



Chevron Varnish Technology

VARTECH[®] Industrial System Cleaner

GST[®] Advantage Turbine Oil with VARTECH[®] Technology

INDUSTRIAL
LUBRICANTS

All data shown in this presentation reflects the results from Chevron's field trials and internal testing/analyses.

Varnish in turbines and compressors: learnings



Existing varnish can keep new oil from performing

- We need to clean out varnish to get good oil performance

New oil doesn't clean up existing varnish

- Just changing the oil isn't good enough

Many cleaners are not effective

- Some cleaners are not compatible with turbine oil

- A cleaner needs to be effective and compatible
- Anti-varnish performance is needed in turbine oil



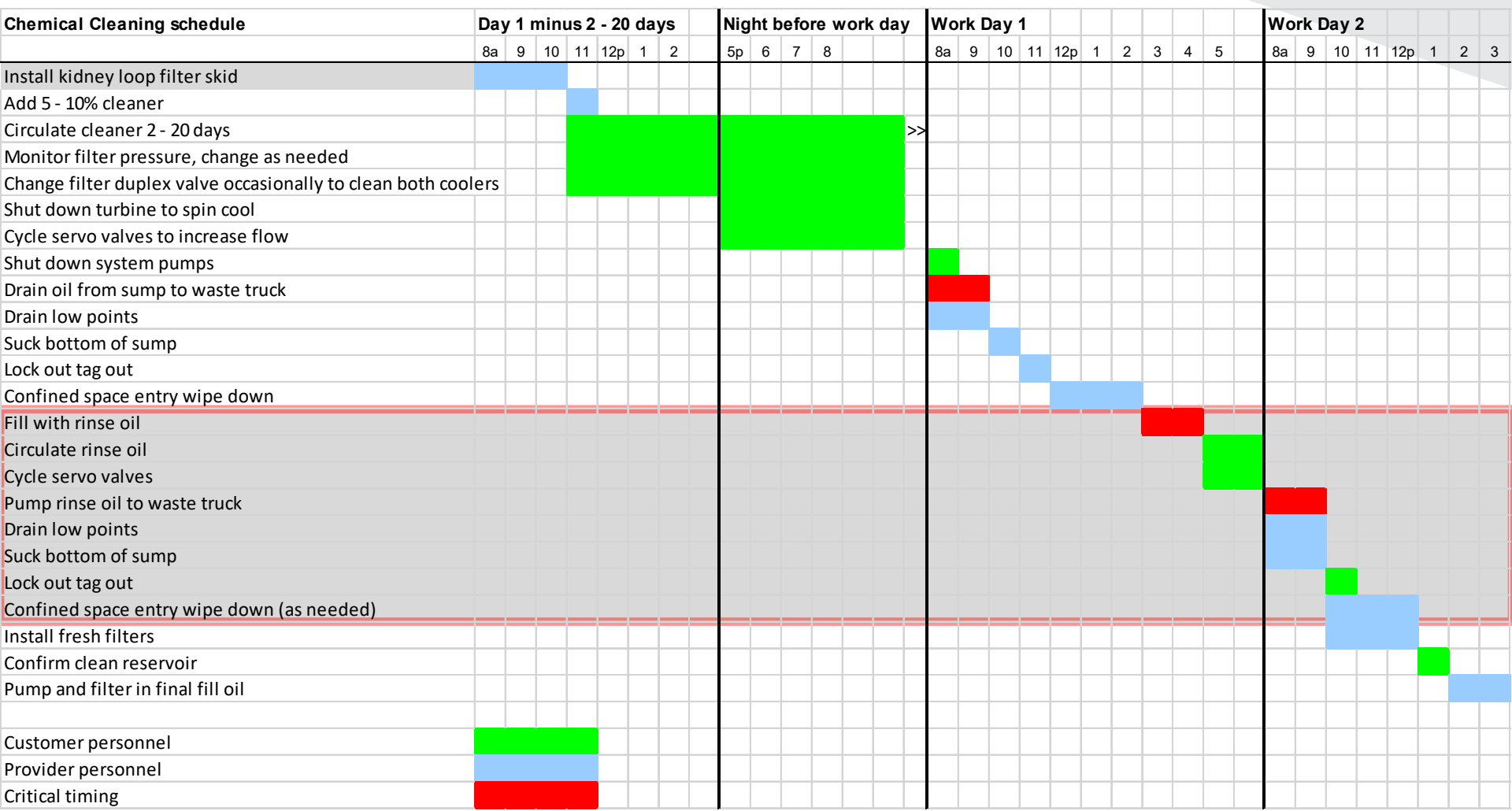
What is varnish cleaning

- Add chemistry to the old oil during operation
- Lift varnish deposits from the surfaces
- Stabilize the varnish deposits in the old oil
- Drain the old oil and removed varnish
- Rinse the system if needed





With incompatible cleaner





With compatible cleaner

Chemical Cleaning schedule	Day 1 minus 2 - 20 days							Night before work day				Work Day 1									
	8a	9	10	11	12p	1	2	5p	6	7	8			8a	9	10	11	12p	1	2	
Install kidney loop filter skid	█																				
Add 5 - 10% cleaner				█																	
Circulate cleaner 2 - 20 days				█							█										
Monitor filter pressure, change as needed				█							█										
Change filter duplex valve occasionally to clean both coolers				█							█										
Shut down turbine to spin cool				█							█										
Cycle servo valves to increase flow				█							█										
Shut down system pumps				█							█				█						
Drain oil from sump to waste truck				█							█				█	█					
Drain low points				█							█				█	█					
Suck bottom of sump				█							█					█					
Lock out tag out				█							█						█				
Confined space entry wipe down				█							█							█			
Install fresh filters				█							█								█		
Confirm clean reservoir				█							█									█	
Pump and filter in final fill oil				█							█									█	
Customer personnel	█																				
Provider personnel	█																				
Critical timing	█																				



VARTECH[®] Industrial System Cleaner Development Process Review

Varnish removal lab testing: Stage 1 beaker test



New Varnish
Coupon



Cleaning Test Apparatus



Varnish Coupon
After Cleaning

Some cleaners just don't clean

VARTECH® ISC

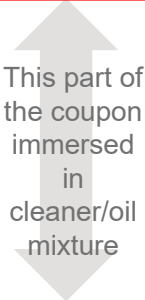


Varnish Coupon Before Cleaning



Varnish Coupon After Cleaning

Approximately 95% of the varnish exposed to the cleaner was removed within 2 hours.



COMPETITIVE CLEANER



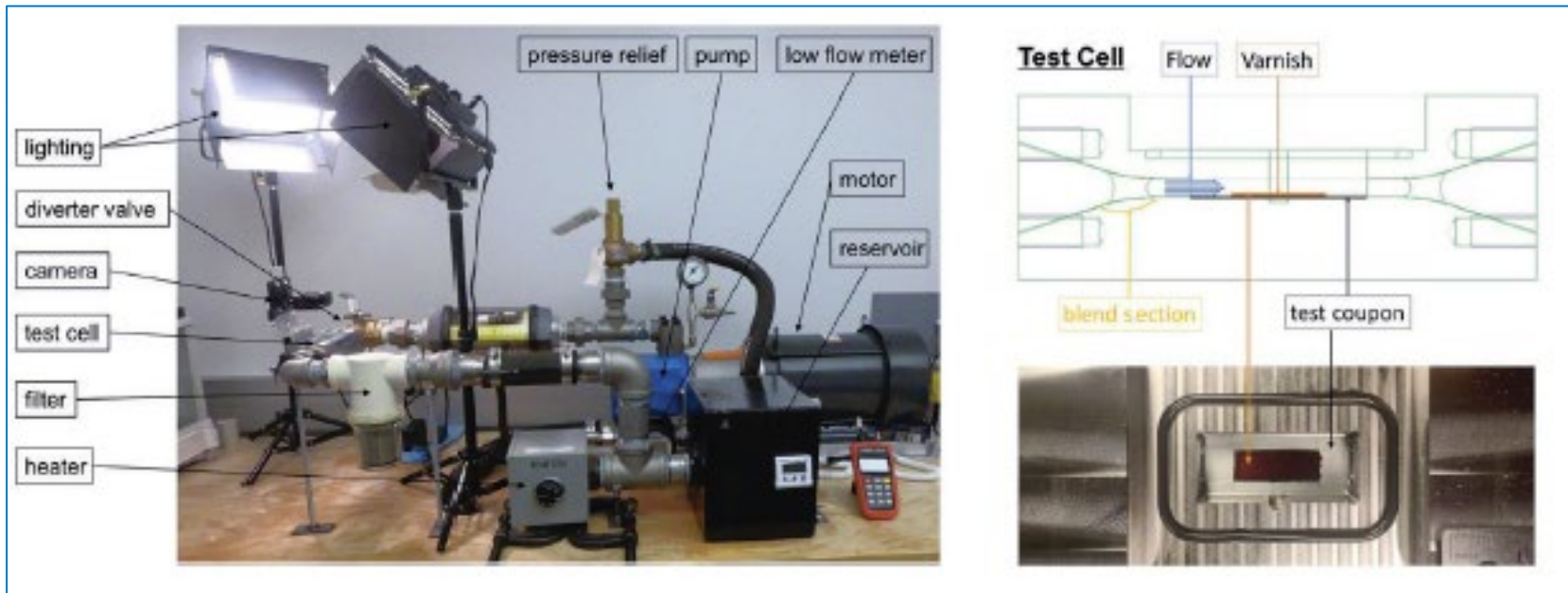
Varnish Coupon Before Cleaning



Varnish Coupon After Cleaning

No evidence of varnish removal after 24 hours of testing.

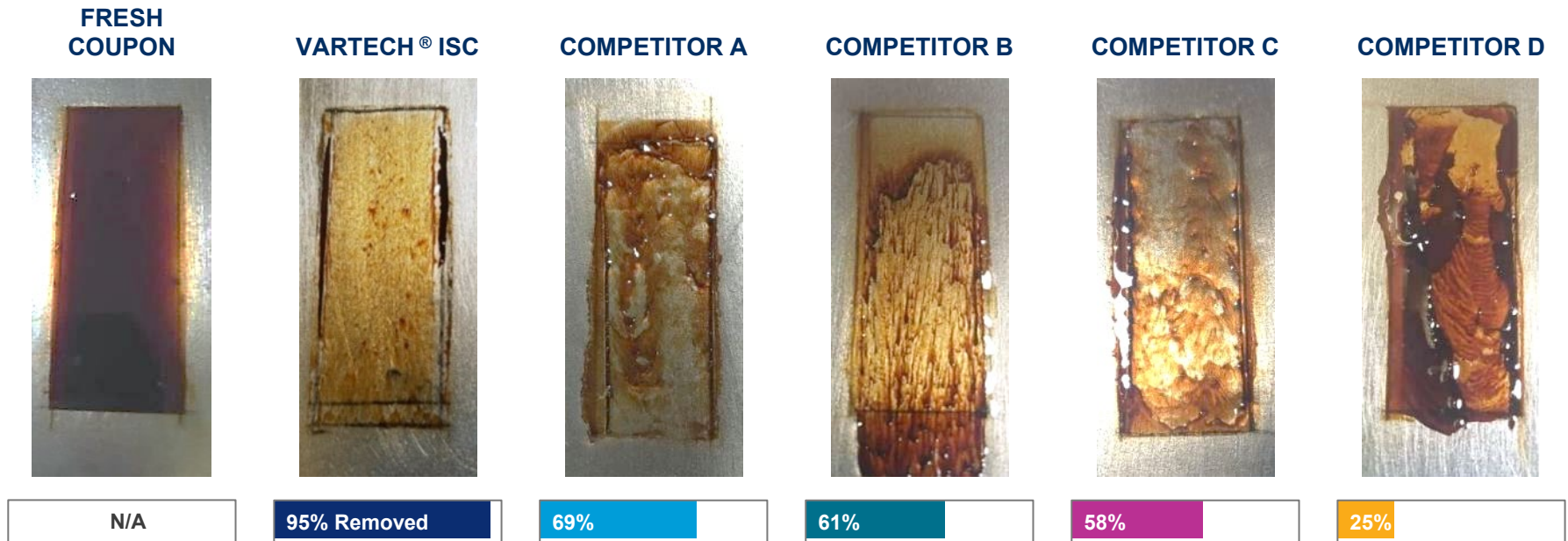
Flowing test rig to replicate a lube oil system



Flow cell test system: varnish removal results



- End-of-test coupons demonstrate effectiveness of cleaner



[Time-lapse video of
varnish removal](#)

More on this later



Field testing

Focused on Chevron sites with known varnish history
MEASURABLE varnish impact

chevronlubricants.com



Tahiti Unit 2 – January 2019

- Solar Titan turbine – Chevron Tahiti
- High oil temperature due to oil cooler fouling with varnish
- Previously cooler was swapped and sent for cleaning every four months
- Two turbines running continuously – 6 coolers / year



Pre-trial: tested cooler plate in the lab

Varnish on cooler plate
Reduces cooling efficiency



30min

Turbine oil + VARTECH® ISC

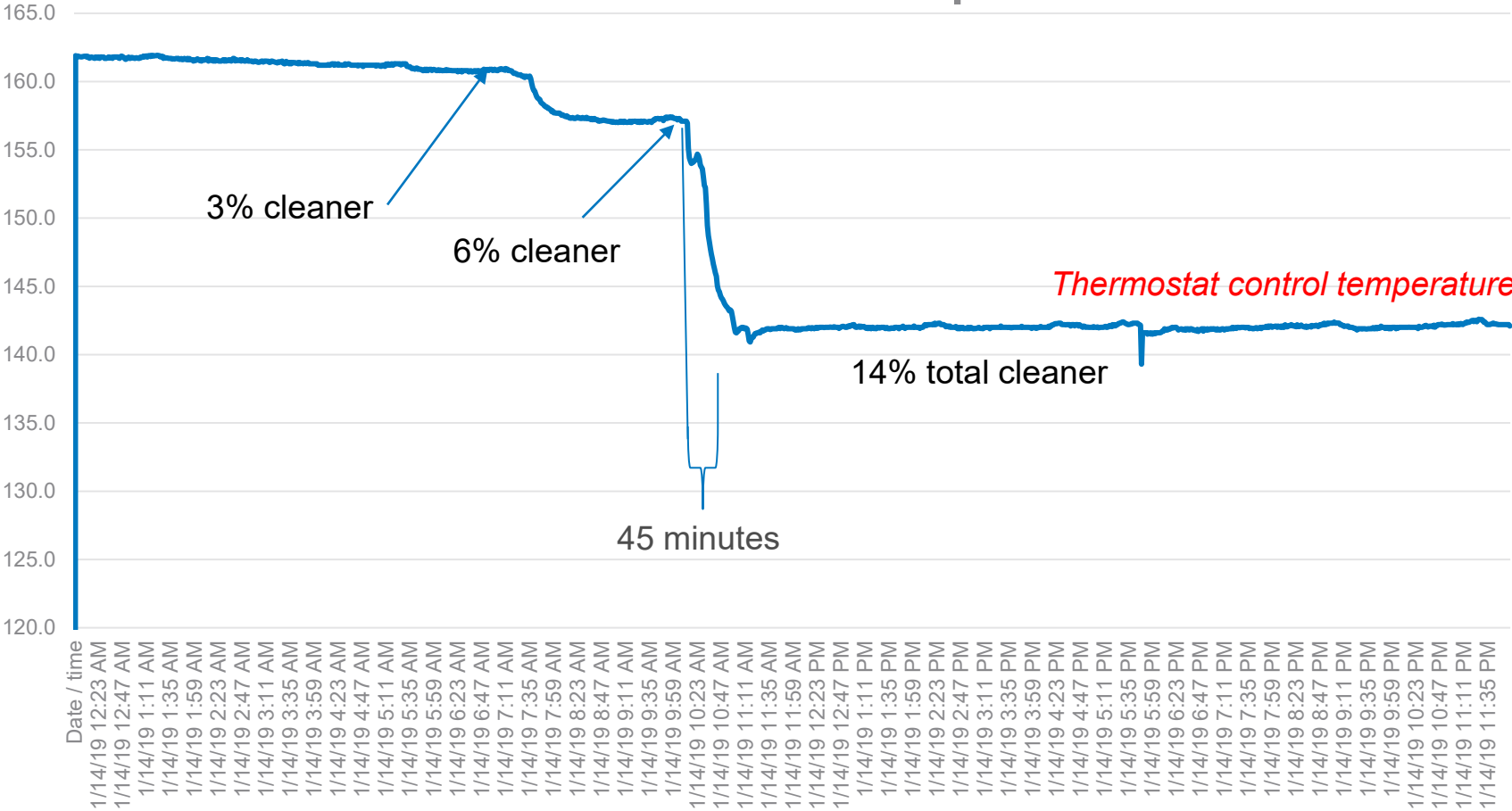
Next test: real life at 100 miles offshore





Solar Titan: Chevron Tahiti

Main Oil Header Temperature





Filter Debris after 2 days
DP remained at 6.5 psi

Cleaning process comparison: same turbine



Competitor– 2017

- Filter plugging – every 10 minutes
- Cooler temps dropped – 2 days
- Varnish in sump remained
- Flushing required
- Auxiliary oil pump seized



Picture of seized aux oil pump
after cleaning with competitor
product in 2017

Chevron VARTECH® ISC – 2019

- No filter plugging over 2 days
- Cooler temps dropped – 1 hour
- Varnish in sump remained
- Flushing not required
- Auxiliary oil pump remained in service

Tahiti Unit 3 and Unit 1

- Installed 5% VARTECH[®] ISC
- Temperatures reduced
- VARTECH ISC circulated for five months on each
- No oil degradation
- No temperature rise
- All 3 units were refilled with GST[®] Advantage RO 46 with VARTECH[®] Technology
- No temperature increases since – 2 years



Further investigation on previous filter plugging:
Calcium sulfonate + corrosion inhibitor = floc (salts) which plugged the filter

CASE STUDY: SOLAR TAURUS 60

Treat, 2-week run, oil drain, rinse



- Generate Steam + Sell Electricity
- 350-gallon sump
- Varnish fouling fin-fan oil cooler
 - High lube oil temps
 - High bearing temps (1°F under trip temp)
 - Header temp 172°F
 - Thrust bearing temp 221°F
 - Bearing oil drain temp 197°F
- Derating power output from 5.4MW to 3.2MW (40%)
 - 6+ months of each year



Air exchange (fin/fan) oil cooler

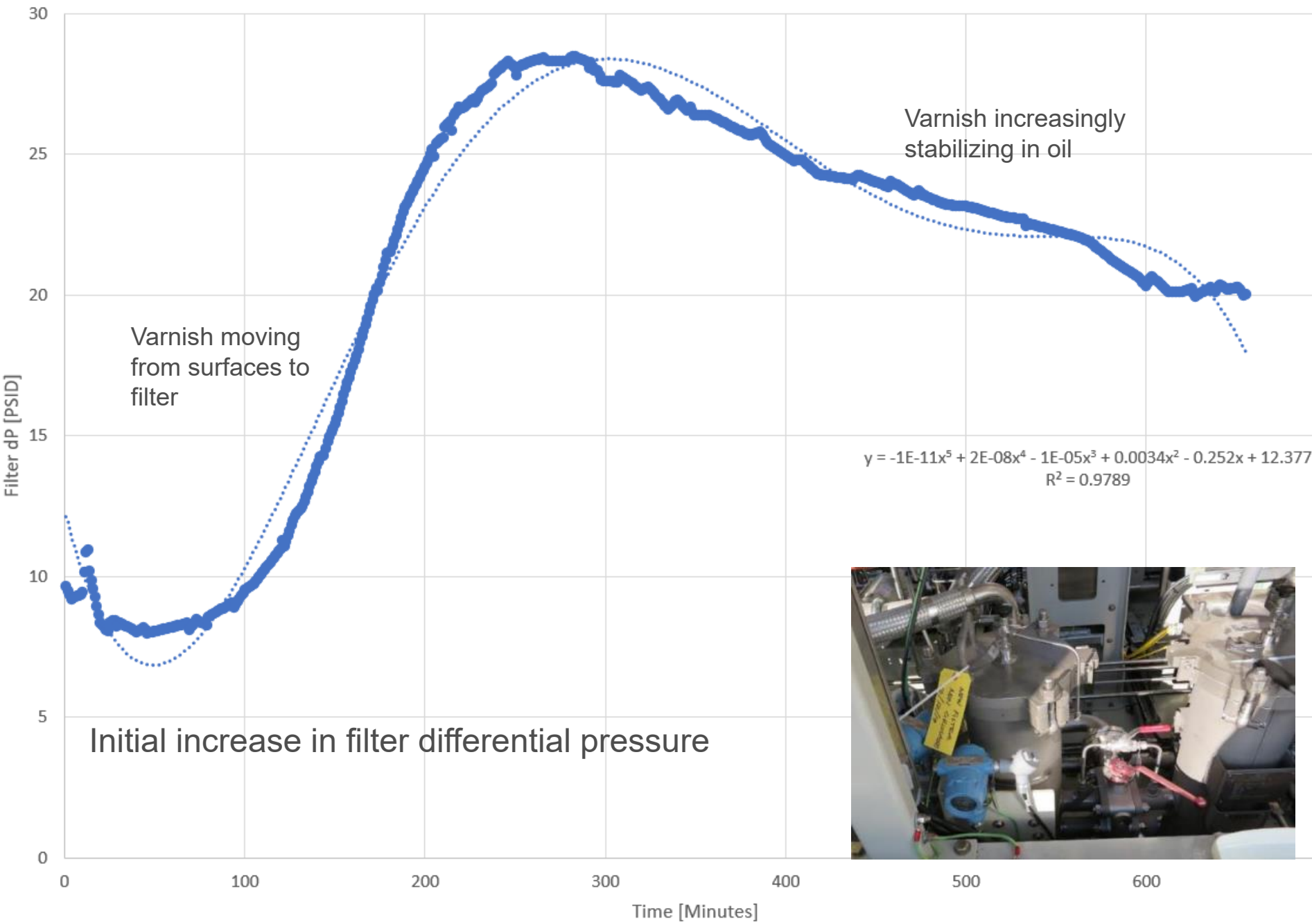
Results

- Installed 10% VARTECH[®] Industrial System Cleaner 9/26/19
 - Header temp drop 11°F
 - to 161°F
 - Thrust bearing temp drop 19°F - to 202°F
 - Bearing oil drain temp drop 7°F – to 190°F
- 24 hours later – no derate, **full output**, same ambient
 - 3.3 MW → 5.5 MW

- Cleaner in system 2 weeks
- Visibly reduced bathtub ring
- Initial increase in filter delta P



Lube Oil Filter dP vs Time



Experience

- 4 Solar Taurus 60 turbines
- 3 Solar Titan 130 turbines
- 1 GE Frame 7EA turbine
- 1 Mitsubishi steam turbine
- 1 Quincy screw compressor
- 1 Atlas Copco screw compressor
- 2 MAN centrifugal compressors with Renk gearboxes

Completing now

- 2 centrifugal compressors
- 1 heat transfer system



Conclusion of turbine field trials

More discussion on performance testing



Benchmarking Against Commercial Cleaners



Commercial cleaners evaluated:

- VARTECH[®] ISC
- Step One (DuBois)
- Mobil System Cleaner
- Varnasolv (Summit)
- EcoSafe Revive (ACT)
- Compkleen (Citgo)
- Techniclean SC (Castrol)
- Clean & Flush (Royal Purple)
- Exxon Synesstic 5** Alkylated Naphthalene
- Na-lube KR-008** Alkylated Naphthalene
- Fluitec Decon

**Not commercial cleaners, but are currently used in the field as oil top treats for varnish control

Patented artificial varnish process

- Chevron developed and patented a process to produce an artificial varnish. The process:
- Mimics the oxidation mechanisms occurring in turbines and compressors by leveraging common lubricant aging tests to create insoluble varnish precursors,
- Applies heat and pressure to varnish precursors on a steel test plate to form varnish film,
- Produces consistent test coupons for laboratory testing.



VARNISH COUPON

Varnish removal flow cell test system

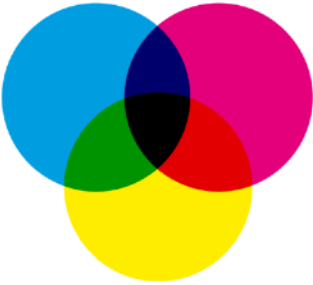
VARNISH REMOVAL FLOW CELL TEST SYSTEM*



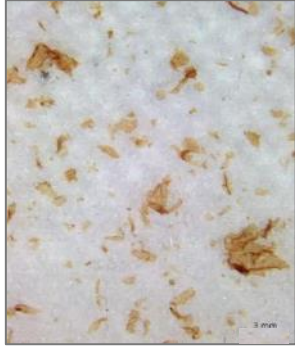
TEST CELL CONTAINING VARNISH COUPON



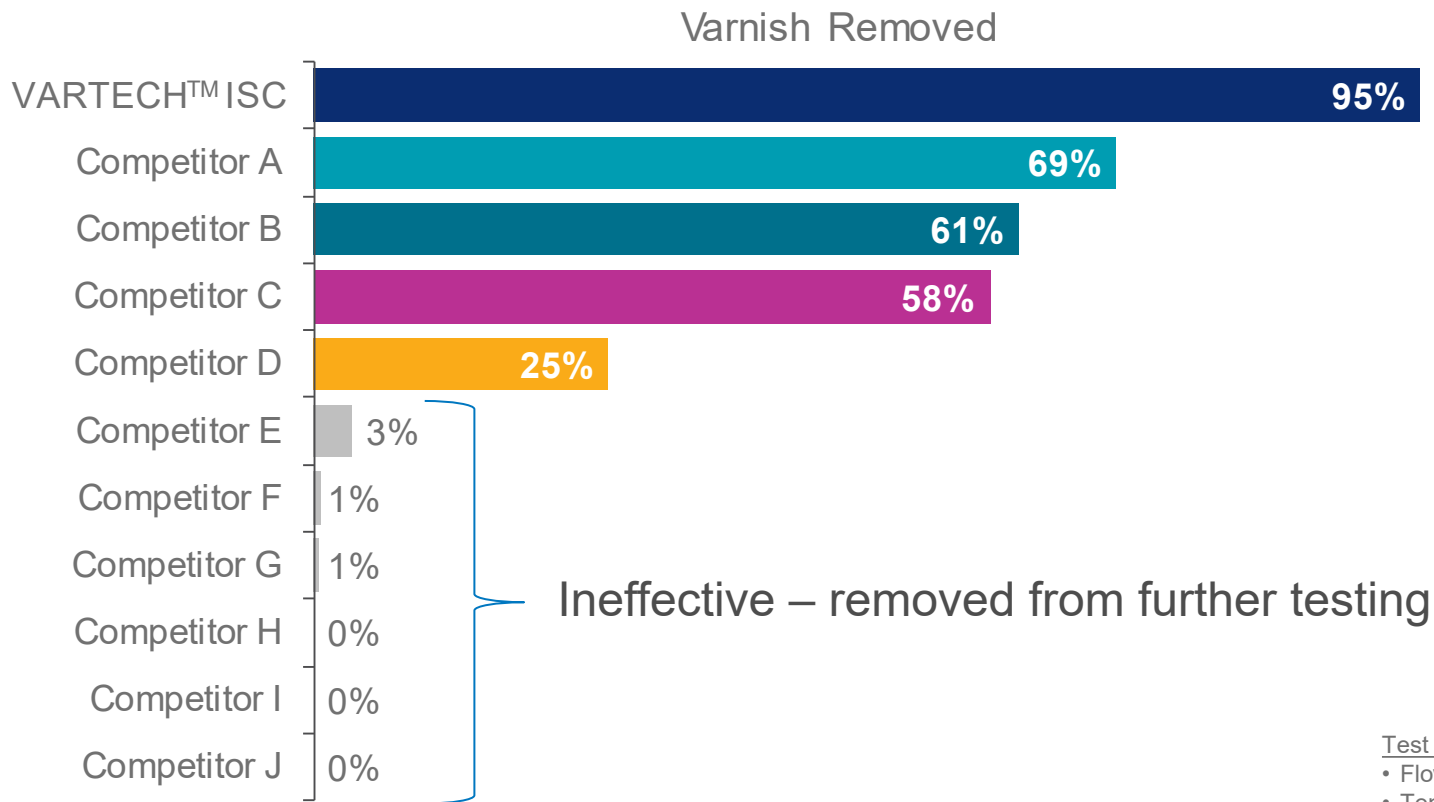
* Images and full article [here](#) in *Tribology & Lubrication Technology*, Aug. 2018



- Coupon evaluation
- 1) CMYK COLOR SCALE
 - 2) Weight
 - 3) Removal characteristics
 - 4) Filter debris



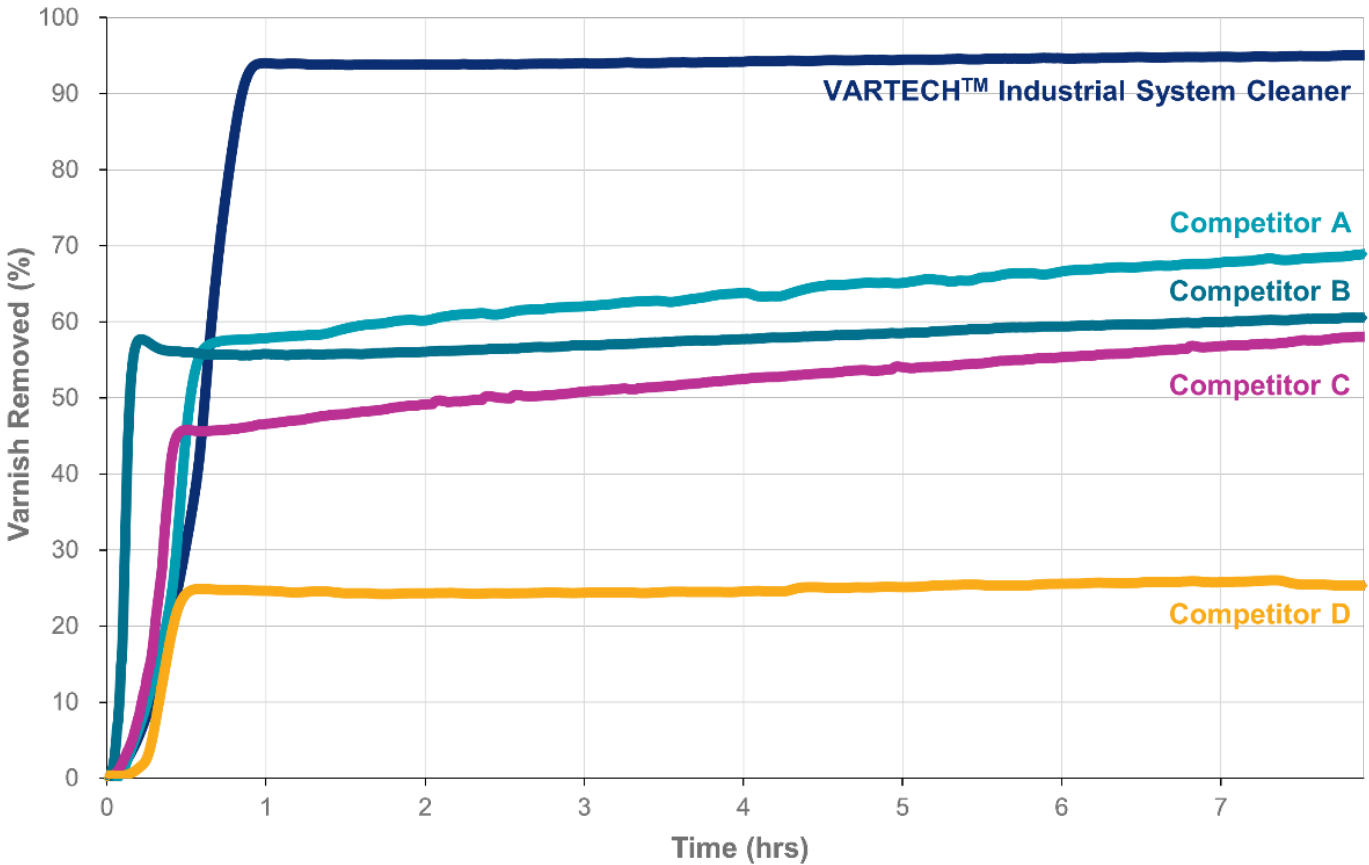
Varnish removal flow cell test system results: total varnish removed



Test Parameters:
• Flow Rate: 2 GPM
• Temperature: 90°C
• Time: 8 hours



Benchmarking VARTECH[®] ISC against competitive varnish cleaners over time

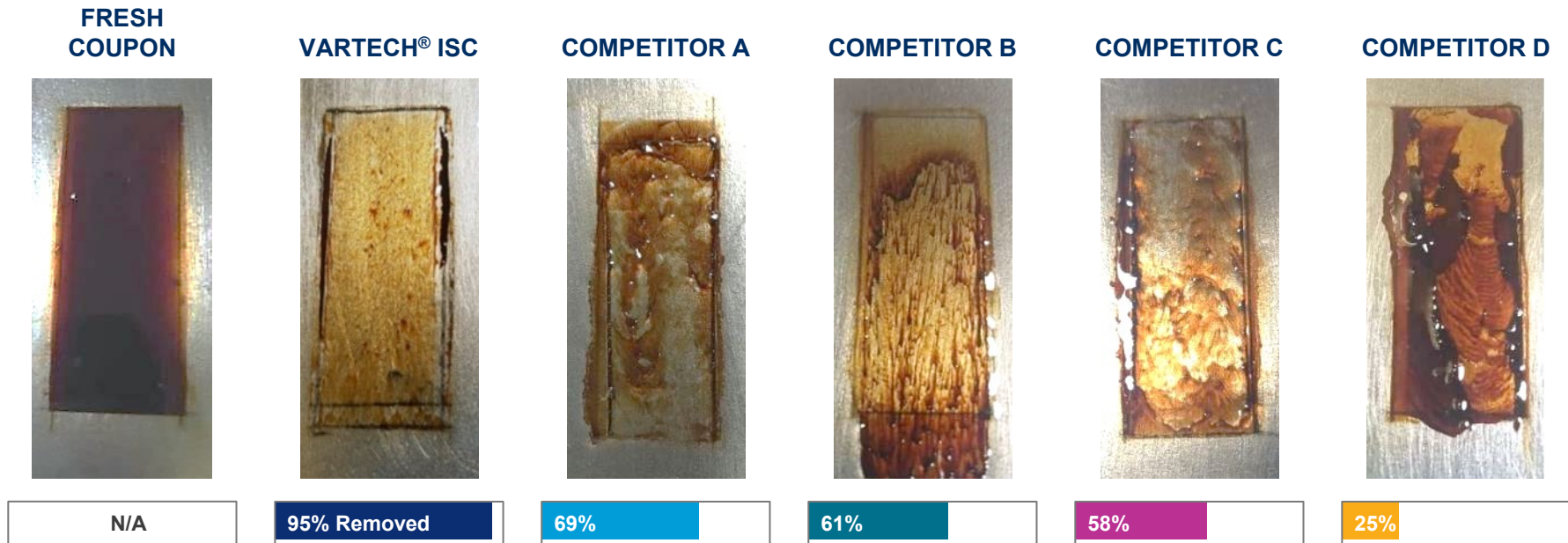


Test Parameters:
• Flow Rate: 2 GPM
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• Time: 8 hours

Varnish removal flow cell test system results



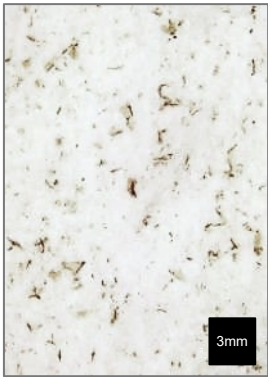
- End-of-test coupons demonstrate effectiveness of VARTECH[®] ISC



VARTECH[®] Industrial System Cleaner (ISC) removes far more varnish than the leading competitive products.

End-of test filters displaying captured varnish

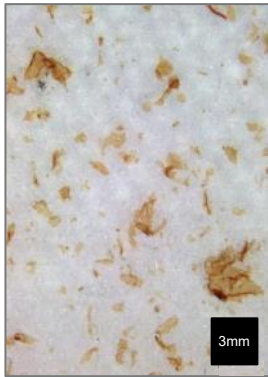
VARTECH® ISC



95% Varnish Removed

Varnish particles removed are small and do not agglomerate, thus mitigating potential filter clogging and unplanned system shutdowns

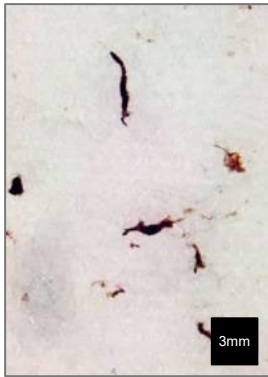
COMPETITOR A



69%

Larger varnish clusters, potentially causing filter clogging. Increased potential for softened varnish re-adhering to critical components elsewhere in system

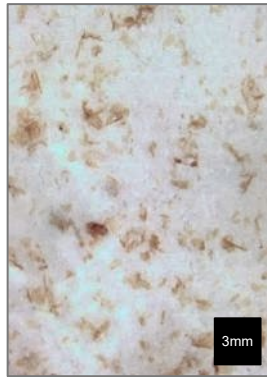
COMPETITOR B



61%

The softened, sticky varnish smeared into 'string-like' clusters rather than being removed - potential to re-adhere to critical components and filters

COMPETITOR C



58%

Larger varnish clusters, potentially causing filter clogging. Increased potential for softened varnish re-adhering to critical components elsewhere in system

COMPETITOR D



25%

The minimal varnish removed in large chunks that are more likely to clog filters and systems passageways

Compatibility of VARTECH® ISC after incomplete drain



Vartech compatibility testing	Water sep	RPVOT	% of new	Seal swell	Seal softening	Flash point
GST 32 neat	40-40-0 (10 min)	1818				222
GST 32 20% VARTECH	42-38-0 (10min)	1032	57%	0.36%	-0.94	238
GST 32 2% VARTECH	42-38-0 (10min)	1807	99%			230
GST 32 20% Competitor	0-20-60 (>60min)	81	4%	7.64%	-6.14	194
GST 32 2% Competitor	8-0-72 (>60min)	619	34%			220
GST Advantage RO neat	40-40-0 (10 min)	1500				224
GST Advantage RO 2% VARTECH	40-40-0 (5 min)	1202	80%			232
GST Advantage RO 2% Competitor	5-26-49 (>60min)	181	12%			236
GST Advantage EP neat	40-37-0 (5 min)	2328				226
GST Advantage EP 2% VARTECH	40-37-3 (15 min)	2025	87%			224
GST Advantage EP 2% Competitor	0-28-52 (>60min)	955	41%			226
Mobil DTE 732 neat	40-40-0 (15 min)	1070				236
Mobil DTE 732 with 20% VARTECH	40-40-0 (5 min)	854	80%			232
Mobil DTE 732 with 20% Competitor	40-37-0 (10 min)	81	8%			198
Mobil DTE 732 with 2% Competitor	5-22-53 (>60min)	236	22%			225

Note: Competitor cleaner is calcium sulfonate detergent dispersant technology

Rinse flush – always recommended - is it required?

- What cleaner was used, is it compatible?
- How much cleaner and degraded oil got left behind?
- Balance flush oil cost vs. new oil performance loss – commercial decision



Compatible with most turbine oils

The following other competitive oils also tested compatible at 20%

- Conoco Diamond Class
- Mobil DTE 832
- Mobil DTE 732
- Mobil DTE Lite
- Shell Turbo T
- Shell Turbo S4 X
- Shell Corena S4 R
- Mobil SHC Rarus



New Chevron Turbine Oils With VARTECH[®] Technology

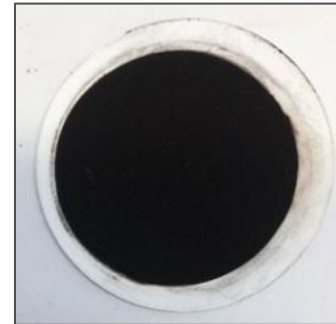


What is VARTECH[®] Technology

Tailored balance of additives

- Premium Group II base oil
- Antioxidants
- Corrosion inhibitor
- Foam inhibitor
- Anti-wear / Extreme Pressure – for highly loaded gear sets
- Varnish stabilizer

Conventional EP
Turbine Oil



0.0769g

GST[®] Advantage EP
ISO 32

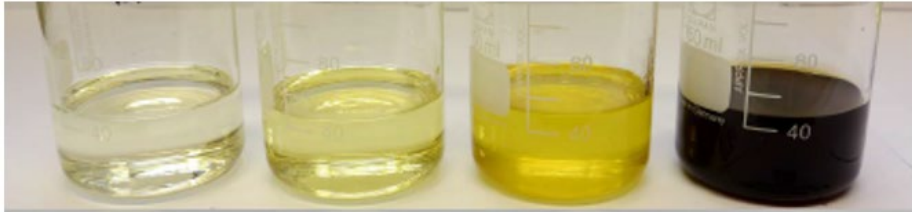


0.0020g



GST[®] Advantage RO

End of Test of Conventional Turbine Oil



End of Test GST Advantage RO



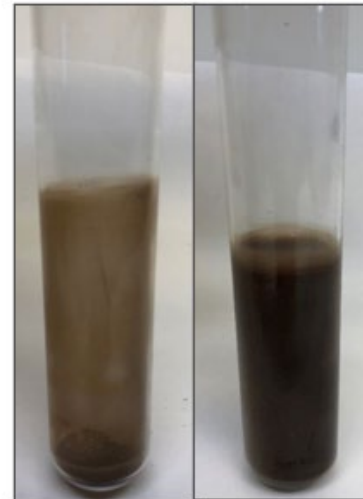
22°C 120°C 150°C 180°C

MAN Lubricant Temperature Aging Test Thermal Stability (LTAT)

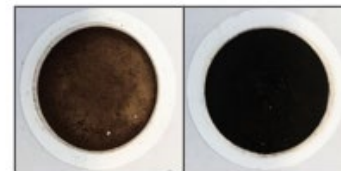


GST Advantage EP

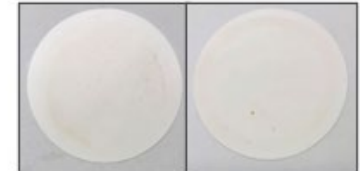
Conventional EP
Turbine Oil



GST Advantage EP
ISO 32



0.0116g 0.0134g



0.0007g 0.0020g

High Temperature Fluid Aging Test



Chevron turbine oils: legacy products

- Regal R&O – ISO 22 – 680
 - Excellent product compatibility
 - Good oxidation resistance
 - Meets EP requirements for geared turbines
 - Special considerations for Hydro market
- GST – ISO 32 – 100
 - Strong history of performance since 1983
 - High oxidation resistance
 - R&O oil to include lightly loaded geared systems
- Regal SGT
 - Synthetic Polyol Ester
 - Aero derivatives like GE LM6000, LM2500, LMS100, Rolls Royce etc.



Chevron turbine oils: new products

- GST Advantage RO – ISO 32 - 46
 - Formula introduced in 2012 as GST Premium
 - Tailored with VARTECH Technology for vastly improved varnish resistance
 - Balances oxidation resistance and deposit control for tough applications
 - R&O oil to include lightly loaded geared systems
- GST Advantage EP ISO 32 - 46
 - New formula – Replacing GST 2300
 - Tailored with VARTECH Technology for vastly improved varnish resistance
 - Meets EP requirements for high load geared turbines
 - Very high oxidation resistance
- VARTECH Industrial System Cleaner
 - Varnish cleaner for turbine oil systems
 - Compatible with Group I – IV oils



By the numbers

Performance statistics		FZG, Pass Stage, DIN 51354, ASTM D5182	Viscosity Index, ASTM D 2270	RPVOT ASTM D2272, min to 25 psi drop	TOST, ASTM D 943, Hours to 2 NN
Chevron	GST 32	6-7	102	1700	17,000
Chevron	GST Advantage RO 32	7	105	1500	10000
Mobil	DTE 732		117	1000	10000
Conoco	Diamond Class	NR	103	1700	>35,000
Shell	Turbo T	NR	105	1100	11000
Shell	Turbo S4X	7	141	1400	10000
Chevron	GST EP 32	12	102	1700	10,000
Chevron	GST 2300	12	102	2300	>10,000
Chevron	GST Advantage EP 32	10	112	2200	10000
Mobil	DTE 832	9	110	1200	>10,000
Mobil	DTE Light	8	102	NR	5000
Conoco	Diamond Class AW	10	103	>1700	>24,000
Shell	Turbo CC	8	95	500	3000
Shell	Turbo S4GX	10	139	1400	10,000

Summary

- Clean out old varnish – to make new oil work
- Use a cleaner compatible with turbine oil
- Use a cleaner that is proven effective
- Choose an oil that will prevent varnish



