The Critical Role of Bench Tests in Automotive Lubricant Specifications, Development and Production Control

How Tannas & King Instruments Serve the Industry

Savant Group

TannasKing.com

Savant Group

Midland, Michigan USA

Independent Testing Laboratory

1969

SAVANT LABS

SAVANT

SavantLab.com

Laboratory Testing Instruments

1981

TANNAS

1994

KING

REFRIGERATION

TannasKing.com

Global Engine Oil Database

1984

IOM

INSTITUTE OF MATERIALS

InstituteOfMaterials.com

Precision Machining

2019

EXCELL

MANUFACTURING INC.

ExcellMfgInc.com


Midland,
Michigan

Savant Group

Founder & Inventor
(1928 – 2022)

Theodore (Ted) Selby

(58 Patents)

TANNAS

KING REFRIGERATION

IOM INSTITUTE OF MATERIALS

SAVANT LABS SAVANT

50th Anniversary Celebration

1969 - 2019

Tannas & King Philosophy

Serve CUSTOMER Needs

- Produce the finest available equipment
- Solve critical problem areas in industry
- Training & consultation

Serve INDUSTRY Needs

- Bench test development
- Critical information production
- High correlation with engine tests & field performance

Instrument Innovations - Tannas

Quantum®
Oxidation Tester

- Non-liquid dry cylinder
- RPVOT (D2272, D2112, IP 229, SH/T 0193)
- TFOUT (D4742)
- Grease Oxidation testing (D942)

TBS HTHS Viscometer
2100*E-F* / 3000

- Tapered Bearing Simulator
- 40°C to 150°C
- 40+ position Auto-Sampler
- ASTM D4683, D6616, CEC L-036, SH/T 0618

TFAB
Tannas Foam Air Bath

- Non-liquid dry bath
- Direct Drive motor - quiet
- Touchscreen interface
- ASTM D892, D6082, IP 146, GB/T 12579, SH/T 0722

Direct Cool II
(non-liquid)

- Low temperature pumpability
- Gelation Index
- 90°C to -40°C
- ASTM D5133, D7110, SH/T 0732
- ASTM D2983, Procedure D (Automated)

Instrument Innovations - Tannas

Tannas Noack S2®

(non-Wood's Metal)

- Evaporation Loss
- 'Tunable'; Calibrate to lab environment
- Collection of volatiles – PEI
- ASTM D5800-Procedure **D**, SH/T 0059

TEOST®

Thermo-oxidation Engine Oil Simulation Test

- High Temperature Deposit Control
- TEOST® 33C ➔ ASTM D6335, SH/T 0750
- TEOST MHT® ➔ ASTM D7097, SH/T 0834
- TEOST Turbo® ➔ ASTM D8447

SBT®+2

(Multi-Purpose Low-Temp Liquid Bath)

- Easily replaceable Insert Modules for each test
- ASTM D5133, D2983, D7110, D4684, D445, D97, D2500, SH/T 0732

Instrument Innovations - King

BLB

Brookfield Liquid Bath

- SimAir™ Test Cells
- Independent Sample Analysis
- 30°C to -70°C
- ASTM D2983, DIN 51398

MRV TP-1

Mini-Rotary Viscometer

- Low-Temp Pumpability & Yield Stress
- Direct Refrigeration Technology
- ASTM D3829, **D4684**, D6821, D6896, SH/T 0562

Tannas & King Refrigeration

Lab Instruments

50+ Distributors

Worldwide

Instruments sold to over

70 countries

Instrument Sales Worldwide

2022

Industry Specifications

SAE J300

Engine Oil Viscosity Classification

API & SAE Viscosity Grade Symbol

ILSAC

International Lubricant Standardization & Approval Committee

GF-2 thru GF-5+, GF-6(a&b)
API S? Category equivalent

OEM

OEM-Specifications

ACEA -Europe

ACEA European Automobile Manufacturers Association

IFC

INTERNATIONAL FLUIDS CONSORTIUM

General Motors

dexos1 APPROVED-GEN 2

dexos2 APPROVED

Industry Specifications

ATF

Automatic Transmission Fluid:

GM Dexron®
Ford Mercon®
Chrysler (FCA) ATF+4
OEM Genuine

Industrial Oils

Wind & Gas Turbine Manufacturers:

GE
Siemens
Vestas
Goldwind
United Power
Kawasaki Heavy
Alsaldo Energia

China National Standard

GB 11121
Gasoline Engine Oils

GB 11122
Diesel Engine Oils

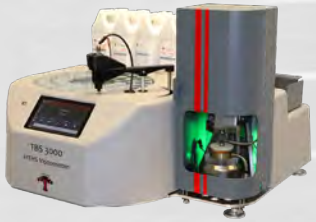
New D1 Specification for Diesel

New Gasoline & EV Specification Coming

SAE J300 Viscosity Classification

Tannas/King Instruments included in

J300



SAE Viscosity Grade	Low Temp. (°C) Viscosity, cP		High Temperature (°C) Viscosity		
	Cranking, Max. (CCS)	Pumping Max. (NYS) (MRV TP-1)	Kinematic (cSt) @ 100°C Min.	Kinematic @ 100°C Max.	High-Shear (cP) @ 150°C D4683, D4741 and D5481
0W	6200 @ -35	60,000 @ -40	3.8	--	--
5W	6600 @ -30	60,000 @ -35	3.8	--	--
10W	7000 @ -25	60,000 @ -30	4.1	--	--
15W	7000 @ -20	60,000 @ -25	5.6	--	--
20W	9500 @ -15	60,000 @ -20	5.6	--	--
25W	13,000 @ -10	60,000 @ -15	9.3	--	--
8	--	--	4.0	< 6.1	1.7
12	--	--	5.0	< 7.1	2.0
16	--	--	6.1	< 8.2	2.3
20	--	--	5.6	< 9.3	2.6
30	--	--	9.3	< 12.5	2.9
40	--	--	12.5	< 16.3	3.5 (0W-40, 5W 40, 10W-40)
40	--	--	12.5	< 6.3	3.7 (15W-40, 20W-40, 25W-40, 40)
50	--	--	16.3	< 21.9	3.7
60	--	--	21.9	< 26.1	3.7

ILSAC GF-6 (A & B) Engine Oil Specifications

SAE J300 Multi-grade Oils:

- CCS (D5293)
- **MRV** (D4684)
- KV @ 100°C (D445)
- **HTHS @ 150°C** (D4683, D4741, D5481)
- **SBT®/ Gelation Index** (D5133)

Engine Test Requirements:

- Oil Thickening (Sequence IIIH)
- Sludge and Varnish Test (Sequence VH)
- Valvetrain Wear (Sequence IVB)
- Bearing Corrosion (Sequence VIII)
- Fuel Efficiency (Sequence VIE)
- Chain Wear, Low Speed
- Pre-ignition Prevention

ILSAC
Starburst & Shield

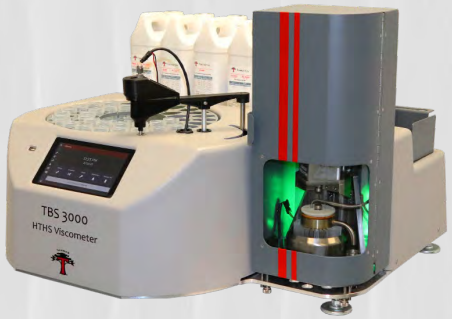
Bench Test Requirements:

- Phosphorous % (D4951)
- Phosphorous Volatility (D8111)
- Sulfur Content (D4951, D2622)
- **Volatility (D5800 B/D)**
- **TEOST 33C (D6335)**
- Filterability (D6794, D6795)
- **Foam Tendency (D892, D6082 high temperature)**
- ROBO (D7528) or Sequence IIIHA Test (D8111)
- Shear Stability (D6709)
- Homogeneity (D6922)
- Ball Rust Test (D6557)
- Emulsion Retention (D7563)
- Elastomer Compatibility

OEM Engine Oil Specifications

Tannas/King instruments included in:

ILSAC, ACEA, IFC, dexos



Tapered Bearing Simulator (TBS) Viscometer

HTHS Viscometer
TBS 2100*E-F*

The instrument that opened the door to understanding engine dependence on high shear viscometry

High Shear Rate Viscometry - Automotive Oils

Newtonian Oil

- Straight weight
- SAE 30
- No Viscosity Modifier
- Viscosity = Shear Stress/Shear Rate

Non-Newtonian Oil

- Multi-grade
- 5W30
- Viscosity Modifier (VM)
- Viscosity decreased with increasing shear rate (temporarily)

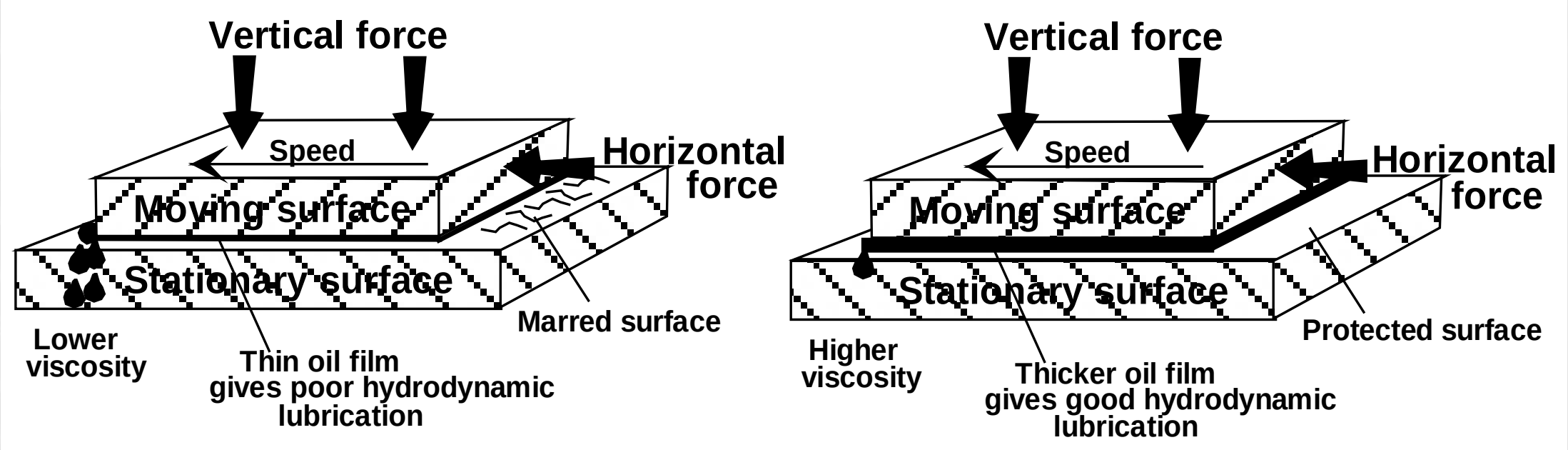
High Shear Rate Viscometry

Multigrade oils benefits, easier engine cold starting with acceptable viscous protection of operating engine.

As **multigrade** engine oils increased, it was found they had interesting viscometric properties that required **new understanding**.

New area of viscous measurement was developed to further this understanding – **HTHS** testing.

High Shear Rate Viscometry



High shear rate viscosity influences whether sufficient hydrodynamic lubrication occurs to protect opposing moving surfaces.

Viscosity

is a form of

friction

A resistance to flow caused by the internal molecular interaction of the oil.

Viscosity **protects** the engine from wear,

but is a major source of

fuel consumption.

High Shear Rate Viscometry

Viscosity Losses are caused by viscosity contributions of **VI Improvers** before and after shear degradation.

High Temperature, High Shear rate viscosity predicts how well the oil will protect engine bearings at very high shear rates.

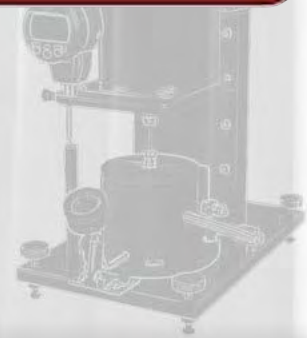
The **TBS Viscometer** has generated the most published information.

History of TBS HTHS Viscometer

In 1979, Exxon's Paramins division commissioned the development of a very high shear rate, relatively high temperature (HTHS) viscometer with commercial development rights to **Savant Inc.**

Tannas Co. was formed in 1981 to manufacturer and market **first commercially** available HTHS device… the rotational **TBS** Viscometer.

The **importance** of TBS became evident with ASTM studies correlating engine bearing oil-film thickness (BOFT) with high shear viscometry.



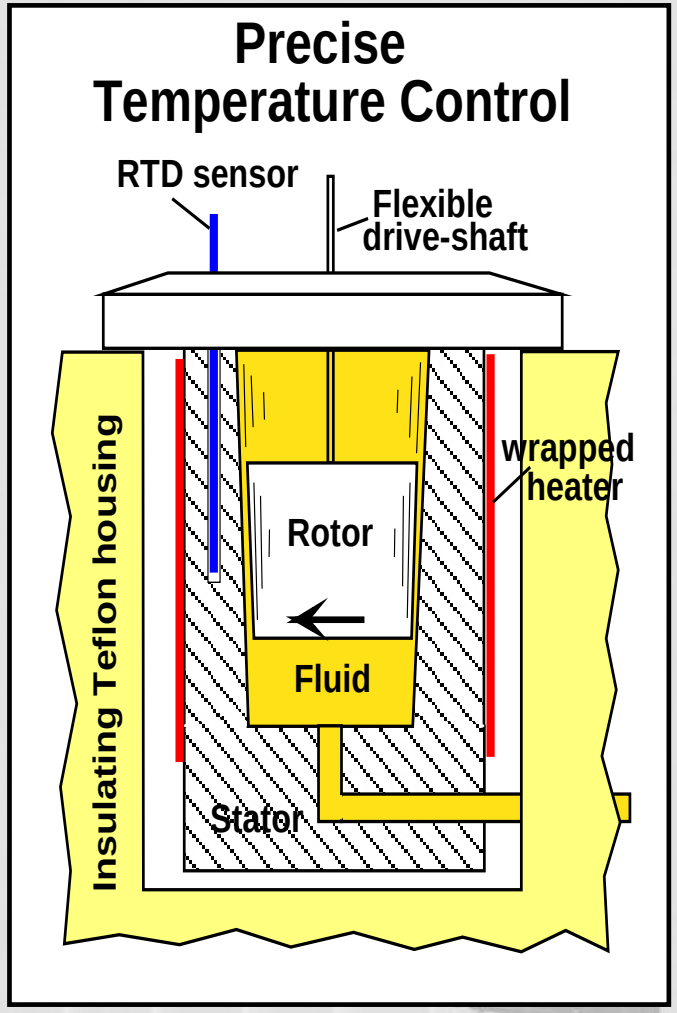
TBS Viscometer Basics

Tapered Rotor & Stator Geometry

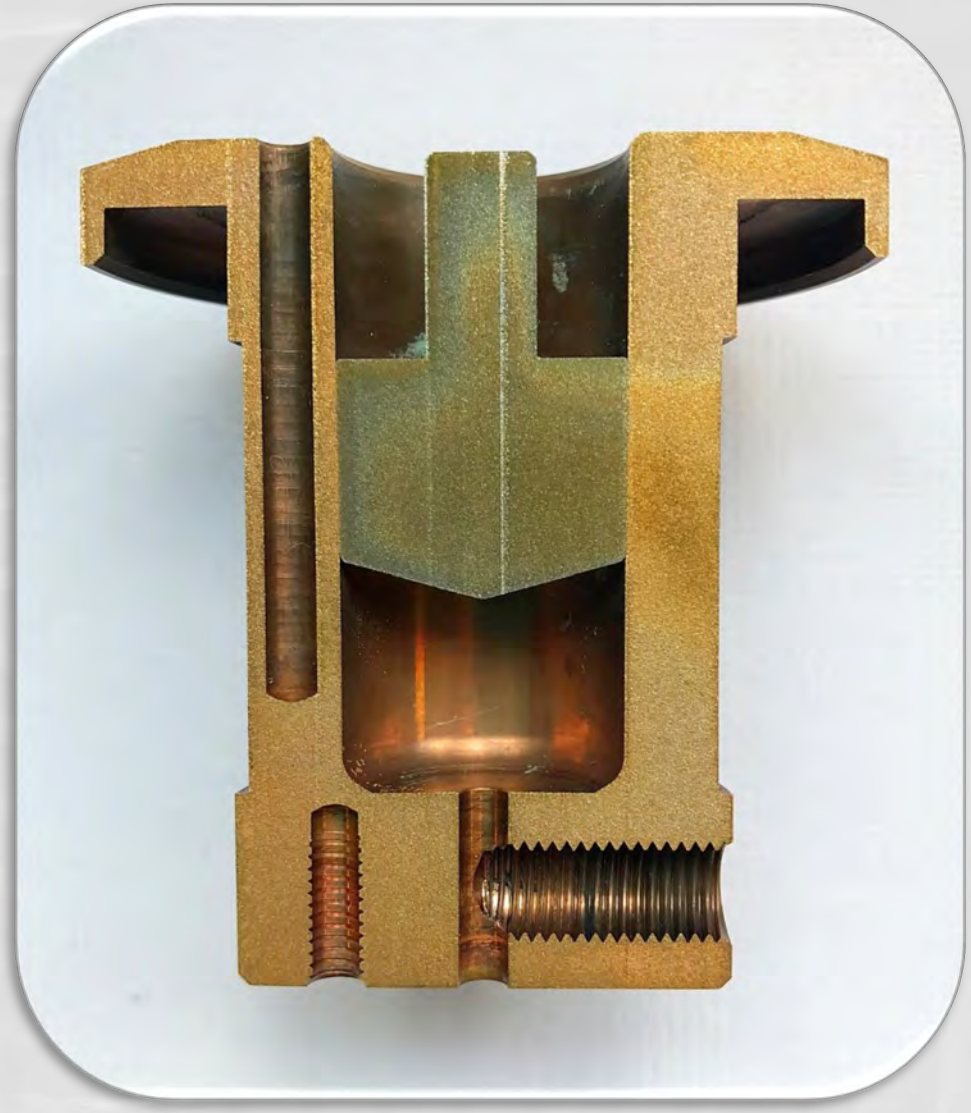
- High speed rotation
- 3.5 micron gap (~1/30 human hair)
- Change shear rate (rotor position & speed) during operation

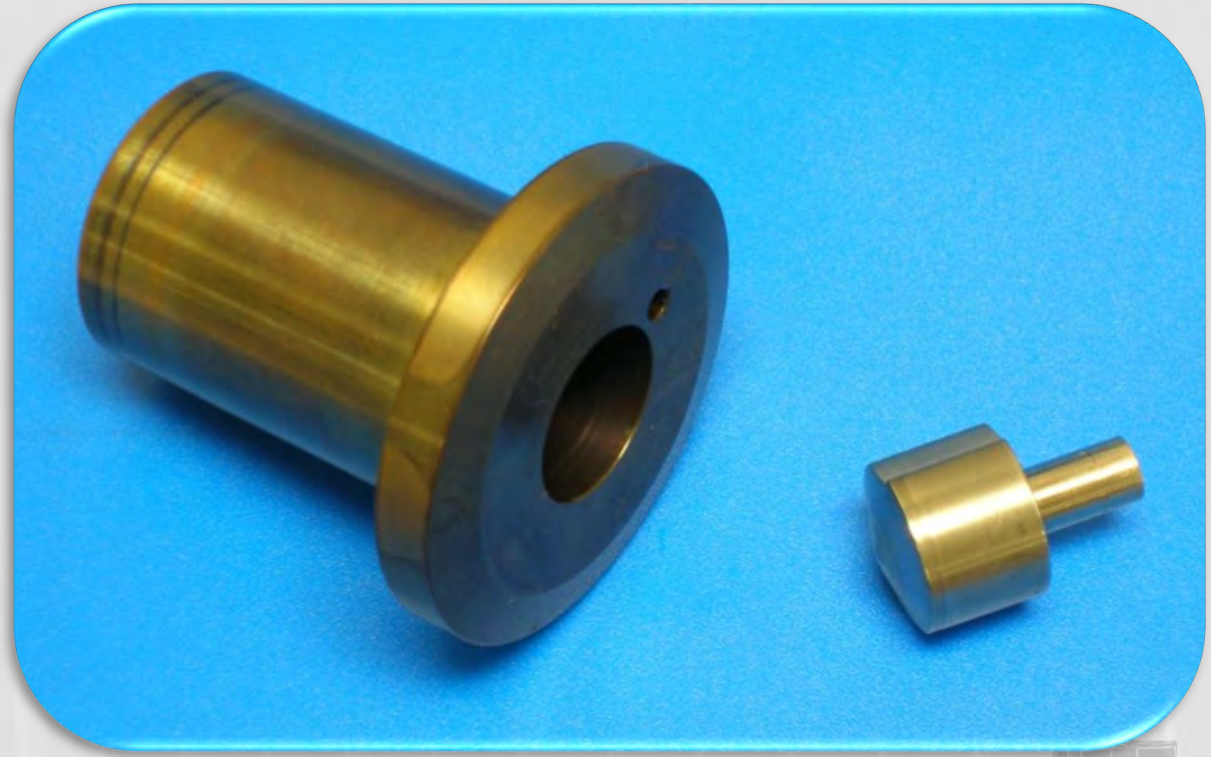
Electric Thin-Film Heater

- Constant temperature control
- 40°C to 200°C ±0.1°C
- Rapid temperature recovery between measurements

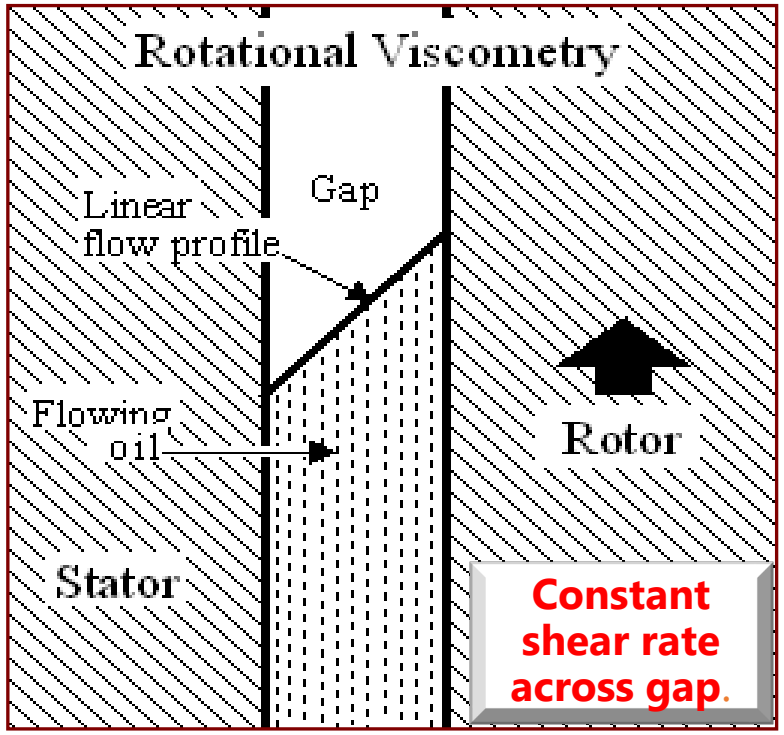


TBS Rotor & Stator



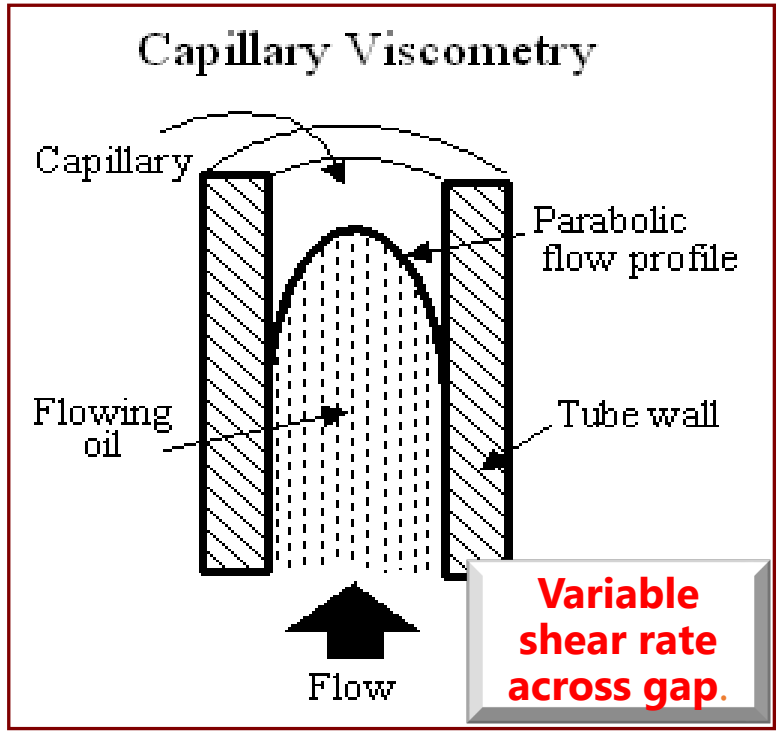


High Shear Testing Fundamentals



Rotational HTHS Viscometer

simulates engine bearing lubrication conditions

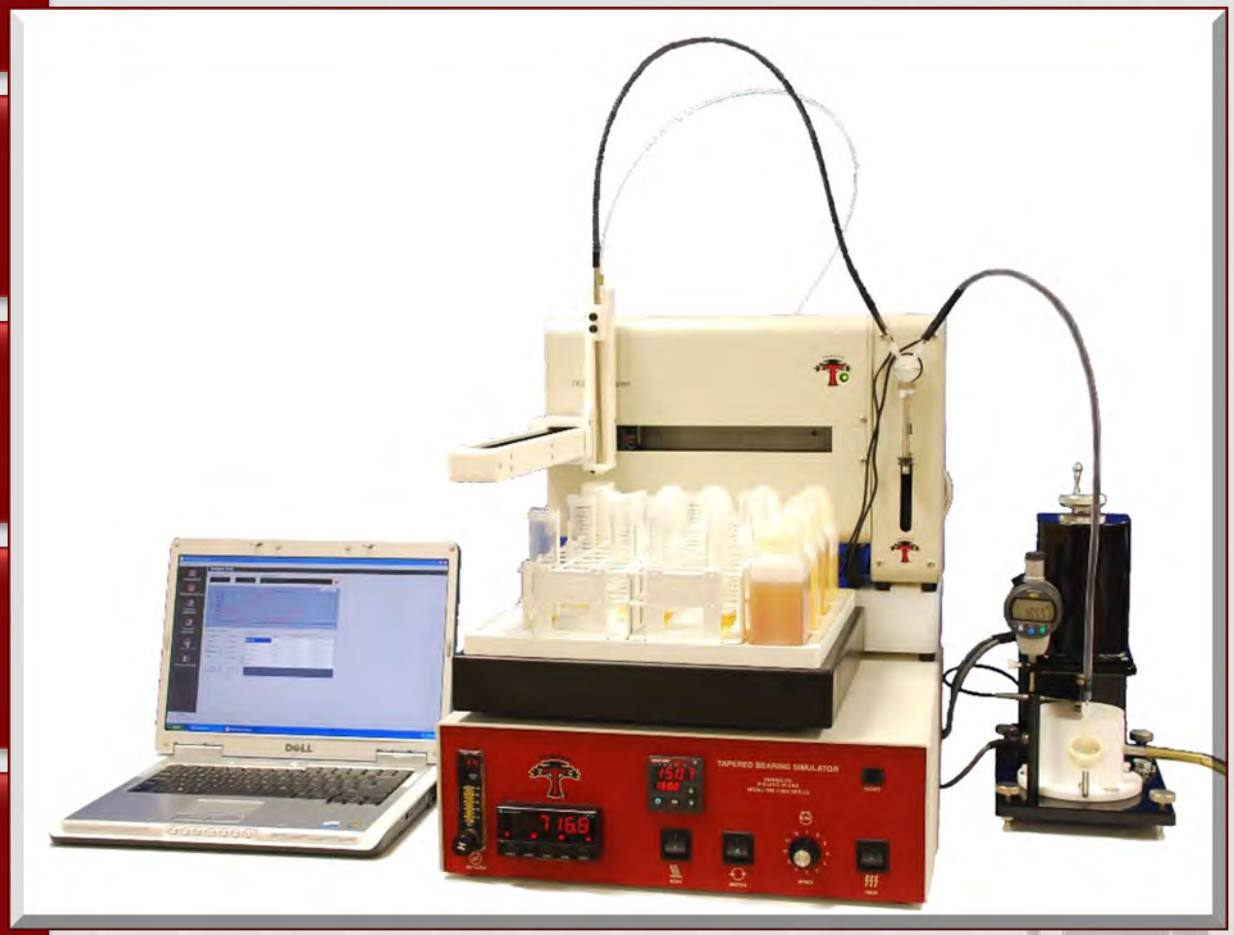


Capillary Viscometer

--does not simulate engine
--adds flow complexity with parabolic flow behavior

TBS 2100*E-F*

- 12 Speed Selections: **800-8,000 RPM**
- Shear rates: **50,000 to $7x10^6$ sec^{-1}**
- ***Chase Flush*** Sample Injection
- **42-position AutoSampler** with PC controlled calibrations, injections, etc.
- Only **'Absolute'** HTHS Viscometer



New

TBS 3000
HTHS Viscometer

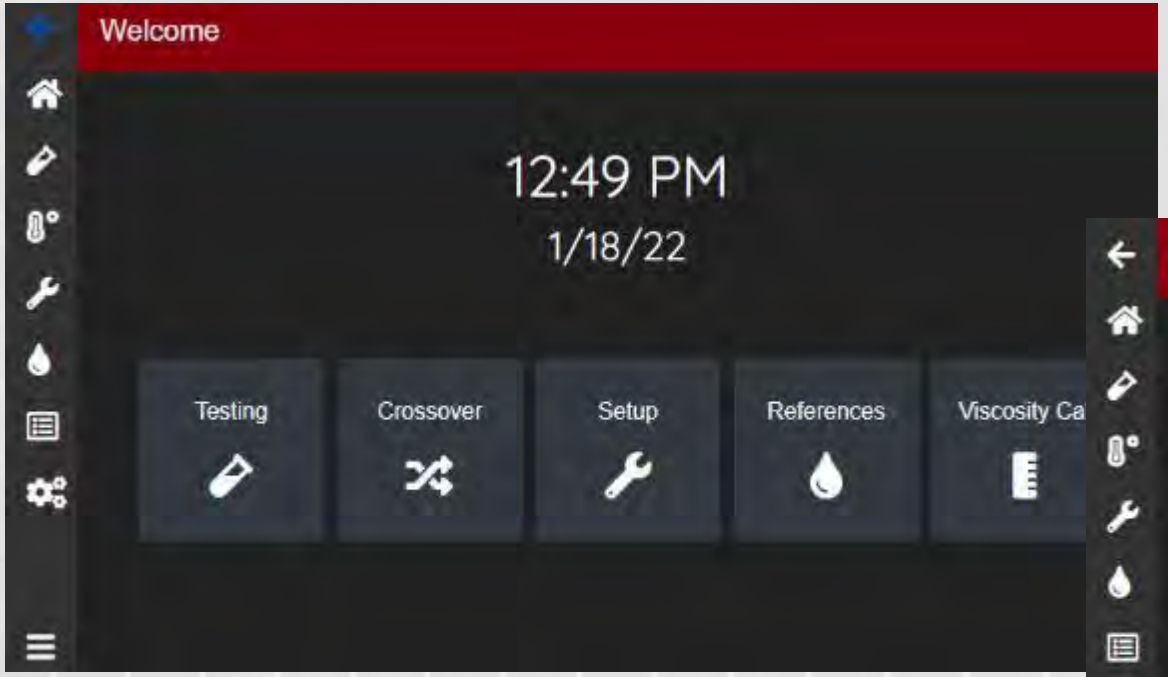
Customer feedback and advancing technology lead to new redesigned TBS model for 80°C, 100°C, and 150°C operation.

High Shear Rate Viscometry

- Dual-ring 40-position Autosampler
- Reduced sample volume per test (40 mL)
- 10 easily replaceable Cal. Oil Containers
- Remote Access via Ethernet/ Connection to LIMS

High Shear Rate Viscometry

HMI Touchscreen with TBS Touch Integrated Software.

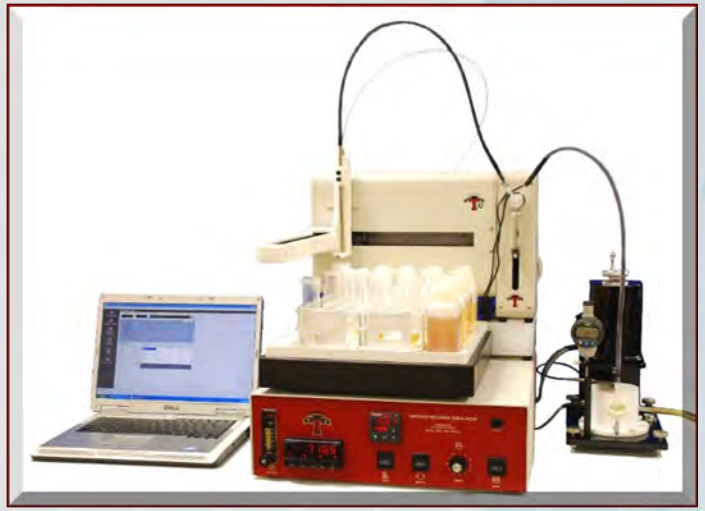


High Shear Rate Viscometry

- Integrated Custom Temperature Control System (80°C to 150°C)
- No computer, DAQ Board, reducing Cabling
- Auto Rubbing Contact
- Custom LED lighting based on operating conditions

TBS Viscometer Models

Semi-Auto TBS 2100*E-F*
Full-Auto w/Manual Injection



Full-Automation TBS 2100*E-F*

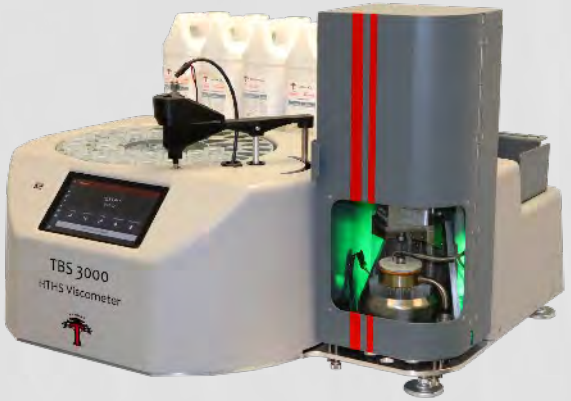
***New* TBS 3000**

TBS Industry Status

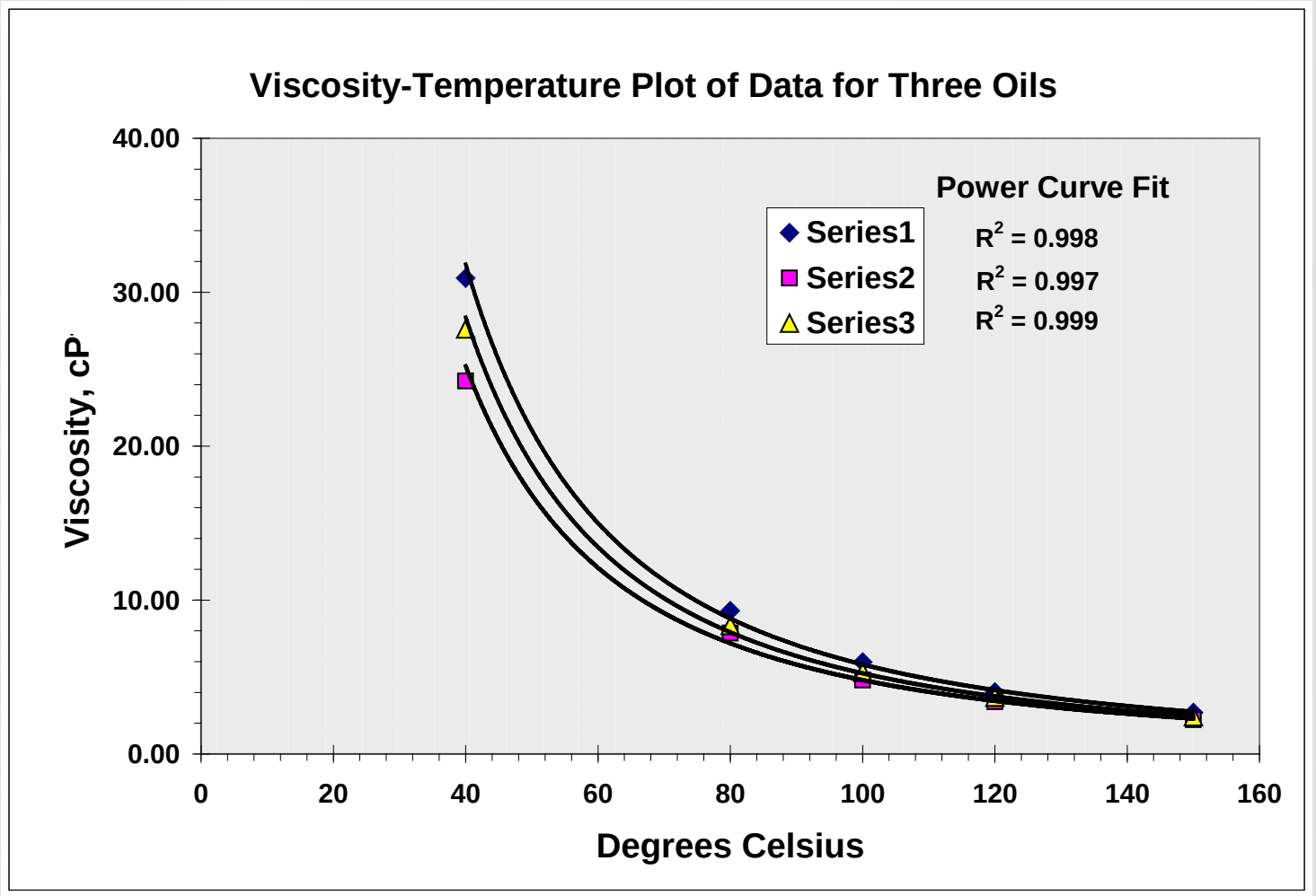
ASTM D4683	• 150°C at $1x10^6$ reciprocal seconds • JPI-5S-36-03 (Japanese)
ASTM D6616	• 100°C at $1x10^6$ reciprocal seconds • Required for railroad engine oils & dexos™ specs.
CEC L-036	• European method • 100°C and 150°C operation at $1x10^6$ reciprocal seconds • SH/T 0618
SAE J300	• Referee Method = D4683,150°C at $1x10^6$ sec -1 • ILSAC GF-1 to GF-6
GB-11121 **GB-11122**	• Chinese National Standards (Gas & Diesel) • via SAE J300 & SH/T 0618

Advanced TBS Applications

- Multi-Temperature Analysis
- Multi-Shear Rate Analysis
- Viscosity Loss Trapezoid (Profile) - VLT

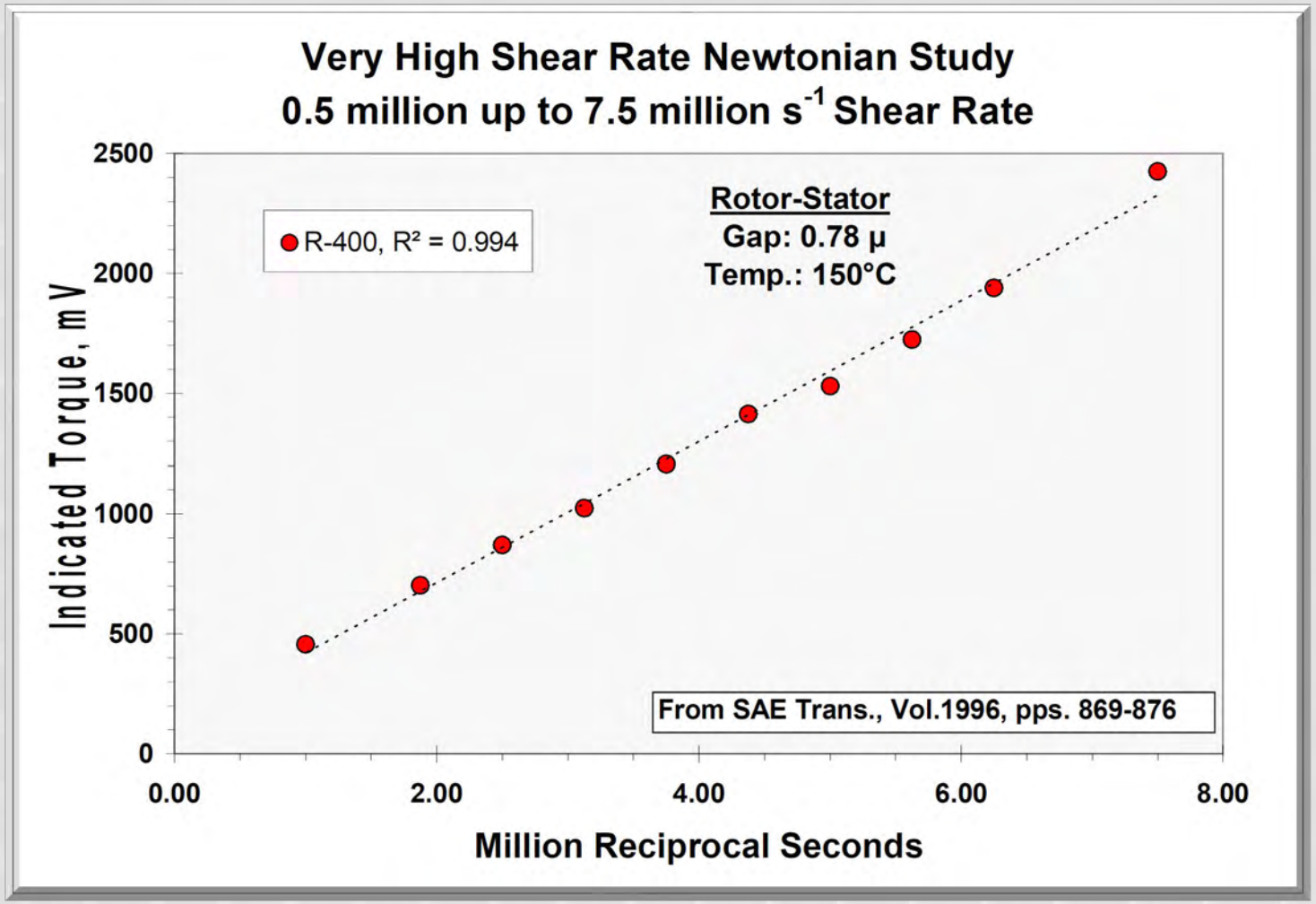


Multiple Temperature Viscometry



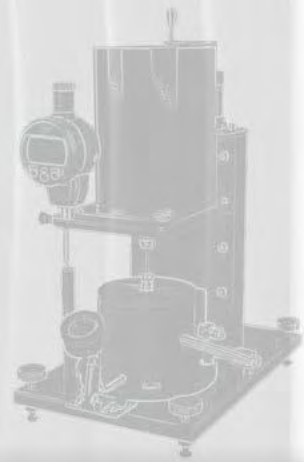
Smooth viscosity-temperature data over broad temperature range

Multiple Shear Rates



Broad shear rate range:

- Evaluates properties and types of VI Improvers based on their response to very high shear rates



Comments or Questions?

explore our new website
TannasKing.com

Oxidation Stability of Lubricating Oils

Quantum® Oxidation Tester

RPVOT

TFOUT

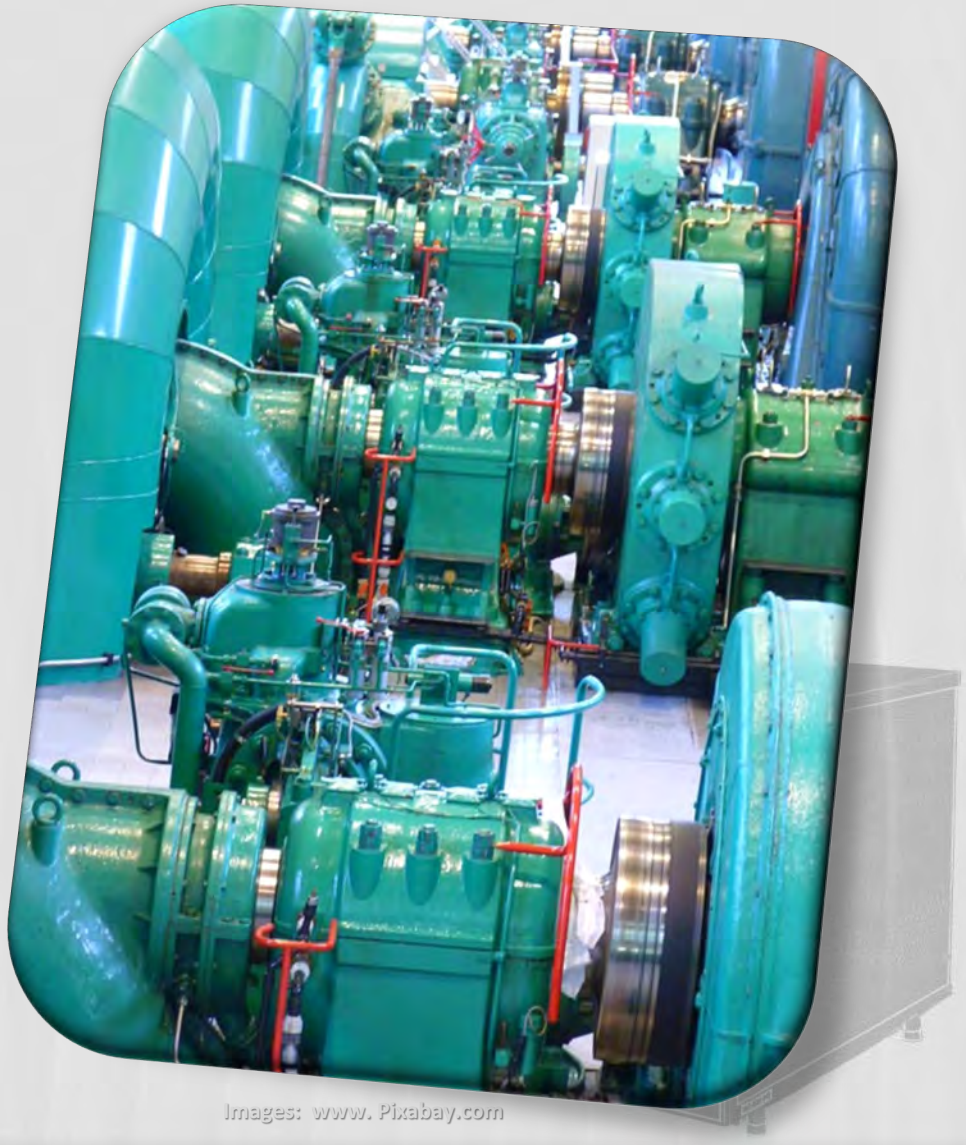
Grease D942

Advanced Applications

Introduction – RPVOT

(Rotating Pressure Vessel Oxidation Test)

- Originally designed to simply compare in-line samples of turbine oils.
- Later the test developed into testing fresh and in-service turbine and engine oils.
- This test eventually developed limits and is in several specifications.



Images: www.Pixabay.com

Introduction – RPVOT

(Rotating Pressure Vessel Oxidation Test)

The RPVOT per ASTM D2272 / IP229 is the primary tool used in the analysis and prediction of turbine oil life.

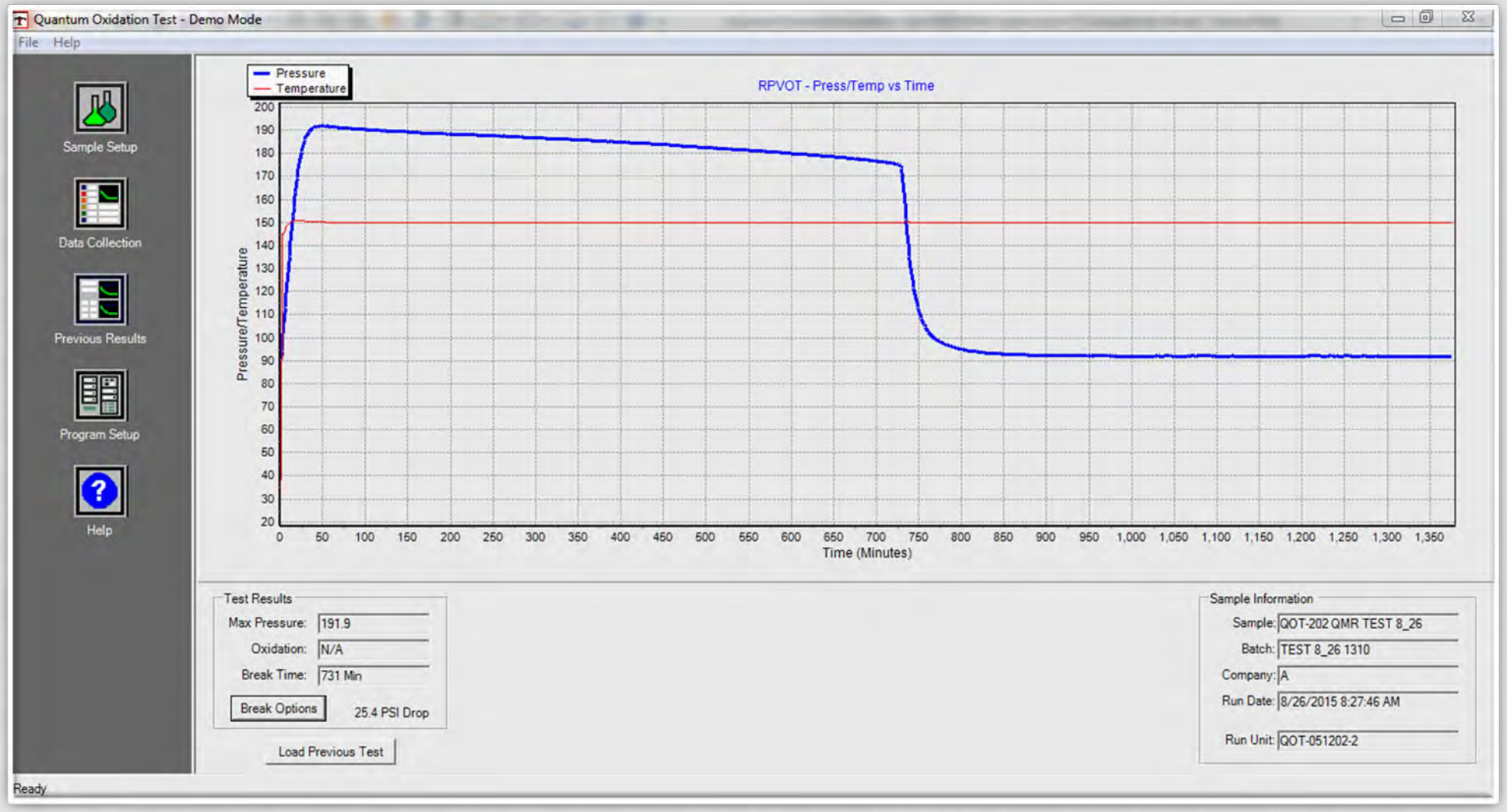
Parameters

- Sample Size: 50g
- Temperature: 150C
- Initial O_2 Pressure: 90 psi
- Pressure increases to ~190 psi
- Copper Catalyst Coil
- 10 mL of water (oil sample)
- Rotational Speed: 100 ±5 rpm
- Rotational Angle: 30°
- Test monitored by Computer or Strip Chart

- Pressure drop of 25.4 psi signals end of test (Break-point).

Introduction – RPVOT

(Rotating Pressure Vessel Oxidation Test)



Introduction - RPVOT

RPVOT Liquid baths utilize a high-temperature oil bath (often silicone)

Silicone vapors are a health hazard and can be very expensive to replace

RPVOT liquid baths use multiple pressure vessels (requiring considerable hood space).

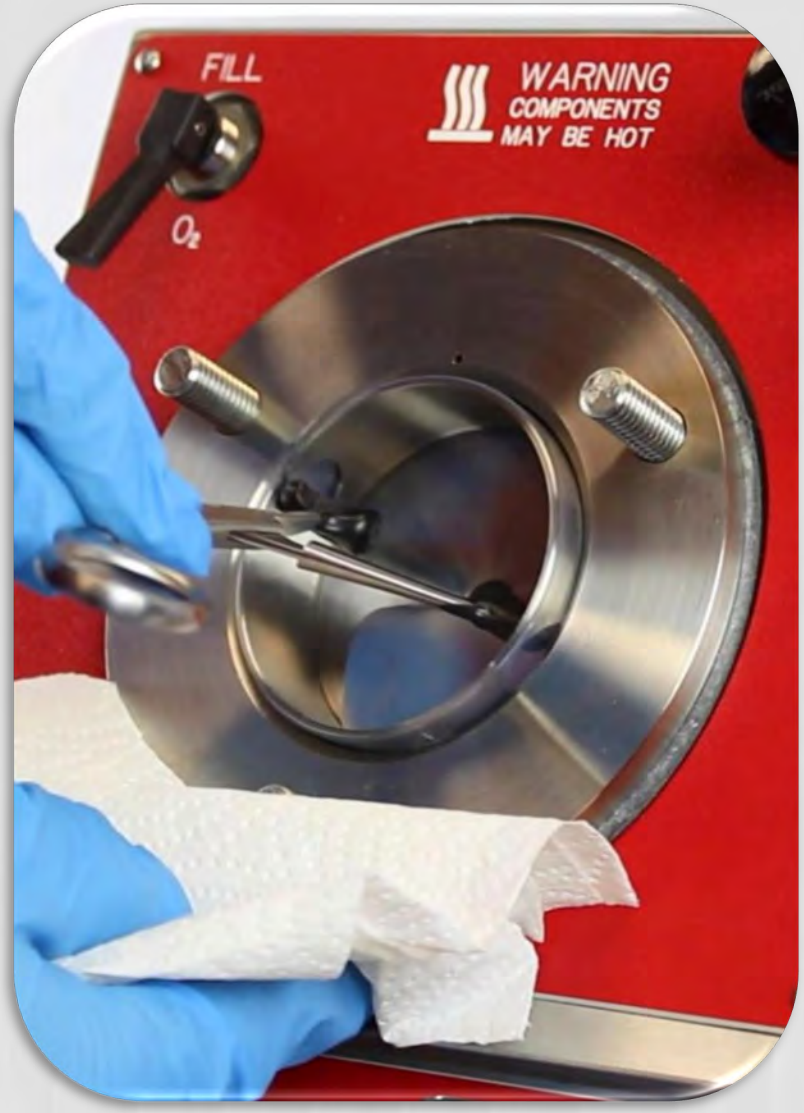
RPVOT liquid baths ➔ messy, smelly, & time-consuming to replace & repair

Quantum® RPVOT Oxidation Tester

Developed in response to customer needs for safe and efficient means of running RPVOT tests.

Single position 'Dry Cylinder' heated stainless steel oxidation vessel with pressure transducer.

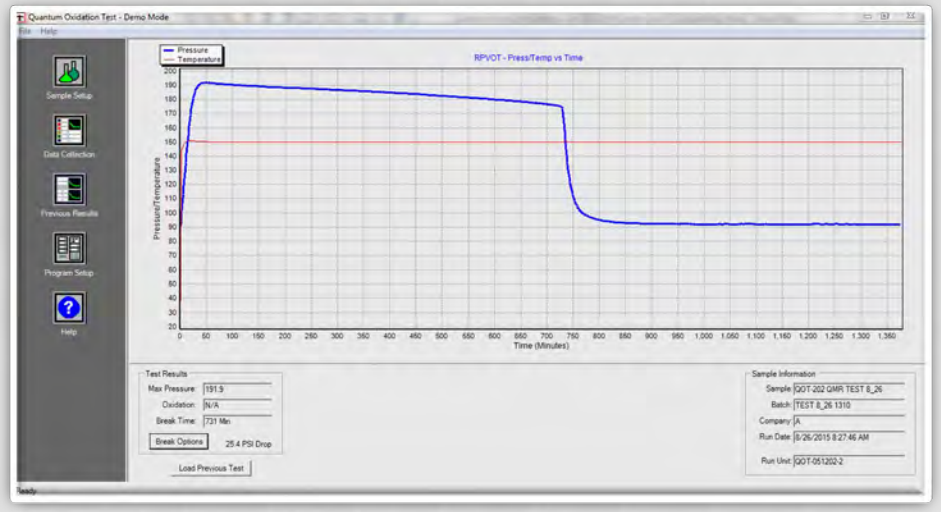
Convenient front-loading of samples, oxygen charge & release valves. *(No Hood Requirement)*



Quantum® RPVOT Oxidation Tester

Designed for either multiple (side-by-side) bench-top alignment or "stand-alone" operation

Automation Package capable of monitoring and recording up to four (4) *Quantum*® *units independently.*



Grease Oxidation Testing (D942)

Grease Oxidation test D942 is used with a special tipping Rack.

This Rack allows the unit to sit at 90° in order to load the Grease Tray.

Quantum® Industry Status

ASTM D2272	• **IP229; SH/T 0193** • **RPVOT -- Oxidation stability of Turbine Oils**
ASTM D2112	• **Oxygen Stability of inhibited mineral insulating oils** • 140°C @ 90 PSI oxygen & all other D2272 parameters
ASTM D4742	• **TFOUT -- Oxygen Stability of engine oils** • 160°C @ 90 PSI oxygen • TFOUT Catalyst Package (Metal & Fuel Catalyst, Water)
ASTM D942	• **Oxygen Stability of Grease** • 99°C @110 PSI oxygen • 20g of grease in 5 glass dishes (4g per dish)

Advanced *Quantum*® Applications

Sample Temperature Monitoring

Sample Extraction & Injection

Sample Extraction/Injection Device

New

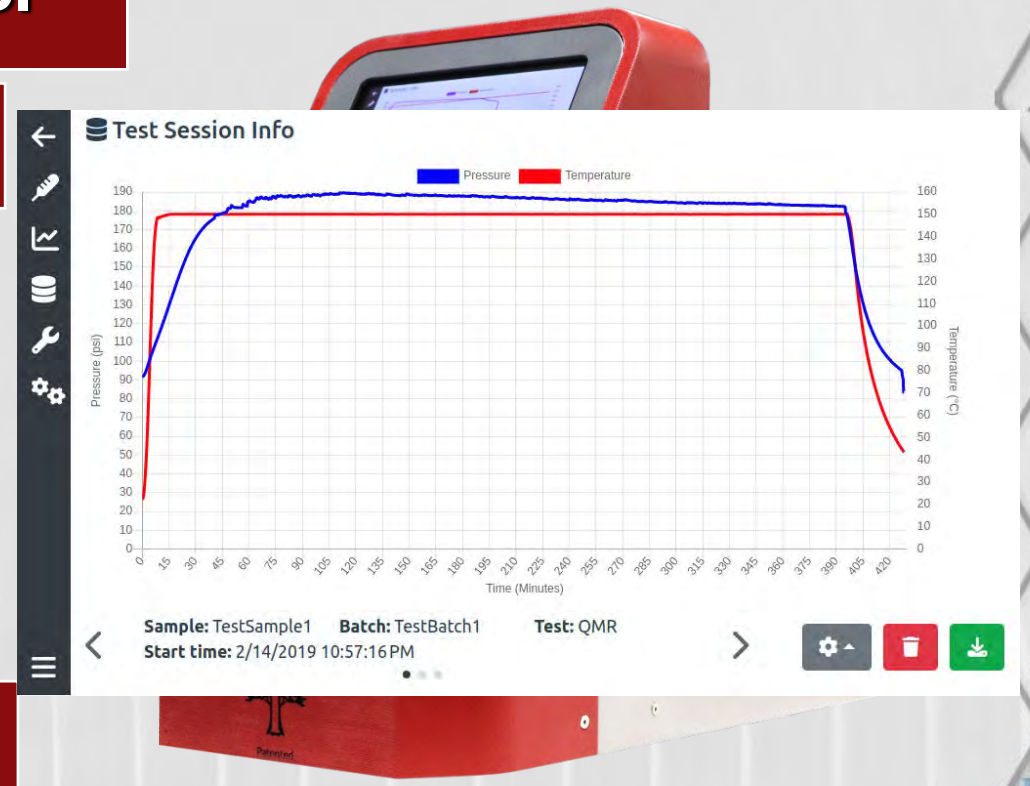
Available NOW!

Quantum® Pro

Oxidation Stability of Lubricating Oils

New Quantum® Pro

- Automated Fill and Purge Control
- Integrated Water Calibration
- Live Graph of Test Data
- Integrated Sample Temperature Probe
- Lower Power Usage (20 - 30%)
- USB Ports to Transfer Records to Flash Drive or PC
- Automated Test Report Submission Over Ethernet



Comments or Questions?

explore our new website
TannasKing.com

Foam Tendency & Stability of Lubricating Oils

Tannas Foam *Air* Bath

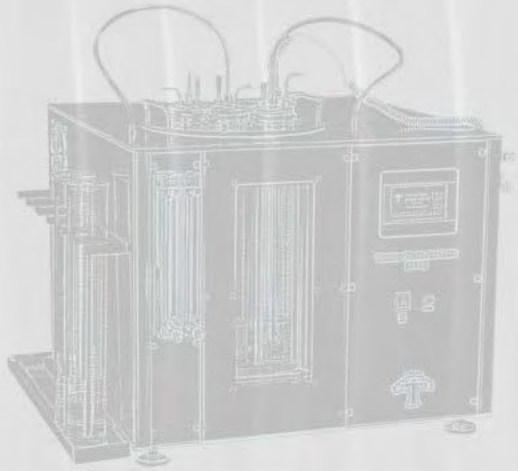
TFAB

Introduction

Because foam is mostly entrained air, and air is a poor heat conductor, foam interferes with the fluids' cooling performance. Moreover, air is a poor lubricant.

Tendency of oils to foam can cause inadequate lubrication, cavitation, and overflow loss of lubricant, resulting in mechanical failure.

Antifoaming agents are used to reduce and control the amount of foam, and this foam test is a gauge to determine the effectiveness of the additive.



Tannas Foam *Air* Bath

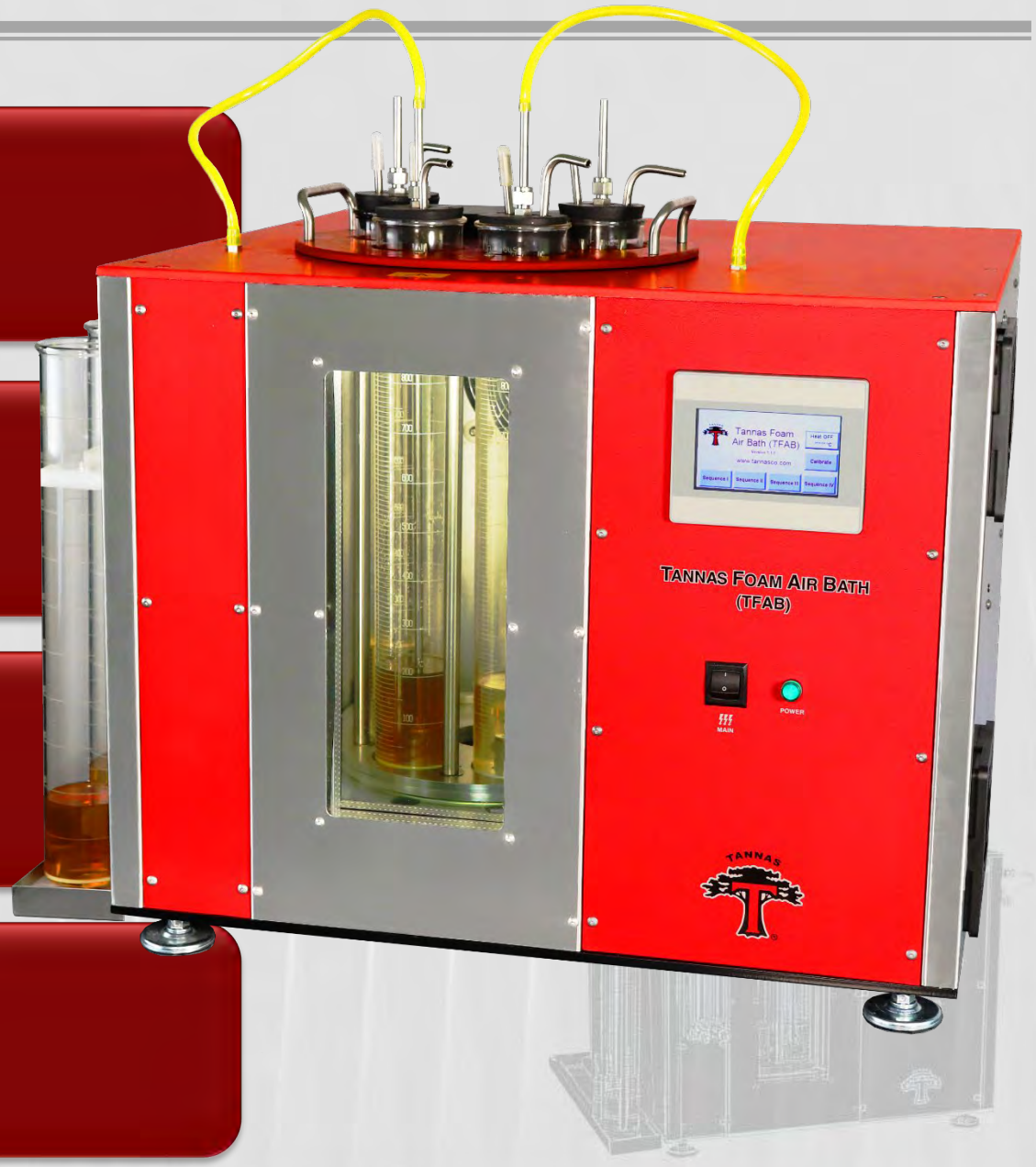
Bench-top AIR BATH – safe & clean alternative to messy liquid baths

DIRECT DRIVE motor for quiet, maintenance-free operation

- 6-sample load capacity
- Touchscreen controller

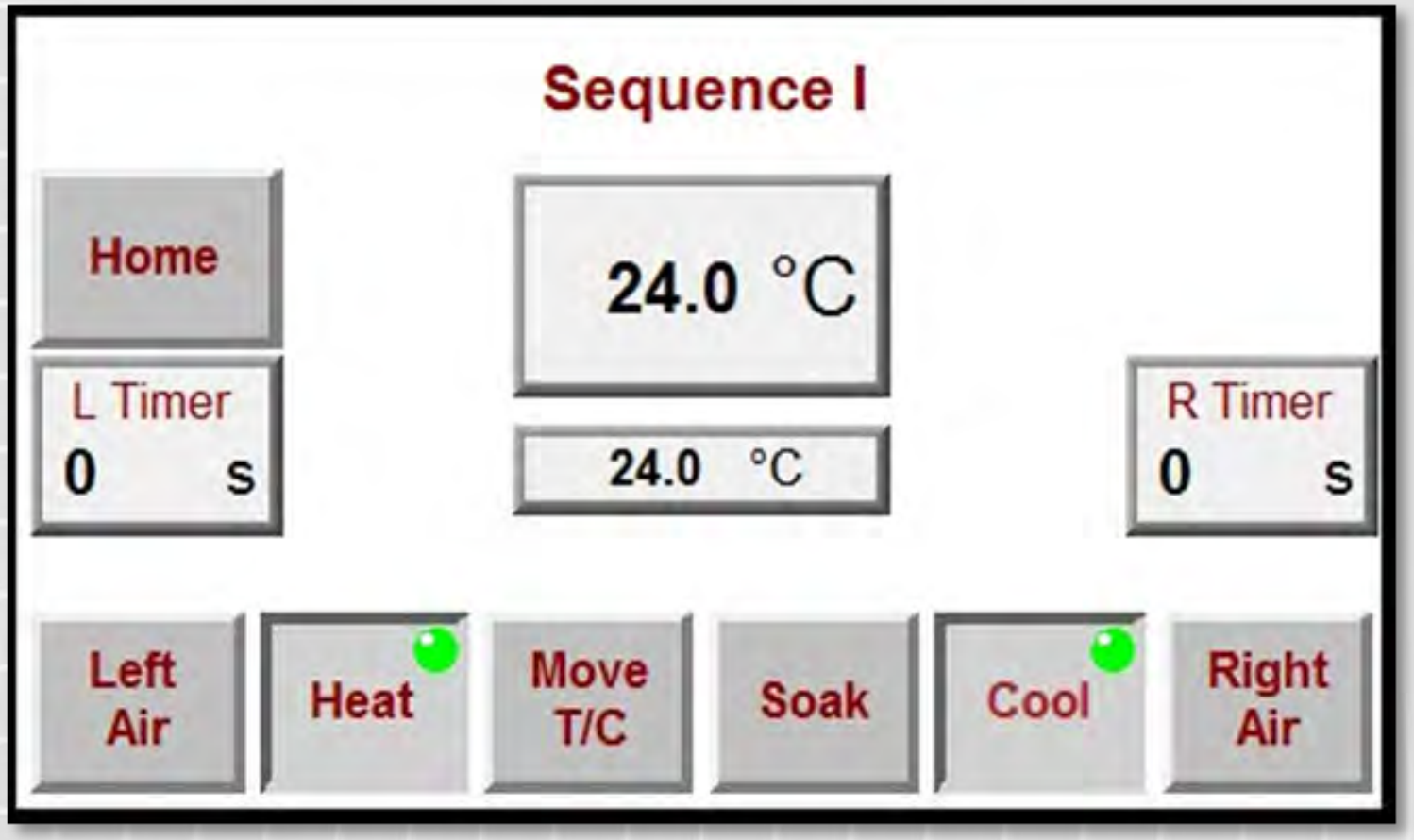
Tight Temperature Control

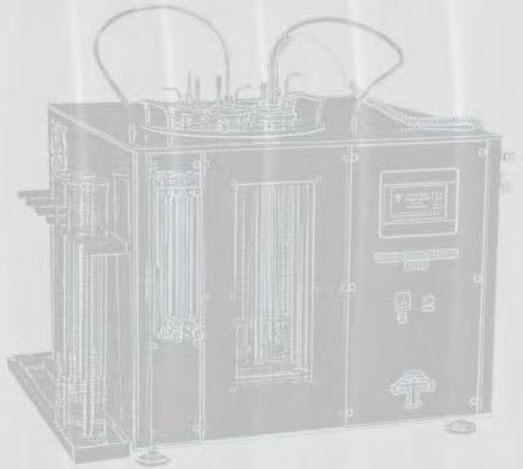
Cooling Connections to water supply



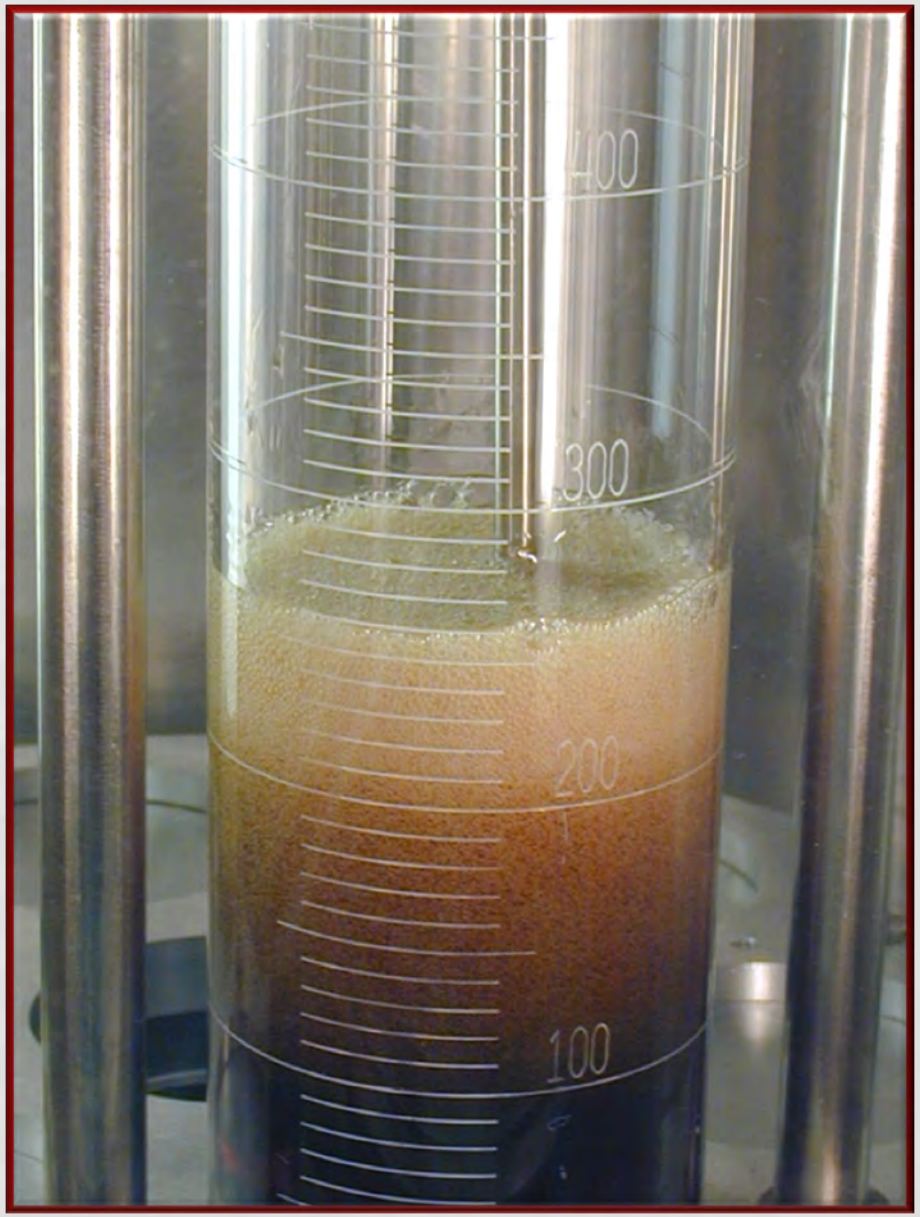
TFAB Overview

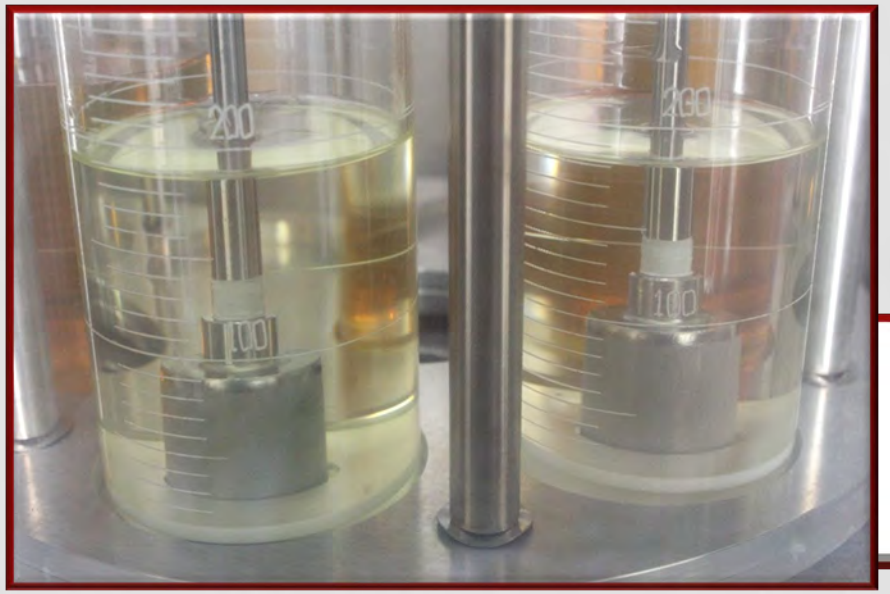
Touchscreen Controller





TFAB Parts





Diffuser Stones w/Centering Ring

Certificate of Verification

Foam Gas Diffuser

Diffuser Type: Cylindrical, Stainless Steel

Serial #: 16-120

Critical Measurements

Maximum Pore Diameter: 26.19 micrometers

421 mm of water

Acceptance Criteria:
(Not greater than 80 micrometers)

Acceptance Date
2016.8.24

- *After initial use, re-verification should be performed every 3 months or 100 tests.*
- *Verification testing can be performed at Tannas Co.*
- *Call at 989-496-2309.*

Permeability: 4640 mL air/min @ 250 mm water

Acceptance Criteria:
(3000 to 6000 mL of air/minute)

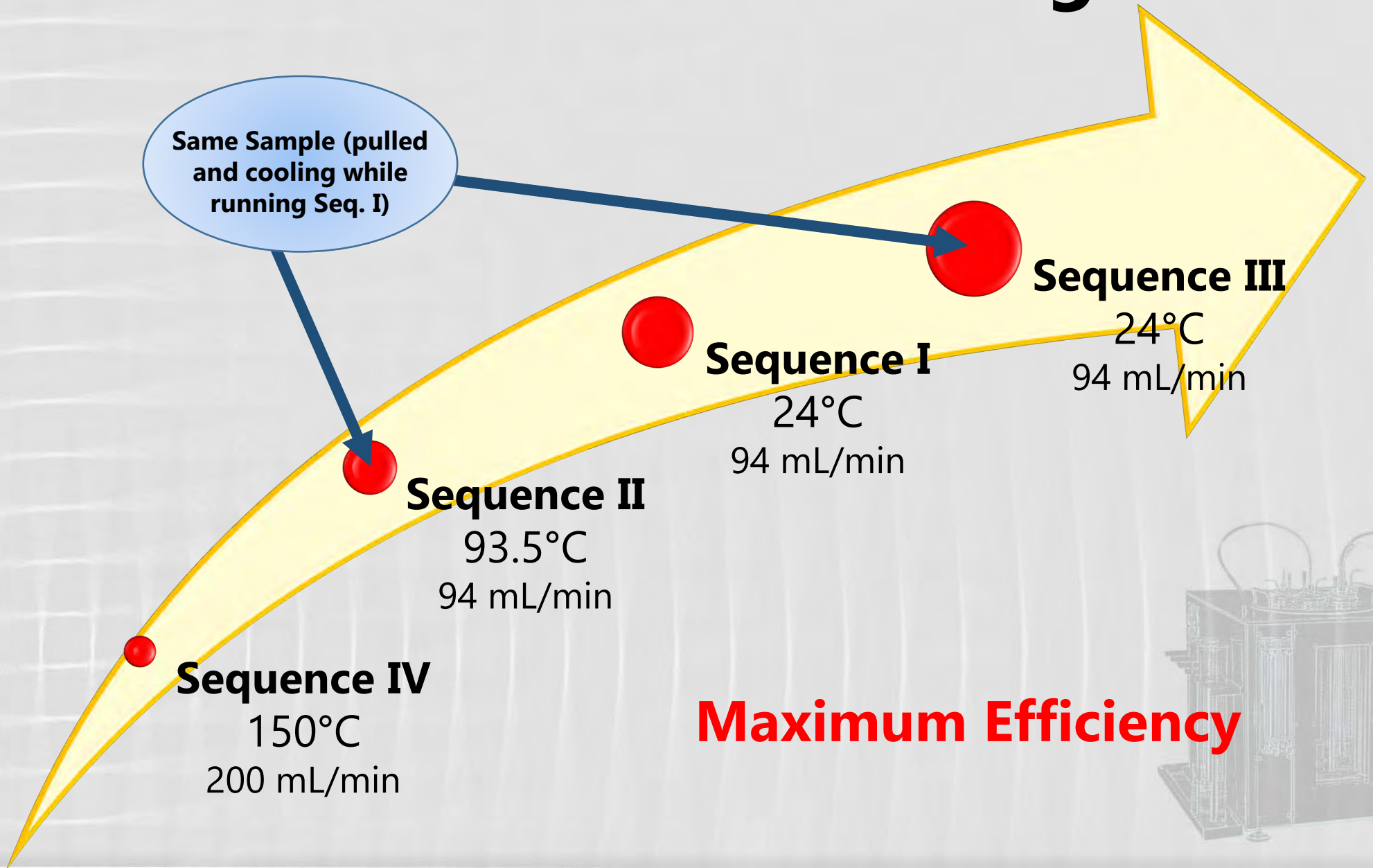
Calibration Equipment:
Digital Manometer
Digital Precision Flowmeter, Humonics Model 730

Tannas Co.
Quality Control

QA 03

Diffuser Stone with Certificate

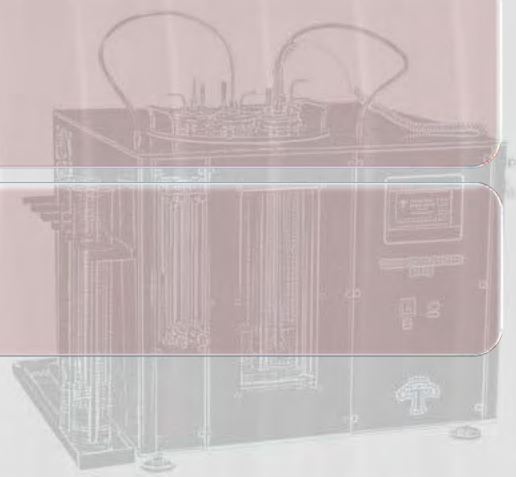
Recommended TFAB Testing Order



Maximum Efficiency

TFAB Industry Status

ASTM D892 / IP146	• Foaming Characteristics of Lubricating Oils • Sequence I, II, III (24C & 93.5C)
ASTM D6082	• High Temperature Foaming Characteristics of Lubricating Oils • Sequence IV (150C)
ASTM D1881 & D7840	• Foaming Tendencies of Engine Coolants • Foaming Tendencies of Non-Aqueous Engine Coolants
Chinese Standard	• GB/T 12579 = D892 • SH/T 0722 = D6082 • SH/T 0066 = D1881
ILSAC GF specs	• Many other industry specifications



Comments or Questions?

explore our new website
TannasKing.com

Engine Oil Volatility…

w/Expanded Capabilities

Tannas Noack S2®

Noack Volatility Test

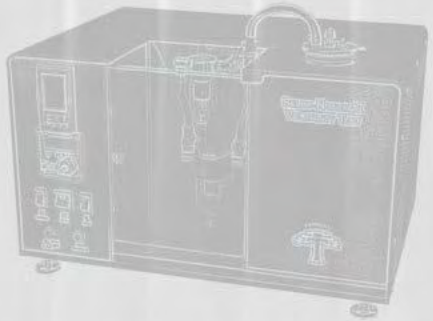
Why Study Evaporation Loss?

Evaporation loss impacts **ENGINE LUBRICATION**

Where high temperatures occur, **OILS EVAPORATE**

Evaporation leads to **OIL CONSUMPTION**

Evaporation leads to **CHANGES in OIL PROPERTIES**



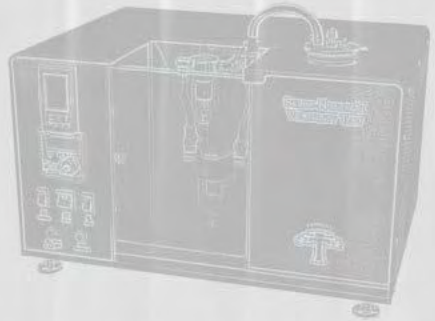
Noack History

Oil formulators have long-since recognized the value of determining the volatility of automotive lubricants.

However, the only test considered sufficiently meaningful was the Noack test that had been developed by Dr. K. Noack in the 1930s.

This test used Wood's Metal as a heat-transfer medium – a toxic substance which had carcinogenic properties **– a seriously negative factor.**

Despite this, in the mid-1990s it became an ASTM Test Method and thus a standard in choosing base stocks and finished lubricants.



History

During this timeframe, Savant Laboratories in cooperation with Tannas Co. developed an alternative Noack volatility approach.

A new instrument that eliminated the toxic Wood's Metal heating and also collected the volatiles was conceived and patented.

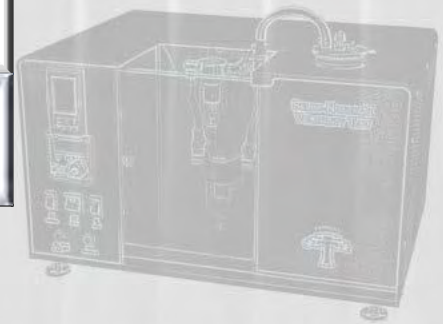
In addition to gathering Noack volatility data needed for industry specs., this innovation permitted study of the volatilized oil and comparison to the original and residual oil (with some interesting and important findings).

The original Selby-Noack™ is ASTM D5800C and the new Tannas Noack S2® is included as D5800D (which matches Procedure B results) and CEC L-40.

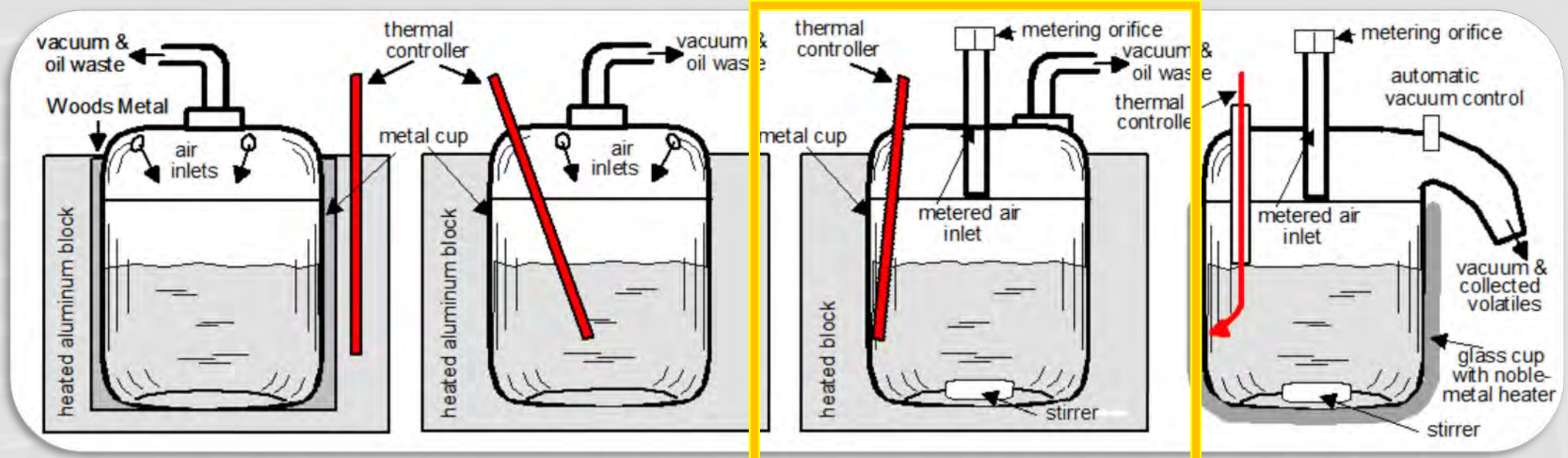
Noack Volatility Test

ASTM D5800

PARAMETER	VALUE
Sample Size	65 grams
Operating Temperature	250°C
Vacuum Control	20 mm of H_2O
Test Time	1 Hour
Result	% weight difference



Noack D5800 Volatility Test



Wood's Metal Procedure A

Procedure B

Noack S2® (Procedure D)

Selby-Noack Procedure C

Tannas Noack S2® → Included as D5800 Procedure D

(matches Procedure B results)

Tannas Noack S2® Volatility Test

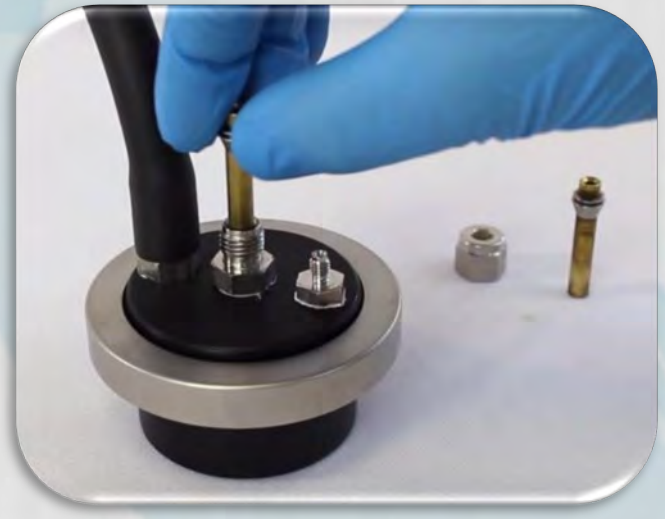
Redesigned for easier operation & improved precision

- ➔ Metal Reaction Vessel
- ➔ Quick Connect Fittings

Interchangeable Orifice Tubes to ‘Tune’/calibrate to lab environment

Non-Wood’s Metal with same D5800 test parameters

Collects volatilized materials for PEI

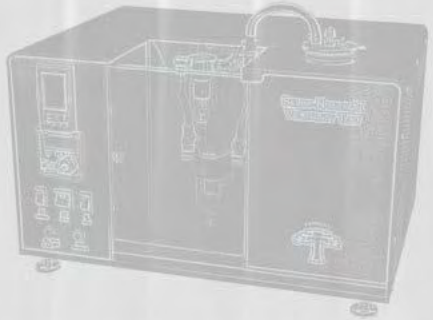


Volatilized Material Analysis

This instrumental approach to the Noack volatility test permitted collection of nearly all volatilized material. Used to calculate the Phosphorus Emission Index (PEI). Characterizes phosphorus emission potential into exhaust stream.

Clean Coalescing Filter

After Test



Tannas Noack S2® – Parts

Reaction Vessel Assembly

Tannas Noack Industry Status

ASTM D5800	• Procedures A & C correlate (Annex). Procedure B & D correlate – and to Procedures A and C with correction factors. • SH/T 0059 Chinese Standard
API / PC-11	• SJ | SL | SM | SN | SP Categories • 15% Spec limit
ILSAC	• GF-2, GF-3, GF-4, GF-5+, GF-6 (A&B) Specifications • 15% Spec limit (Proc. B or D only)
CEC L-040	• Fully accepted and included in early 2022.
dexos™	• Gen 1 & 2 = 13.0% limit (avg. of 3 runs) • Gen 3 = 12.5% limit (avg. of 3 runs)

Expanded Capabilities

Historically, 250°C was intended to expedite the test. Recently, industry members are realizing this temperature may be too high with questionable correlation to engine oil consumption for modern engines and EV powertrains.

Industry partners have been working with Savant Labs to test at a variety of temperatures and times.

Recent data has shown that 150°C is the average temperature for critical engine areas.

OEMs are considering Noack testing at 150°C @ 12 hr. run time for future specifications.

Comments or Questions?

explore our new website
TannasKing.com

Low Temperature Behavior of Engine Oils

Pumpability

Gelation Tendencies

ASTM D5133
SH/T 0732

ASTM D4684
SH/T 0562

Low Temperature Behavior

Low-temperature

STARTABILITY

Modern Engine designs, fuel injection

is a problem of the

PAST

modern **HYDRO-TREATED BASE OILS**

+

+

the need for special **POUR POINT DEPRESSANTS**

VI IMPROVERS

Controlling **PUMPABILITY** at **LOW SHEAR STRESS** is now a challenging area of **oil** & **additive** development

Low Temperature Pumpability Failures

Flow-limited behavior

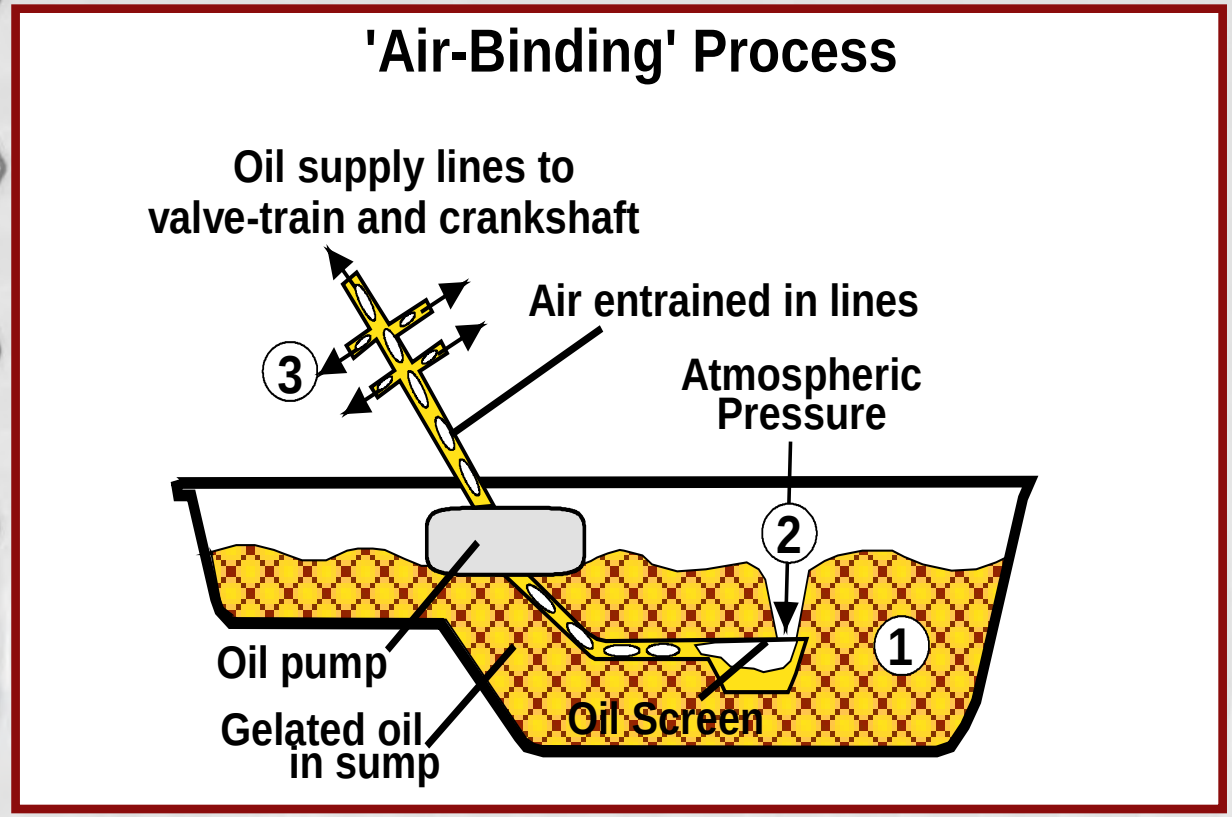
- Too viscous to pump (milk-shake w/straw)
- An inconvenience
- Viscosity reduced by increasing temperatures

Air-binding behavior

- Combination of gelation and viscous flow
- Structure (component nucleation/crystallization)
- Can occur at any low-temperature
- Catastrophic to operating engine

Air-Binding Behavior

Low-Temperature Engine Tests



When oil **GELATES** in the sump,

the **OIL PUMP** draws a **core** of structured oil

forming an **AIR TUBE**

The **OIL PUMP** becomes

AIR-BOUND

causing **ENGINE FAILURE**

Low Temperature Pumpability

ASTM D3829

1979

- Mini-Rotary Viscometer (16hr cooling)
- Correlated to cold-room engine tests (BPT)
- Thought D3829 could predict low-temp pumpability of engine oils

1980-81

- Massive field failures in Europe & North America
- D3829 not correlative to natural cooling cycles

Low Temperature Pumpability

- Imitated field conditions
- Exact cooling condition to pre-set the gelated oil structure

Special Cold-Room Engine Tests

- Became ASTM D4684
- SAE J300 | eventually ILSAC GF series
- TP-1 conditions the sample using a variable programmed cool rate (45+hrs)

MRV TP-1

King MRV TP-1

Direct-refrigeration system (no circulating bath) (Procedure A of D4684)

Tight temperature control (±0.1°C)

(10) Sample Capacity with Removable test cells

New rotor design & cooling air flow (limits water & ice interference)

ASTM D4684 & **D6821** (Driveline) **and D6896** (used Diesel Oils); **SH/T 0562**

Scanning Brookfield Technique (D5133)

1982

SCANNING BROOKFIELD TECHNIQUE (SBT®)

- First pumpability bench test to correlate to field failures
- Forced oils to gelate (if they would)

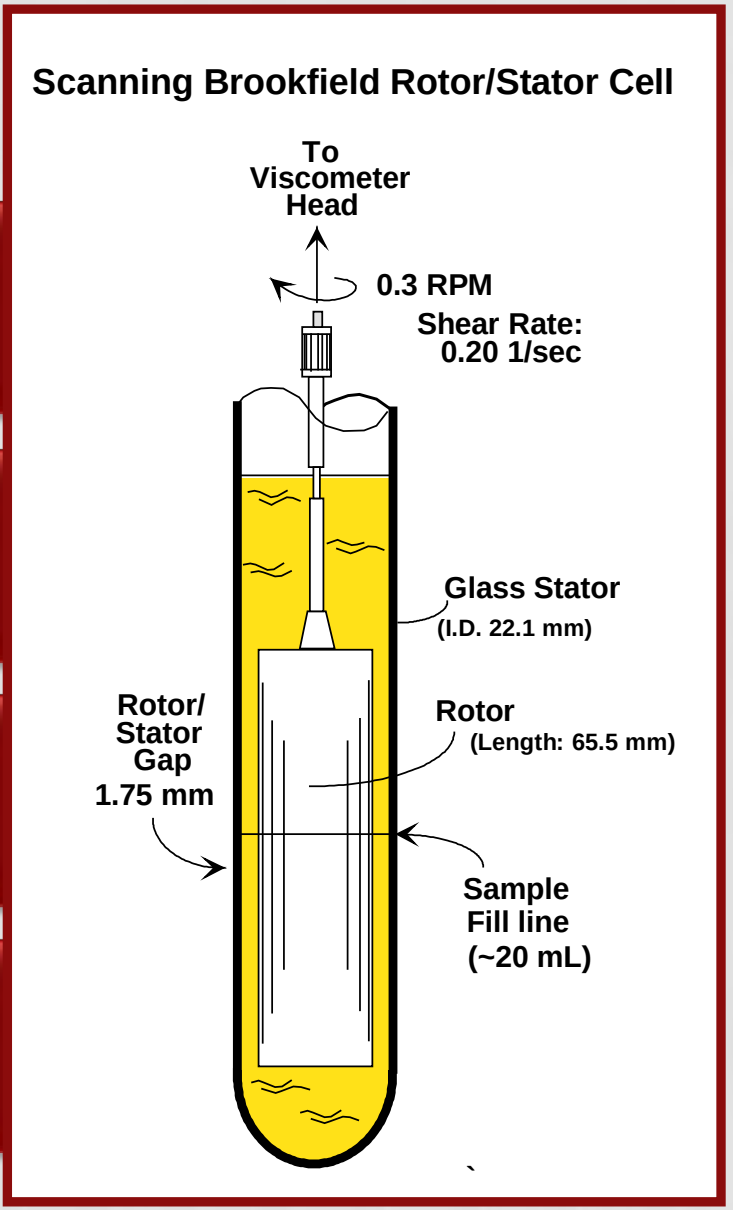
The SBT® Provided:

- **Precise, gradual cooling**
- **Constant laminar motion** (0.3 rpm)
- **Continuous viscosity measurement**
- **Revealed onset and degree of oil Structure-building**

SBT®

ASTM D5133

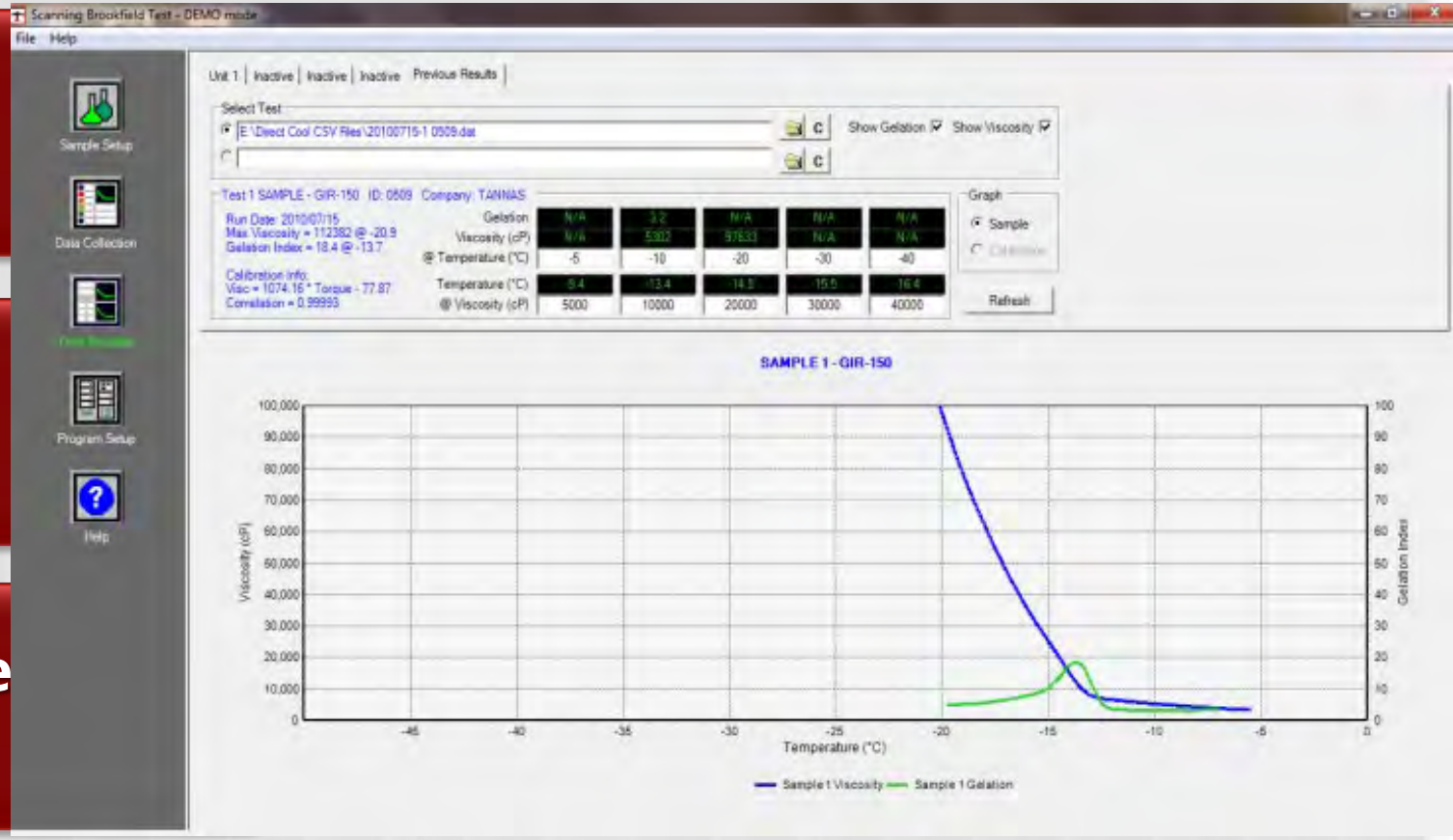
- Slow cooling profile → 1°C/hour (-5 to -40°C)
- Precision made titanium rotor & glass stator
- Specially modified digital viscometer
- Constant recording of sample viscosity



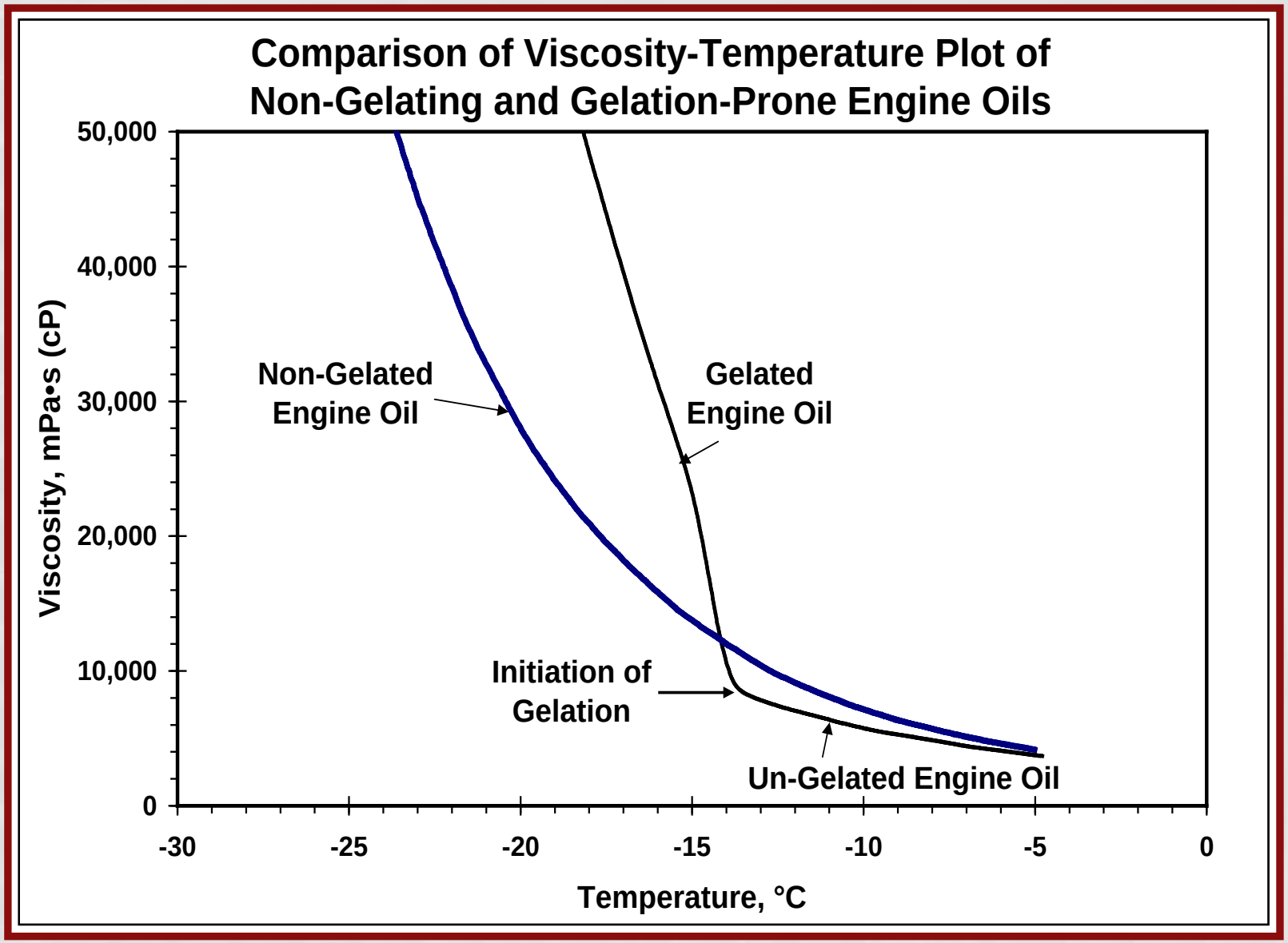
SBT®

ASTM D5133

- **Automation program**
- **Real-time display of data**
- **Program prints composite plots of results**



SBT® (D5133 & D7110)

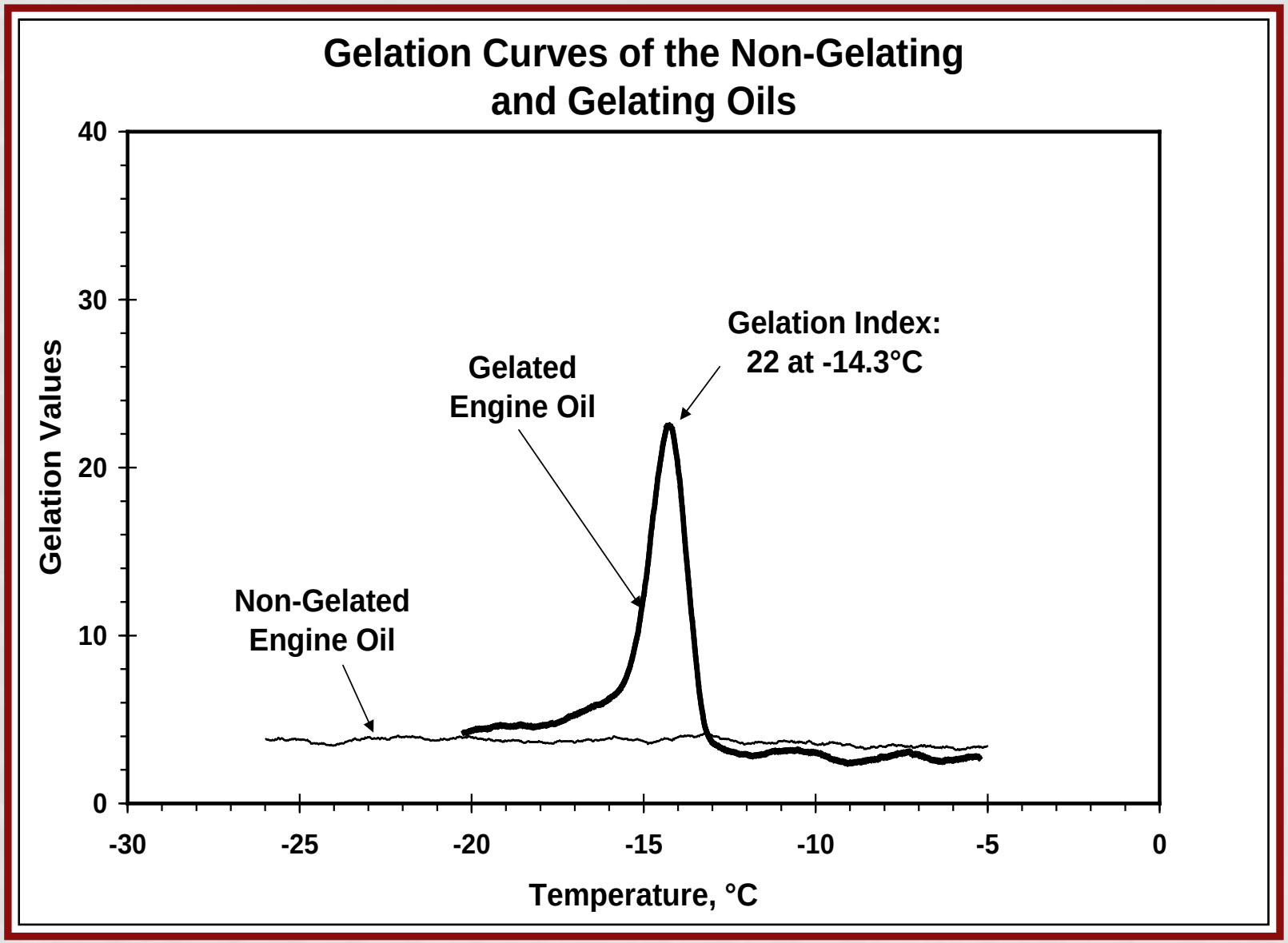


Flow-Limited
viscosity related
behavior

+

Exposes more
subtle
air-binding
tendencies
of field-failing oils.

SBT® (D5133 & D7110)



Obtain the

Gelation Index*

to measure the degree of gelation.

* The first derivative of the MacCoull, Walther, Wright equation

Only technique that generates the

GELATION INDEX

and

GELATION INDEX TEMPERATURE

First procedure to show

field failures

were

OIL-RELATED

rather than

engine-related

SBT

correctly predicted

ALL

field-failing oils

SBT

shows high correlation on both

AIR-BINDING & **FLOW-LIMITED**

oils from ASTM cold-room tests

SBT®

D5133

D7110

Most complete analysis available on engine oil pumpability.

SBT® & MRV

Engine Oil specifications require both **SBT** & **MRV TP-1** methods

(2) SBT® Instrument Models

Direct Cool II

SBT+2 Multi-purpose Bath

Direct Cool II

SBT®
(D5133, D7110)

Low-Temp Viscosity
(D2983, Procedure D)

Customer feedback and advancing technology lead to new redesigned Direct Cool II model.

Direct Cool II

- **Thermal Electric Cooling** (efficient, more robust, no refrigerants)
- **All Digital Output**
- **Automation Package** (up to 4 units)
- **Touch-screen Controller** (easy navigation of test parameters)
- **Self-Contained Pre-Heating to 90C**
- **Eliminate DAQ Board, Universal Power**
- **Multi-Purpose: Automated D2983, Procedure D**

SBT+2 (multi-purpose bath)

- Multi-Purpose Low-Temp Bath
- Programmable & Manual Control
- Cooling to -70°C
- Insert Modules for each Test
- ASTM D5133, D7110, D2983, D445, D97, D2500

SBT+2 – Other Test Insert Modules

D2500, D97
Cloud & Pour Point

D4684
Mini-Rotary Viscometer

D2983-Procedure C
Brookfield Viscosity

D445
Kinematic Viscosity

SBT® Industry Status

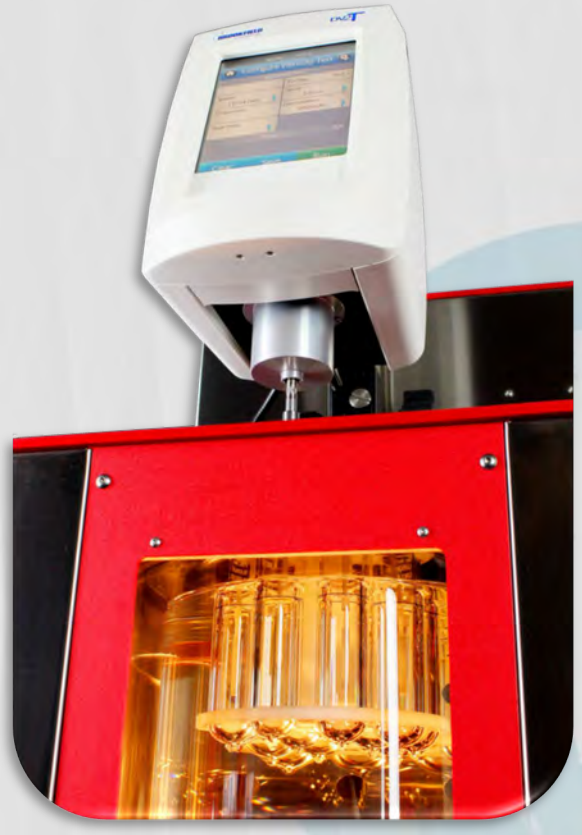
ASTM D5133 **ASTM D7110**	• D5133 ➔ cooling profile: 1°C/hour from -5°C to -40°C • D7110 ➔ cooling profile: 3°C/hour from -5°C to -40°C
API	• SL • SM • SN **SP** } Engine Oil Categories
dexos™	• General Motors specification
ILSAC	• GF series Passenger Car Specifications
GB-11121	• Chinese National Standard • SH/T 0732

Low Temperature Behavior of Engine Oils

Low-Temperature Viscosity Testing

(formerly known as Brookfield Viscosity)

ASTM D2983, Procedure C
IP 267
DIN 51398



Low Temperature ATF Pumpability

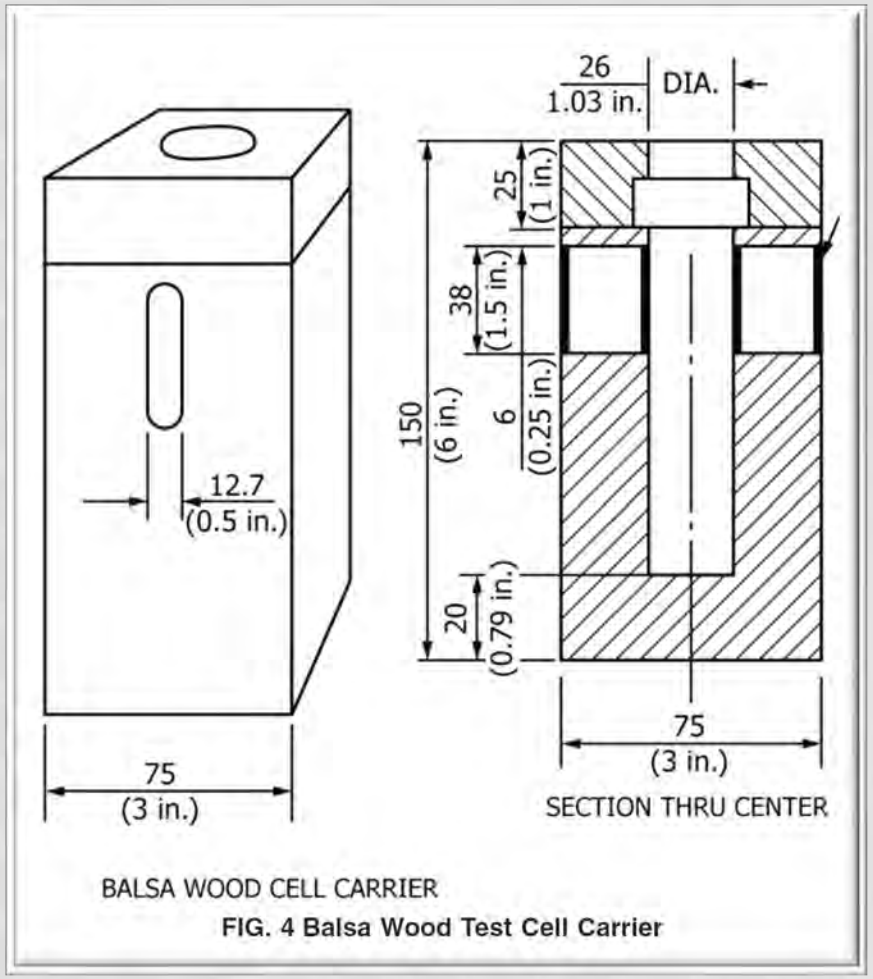


Image: © ASTM D2983-15, pg. 4

Low-Temperature Viscosity

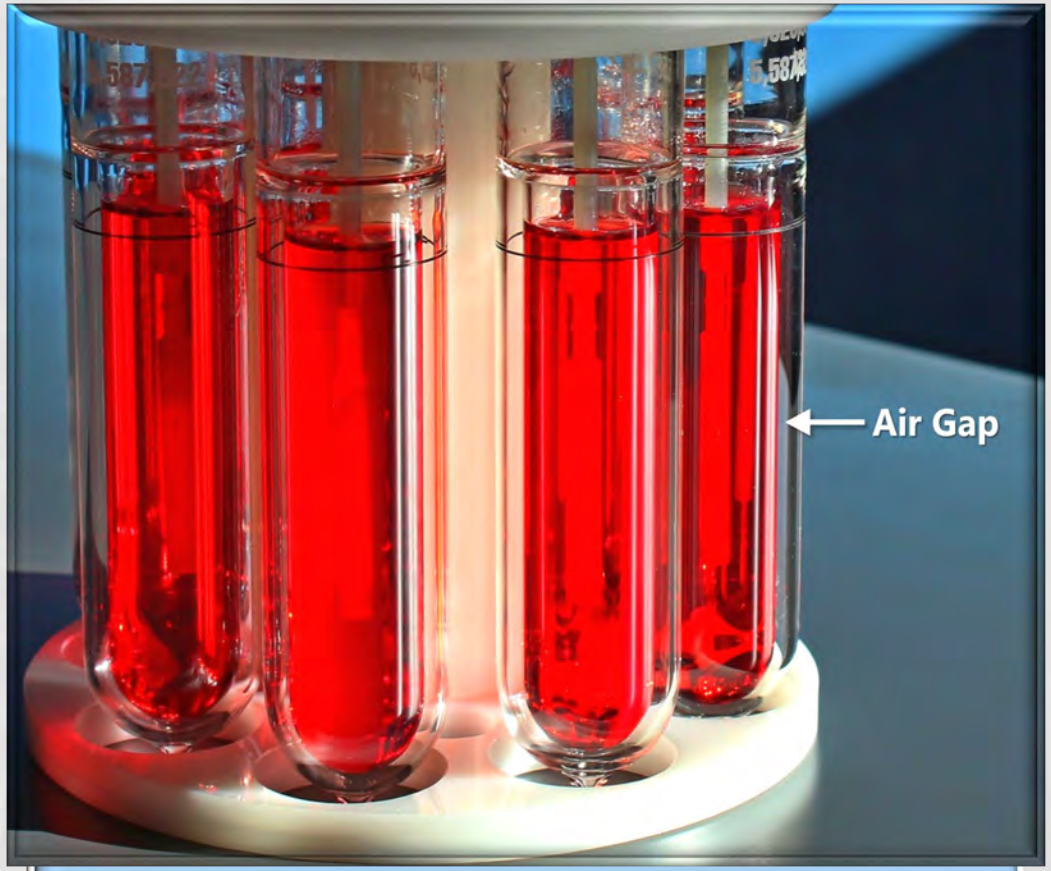
1950's

- Automatic transmission failures in cold temperatures
- Auto manufacturers began low-temperature studies

1971

- Procedure written and accepted as ASTM D2983
- Balsa wood block & cold Air cabinet
- Samples removed & tested with a rotational, bench-top Viscometer (Brookfield originally used)

Liquid Baths with Tannas SimAir® Test Cell



A modified stator incorporates:
- A thin, gas-filled Dewar section
- This modulates heat transfer (cooling rate) from test fluid to liquid bath

1990's

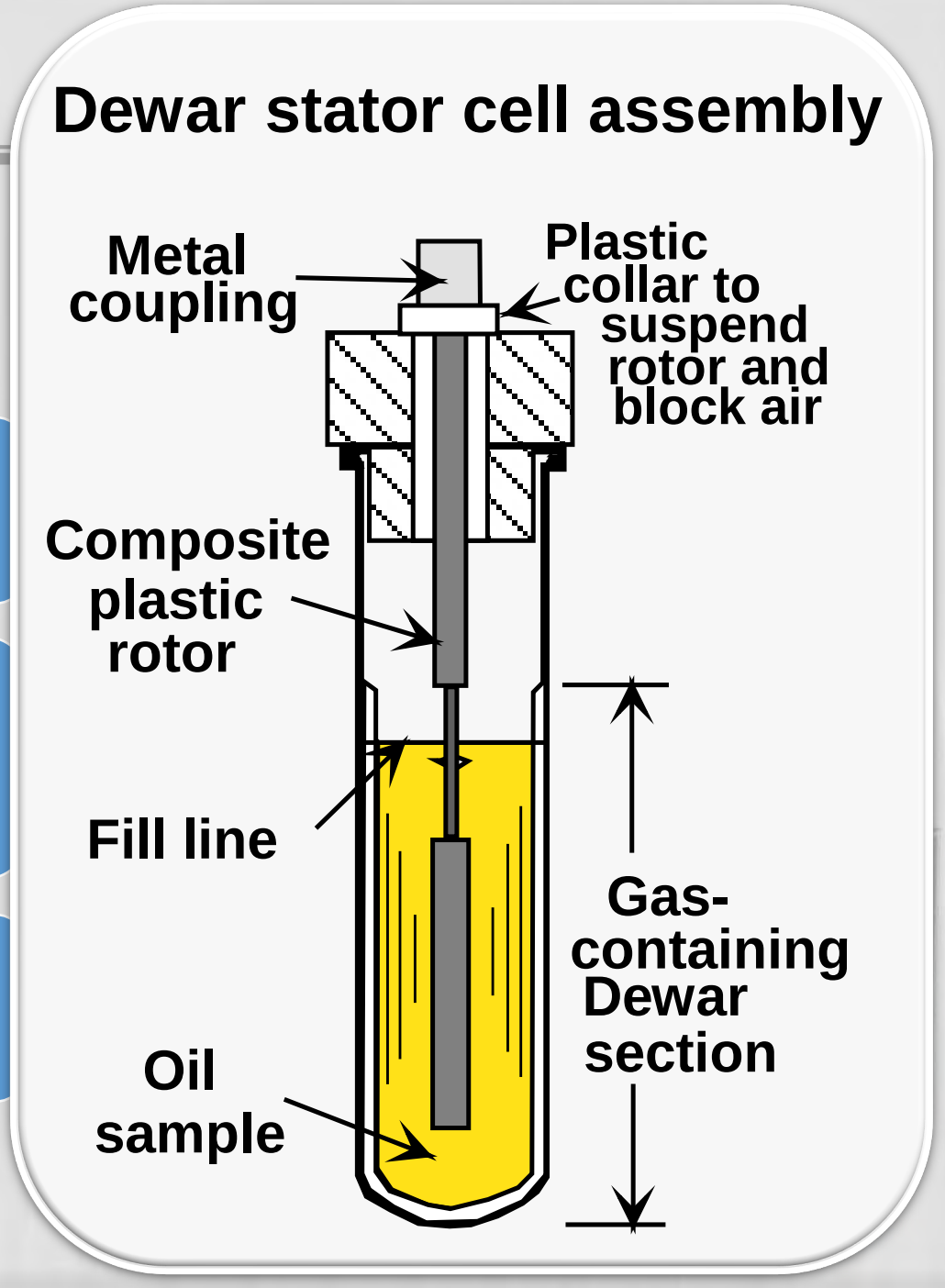
- Tannas developed and patented the SimAir® Test Cell
- Used in a constant temperature liquid bath

- The SimAir® Test Cell led to dramatic improvements with:
  - Test Operation
  - Usability
  - Precision

SimAir® Test Cell

Innovation for ASTM D2983

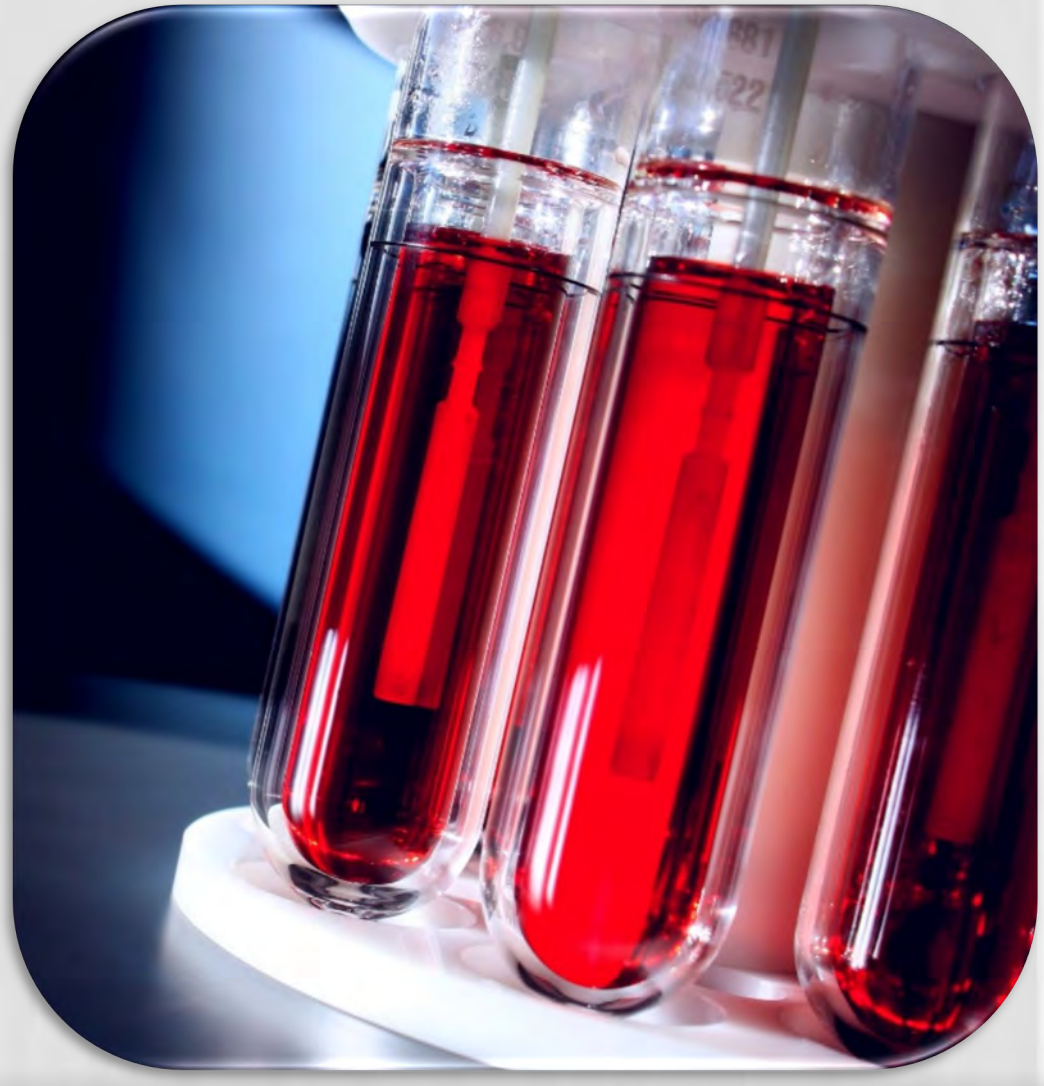
- No duplicate sample runs required.
- Simply set the liquid bath at the desired final temperature.
- Insert sample for 16-hour exposure.

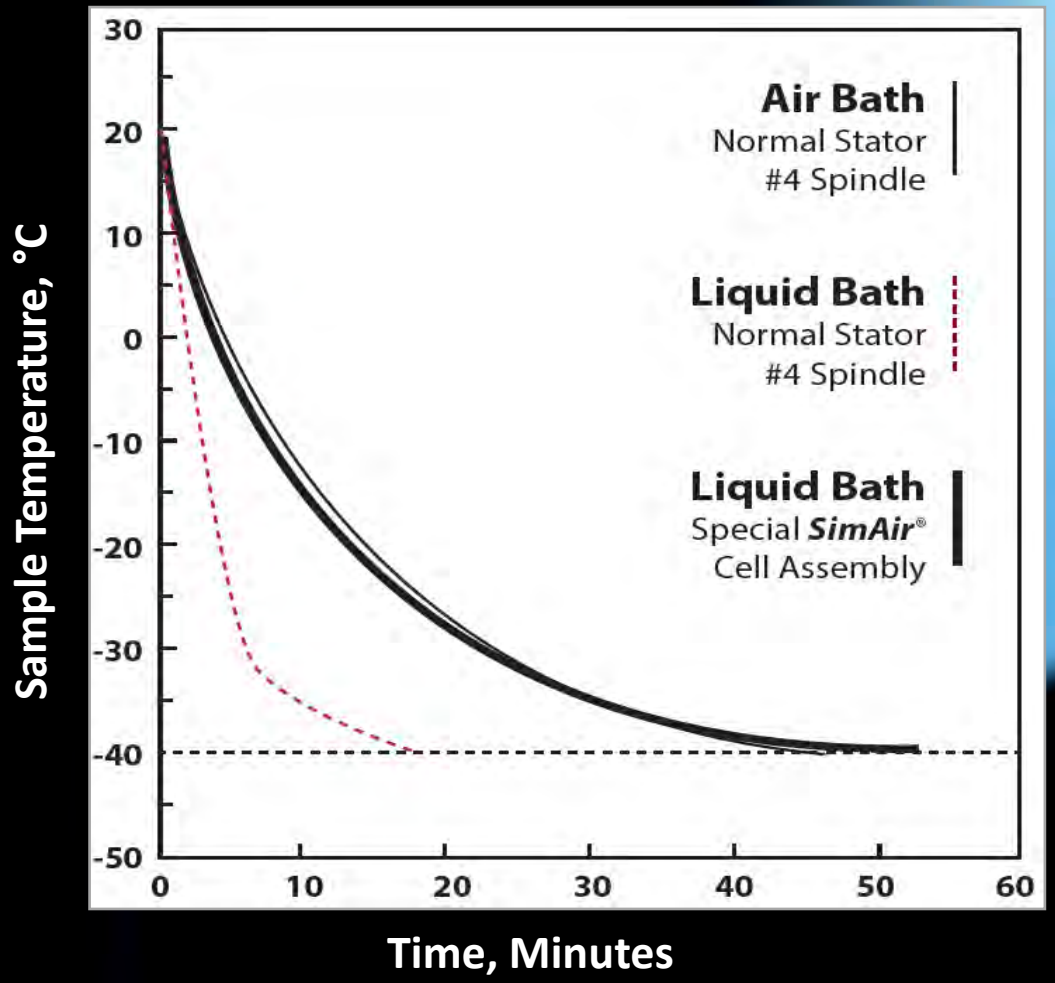


BLB Innovation

SimAir® Test Cells

- Provides proper sample temperature control
- Used exclusively in King BLB or Tannas SBT+2 liquid baths
- Each Test Cell has its own independent cooling profile
- Each cell can be added or removed from the bath at any time
- Increased productivity and accuracy





Comparison of a single wall stator and #4 spindle to the SimAir® Cell.

Note the effectiveness of a constant temperature liquid bath in simulating air bath results when using the SimAir ® Test Cell.

Low-Temperature Viscosity *(Air baths – Liquid baths – SimAir®)*

Air

Transfer samples from air bath to Benchtop Viscometer

Balsa wood carrier

Air to Liquid

Transfer samples from air bath to constant temperature liquid bath 30 minutes before analysis

Viscometer mounted on bath

Programmable Liquid Bath

Energetic Refrigeration System

Attempts to emulate cooling rate of air bath

Force cool each sample the same

SimAir® Test Cell

Simpler approach

Constant temperature liquid bath

Simulates cooling rate of samples as in air bath

Each Cell independent of others in bath

Liquid Baths with Tannas SimAir® Test Cell

King
BLB Liquid Baths

Holds up to 12 samples
Broad Temperature Range

(±0.1°C control)

BLB 701: +30°C to -40°C
BLB 702: +30°C to -70°C

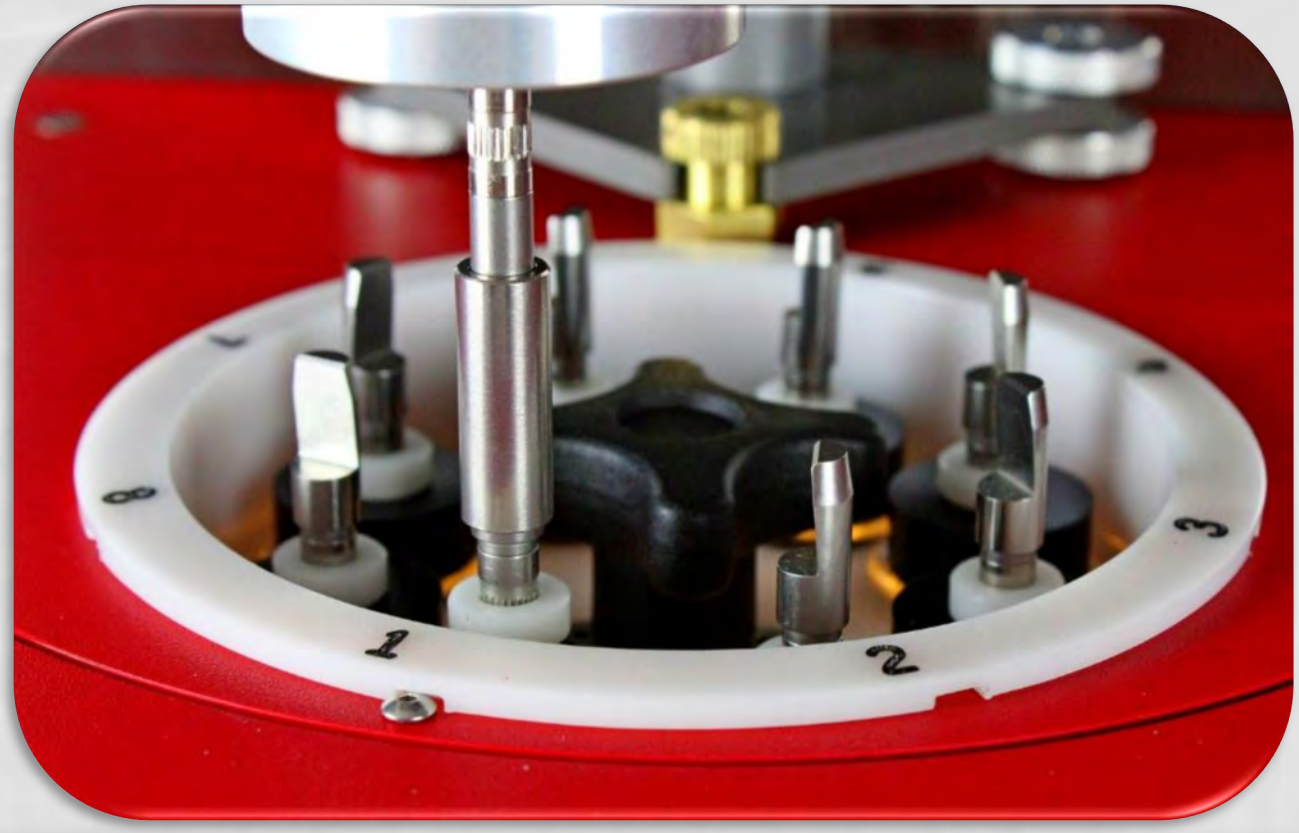
King BLB-DIN Liquid Bath

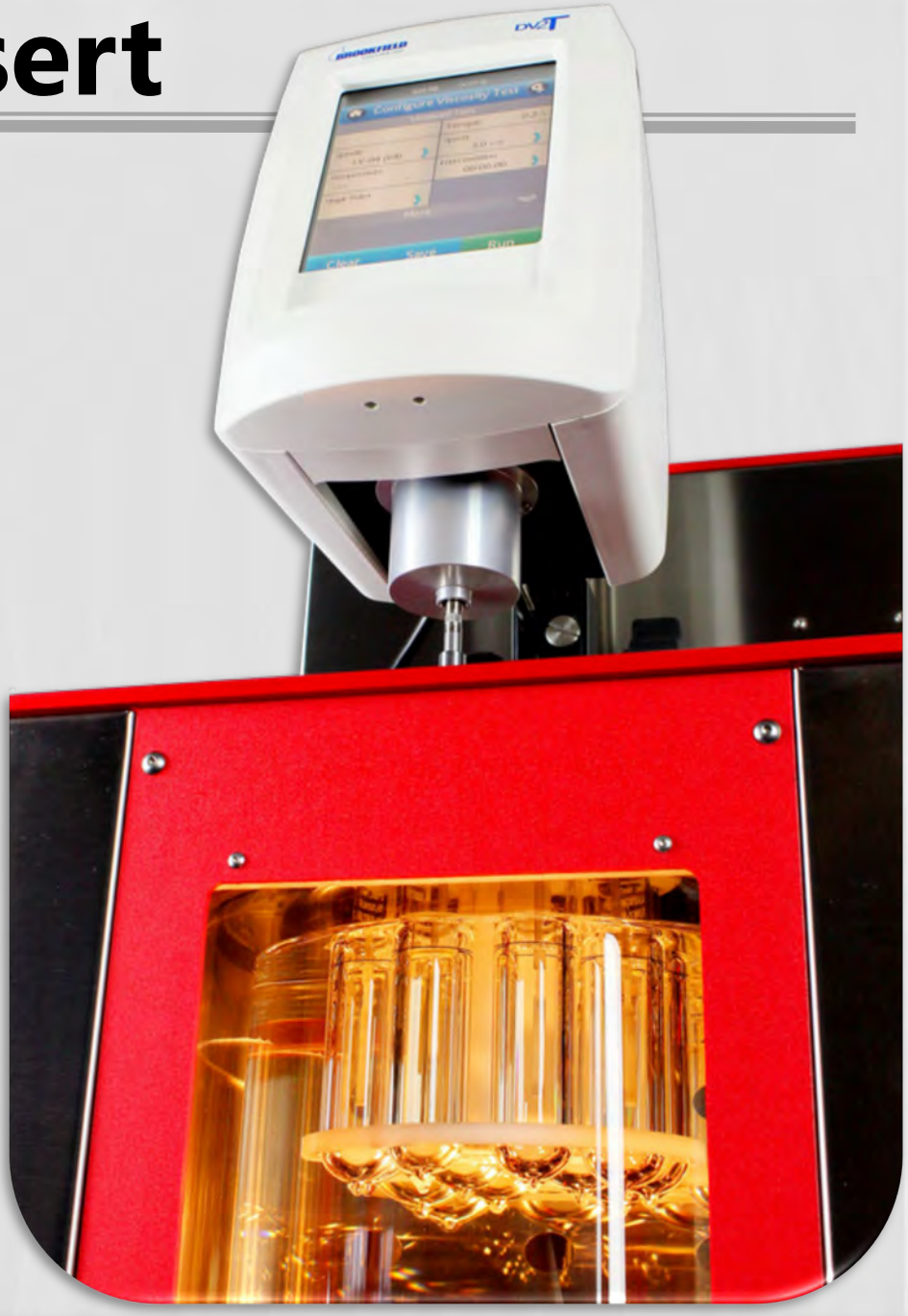
- Meets ASTM D2983 & DIN 51398
- Constant temperature for ASTM (SimAir®)
- Programmed for DIN (1°C/min) (Single wall stator)
- +30°C to -55°C
- Holds up to (12) samples

SBT+2 with D2983 Insert

SimAir® Test Cells

Holds up to (8) samples





Comments or Questions?

explore our new website
TannasKing.com

Improving Prediction of Deposits

High Temperature Deposits

TEOST® 33C

TEOST MHT®

TEOST® ***Dual***

TEOST Turbo®/ NEW

(3 tests, 4 models)

TEOST® 33C for *Turbocharger Deposits*

1985

Savant understood **DEPOSIT CONDITIONS** fall into two categories ➔

1: Precursors at high-normal engine temps

2: High temp deposit-inducing zone

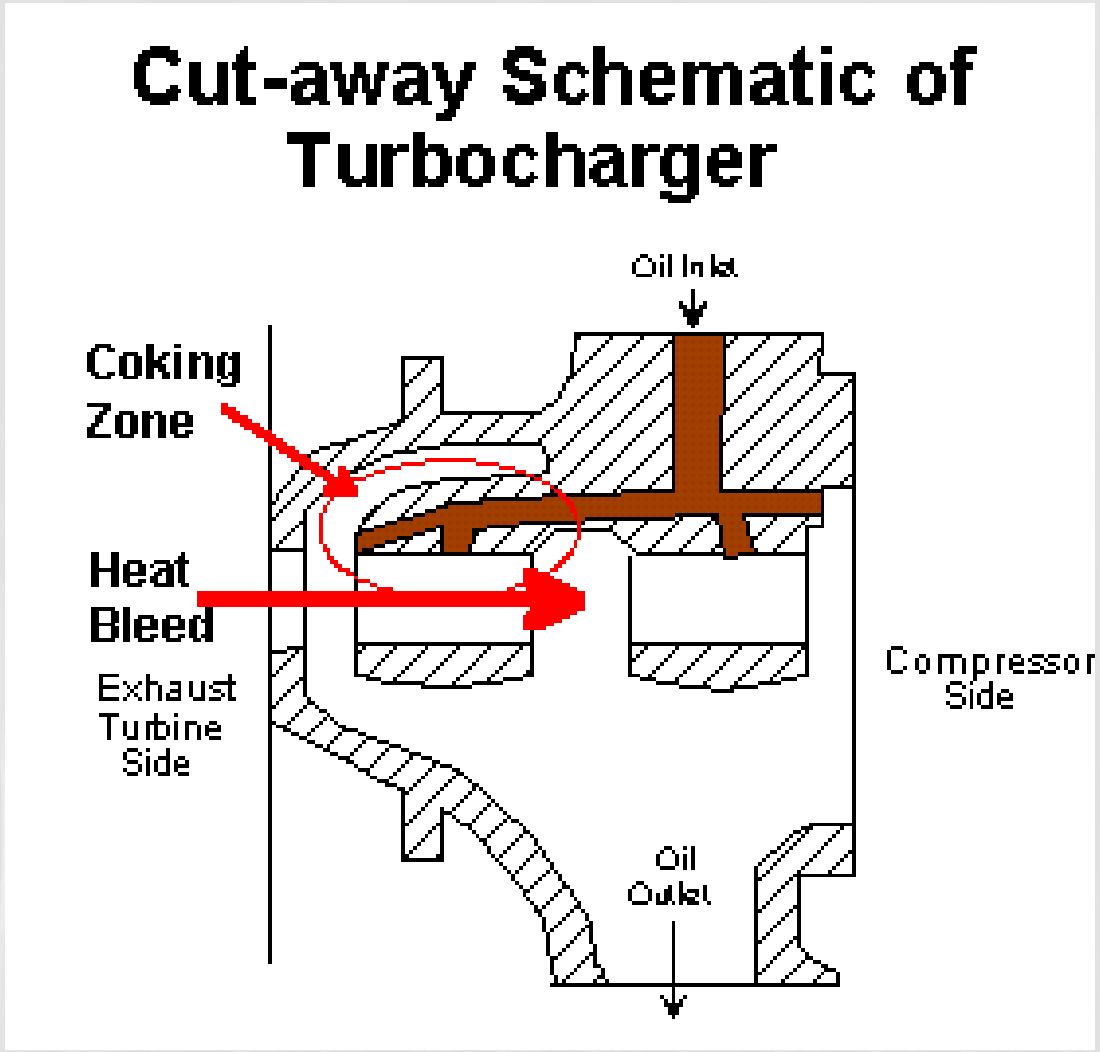
1989

Cooperative efforts with **CHRYSLER** Corporation

Development of bench test to predict the **DEPOSIT PROTECTION** of an oil

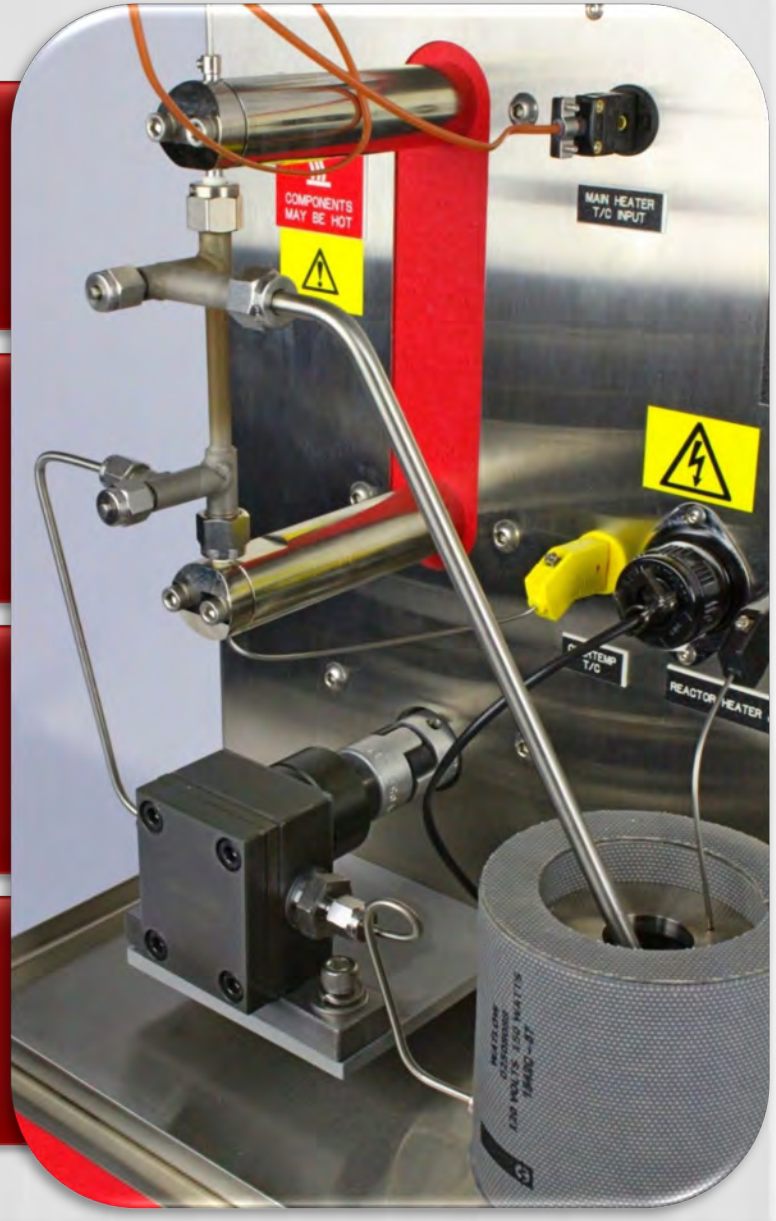
TEOST® 33C for *Turbocharger Deposits*

- Exhaust heat from turbine shaft (600-700°C) is absorbed by the engine oil pumped through the bearings.
- Earliest stages of coking occur just after the engine is shut off.
- Heat damages the oil when engine oil circulation is stopped causing deposits to form, blocking oil passage and leading to failure.

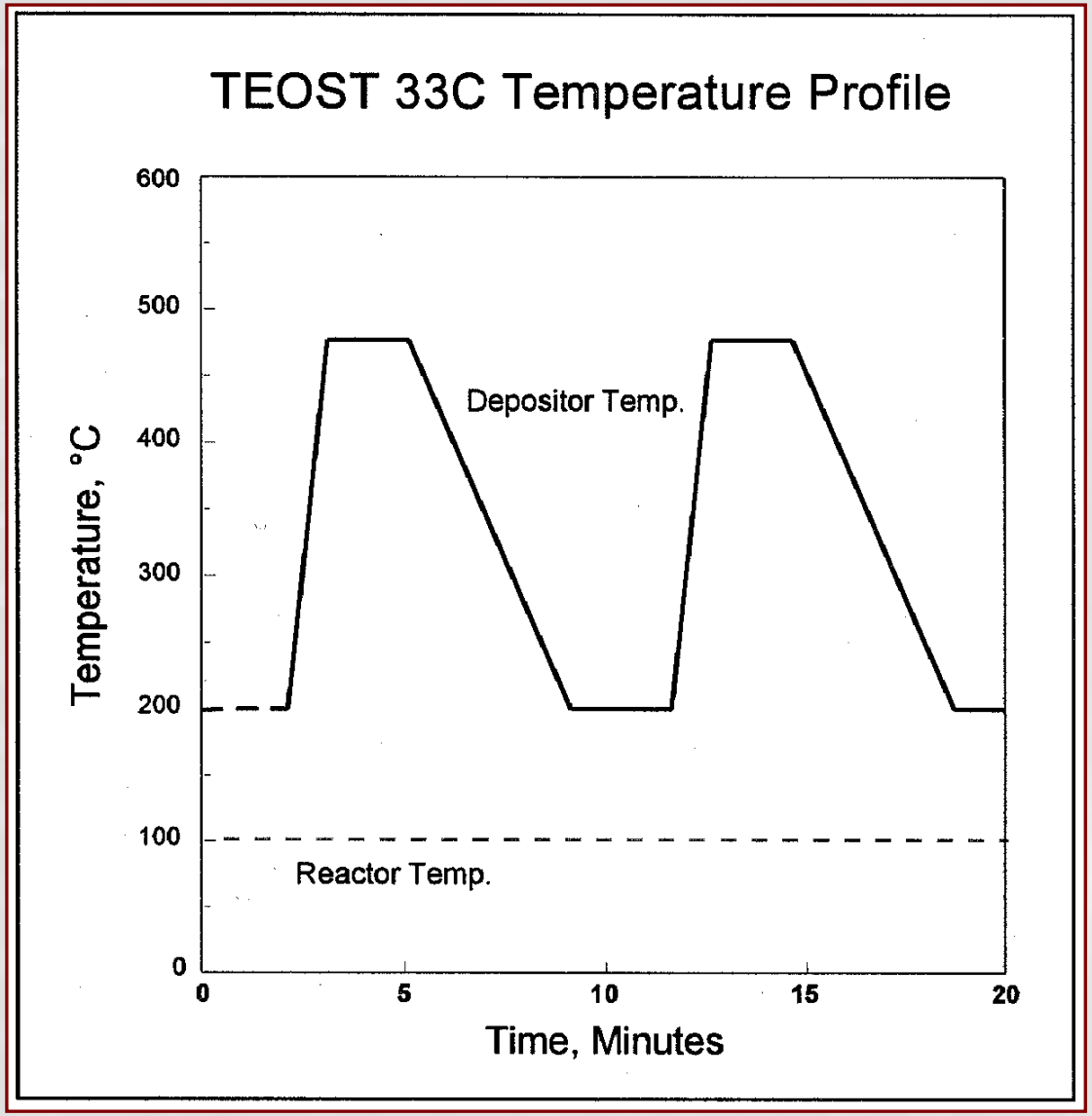


TEOST® 33C for *Turbocharger Deposits*

- **2-hour performance test**
- **Steel depositor rod heated cyclically between 200°C & 480°C for 12 cycles**
- **Rod weighed before & after test to determine deposit levels**
- **Deposit level of rod + filtered oil (mg)**
  - *60 mg for GF-2 and 30 mg for GF-5 & GF-6*



TEOST® 33C Cyclic Heating Conditions



Based on oil temperatures in the turbocharger shaft during operation and cool-down.

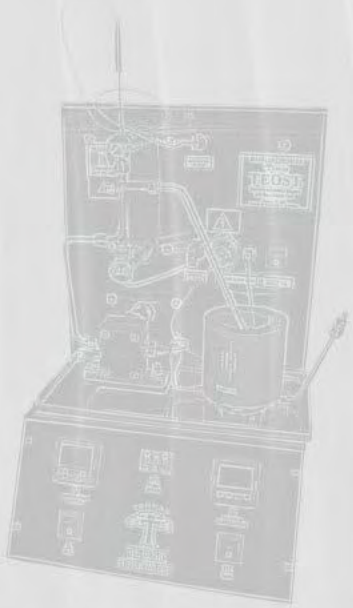
Depositor Rod Heat Cycle Range:
200°C to **480°C**

Depositor Rod Total Heat Cycle Duration:
9 minutes

Number of Heat Cycles per Test:
12

33C Operating Parameters

PARAMETER	VALUE
Total Oil Volume	116 mL
Oil Pumping Rate	0.40 g/min
Reactor Temperature	100°C
Moist Air Flow	3.5 mL/min
N_2O Flow	3.5 mL/min
Iron Naphthenate	193 microliters
Position of controlling Thermocouple in Rod	~70 – 75 mm from top of Rod



TEOST® 33C Industry Status

ASTM D6335	• Part of ASTM Test Monitoring Center Program
ILSAC	• GF-2, GF-5+ & GF-6 Engine Oil Specifications • GF-2 = 60 mg; GF-5+, GF-6 = 30 mg
API	• SJ, SN & SP categories for engine oils • ASTM D4485
GB-11121	• SH/T 0750

Development of TEOST MHT®

TEOST MHT® bench test developed for Chrysler to predict **PISTON VARNISH** & **DEPOSIT TENDENCIES** of engine oils.

MHT developed to correlate with **Peugeot TU3MH**
(a European piston varnish & deposit rating test)

Correlation using the MHT was considered good, with:

- **Specially modified pistons** (required by engine test) **AND**
- **Commercially available pistons**

TEOST MHT® for *Engine Deposits*

24-hour performance test

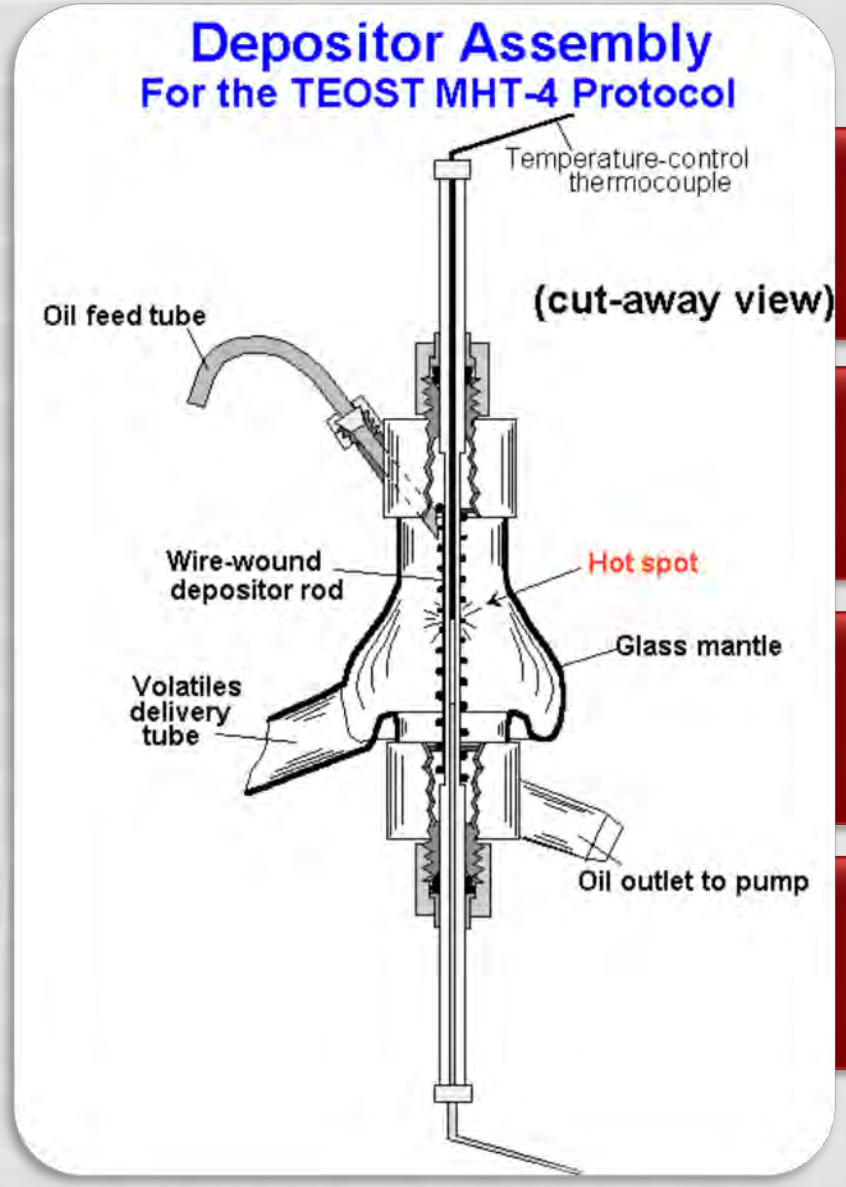
Wire-wound depositor rod (Specially treated)

- **Rod held at 285°C**
- **8.5 g of oil recirculating at 0.25g/minute**

MHT Catalyst – represents concentration of certain metals in used oil

Rod & Filter weighed before & after test to determine deposit levels

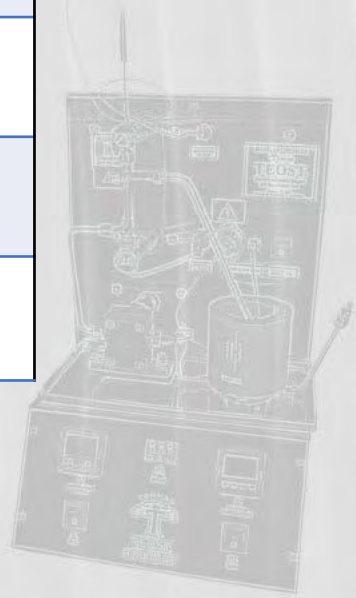
TEOST MHT®



- Oil flows down spiral path of wire
- Air flow of 10 mL/minute
- Volatile oil removed & collected
- Deposit level of rod + filtered oil (mg)

MHT® Operating Parameters

PARAMETER	VALUE
Total Oil Volume	~ 8.5 g
Oil Pumping Rate	0.25 g/min
Operating Temperature	285°C
Test Time	24 Hours
Dry Air Flow Rate	10 mL/min ±0.2
MHT® Catalyst	~0.0131 g/g of Oil



TEOST MHT® Industry Status

ASTM D7097	• Part of ASTM Test Monitoring Center Program
ILSAC	• GF-3, GF-4 & GF-5+ Engine Oil Specifications • 35 mg limit spec in GF-5+
API	• SL, SM & SN categories for engine oils • ASTM D4485
GB-11121	• SH/T 0834

Updating the Turbocharger Bench Test

To align with new turbocharger technology, development of an updated bench test began in early 2017 for key reasons:

- To assist with development of new oil formulations
- For screening engine oil formulations prior to running updated turbo engine tests
- To provide on-going evidence of engine oil quality

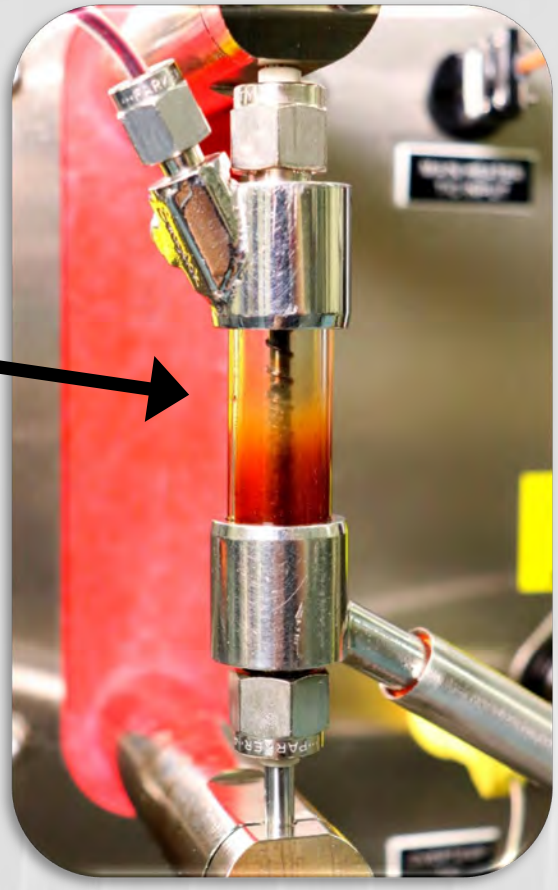
TEOST Turbo®: *Experimentation & Design*

The TEOST Turbo Bench Test incorporates the following design:

- ¼ the sample size, increasing exposure to the reaction vessel and rod temperatures.
- Reversed the direction of flow down the Depositor Rod to increase oil contact.
- Used a wire-wound Depositor Rod to control oil exposure time and amount.
- Reduced operating temperatures.
- Removed Nitrous Oxide gas.
- Modified cyclic temperature exposure.
- Redesigned glass mantle for controlling volatile movement within the test.
- Added moist air flow over the Depositor Rod.

TEOST Turbo®: *Test Equipment*

New



TEOST Turbo®: *Test Parameters*

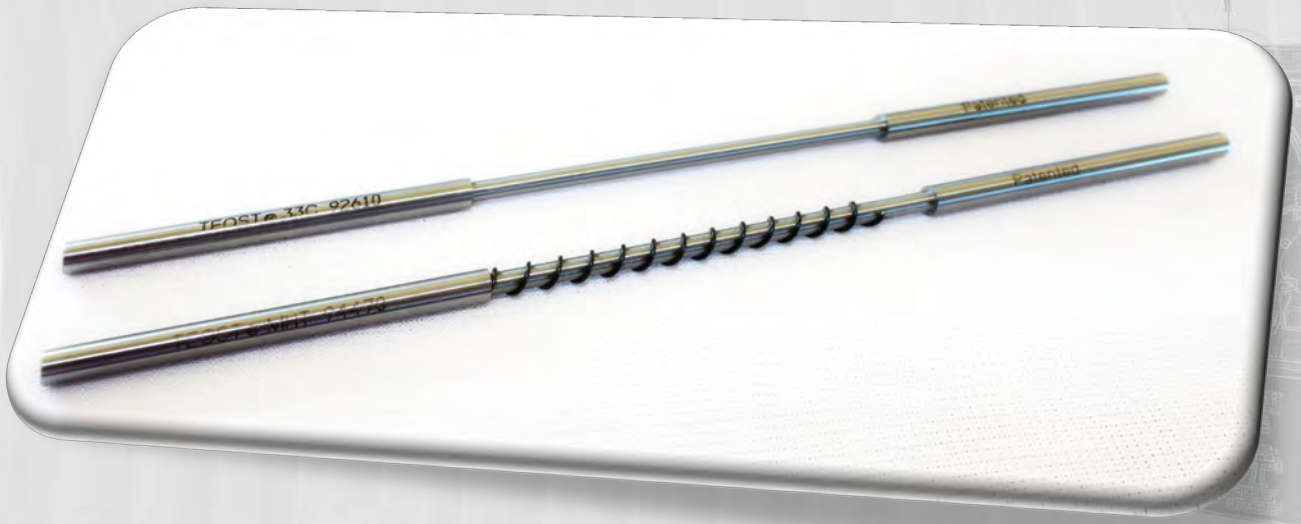
Parameter	33C	MHT®	Turbo®
ASTM Method #	D6335	D7097	D8447
Rod Type	Non-Wound	Wire Wound	Wire Wound
Total Oil Volume	116 mL	~8.5 g	30 mL
Catalyst	6% Fe Naphthenate	MHT®	6% Fe Naphthenate
Gas Induction Location	Reservoir	Upper End Cap	Upper End Cap
Oil Flow	Up the Rod	Down the Rod	Down the Rod
Rod Temp. (Peak)	200°C to 480°C cycle	285° C	290°C w/320°C pk
Reservoir Temp	100°C	N/A	100°C
Test Duration	<2 Hours	24 Hours	18 Hours

TEOST Turbo® Industry Status

ASTM D8447	• **ASTM method approved in 2022.**
Industry Specs.	• **Being considered for industry specification limits.**

TEOST® Depositor Rods

33C: unwound
MHT/Turbo: wire-wound



Comments or Questions?

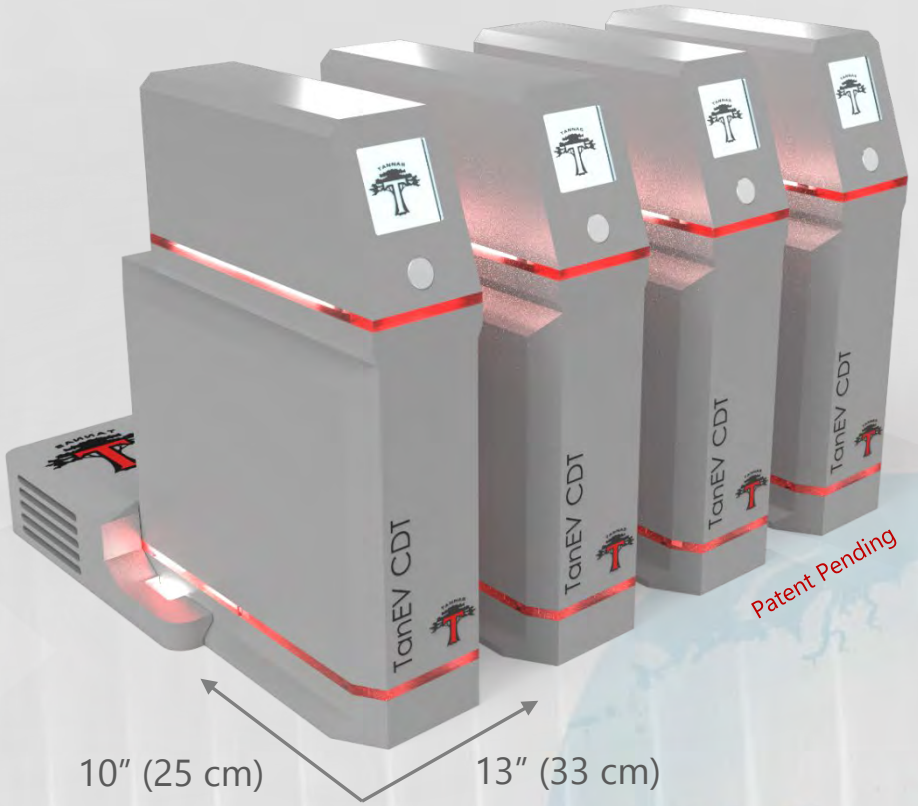
explore our new website
TannasKing.com

EV Lubricant Tests

Coming Soon

Conductive Deposit Test
(TanEV CDT)

Wire Corrosion Test
(TanEV WCT)



Brief Introduction

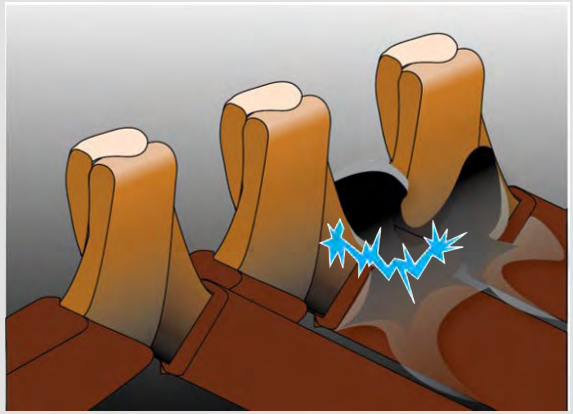
The CDT and WCT data enables a holistic view of the corrosion process and provides the assurance that lubricants which perform well in these tests will be less likely to suffer real world failures in the electrical devices they are supporting.

Conductive Deposit Test (CDT)

The formation of a deposit that is electrically conductive is problematic in electric motor designs as this creates a pathway for current to flow away from the intended route and lead to immediate failure of the device.

CDT provides a quantitative measure of conductive deposit or conductive film formation as a function of time and temperature.

Evaluates the potential risk of hardware failures caused by the deposition of conductive corrosion products on electrical components.



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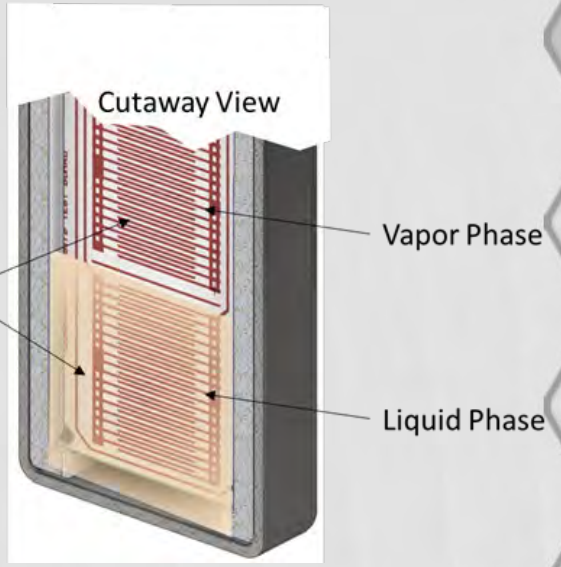
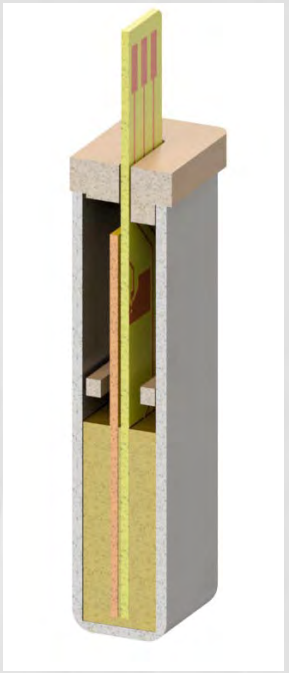
Evaluates the potential risk of hardware failures caused by the deposition of conductive corrosion products on electrical components.

Specially designed PCB with gaps between copper traces, powered by a 5v DC signal, supplied to the voltage loops. Resistance is tracked during the duration of the test.

PCB lowered into the 20 ml of test fluid at 150C for 500+ hrs. with both liquid and vapor phases being measured for the rate of change in resistance.





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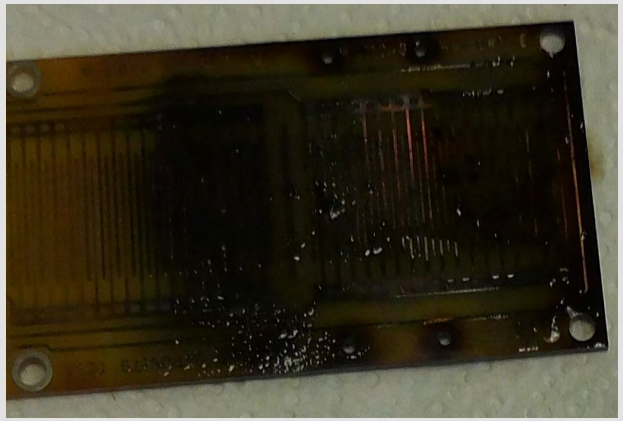
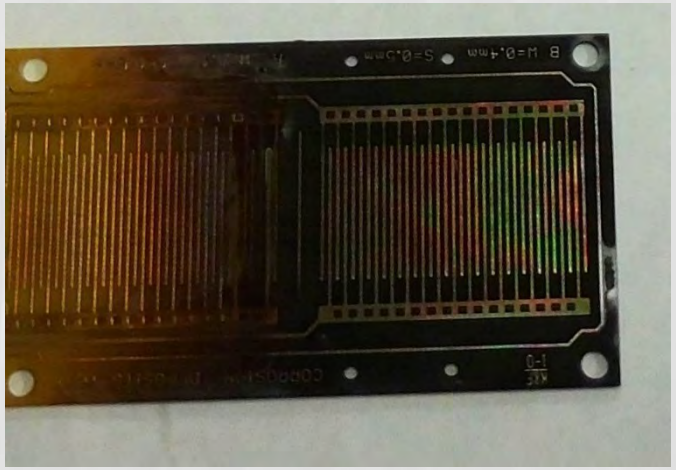
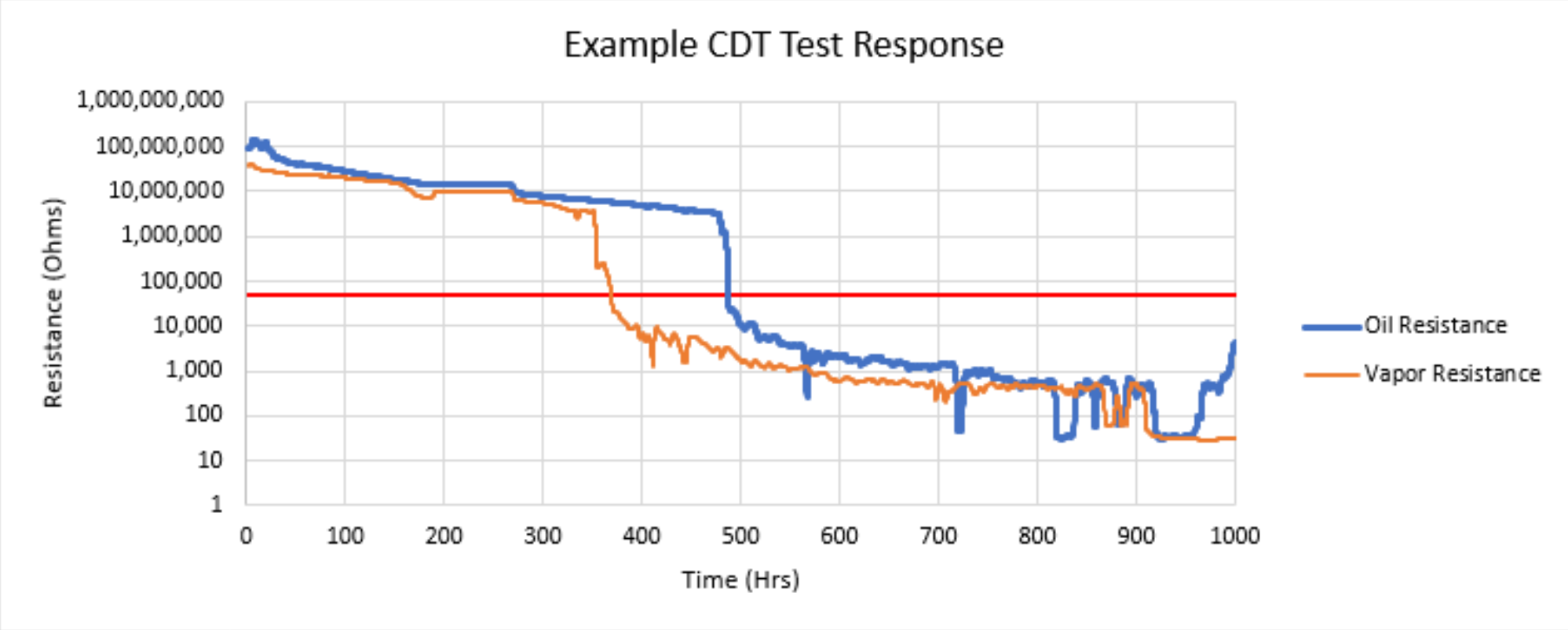
Failing Board



Passing Board



Conductive Deposit Test (CDT)



- 4-hour moving average of resistance drops below 50,000 ohms
- Oil fails in Liquid phase at 490 hours
- Oil fails in Vapor phase at 370 hours

Wire Corrosion Test (WCT)

Motor windings / Gaps / Connections and Circuit Boards

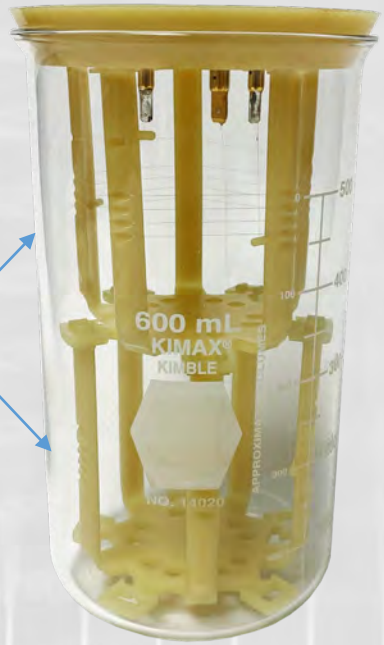
- Wide temperature range (80C – 150C)
- Vapor corrosion is a concern

WCT enables a quantitative and mechanistic evaluation of the corrosion tendency of a lubricant in both the solution and vapor phases over a wide range of temperatures (80 to 150C).

Oxidation and the ensuing chemical reactions can cause depletion of critical copper components such as motor windings and interconnects in the EV powertrain.

Wire Corrosion Test (WCT)

400 mL sample,
1 m of Cu wire
(64 µm diameter)



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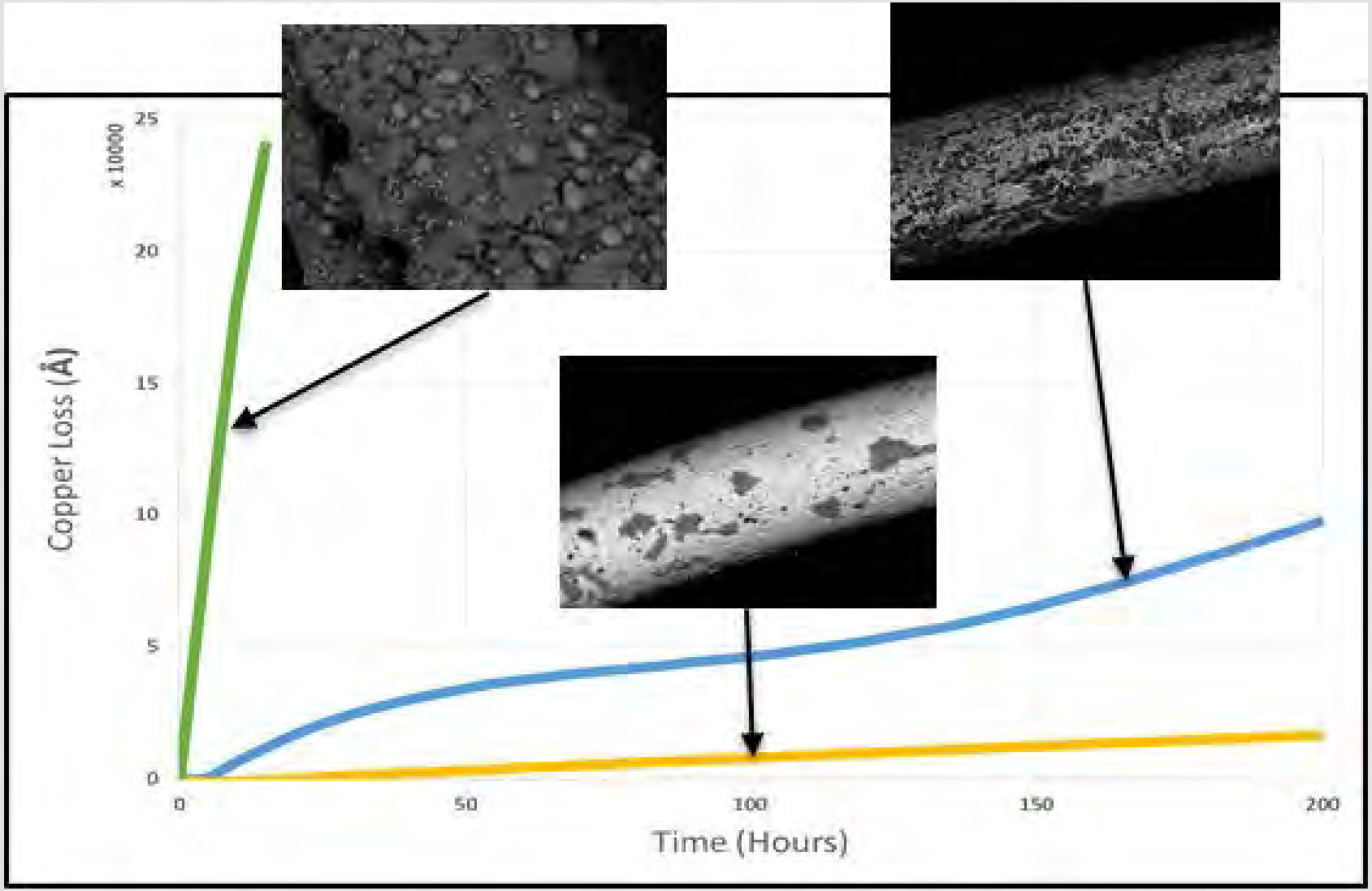
Oxidation and the ensuing chemical reactions can cause depletion of critical copper components such as motor windings and interconnects in the EV powertrain.

Nominal conditions are 130C at 72 hrs. with a constant current applied to the test wire. Test temp and duration can be varied to determine corrosion rate as a function of temperature and time.

Wire Corrosion Test (WCT)



Copper Loss (Angstroms) vs. Time

CDT & WCT Industry Status

ASTM

- Both have open working groups in Subcommittee D02.09. Methods expected in late 2023.

Industry

- Written as US Army MILSPEC/FTM and awaiting approval.
- Global EV specifications are being developed via industry OEM groups.
- Included in SAE J3200 for electrified drivetrains.

Tannas Instruments

King Instruments

Precision Laboratory Instruments
for testing Lubricants & Fluids

King MRV TP-1

Mini-Rotary Viscometer

ASTM D3829, D4684, D6821, D6896

Low-Temperature Pumpability & Yield Stress: Determines borderline pumping temperatures of oils and lubricants with patented *direct refrigeration* technology. Features a small bench-top footprint, 10 sample capacity, and removable test cells for ease-of-use.

Required test for SAE J300; ILSAC GF Specifications; API *SM, SN, SP*; ASTM D4485; JPI 5S-42-04; Chinese GB-11121; OEM factory fill.

King BLB

Liquid Bath

ASTM D2983, D97, D2500, D5853 | IP267

Low-Temperature Viscosity: Measures low temperature viscosity of lubricants using the patented SimAir® technique with a small, less costly, *constant* temperature liquid bath. Only technique for independent sample analyses to eliminate batch sample testing. Features a 12-position carousel.

BLB 701 Model: +30°C to –40°C
BLB 702 Model: +30°C to –70°C

King BLB-DIN

BLB-DIN Liquid Bath

DIN 51398 | ASTM D2983 | IP267

Low-Temperature Viscosity: Similar to D2983, the German Standard DIN 51398 determines the apparent viscosity of gear oils and related fluids at low-temperature. Features programmable control, digital display to 0.01°C, and cooling at 1°C/min to –55°C.

The BLB-DIN can be adjusted to run either the D2983 test (using SimAir® Cells) or the DIN standard.

SimAir® Test Cells

Patented Test Cell Innovation for ASTM D2983

ASTM D2983 | IP267

SimAir® Test Cells offer simple, precise, and more efficient data acquisition than Air Baths. Used exclusively in the King BLB and Tannas SBT®+2 liquid baths, the SimAir® Glass Stator design incorporates an insulating chamber between two glass walls to simulate the cooling profile of the original cold air cabinet. Each Test Cell functions with its own independent cooling profile, and can be added or removed from the bath at any time.

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