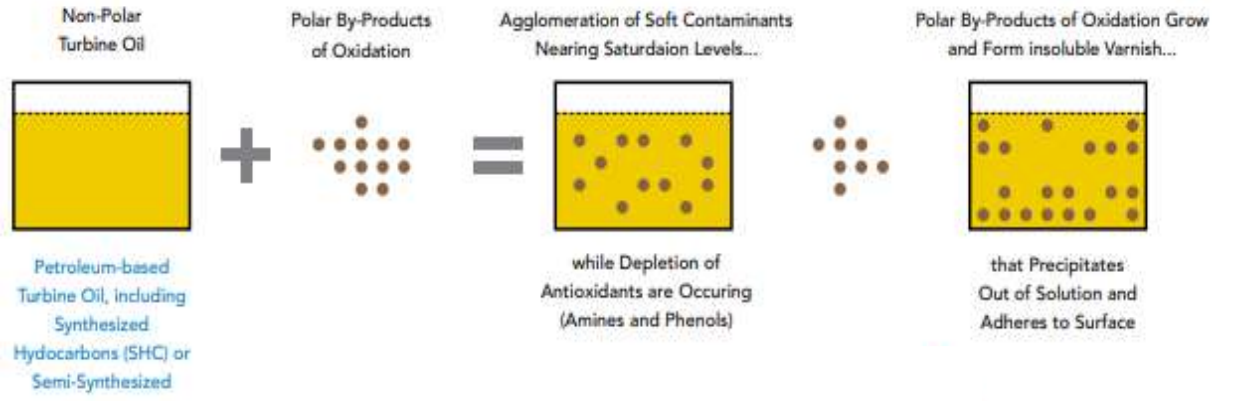
PTT T46,
Mobil DTE 846
PTT M46

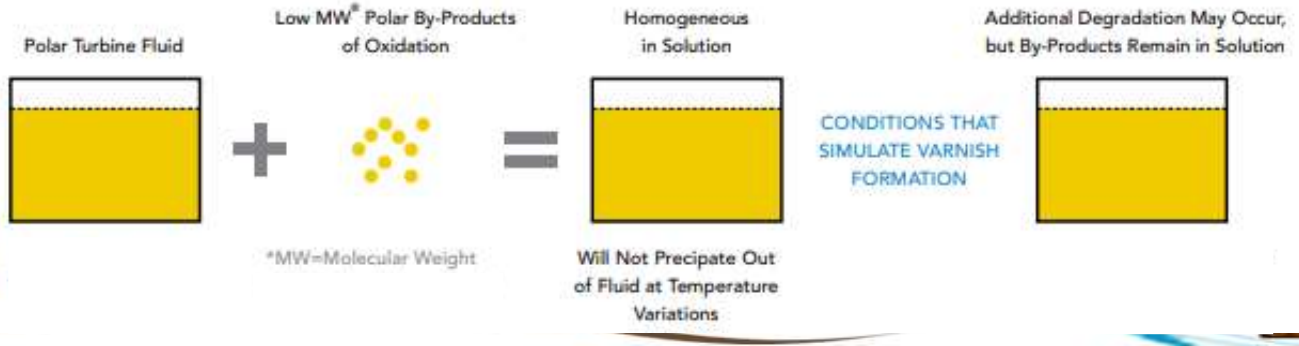
API BASE OIL CATEGORIES

	Base Oil Category	Sulfur (%)		Saturates (%)	Viscosity Index
Mineral	Group I (solvent refined)	>0.03	and/or	<90	80 to 120
Mineral	Group II (hydrotreated)	<0.03	and	>90	80 to 120
Mineral	Group III (hydrocracked)	<0.03	and	>90	>120
Synthetic	Group IV	PAO Synthetic Lubricants			
Synthetic	Group V	All other base oils not included in Groups I, II, III or IV			

Non-Polar Oil

PAG, Esters,
Napththenic,
Silicone,
Polyolester,
Biolubes etc.





New Improvement to Best Practice

Solve Varnish at Root Cause (RAI Strategy Consideration)

01

Design Integrity

New Machine ✗

Or

New Lube ✓

02

Technical Integrity

Lube Oil Analysis & Control ✓

03

Operation Integrity

IOW Alarm & Control ✓

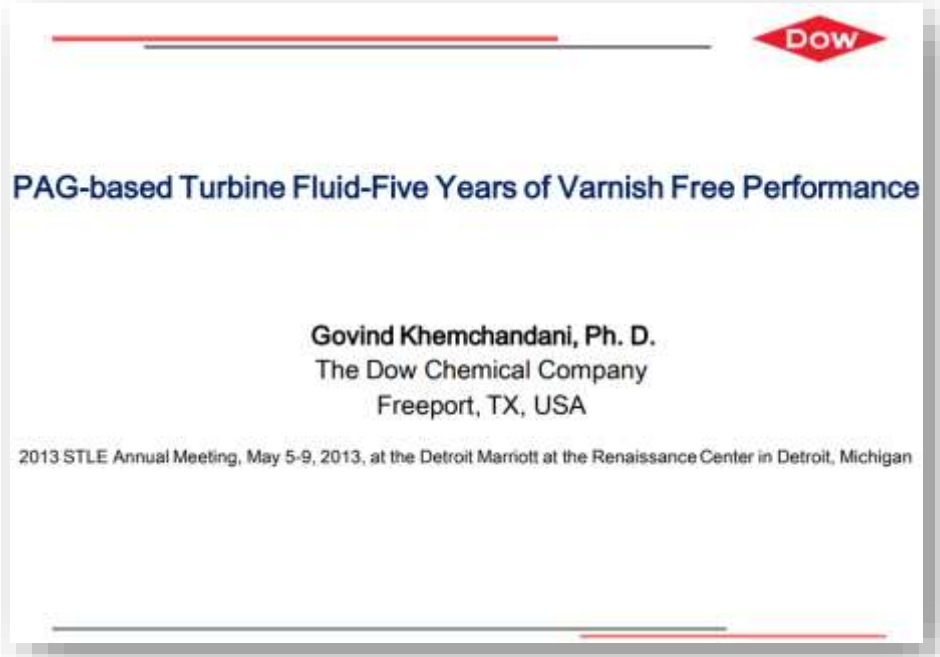
New Improvement to Best Practice

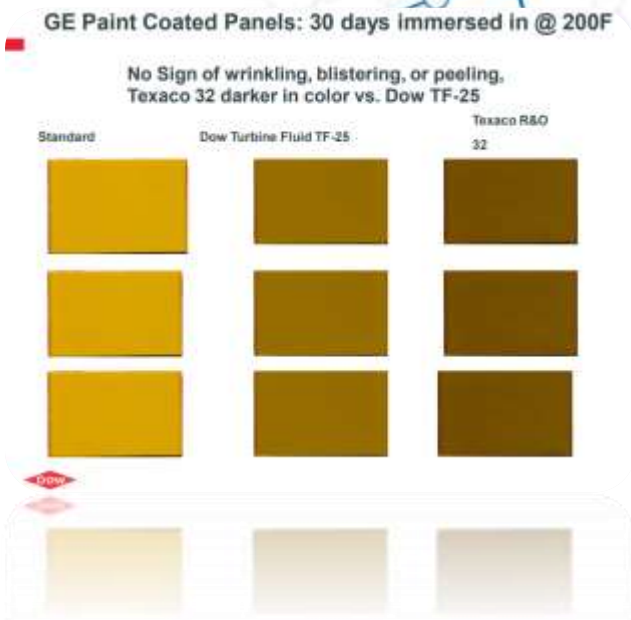
New PAG Oil Development [Best Practice Improvement Circle]

1. Study KM, New or History (GSP KM Portal)
2. Find Root Cause & Improvement (RCA, QC7 tools, etc.)
3. Evaluate Solution, New or History (RAGAGEP, ES, etc.)
4. Real Test Solution & Final Evaluate (RAGAGEP, ES, etc.)
5. KM Record & Announcement in GSP KM Portal
6. Review & Update KM (Depend on KM such as 3m, 6m, 1y etc.)

New Improvement to Best Practice

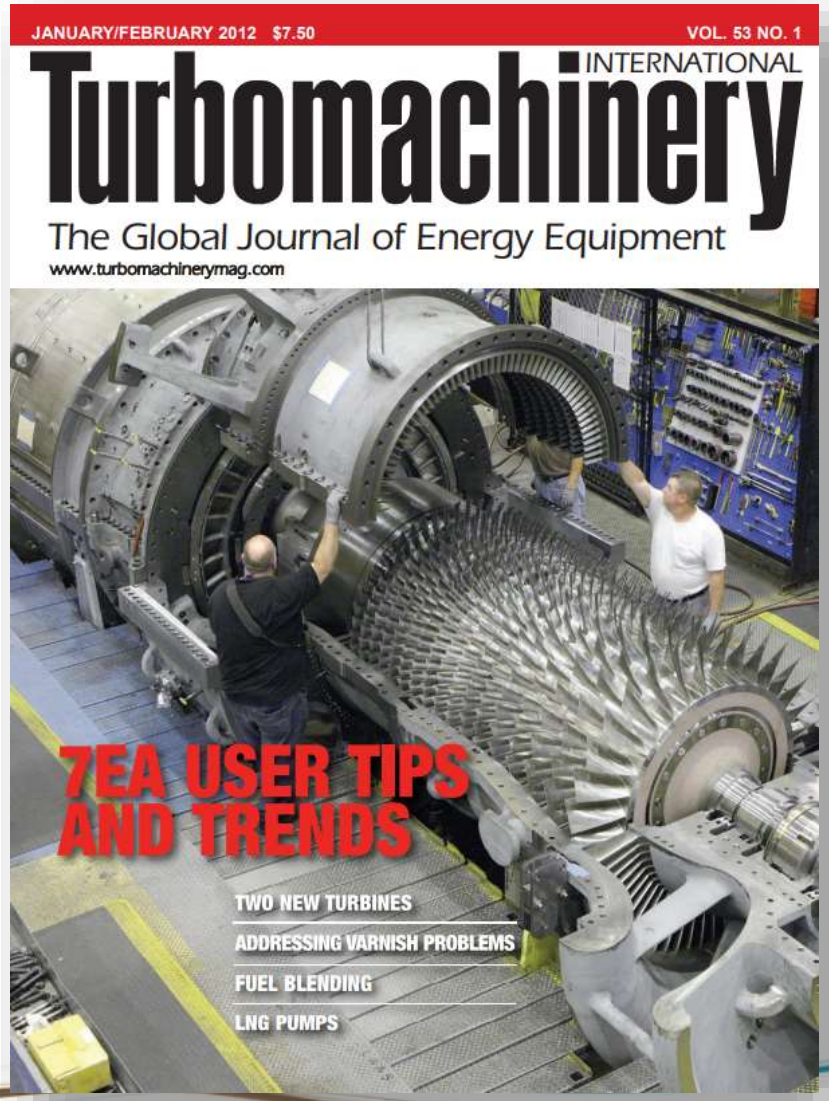
New PAG Oil Development





New Improvement to Best Practice

New PAG Oil Development



USER GROUP

GE 7EA USER GROUP ZEROED IN ON OIL ANALYSIS AND SELECTION

OTHER TOPICS INCLUDED GENERATOR RELIABILITY, BORESCOPES AND FILTRATION

DREW ROBB

The GE 7EA User Group met in early November in San Antonio, Texas. Some 100 users gathered to discuss all things related to the 85.1 MW MS7001EA turbine, which can accommodate a wide range of fuels, including natural gas, distillate oil, naphtha, crude oil and syngas. With more than 900 units in service, the 7E/EA fleet has accumulated over 20 million of hours of service.

Battery health and longevity, lube oil varnish, generator reliability, filter house best practices, Dry Low NOx (DLN) and combustor refurbishment were just a few of the topics under review. User discussion and questioning was encouraged by Pat Myers, plant manager at AEP's Ceredo Generating Station in Huntington, West Virginia, and a member of the 7EA User Group steering committee.

Eliminating varnish

The event kicked off with a day focused on reliability. Initial talks centered on a major turbomachinery issue — varnish.

David Kirkwood, Business Development Manager for Insight Services, spoke for much of the first morning on the importance of proper lubrication maintenance. He covered the basics of oil analysis testing and advanced fluid study beyond routine analysis, such as the analyses of varnish potential and filter debris.

Dow Chemical followed with a possible solution to varnish issues. Instead of using mineral oils or Polyalphaolefin (PAO) synthetic oils, which are both hydrocarbon-based, the company is promoting Polyalkylene Glycol (PAG) synthetic turbine fluids as a non-varnishing lubricant for gas and steam turbines. This approach has been used for years in metal-working fluids, fire resistant hydraulics, compressor and gear oils, and now catching the eyes of the turbomachinery sector, said Govind Khemchandani, Senior Technical Specialist at Dow.

High temperatures are believed to be one of the key factors leading to oxidation, said Khemchandani. Petroleum-based oils and synthetic hydrocarbons degrade at high temperatures due to oxidation, which creates decomposition byproducts of high molecular weight and the agglomeration of salt contaminants. This is what forms an insoluble varnish that adheres to surfaces. "Varnish leads to trips," he said. "Yet traditional tests are incapable of detecting the onset of varnish."

PAGs, on the other hand, are less likely to produce varnish. With PAGs, every third atom is oxygen, and this provides polarity that promotes their non-varnishing capability. With PAGs, degradation products may exist, but they do not agglomerate and remain in solution rather than being deposited on metal surfaces as a varnish. "PAGs also have a lower coefficient of friction than hydrocarbons," said Khemchandani.

He made the distinction between foaming of lube oil and aeration. The former is not an issue, he said, as the foam dissipates. Aeration, on the other hand, means that micro-bubbles remain trapped within the fluid and this heightens oxidation of the lube oil.

"PAG fluids can absorb water without degradation," he said. "Hydrocarbon lubes can't."

PAGs, it turns out, can absorb significantly more water, at least 7,500 ppm without issues compared to 500 ppm for conventional mineral oil-based turbine lubricants.


Figure 1: Rotor blade damage

Since 2007, Dow Chemical has converted eight gas turbines to the use of PAGs. All fluid monitoring conditions track well. The "last chance" filter showed no gelling, deposits or varnish after three years of continuous use in GE 7 FA gas turbines.

Khemchandani advised users to clear their systems before the switch, to minimize residual contaminants and pre-existing varnish. This approach has been applied by Dow to four sites using a variety of gas turbines. (See page 34 for more on varnish)

Some sessions dealt with rotor breakdown and reassembly during outages, while others delved into the intricacies of the 7EA exhaust system. W. Howard Moudy, Director of Service Management for National Electric Coil, however, concentrated upon generator reliability.

The primary factors affecting reliability, he said, include the unique design characteristics of each machine, its age and condition, history, operational and operator actions (cycling, loading, trips, restarts, synchronous condensing, motoring, and so on), as well as environment, external events and acts of God.

The smart approach is to formulate a maintenance plan and carry it out systematically. "A lot of people work out a fine maintenance plan and then file it away," said Moudy. "A great plan is worthless if you never execute it."

Generator concerns

He also said that generators have changed dramatically over the last 30 years. Generator insulation systems have shifted from asphalt to polymer systems, and coil geometry has evolved. The generators are being cycled more, and they are producing more power out of the same footprint. These changes have lead to increased incidences of some generator concerns such as partial discharge, spark erosion, and stator end winding vibration, looseness, and resonance issues.

Moudy expressed that some aspects of Reliability Centered Maintenance (RCM) are more applicable or valuable than others but certainly some aspects are well worth implementing. For instance, many users only consider one failure pattern — years of dependable service followed by the onset of deterioration and end of life.

RCM, on the other hand, describes six possible patterns of failure. Moudy found the Bell Pattern most illuminating because it better illustrates fleet data patterns with some early failures followed by a long period of reliability then late in the cycle, increasing failures.

He advised users not to get so wrapped up in methodology that they forget the basics: Starting with general characteristics (name plate) and the operational characteristics and idiosyncrasies of each generator. Make the best use of online monitoring tools for temperature, vibration, and other characteristics. A visual inspection by experienced personnel is in most cases the most cost effective tool. Findings should be documented in the outage report and any areas of concern investigated further.

The importance of keeping accurate and thorough records was pointed out

MAINTENANCE

ADDRESSING VARNISH PROBLEMS

BALANCED CHARGE AGGLOMERATION RESULTS IN 50,000 HOURS OF LUBE OIL OPERATION ON GE FRAME 7 TURBINES

RAY GOMES

Operators at a large South Eastern U.S. power utility with seven GE Frame 7 turbines began to notice varnish buildup in their tanks. They heard that other companies were experiencing significant varnish issues with the same turbines at 8,000 run hours. Before a serious varnish issue could arise, they decided to try a different approach to varnish control.

GE was aware of the varnish problems being caused by using group II lubricating oil and had offered advice in a Technical Information Letter to all GE turbine users. GE TIL 1528-3 described the issue and recommended that users add either an Electrostatic Precipitator (EP) or a Balanced Charge Agglomeration (BCA) system.

This utility decided to add nine BCA systems, seven on gas turbines and two on steam turbines. Oil analysis and operational results on these turbines have been closely tracked since January 2005.

Turbine	Varnish Potential	Gravimetric Patch mg/l	ISO Particle Count	RPVOT Minutes to 25%	RPVOT Remaining Life
New Oil	< 5	75	18/16/3*	1700	100%
Unit 1	13	4	14/12/10	1216	72%
Unit 2	9	30	13/12/9	1377	81%
Unit 3	3	3	19/17/14	1228	72%
Unit 4	3	16	17/14/10	1140	67%
Unit 5	5	4	14/12/10	1324	77%
Unit 6	5	16	14/12/9	1157	68%
Unit 7	3	18	15/13/10	1275	75%

Chart: Oil Analysis at 48,000 Hours vs. New Oil
** Conoco Phillips' Ultra Clean Turbine Oil ISO Particle Count*

Charged particles

BCA charges the particles in oil with a positive and negative high voltage in two separate flow paths. The charged particles are allowed to mix in a single flow path. Due to electrostatic attraction in the mixer the particles, some as small as .01 micron, stick together and agglomerate. The resulting large particles are then easily filtered out. The cyclical nature of the BCA-based cleanup is achieved by the purifier cleaning the oil of contaminants and varnish, followed by the oil cleaning the machine internals which saturates the oil with more contaminants, which are then cleaned.

In reality, it took several months to fully clean varnish-covered spool valves and tank walls. When these internal components were finally clean of all varnish, contamination levels fell dramatically (Chart).


Figure 1: Thrust Bearing at 7-Years of Operation


Figure 2: Turbine Journal Bearing at 50,000 Hours and No Varnish Buildup

In 2009, the thrust bearing on one unit was opened for inspection. The internal surfaces of the bearings, seals and thrust bearing components were all found to be free of varnish buildup (Figures 1 & 2). By comparison, a unit in another plant with no purification system was covered with a heavy orange varnish buildup after four years of operation.

The first three of the turbines are at 50,000 run hours and approaching their tenth year in operation. They have never had an oil related shutdown or a servo valve failure due to varnish. Some experts claim varnish can only be removed at oil temperatures under 40°C with electrostatic-based purification systems. Although located in a semi-tropical location, the oil in these GE 7FA turbines rarely goes below 40°C yet all varnish has been removed.

These turbines recently completed their first tear down. The journal bearings showed no wear and no varnish buildup. The tanks, however, did have a small patch of varnish on one pipe. It was later determined that the high voltage power supply had failed in this purifier.

Improved lube oils

Lubricating oil manufacturers have developed new additives that can hold varnish in suspension longer, so that it is less likely to buildup. They guarantee the oil for 15 to 20 thousand run hours. These plants have already achieved 50,000 run hours on the original oil. The oil's remaining useful life determined by Rotating Pressure Vessel Oxidation, ASTM D2272 (RPVOT), a test for remaining antioxidants, is around 70% in all seven turbines.

As a result, this plant has avoided two or three oil changes. This adds up to savings of 2.5 to 4 million dollars across the plant in oil change costs for a relatively small initial investment. And, since the remaining life of the oil is still around 70% it will last many more years.

Author
Ray Gomes, CEO of ISOPur Fluid Technologies, has an EE Degree from the University of Rhode Island where he worked in Ocean Engineering and Ship Analytics in charge of hardware design for simulation systems. Prior to ISOPur, he was VP Technology at Hi-Tech Extrusion.

New Improvement to Best Practice

New PAG Oil Development

GEK32568h
Revised April 2013

GE Power & Water

GEK32568h
Revised April 2013

Lubricating Oil Recommendations for Gas Turbines
With Bearing Ambients above 500°F (260°C)

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to General Electric Company. These instructions contain proprietary information of General Electric Company, and are furnished to its customer solely to assist that customer in the installation, testing, operation, and/or maintenance of the equipment described. This document shall not be reproduced in whole or in part nor shall its contents be disclosed to any third party without the written approval of General Electric Company.

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

EcoSafe® TF-32

Super Premium Turbine Oils

DESCRIPTION:

EcoSafe® TF-32 is a synergistic blend of polyalpha olefin (PAO) with polyol ester (POE) long life synthetic lubricants. It is designed exclusively for applications where fluid is exposed to elevated temperatures for extended periods of time. These fluids have been specifically formulated to provide superior oxidation and thermal stability relative to mineral-based turbine oils. It is especially advantageous in high temperature applications and does not leave varnish or sludge as polyalphaolefin (PAO) or mineral oil based products often do.

BENEFITS:

EcoSafe® TF-32 is blended from premium quality base stocks, coupled with state of the art additive technology. The result is performance improvements beyond other turbine fluids.

- Extremely low volatility (carry over)
- Outstanding low and high temperature properties
- Excellent corrosion protection
- Excellent oxidative stability
- Excellent thermal stability
- Good natural lubricity

DISPOSABILITY:

EcoSafe® TF-32 is blended from readily biodegradable basestocks. Disposal of these fluids should be done in accordance with Local, State and Federal regulations.

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

EcoSafe® TF-25

Premium Non-Varnishing Lubricant for Heavy-Duty Gas Turbines

DESCRIPTION:

EcoSafe® TF-25 is a fully-synthetic turbine fluid designed for high-output gas and steam turbines. This fluid has been specifically formulated to provide superior oxidation and thermal stability relative to mineral-based turbine oils. EcoSafe® TF-25 meets all of the requirements of the GEK32568.

PROPERTIES:

	Test Method	ESTF25
ISO Viscosity Grade	ISO 3448	25
Viscosity @ 40°C	ASTM D445	25.12cSt 27.94 cSt
Viscosity @ 100°C	ASTM D445	5.19 cSt 5.11 cSt
Viscosity Index	ASTM D2270	152
Pour Point	ASTM D97	-48°C (-55°F)
Air release @ 50°C	ASTM D3427	0.0 minutes
Specific Gravity @ 25°C	ASTM D1298	0.985 g/cm3
API Gravity	ASTM D287	11.2
Specific Heat @ 40°C	ASTM D1269	2.067 J/g/K
Thermal Conductivity @ 40°C	FLTL-71	0.145 W/m/K
Flash Point	ASTM D92	265°C (509°F)
Total Acid Number	ASTM D664	0.25 mg KOH/g
Foot Prevention (24h)	ASTM D665A,B	Pass
Copper Strip Corrosion	ASTM D130	1b
Oxidation Stability by OPV	ASTM D2272	395 minutes
Oxidation Stability by OPV modified (% of initial fluid)	ASTM D2272 modified	94.3%
Oxidized Characteristics for EP	ASTM D189/D08	12.80%
Precipitation Number		0.66
Hydrolytic Stability	ASTM D2619	
Weight Change of Copper Panel		-0.842 mg
Appearance of Copper Panel		Heavy 1B
% Change in Viscosity		0.56%
Change in Total Acid Number		+0.61 mgKOH/g
Total Acidity of Water Layer		3.56 mgKOH/l
% Insolubles		0.007%
Thermal Stability	ASTM D6378	
Rod Weight Change		Copper +0.1 mg, Steel -1.9 mg
Rod Visuals		Copper Heavy, #2, Rust Heavy #2
Total Sludge		7.3 mg/100ml
Kinematic Viscosity Change		+2.00%
Neutralization Number Change		0.07%
Foam Tendency/ Stability (I, II, III)	ASTM D892	10/0, 0/0, 0/0

	Test Method	ESTF25
Four-Ball Wear	ASTM D2266	0.63 mm
FZG Scuffing	ASTM D5182	5+

The information contained herein is correct to the best of our knowledge. The recommendations or suggestions contained in this bulletin are made without guarantee or representation as to results. We suggest that you evaluate these recommendations and suggestions in your own laboratory prior to use. Our responsibility for claims arising from breach of warranty, negligence, or otherwise is limited to the purchase price of the material. Freedom to use any patent owned by American Chemical Technologies' or others is not to be inferred from any statement contained herein.

EcoSafe® TF-32

PROPERTIES:

	Test Method	TF-32
ISO Viscosity Grade	ISO 3448	32
Viscosity @ -17 °C	ASTM D445	790 cSt
Viscosity @ 0 °C	ASTM D445	226 cSt
Viscosity @ 40 °C	ASTM D445	32 cSt
Viscosity @ 100 °C	ASTM D445	6.55 cSt
Viscosity Index	ASTM D2270	165
Pour Point	ASTM D97	-48°C (-55°F)
Density @ 15 °C	ASTM D4052	0.985 g/cm3
Flash Point	ASTM D92	>260°C (>500°F)
Typical particle count	ISO 4406:1999	20/19/16
Total Acid Number of new fluid	ASTM D664	0.3 mgKOH/g
FZG	ASTM D5182	7+
Weight loss		333.3 mg

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EcoSafe® TF-25

	Test Method	ESTF25
Four-Ball Wear	ASTM D2266	0.63 mm
FZG Scuffing	ASTM D5182	5+

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New Improvement to Best Practice

New PAG Oil Development

WHITEPAPER

VARNISH FORMATION IN GAS TURBINES FROM MINERAL-BASED AND PAG-BASED LUBRICANTS

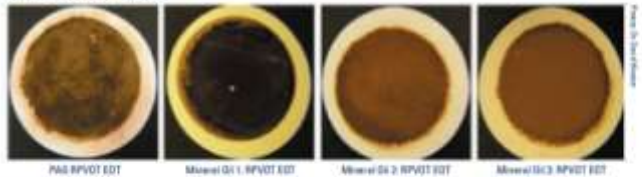
Varnish created by lubricant oxidation in gas turbines is a major concern for power generation companies. Varnish can cause gas regulation valves to stick and impair oil cooler performance, resulting in serious operational issues or, in the worst case, an automatic shutdown or failure to start. Lubricant producers are responding to the demand to deliver products that mitigate varnish problems before they occur.

The industry has recently seen the introduction of polyalkylene glycol or PAG-based turbine oils. Some of these are purported to be "varnish free." However, testing by Dr. David Wooton, an independent lubrication and technical consultant, calls these claims into question.

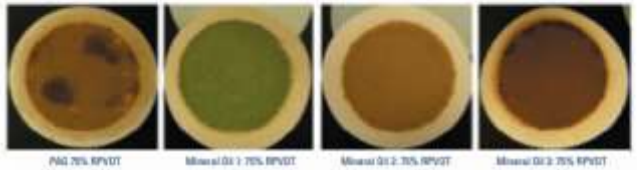
Dr. Wooton conducted a series of 10 industry-standard ASTM tests comparing PAG-based and mineral-based turbine oils. The fluids studied included a PAG formulation and three different mineral oils representing older, newer, and premium formulations. Testing included both off-the-shelf and in-service fluid samples.

Though the tests analyzed many performance factors, they did shed some light on the issue of varnish formation from mineral-based

MPC Patch Test Results



MPC Patch Test Results with 25% of the RPVOT Time Remaining



Wooton, David, "How to Evaluate a New Lubricant, Machinery Lubrication, October 2017
https://www.machinerylubrication.com/Read/30938/evaluate-new-lubricant

STLE 2018
Turbine Oil Developments

Paul Sly
Chevron Lubrication Technical Advisor
BSME, CLS, OMA 1

High varnish solvency – PAG lubricant

- Keeps degradation byproducts dissolved well
- Mineral oil compatibility test – surprisingly good
- Low RPVOT oxidation life test
- Poor paint compatibility
- No water separability 2000 – 7000 ppm "normal"
- Poor hydrolytic stability
- Mid use varnish potential good
- End of life varnish similar to mineral oil

Varnish Mitigation: Relative Effectiveness of Non-Deposit-Forming Next Generation Lubricants vs. the Use of Varnish-Removal Filters with their Conventional Counterparts

Matthew G. Hobbs, Peter Dufresne Jr.[1]
[1]EPT, 4772 50th Avenue S.E. Calgary, AB, Canada

Abstract
Turbine lubricants employ a variety of base fluids. Mineral oil-derived base stocks remain the most prevalent, however, synthetics are becoming increasingly common. These fluids are exposed to severe oxidative stress during service, leading to breakdown and varnishing (the primary cause of downtime in gas turbine applications). Recently, PAGs have been positioned as varnish-free alternatives to more conventional mineral turbine oils. Our findings suggest that this claim is overstated. PAGs possess several advantages relative to conventional oils, however, well-formulated mineral oils proved almost as resistant to varnishing. Moreover, the risks associated with mineral oil varnishing can be effectively mitigated using established varnish-removal technologies.

Keywords:
Gas Turbine Oil; Polyalkylene Glycol; Soluble Varnish Removal.

1 INTRODUCTION

Modern lubricants are formulated using a variety of base fluids and additives [1]. Many different base stocks are available. Those derived from crude oil (Groups I, II and III) are the most common as a result of their favorable lubrication properties and relatively low cost. Group IV and V fluids are made up of synthetic hydrocarbons and non-hydrocarbon synthetics, respectively. These synthetics generally feature improved performance and resistance to breakdown relative to their naturally-derived Group I – III analogs. These improved characteristics, however, typically come at a higher cost.

In gas turbine applications, the trend towards smaller, more powerful units and peaking in place of base load service has resulted in increased lubricant stress. Indeed, modern gas turbine peak temperatures may reach 150 - 280°C [2]. During service, thermo-oxidative lubricant breakdown yields polar degradation products (acids and other varnish precursors) from non-polar base fluid hydrocarbons. With regards to polarity, "like dissolves like", therefore, polar degradation products often precipitate from non-polar hydrocarbon oils. As these breakdown products fall out of solution, organic varnish deposits form, leading to numerous problems including: filter plugging, restricted oil flow, poor heat transfer, valve sticking, fail-to-start conditions and costly unit trips [3]. Varnish is now the leading cause of unplanned downtime in the power generation industry.

Polyalkylene glycols (PAGs) are specialized Group V synthetics that have been positioned as more oxidatively stable, non-varnishing substitutes to conventional turbine lubricants [4]. PAGs are polyethers which feature oxygen amongst the carbon and hydrogen in their base oil molecular structure (Figure 1). As a result, they are more polar than hydrocarbon mineral oils. Like mineral oils, thermo-oxidative PAG stress yields polar breakdown products. PAG lubricants are, however, better able to dissolve these polar varnish precursors as a consequence of their own polarity. As a result, PAGs are often referred to as "non-varnishing" lubricants. While PAGs may indeed offer technical advantages over conventional turbine lubricants (lower coefficient of friction, greater viscosity index, faster air release), relatively inexpensive varnish removal technologies have been shown to effectively mitigate the risks associated with varnishing [5].

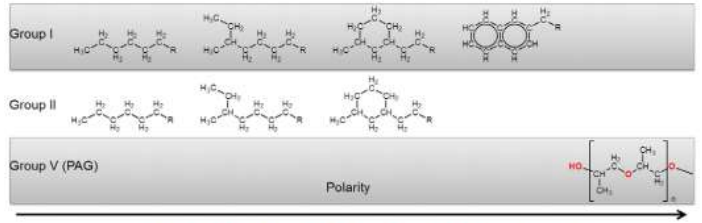


Figure 1 : Molecular Structure of Mineral Oils *vs.* PAGs (Where R is an Arbitrary Organic Fragment).

New Improvement to Best Practice

New PAG Oil Development

From: SUTEE AMORNKUNPHITTAYA
Date: 2019-09-15 14:31
To: xutikang@actlube.com
CC: kkovanda; michael; xyc; SUKSAN PINTONG; CHANINT SRIKANKEAW; SUPARP SRIYANT; CHA
Subject: RE: RE: Interesting the polyalkylene glycol (PAG)-based turbine fluids

Dear Xu,

We need the sample oil by below;

TF-25 : 18 Liters

TF-32 : 18 Liters

And please send to Mr. Pongpol Thaveema, Researcher, Petroleum Product and A

Address : PTT Research and Technology Institute, PTT Public Company Limited, 7

Best Regards,

MR. SUTEE AMORNKUNPHITTAYA
Engineer
Plant Inspection Division
E-mail sutee.a@pttplc.com
T. 038676429 / 0945459635

From: Volz , Jeff (EthosEnergy) [mailto:Jeff.Volz@ethosenergygroup.com]
Sent: Tuesday, September 17, 2019 10:06 PM
To: SUTEE AMORNKUNPHITTAYA <sutee.a@pttplc.com>
Cc: xutikang@actlube.com
Subject: RE: Request for support for the Ecosafe TF-25 oil

Dear Mr. Sutee Amornkunphittaya,

We have had very good luck with TF-25 in our 7FA application. No oil related issues since installing the product. I will give you our time line. If you have more questions please let me know.

2002 GT commission with Mobil 832
2004 First varnish related trip
2005 Varnish noted in seal area during inspection
2007 Installed TF 25
2009 Inspected bearings and seals no sign of varnish
2015 Inspected bearings and seals no sign of varnish
2018 Inspected bearing, seals and tank with no signs of varnish

Best Regards,

Jeff Volz
Operations Manager
Oneta Power
Office: 918-486-1840
Cell: 918-645-8401
Jeff.volz@ethosenergygroup.com

EthosEnergy

From: Don Roberts [mailto:drroberts@aep.com]
Sent: Wednesday, September 11, 2019 12:12 AM
To: SUTEE AMORNKUNPHITTAYA <sutee.a@pttplc.com>
Subject: RE: Request for support for the Ecosafe TF-25 oil

Sure, we had a lot of varnish issues with our control oil solenoids. This was causing reliability issues with our combustion turbines. (we were using conventional mineral oil).

I don't recall the year we switched to the tf-25 but I can vouch for the fact it has all but eliminated the varnish problems. It has been a success story for our facility.

ACT can give you the specifics but even after all the years of service our tests come back indicating many more years of useful life left.

PUBLIC SERVICE COMPANY OF OKLAHOMA
An AEP Company

DON ROBERTS | MAINTENANCE SUPV SR
DRROBERTS@AEP.COM | A:8.719.0084 | C:918.729.9398
7300 E HWY 88, OOLOGAH, OK 74053-0399

New Improvement to Best Practice

New PAG Oil Development

Eliminate Varnish LO Problem

Objective

Strategic Objective :

I6) Product Innovation

L2) Innovation & Innovation Culture

Lagging KPI & Target :

- Completed in Aug 2021

Expected Result & Target (Short & Long Term)

- New PTT Lubrication Product & S-Curve

Budgetary:

- 0 MTHB

Responsibility:

- Sutee

Initiative Detail

Initiative Idea, Problem or Background

โรงแยกก๊าซฯ ระยอง พบปัญหา Varnish ใน Turbine LO มาอย่างยาวนาน แต่ก็ไม่สามารถแก้ไขปัญหาได้อย่างถาวร จึงมีแนวคิดในการศึกษาและหาวิธีการแก้ไขดังกล่าว

Shor-Term and Long-Term Plan :

1. ร่วมพัฒนาสูตรน้ำมันชนิดใหม่ (PAG) ร่วมกับทาง วผว. ซึ่งไม่เคยมีการผลิตใน PTT มาก่อน
2. ทำการทดสอบกับ Unit จริงที่ GSP เพื่อทดสอบประสิทธิภาพ
3. ขยายผลไปยัง Unit อื่นๆ และผลิตเป็น Product เพื่อขายภายนอก GSP ซึ่งน้ำมันชนิดนี้ยังไม่มีคู่แข่งในประเทศไทย และเป็นที่ต้องการของตลาด

Action Plan 2020/2021	2020									2021									
	Q2			Q3			Q4			Q1			Q2			Q3			
	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	
1. Develop New LO Formula																			
2. Get Approval & Sign MOU																			
3. Production 1st Batch																			
4. Test in GTG-9																			
5. Evaluate Result																			

New Improvement to Best Practice

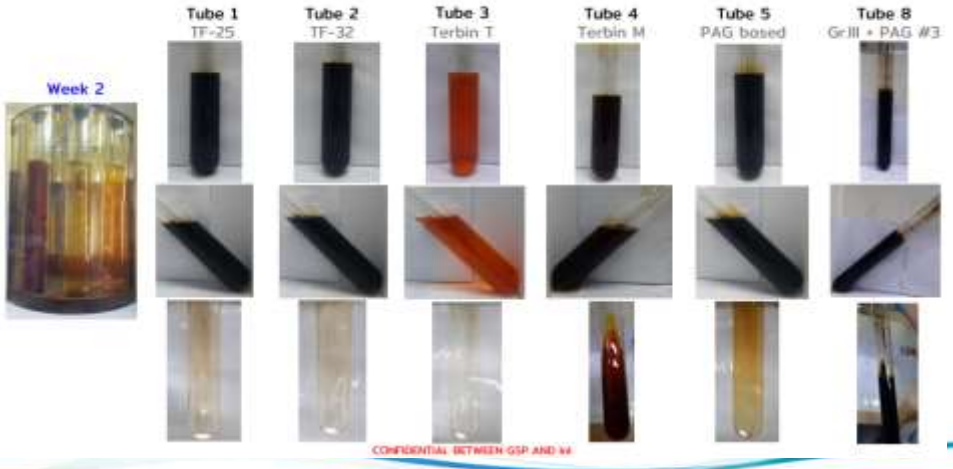
New PAG Oil Development

TOST aging

Test	Sample vol. (ml)	Temp (°C)	Gas flow (L/hr)	Water	Catalyst	Duration (hrs)	Sludge filter (micron)	Test after aging	Remark
ASTM D943 TOST Life	300 ml	95±0.2	Oxygen 3±0.1 L/hr	60 ml	Cu + Fe	• after 500 hrs and every 168 hrs • after 3000 hrs and every 500 hrs	-	TAN	Need shield to eliminate bright light TAN still < 2.0 can continue test
ASTM D4310-10(re15) TOST for Sludge and Corrosion	300 ml	95±0.2	Oxygen 3±0.1 L/hr	60 ml	Cu + Fe	1000 hrs (and 1000 hr interval)	5 micron	• Cu by ICP (Procedure A only) • Water content (Procedure A only) • Catalyst rating (Procedure A only) • Sludge wt. • TAN	Procedure A = Cu, Water, Sludge Procedure B = Sludge
ASTM D2893 TOST Oxidation of EP Lube	300 ml	95±0.2 or 121±1.05	Air 10±0.1 L/hr	-	-	312±1 hrs	-	• KV100 • %KV change after 312 hrs • Hexane precipitation no.	~~Test method A : temp 95±0.2~~ Test method B : temp 121±1.05
ASTM D7873 Dry-TOST	min. 360 ml	120±0.5	Oxygen 3±0.1 L/hr	-	Cu + Fe	User specified	1 micron	• RPVOT • Sludge	Criteria = 100 mg sludge + 25%RPVOT

- คัดเลือก TOST aging method คือ ASTM D2893 ที่ 121 องศา (ตามข้อมูล TF25 ของ Dow chemical)
- ทดสอบ KV40, TAN, Ruler, RPVOT, MPC สำหรับ new oil และ end point
- Monitor ด้วย TAN และ Ruler ทุกสัปดาห์

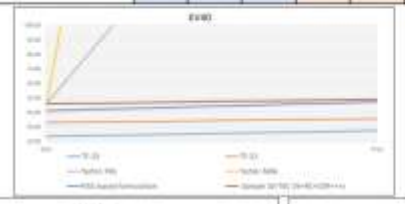
Test Results (Week 20) Week 18-20

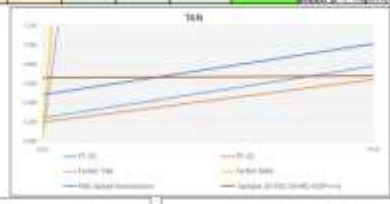


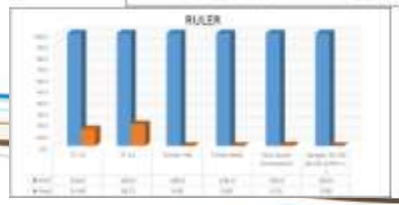
TOST aging

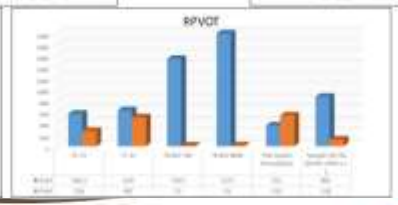
Note : Terbin M46 ใหม่มีค่า RPVOT เริ่มต้น 2127 minutes

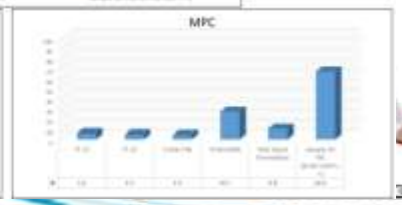
TOST Tube	Sample	KV40 Start	KV40 Final	KV40 %Increase	TAN Start	TAN Final	TAN %Increase	Ruler Start	Ruler Final	RPVOT (min) Start	RPVOT (min) Final	RPVOT (min) %Decrease	MPC (ΔE)	Remark
1	TF-25	23.40	27.35	17	0.244	0.78	220	100.0	14.40	560.5	256	54.3	5.6	
2	TF-32	32.93	35.55	8	0.199	0.64	222	100.0	18.75	624	497	20.4	4.5	
3	Terbin T46	45.91	31.47	-585	0.054	24.43	45141	100.0	0.00	1543	13	99.2	3.9	
4	Terbin M46	44.81	1278	2751	0.066	40.5	61435	100.0	0.00	1306	15	98.9	20.7	หยุดทดสอบที่ week 18
5	PAG based formulation	41.26	47.20	14	0.483	1.81	100	100.0	0.55	352	330	-6.1	9.8	
8	Gr.III + PAG formulation 3	45.94	49.07	7	0.656	0.68	4	100.0	0.00	865	120	86.1	86.8	ค่าน Varnish ต้องเปลี่ยนถ้วย ต้องเริ่ม week 6 + หยุดทดสอบที่ week 18











New Improvement to Best Practice

New PAG Oil Development (Lab Benchmarking)

OEMs for GTG9 Unit

No.	Equipement	Position	Brand	Original Lube Oil
1	Gas Turbine	Driver	Siemens RB211-24GT DLE	Mobil Jet Oil II
2	Power Turbine	Driver	Siemens RT61	Mobil DTE 832
3	Gearbox	Driven	Flender	Mobil DTE 832
4	Generator	Driven	ABB	Mobil DTE 832

OEMs Specification for Lubricants

Test items	Unit	Power turbine & Compressor (Rolls-Royce)		Gear box (Flender)		Generator (ABB)		
ISO VG		32	46	32	46	32	46	68
Kinematic Viscosity @40	cSt	28.8-35.2	41.4-50.6					
Kinematic Viscosity @100	cSt			5.1 min	6.5 min			
Viscosity Index				100 min		90 min		
Flash point COC	℃	232 min		210 min	220 min			
Pour point	℃			-10 max		-30 max	-30 max	-27 max
Air release @50	minute			max 3	max 4			
Demulsibility @54 (to 40/40/0)	ml			max 5	max 10			
Foaming : seq I	ml			10/0				
seq II	ml			20/0				
seq III	ml			10/0				
FZG (Damage load state)	state			7 min				
RPVOT	minute			450 min				
TOST (time to TAN 2.0)	hours			4000 min				
TAN	mgKOH/g	0.1 max		0.2 max				
Auto Ignition Temperature	℃	538 min						
Water content	ppm	500 max		100 max				
Filtration (similar to filterability index)				150 min				
Note for used oil :		ต่อน้ำมันหล่อลื่นชนิด Synthetic oil ทราย TAN สูงกว่าเกณฑ์ ให้ผ่านด้วย Active-media filtration				ถ้าค่า Oil หล่อลื่นจากใช้งาน Generator 1-3 วัน · Clear or negligibly turbid · No acid or burnt smell · Viscosity ± 10-15% · metal impurity ≤ 0.05%wt · TAN ≤ 1.0 mgKOH/g · Foam and etc. · ลากเปลี่ยนถ่าย 3-6 ชั่วโมงต่อไป		

Test items	Combined OEM Spec for Lube oil
ISO VG	32
Kinematic Viscosity @40	28.8-35.2
Kinematic Viscosity @100	5.1 min
Viscosity Index	100 min
Flash point COC	232 min
Pour point	-30 max
Air release @50	max 3
Demulsibility @54 (to 40/40/0)	max 5
Foaming : seq I	10/0
seq II	20/0
seq III	10/0
FZG (Damage load state)	7 min
RPVOT	450 min
TOST (time to TAN 2.0)	4000 min
TAN	0.1
Auto Ignition Temperature	538 min
Water content	100 max
Filtration (similar to filterability index)	150 min

Specification for Lubricants

Test items	Unit	Combined OEM Spec for Lube oil	GEK32568H (PAG based) for new oil	TF25 (Dow)	TF32 (ACT)	PTT PAG Turbine
ISO VG		32		25	32	32
Kinematic Viscosity @40	cSt	28.8-35.2	23-26	26.23	32	
Kinematic Viscosity @100	cSt	5.1 min		5.19	6.55	
Viscosity Index		100 min	125 min	132	165	160
Flash point COC	℃	232 min	230 min	242		
Pour point	℃	-30 max	-40 max	-48	-48	
Air release @50	minute	3 max	1 max	0.4		
Demulsibility @54 (to 40/40/0)	ml	5 max				
Foaming : seq I	ml	10/0	25/0	10/0		
seq II	ml	20/0	0/0	0/0		
seq III	ml	10/0	0/0	0/0		
FZG (Damage load state)	state	7 min		5+	7+	
TOST (time to TAN 2.0)	hours	4000 min				
TAN	mgKOH/g	0.1	0.2 max	0.25 (0.27)	0.30	
Auto Ignition Temperature	℃	538 min				
Water content	ppm	100 max				
Filtration (similar to filterability index)		150 min				
RPVOT	minute	450 min	500 min	597 (561)		>570
RPVOT modified	% of unmodified		85% min	98.30%		
Specific gravity			report	0.985 (@25°)	0.985 (@15°)	
Color			2.0 (max)			
Rust prevention (method A)			pass	pass (A, B)		pass (A)
Copper corrosion			1B max	1A		
%Viscosity change (Oxidation @121°C, 13 days)	%		3.0% max	+2.09%		+2.96%
Thermal conductivity @40	watts/m°K		0.1 min	0.145		
Four-Ball Wear	mm.			0.63		

New Improvement to Best Practice

New PAG Oil Development (Lab Benchmarking)

ptt Lubricants

TERBIN SYNTHETIC

ISO VG 32

Typical Characteristics

Tests	Methods	Units	Results ISO VG 32
Specific gravity at 15.6°C	ASTM D4052		0.9779
Kinematic Viscosity at 40°C	ASTM D 445	mm^2/s	32.39
Kinematic Viscosity at 100°C	ASTM D 445	mm^2/s	6.475
Viscosity Index	ASTM D 2270		158
Flash Point (COC)	ASTM D 92	°C	251
Pour Point	ASTM D 97	°C	-51
Total Acid Number	ASTM D 664	mgKOH/g	0.33
Foaming Characteristic	ASTM D 892		
Sequence I		ml/ml	10/0
Sequence II		ml/ml	nil/0
Sequence III		ml/ml	10/0
Copper strip corrosion, 3hr at 100°C	ASTM D 130	rating	1A
FZG Test (Failure Stage)	ASTM D5182		11
RPVOT at 150 °C	ASTM D2272	min	588

Following OEM Standard or Better ✓

Same to ACT Specification or Better ✓

The Best FZG Value ✓

	OEM Require	PTT	ACT
FZG	7	11	7

New Improvement to Best Practice

New PAG Oil Development (KM Sharing Internal/External & Digitalize)

GSP KM

ptt
บริษัท ปตท. จำกัด (มหาชน)
โรงแยกก๊าซธรรมชาติระยอง

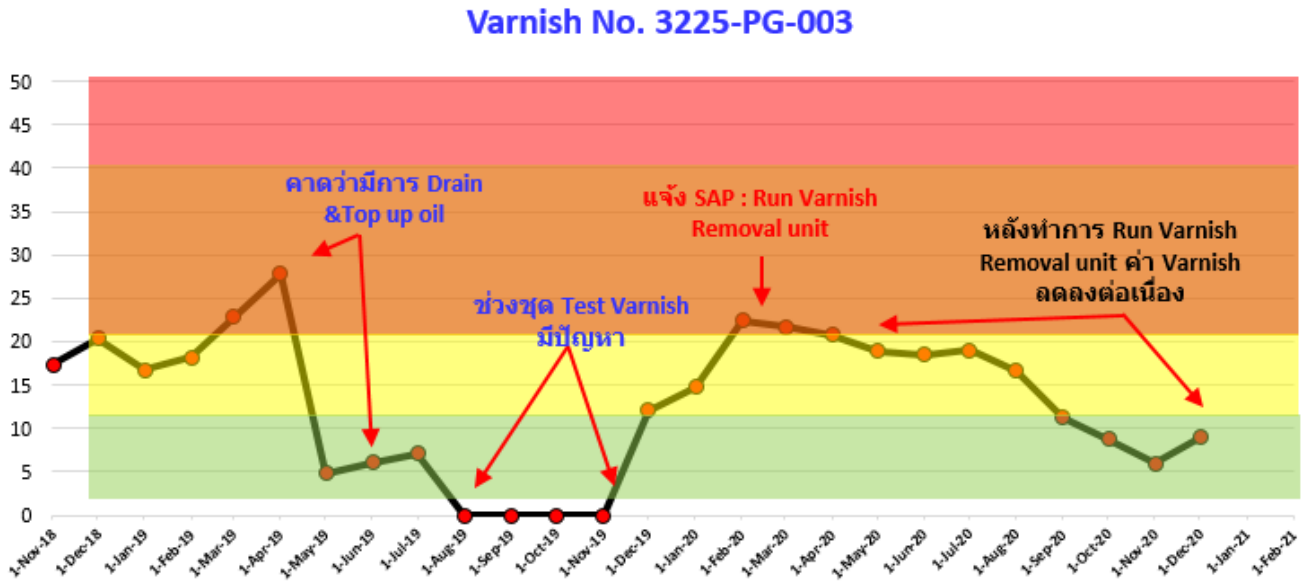
ตร.วนก.

นง.วนก.

ptt

New Improvement to Best Practice

New PAG Oil Implement



PTT Lube Oil Monitoring Criteria for Main L/O (Power Turbine, Generation, Compressor)

Sampling	VARNISH Value	Color code	Recommend Action
	< 10	Good	Monitor ทุก 3 เดือน
	10 - 20	Monitor	Monitor ทุก 1 เดือน
	21 - 40	Abnormal	Run Varnish Removal Unit / ส่ง Test ค่า RPVOT ทุก 6 เดือน
	> 40	Critical	Drain & Top up Lube Oil

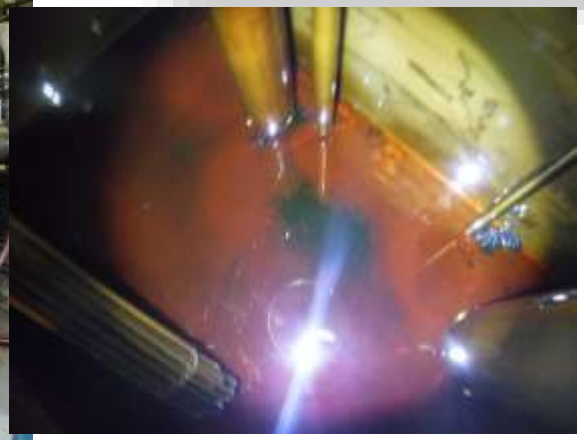
No.	Equipement	Position	Brand	Original Lube Oil	Life Time
1	Gas Turbine	Driver	Siemens RB211-24GT DLE	Mobil Jet Oil II	-
2	Power Turbine	Driver	Siemens RT61	Mobil DTE 832	7 Y
3	Gearbox	Driven	Flender	Mobil DTE 832	7 Y
4	Generator	Driven	ABB	Mobil DTE 832	7 Y

GTG 9	RB211 24GT	Siemens			
	3208-F-03				
	Air Inlet Filter	Viledon			
	PT RT61	Siemens		1/3/2021-20/3/2021	
	Generator			1/3/2021-20/3/2021	PM Level 3
	Flender Gearbox	Flender		1/3/2021-20/3/2021	

New Improvement to Best Practice

New PAG Oil Implement (GSP KM Portal Reference)

M-0109-2021	เพิ่มจุดเก็บน้ำมันขาเข้า Main LO Filter GTG8	ESP	ตร วบก.	Maintenance change	Sign-off	สุธี อมรกุลพิทยา	-	สุธี อมรกุลพิทยา	26/04/2021	09/06/2021
M-0108-2021	เพิ่ม Tube & Valve ที่หน้า Flange จุดเก็บ Sampling LO เส้น เพื่อเพิ่ม ประสิทธิภาพในการทำงาน	ESP	ตร วบก.	Maintenance change	Sign-off	สุธี อมรกุลพิทยา	-	สุธี อมรกุลพิทยา	26/04/2021	09/06/2021



New Improvement to Best Practice

New PAG Oil Implement

สรุปปริมาณน้ำมัน

เตรียม

1. ใช้จริง 50 Drum
2. Flushing 2 ครั้ง 35 Drum
3. สำรอง Flushing 3 อีก 22 Drum

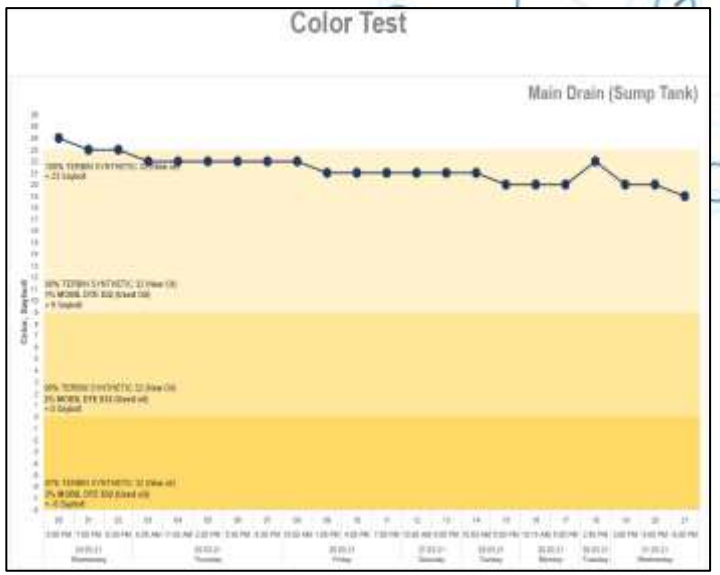
รวม 107 Drum

ใช้จริง

1. Flushing 1 ใช้ 50 Drum
2. ใช้จริง 57 Drum

รวม 107 Drum

Note : น้ำมันที่เหลือจาก Flush 1 ไว้เติมสำรอง
หรือ Flush Unit ใหม่ 35 Drum



Flushing Oil

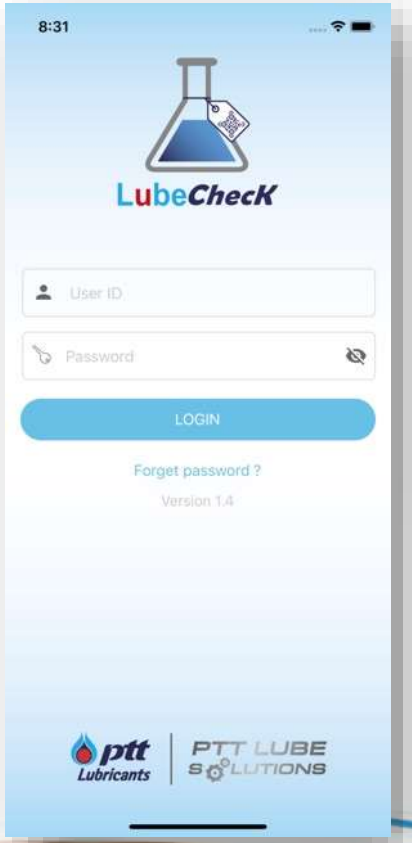
1. ค่าสี Saybolt ต้องไม่เกิน 2% เพื่อ Confirm การปนเปื้อนของน้ำมันเดิม
2. Monitor ค่า TAN
3. Monitor ค่าน้ำ
4. อื่นๆ

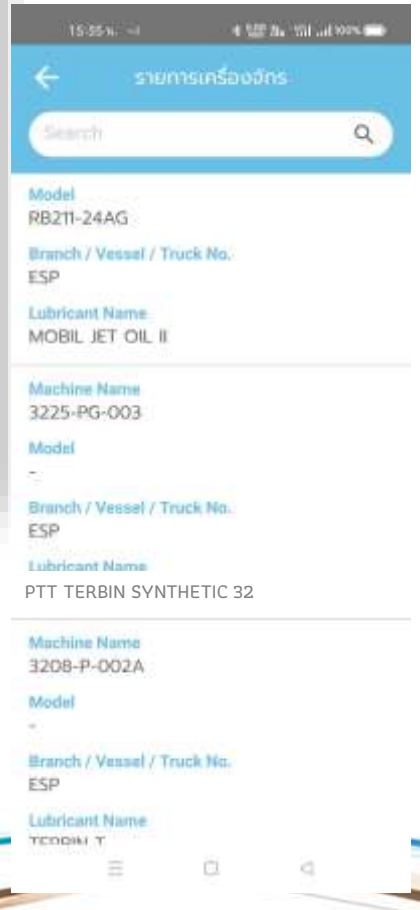
ตารางลงผลทดสอบ Flushing oil#1 (by INI Lab results)

	Date	Time	Sample Name	Color Saybolt (scale 30 to -16)	Color ASTM	KV40 (cSt)	TAN (mgKOH/g)	Water (ppm)	Cleanliness (ISO) คู่มือ ≥ 17/15/12	Cleanliness (NAS)	Density 15	P content	Foam seq I
1	Wed. 24 Mar	17:00	F1-00 (GTG9)	24	0.2	33.19	0.305	720	20/18/13	10	0.9755	122	25/nil
2		21:00	F1-02 (GTG9) day1	23	0.2	33.35	0.306	1350	19/17/12	9	0.9756	123	25/nil
3	Thu. 25 Mar	9:30	F1-03 (GTG9) day2	22	0.2	33.42	0.308	1425	19/17/13	9	0.9756	124	25/nil
4		14:30	F1-05 (GTG9) day2	22	0.2	33.4	0.317	2090	18/16/12	8	0.9758	120	30/nil
5		20:30	F1-07 (GTG9) day2	22	0.2	33.5	0.317	2380	18/15/11	7	0.9758	120	25/nil
6	Fri. 26 Mar	10:00	F1-08 (GTG9) day3	22	0.2	33.56	0.315	2390	18/16/11	8	0.9758	121	25/nil
7		16:00	F1-10 (GTG9) day3	21	0.2	33.44	0.323	2470	19/17/13	9	0.9758	120	25/nil
8	Sat 27 Mar	10:00	F1-12 (GTG9) day4	21	0.2	33.49	0.323	2620	19/17/12	9	0.976	122	25/nil
9		18:00	F1-13 (GTG9) day4	21	0.3	33.54	0.328	2575	19/17/12	9	0.9759	122	25/nil
10	Sun 28 Mar	10:00	F1-14 (GTG9) day5	21	0.3	33.52	0.324	2700	19/17/13	9	0.9759	124	25/nil
11		18:00	F1-15 (GTG9) day5	20	0.3	33.52	0.320	2685	19/17/13	9	0.9759	124	25/nil
12	Mon 29 Mar	10:00	F1-16 (GTG9) day6	20	0.3	33.57	0.321	2810	19/17/11	9	0.9759	124	25/nil
13		18:00	F1-17 (GTG9) day6	20	0.3	33.55	0.338	2565	18/16/12	9	0.9759	124	25/nil
14	Tue 30 Mar	15:00	F1-18 (GTG9) day7	22	0.2	33.46	0.318	2210	20/17/11	9	0.9758	123	25/nil
15	Wed 31 Mar	18:00	F1-20 (GTG9) day8	20	0.3	33.62	0.316	2340	20/17/12	9	0.9758	123	25/nil
16		21:00	F1-21 (GTG9) day8	19	0.3	33.66	0.318	2250	19/17/13	9	0.9758	124	25/nil
17	Thu 1 Apr	15:00	F1-22 (DTD9) day9	19	0.3	33.55	0.318	2085	19/17/13	9	0.9758	125	25/0

New Improvement to Best Practice

New PAG Oil Result (Digitalize)





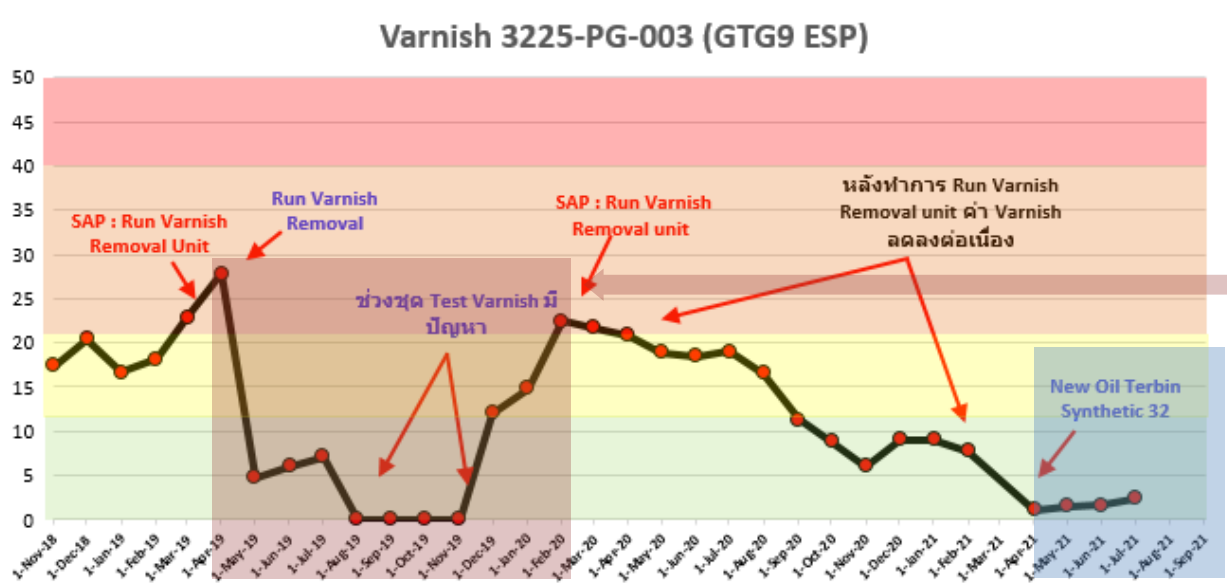
IMHMS Phase II

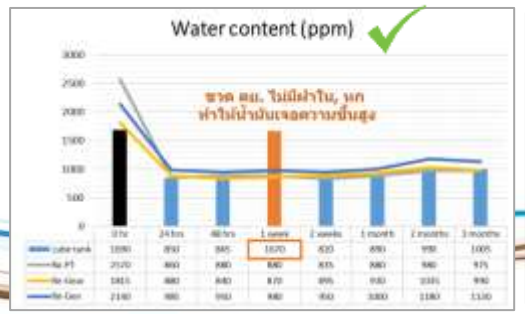
New Improvement to Best Practice

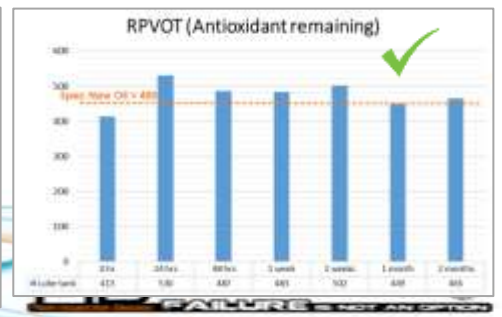
New PAG Oil Result (Real Used Benchmarking)

ค่า Varnish เริ่มต้นลดลง 400% เมื่อเทียบกับน้ำมันเดิม (5 VS 1)

PTT Lube Oil Monitoring Criteria for Main L/O (Power Turbine, Generation, Compressor)			
Sampling	VARNISH Value	Color code	Recommend Action
	< 10	Good	Monitor ทุก 3 เดือน
	10 -20	Monitor	Monitor ทุก 1 เดือน
	21 - 40	Abnormal	Run Varnish Removal Unit / ส่ง Test ค่า RPVOT ทุก 6 เดือน
	>40	Critical	Drain & Top up Lube Oil







New Improvement to Best Practice

New PAG Oil Result (Real Used Benchmarking)

New Improvement to Best Practice

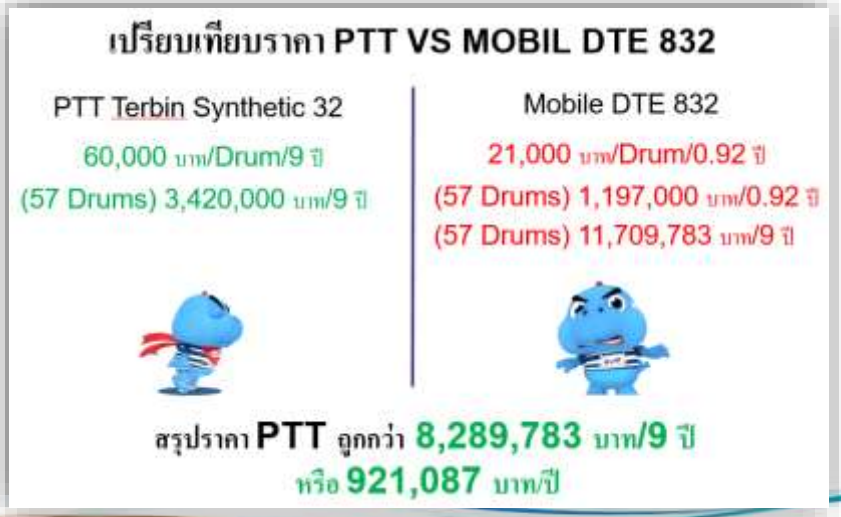
Investment (R&D)

ptt InI INNOVATION INSTITUTE

6,000,000 บาท/10 ปี หรือ 600,000 บาท/ปี

New Improvement to Best Practice

Benefit [Internal, Generator 9 Units]



GTG1, GTG2, GTG3, GTG4, GTG5, GTG6, GTG7, GTG8, GTG9

X 9 [จำนวน Units] = 889,200 บาท/ปี

รวม Benefit/ปี คือ 889,200 + 8,289,783 = 9,178,983 บาท/ปี

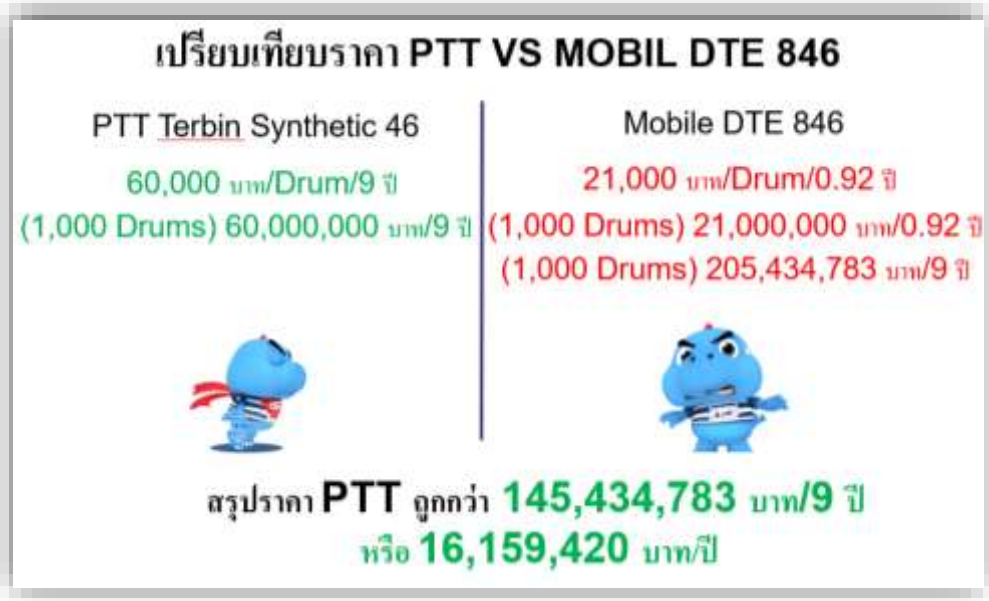
X 9 [จำนวน Units] = 8,289,783 บาท/ปี

บริษัท ปตท. จำกัด (มหาชน)
โรงแยกก๊าซธรรมชาติระยอง

New Improvement to Best Practice

Benefit (Internal, Compressor 26 Units)

SGC GSP1, RFC GSP1, Regen. Comp. GSP1, SGC GSP2, RFC GSP2, SGC GSP3, RFC GSP3, Regen. Comp. GSP3, RGC ESP, GSP2 Booster Comp. ESP, SGC ESP, RFC ESP, SGC GSP5, Regen. Comp. GSP5, RFC A GSP5, RFC B GSP5, SGC A GSP6, SGC B GSP6, RFC GSP6, Regen. Comp. GSP6, OCS2 B, OCS2 C, OCS3 A, OCS3 B, OCS3 C, RGC GSP6



Benefit/ปี 16,159,420 บาท/ปี

บริษัท ปตท. จำกัด (มหาชน)
โรงแยกก๊าซธรรมชาติระยอง

New Improvement to Best Practice

Benefit (Internal, History Loss)

VOITH RFC TA5 GSP3 2018

- Found many varnish in all mechanical part
- Take long time to cleaning especially working oil cooler
- Make TA time delay 3 days from plan loss 105 MB!

Benefit Save Loss/7 ปี 105,000,000 บาท

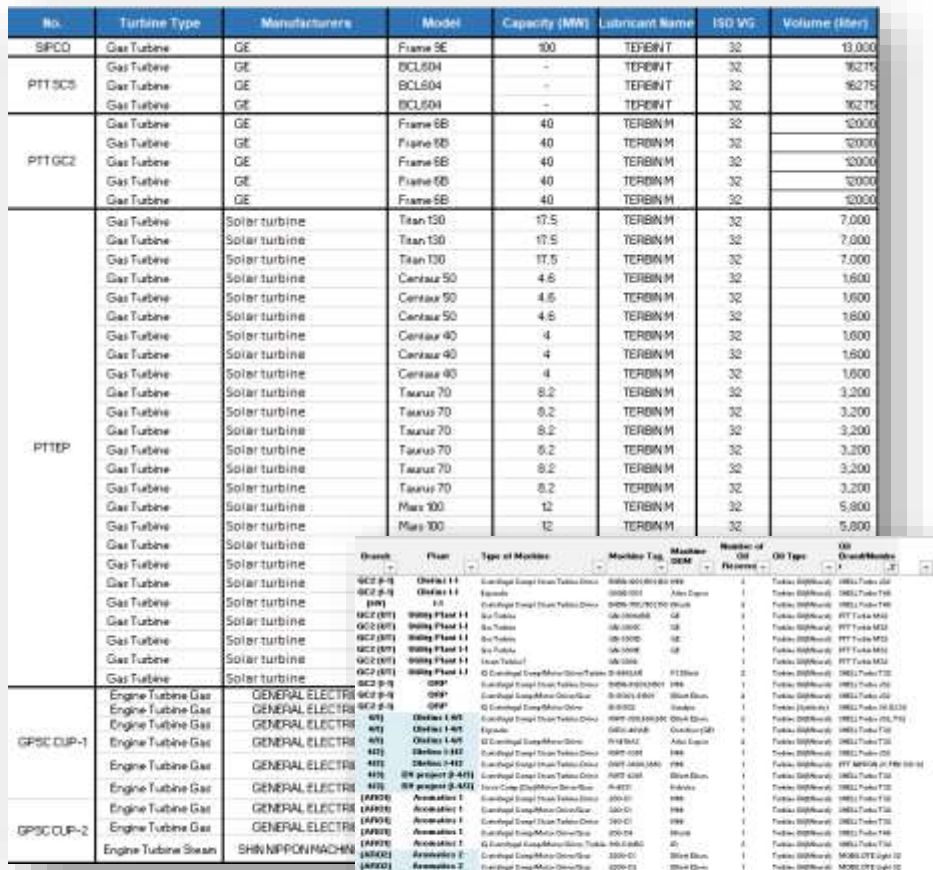
หรือ

15,000,000 บาท/ปี

บริษัท ปตท. จำกัด (มหาชน)
โรงแยกก๊าซธรรมชาติระยอง

New Improvement to Best Practice

Benefit (External)



No.	Turbine Type	Manufacturers	Model	Capacity (MW)	Lubricant Name	ISO VG	Volume (liter)
SPCO	Gas Turbine	GE	Frame 9E	100	TERBINT	32	13,000
PTT SC5	Gas Turbine	GE	BCL604	-	TERBINT	32	16275
	Gas Turbine	GE	BCL604	-	TERBINT	32	16275
	Gas Turbine	GE	BCL604	-	TERBINT	32	16275
PTT GC2	Gas Turbine	GE	Frame 6B	40	TERBINM	32	12000
	Gas Turbine	GE	Frame 6B	40	TERBINM	32	12000
	Gas Turbine	GE	Frame 6B	40	TERBINM	32	12000
	Gas Turbine	GE	Frame 6B	40	TERBINM	32	12000
	Gas Turbine	GE	Frame 6B	40	TERBINM	32	12000
PTTEP	Gas Turbine	Solar turbine	Titan 130	17.5	TERBINM	32	7,000
	Gas Turbine	Solar turbine	Titan 130	17.5	TERBINM	32	7,000
	Gas Turbine	Solar turbine	Titan 130	17.5	TERBINM	32	7,000
	Gas Turbine	Solar turbine	Centaur 50	4.6	TERBINM	32	1,600
	Gas Turbine	Solar turbine	Centaur 50	4.6	TERBINM	32	1,600
	Gas Turbine	Solar turbine	Centaur 50	4.6	TERBINM	32	1,600
	Gas Turbine	Solar turbine	Centaur 40	4	TERBINM	32	1,600
	Gas Turbine	Solar turbine	Centaur 40	4	TERBINM	32	1,600
	Gas Turbine	Solar turbine	Centaur 40	4	TERBINM	32	1,600
	Gas Turbine	Solar turbine	Taurus 70	8.2	TERBINM	32	3,200
	Gas Turbine	Solar turbine	Taurus 70	8.2	TERBINM	32	3,200
	Gas Turbine	Solar turbine	Taurus 70	8.2	TERBINM	32	3,200
	Gas Turbine	Solar turbine	Taurus 70	8.2	TERBINM	32	3,200
	Gas Turbine	Solar turbine	Taurus 70	8.2	TERBINM	32	3,200
	Gas Turbine	Solar turbine	Taurus 70	8.2	TERBINM	32	3,200
	Gas Turbine	Solar turbine	Mars 100	12	TERBINM	32	5,800
	Gas Turbine	Solar turbine	Mars 100	12	TERBINM	32	5,800
	Gas Turbine	Solar turbine					
	Gas Turbine	Solar turbine					
	Gas Turbine	Solar turbine					
	Gas Turbine	Solar turbine					
	Gas Turbine	Solar turbine					
	Gas Turbine	Solar turbine					
	Gas Turbine	Solar turbine					
	Gas Turbine	Solar turbine					
GPSC CUP-1	Engine Turbine Gas	GENERAL ELECTRI					
	Engine Turbine Gas	GENERAL ELECTRI					
	Engine Turbine Gas	GENERAL ELECTRI					
	Engine Turbine Gas	GENERAL ELECTRI					
	Engine Turbine Gas	GENERAL ELECTRI					
GPSC CUP-2	Engine Turbine Gas	GENERAL ELECTRI					
	Engine Turbine Gas	GENERAL ELECTRI					
	Engine Turbine Steam	SHIN NIPPON MACHIN					

ประมาณการลูกค้าในประเทศ (PTT Group) เบื้องต้น

690,530 Liters = 3,453 Drums

1 Drum 60,000 บาท

3,453 Drum = 207,180,000 บาท/9 ปี

ประมาณการลูกค้าในประเทศ บ.อื่นๆ และต่างประเทศ (ลาว, เวียดนาม) เบื้องต้น

5,000 Drums = 300,000,000 บาท/9 ปี

Revenue 56,353,333 บาท/ปี

OR

ptt

บริษัท ปตท. จำกัด (มหาชน)
โรงแยกก๊าซธรรมชาติระยอง

PID FAILURE IS NOT AN OPTION

New Improvement to Best Practice

Benefit [Sum OpEx Criteria]

- 600,000 บาท/ปี
+ 9,178,983 บาท/ปี
+ 16,159,420 บาท/ปี
+ 15,000,000 บาท/ปี

Sum 39,738,403 บาท/ปี

Note : Due to the trade secret, OR can't explain the product price in detail to show the profit for reference.

New Improvement to Best Practice

Benefit (Sum Real Value)

- 600,000 บาท/ปี
+ 9,178,983 บาท/ปี
+ 16,159,420 บาท/ปี
+ 15,000,000 บาท/ปี
+ 56,353,333 บาท/ปี

Sum 96,091,736 บาท/ปี

New Improvement to Best Practice
Benefit [Others]

1st Success PAG turbine Oil
Used in Asia

2nd Brand PAG Turbine Oil
in the World

New Improvement to Best Practice

What's Next? (Internal)

Expansion to Another Compressor & VOITH Unit

Register OEM Vender List

Expansion to Another GTG Unit

New Improvement to Best Practice

What's Next? [External]

01

Share in OPEX

02

Sales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บริษัท ปตท. จำกัด (มหาชน)
โรงแยกก๊าซธรรมชาติระยอง
OR

Thank you