Characteristics of New Oil Soluble Polyalkylene Glycols

Dr. Govind Khemchandani
The Dow chemical Company

STLE HOUSTON CHAPTER

FEBURARY 9, 2011

Performance Fluids from Dow

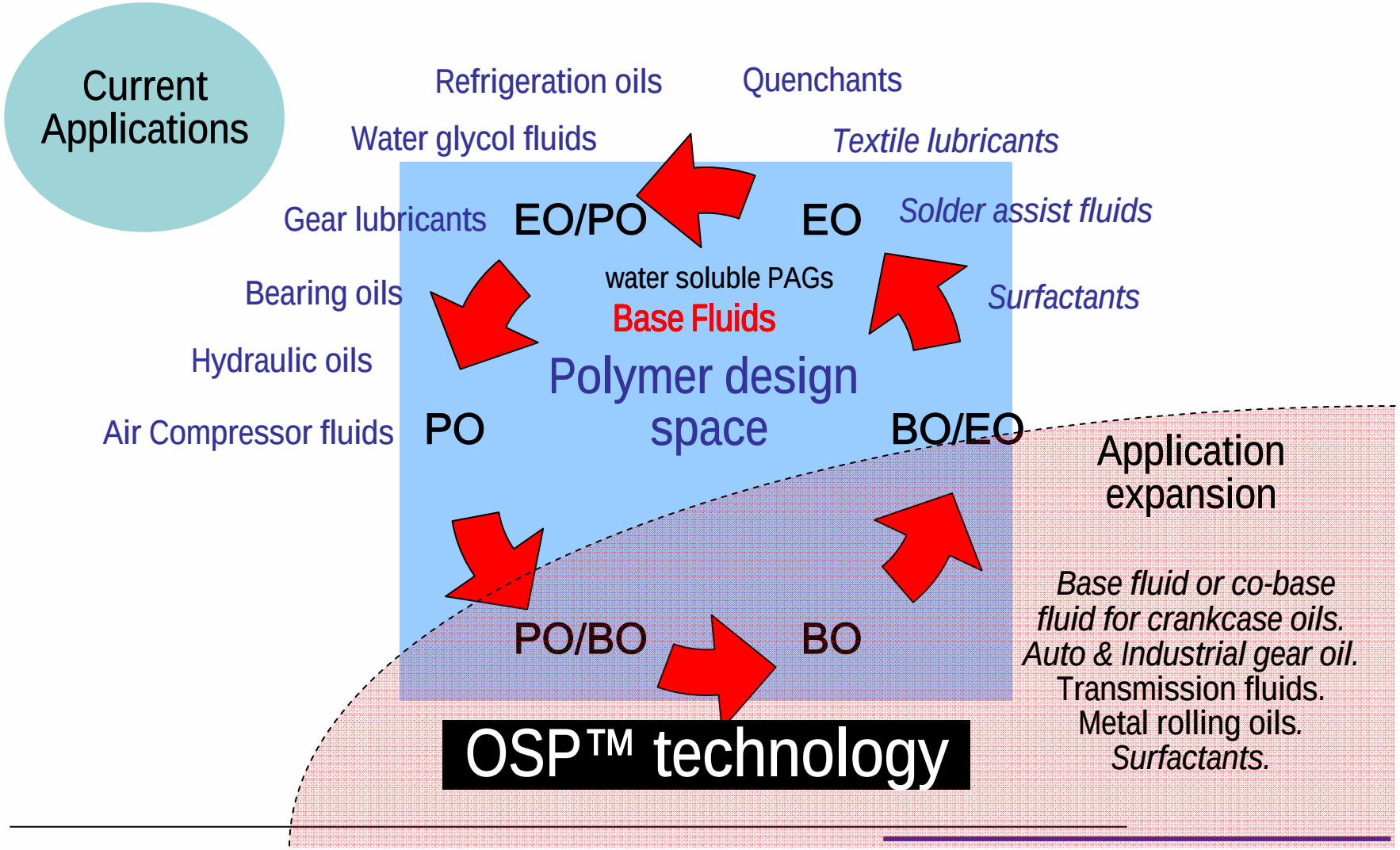
Fluids that Move Your World

gvkhemchandani@dow.com
Tel: 1-979-238-4045

Introduction

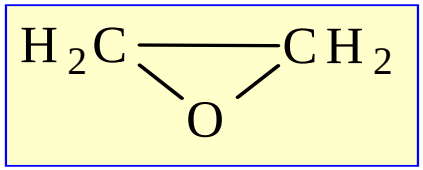
- New OSP technology offers many benefits in lubricant formulations
- OSPs offer options to upgrade hydrocarbon oils to boost viscosity index and improve deposit control
- OSPs can provide improved friction control when used as an additive. They may provide an alternative to synthetic esters as friction modifiers.
- The flexibility of PAG chemistry provides a huge amount of space for innovation and providing solutions to specifications and standards of the future

Evolution to OSP™ technology

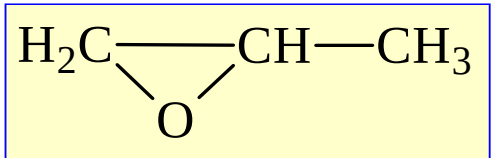


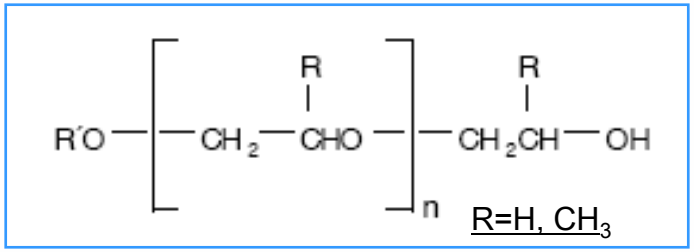
Traditional PAG Polymerization Technologies

Ethylene oxide (EO)

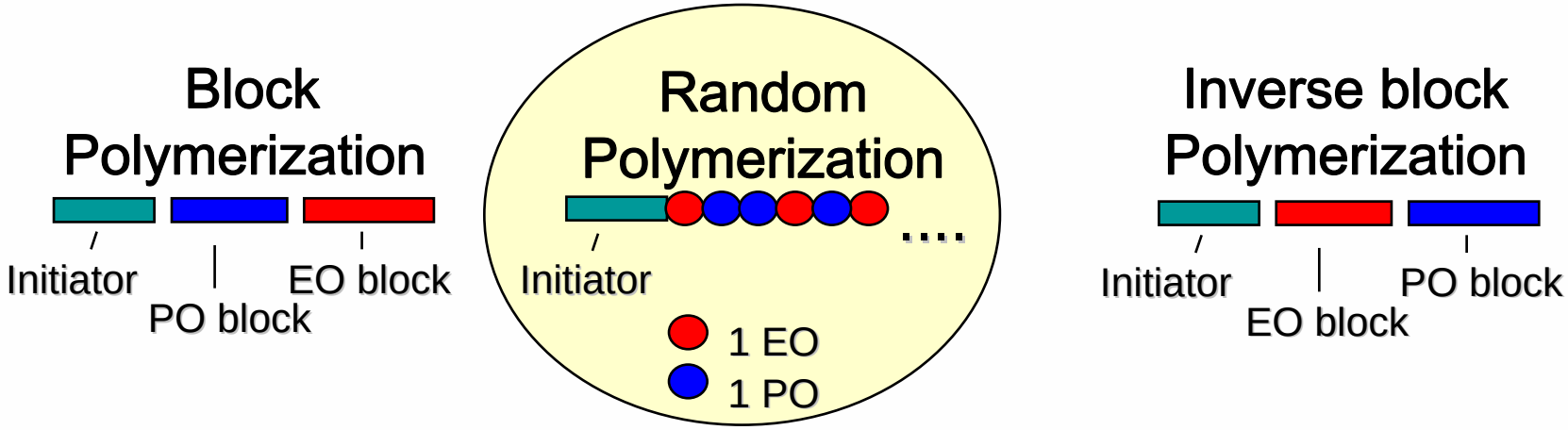


Propylene oxide (PO)





CLASSICAL POLYMER STRUCTURES BASED ON EO & PO



Initiators are typically monols, diols or triols
(for example butanol, propylene glycol, glycerol).

- **Polymers can be designed having a wide range of viscosities (10-20,000 cSt at 40°C)**
- **Extremely versatile and can be tailored designed to have many specific functionalities**

Traditional PAGs – Benefits & Perceived Challenges

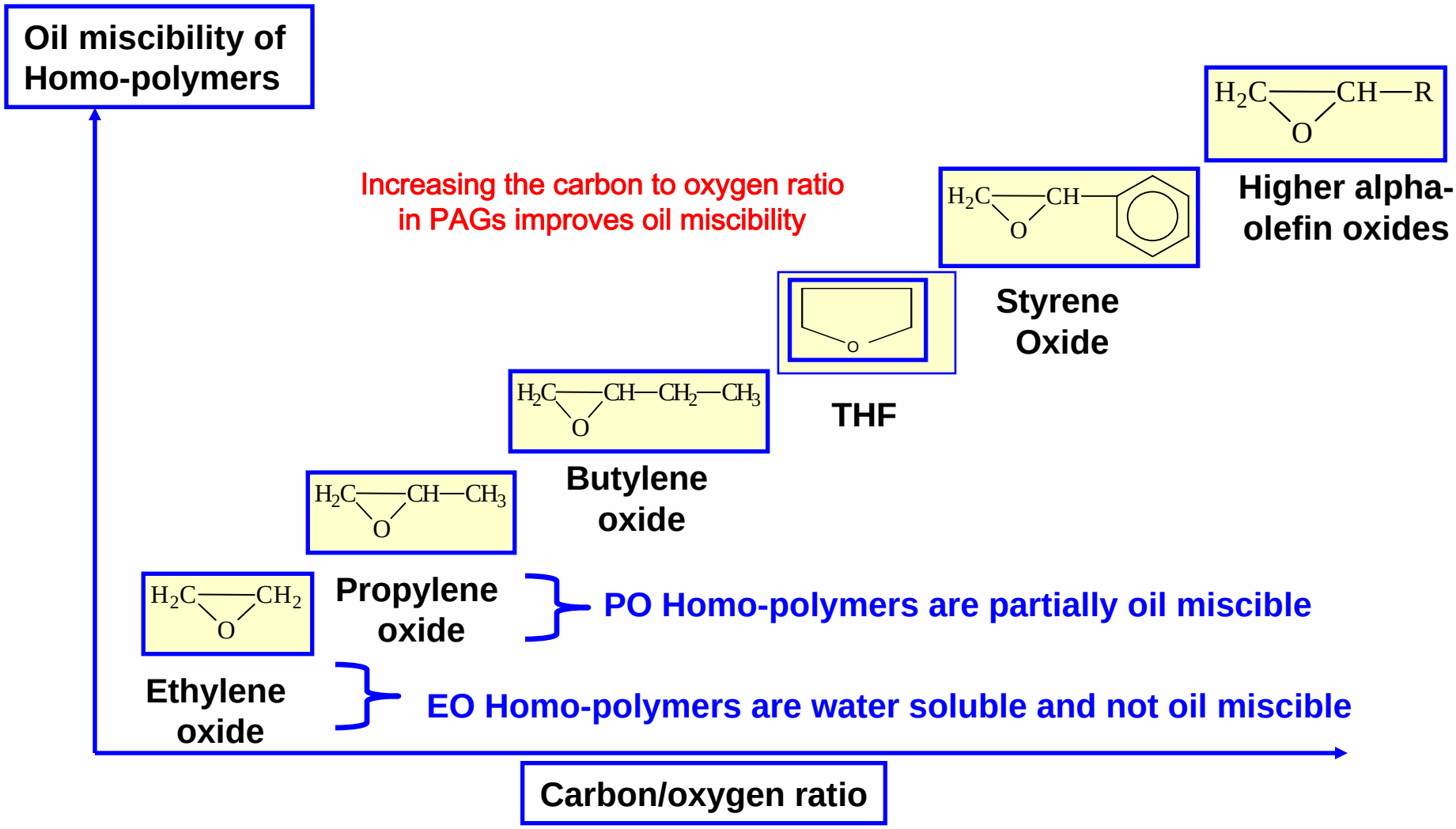
BENEFITS

- ✓ Availability in a very wide range of viscosity grades with design flexibility
- ✓ High viscosity index
- ✓ Good low temperature properties
- ✓ Excellent deposit control and equipment cleanliness
- ✓ Hydrolytic stability
- ✓ Safe to Use

CHALLENGE

- Δ Oil miscibility (compatibility)

Synthetic Options in Designing Oil Soluble PAGs

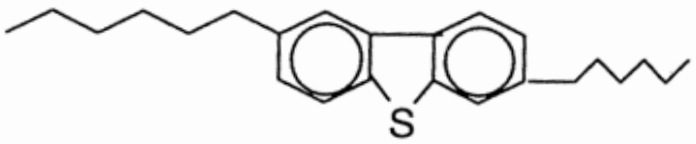


Oil miscibility in reference to Group I-IV Hydrocarbon oils

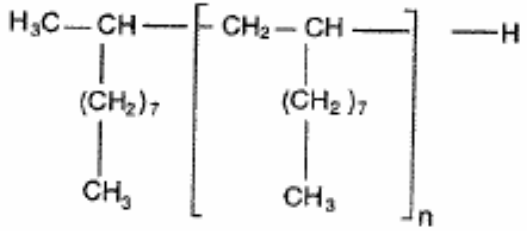
What is different?

CHEMICAL COMPOSITION: POLYALKYLENE GLYCOL VS. HYDROCARBON OILS

Mineral Oil – Petroleum- based Hydrocarbon Group I Base stock



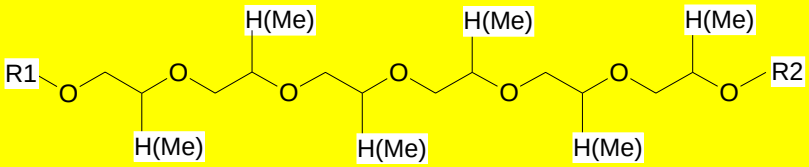
PAO- Poly Alpha Olefin- Synthetic Hydrocarbon Oil Group IV



Non-Polar

Heavily additized for oxidation stability and has poor solvency

PAG – Poly Alkylene Glycol Base Fluid Group V

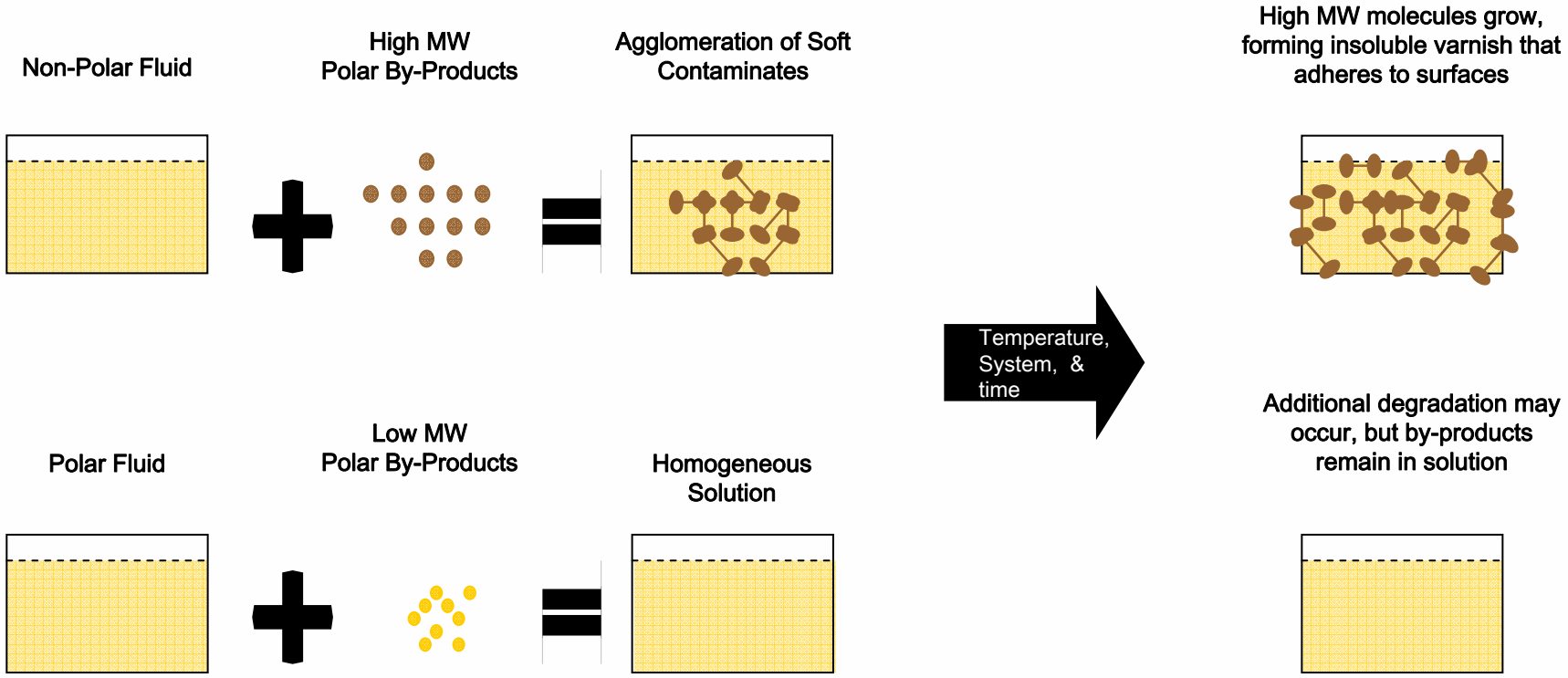


Polar

Inherently thermo-oxidatively stable with high VI

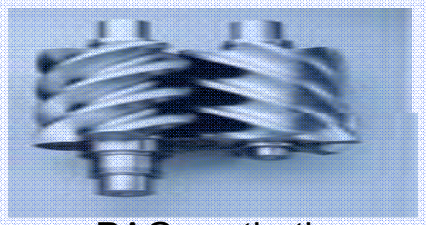
Oxidation Processes Comparison

Mineral & Synthetic Hydrocarbon Oil vs. Polyalkylene Glycols

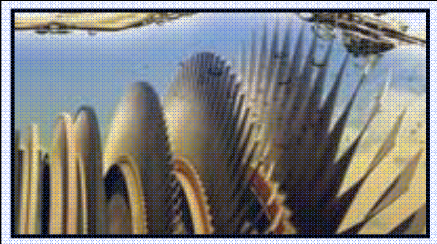


Controlling Deposit Formation using PAGs


Mineral oil

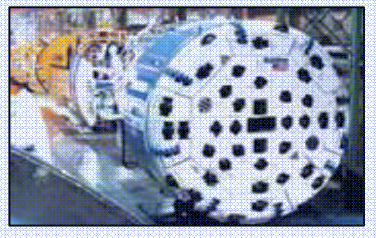

PAG synthetic

Thousands of rotary screw air compressors and other turbo-machinery use conventional PAG technology


Gas turbine

In recent years, there has been an increasing number of reported cases associated with varnish and sludge formation in turbine-generator applications and especially gas turbines. PAGs are providing a solution.


Wind turbine


Tunnel boring

Field studies in emerging applications for PAGs such as tunnel boring and wind turbine lubricants show deposit free operation

Formulating lubricants by upgrading hydrocarbon oils with oil soluble PAGs as a co-base oil may provide solutions to controlling deposits

Oil Soluble PAGs – Typical Physical Properties

Grade	Viscosity at 40°C, cSt	Viscosity at 100°C, cSt	Viscosity Index	CCS viscosity at -20°C, mPa.s
	ASTM D445	ASTM D445	ASTM D2270	ASTM D5293
OSP-32	32	6.5	146	1750
OSP-46	46	8.5	164	2900
OSP-68	68	12	171	5400
OSP-150	150	23	186	17100
OSP-220	220	32	196	29100
OSP-680	680	77	196	n/d

Grade	Flash Point (COC), °C	Fire Point, °C	Four ball wear, mm	Pour Point, °C
	ASTM D92	ASTM D92	ASTM D4172	ASTM D97
OSP-32	216	242	n/d	<-43
OSP-46	210	240	0.58	<-43
OSP-68	218	258	n/d	<-40
OSP-150	228	258	0.43	-37
OSP-220	226	258	0.46	-34
OSP-680	243	260	0.38	-30

Comparison Typical Properties of OSP's / PAO's

UCON Grade	Viscosity at 40°C, cSt	Viscosity at 100°C, cSt	Viscosity Index	Pour Point deg. C
	ASTM D445	ASTM D445	ASTM D2270	ASTM D97
OSP-32	32	6.5	146	<-43
OSP-46	46	8.5	164	<-43
OSP-68	68	12	171	<-40
OSP-220	220	32	196	-34
OSP-680	680	77	196	-30

UCON Grade	Viscosity at 40°C, cSt	Viscosity at 100°C, cSt	Viscosity Index	Pour Point deg. C
	ASTM D445	ASTM D445	ASTM D2270	ASTM D97
PAO-6	31	5.1	138	-57
PAO-8	48	8.0	139	-48
PAO-10	66	10	137	-48
PAO-40	396	29	147	-36
PAO-100	1240	100	170	-30

Expanding functionality of PAGs using OSPs

Use of OSPs
Expansion of formulators options

Primary base oil in formulations

- Compressor/refrigeration oils
  - Hydraulic fluids
  - Gear & Bearing Oils
  - Engine/transmission Oils

Co-base oil

- Upgrade Group I-III mineral oils
- Upgrade PAO's
- Improve additive solubility

Additives

- Deposit control additive
- Friction modifier
- Viscosity builder in mineral oils

Miscibility of OSPs in Common Base Oils

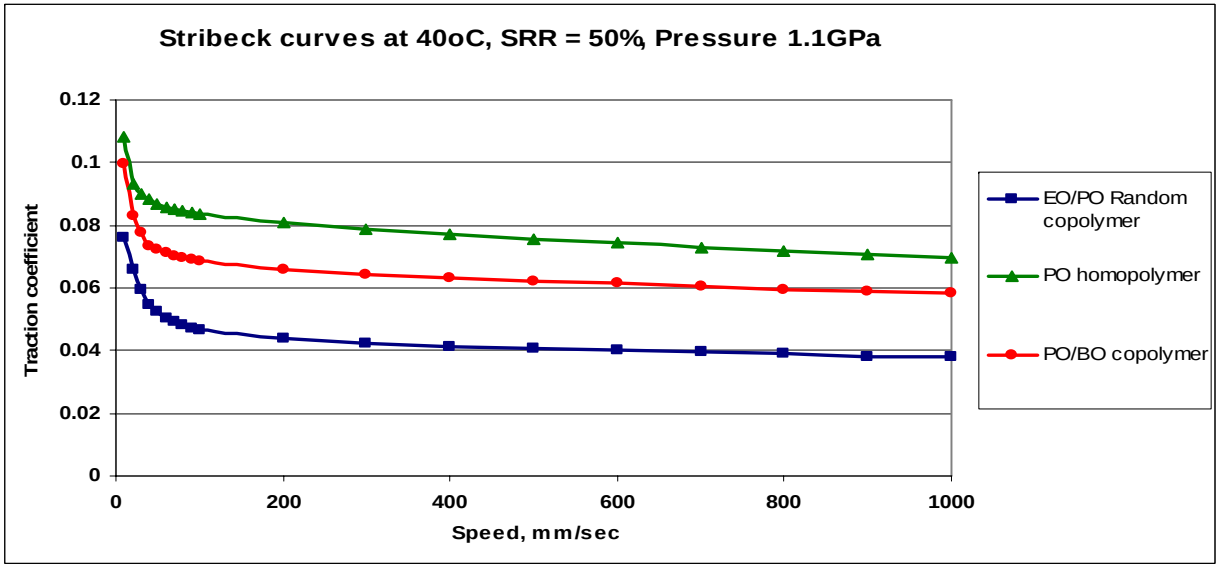
Typical Miscibility Features

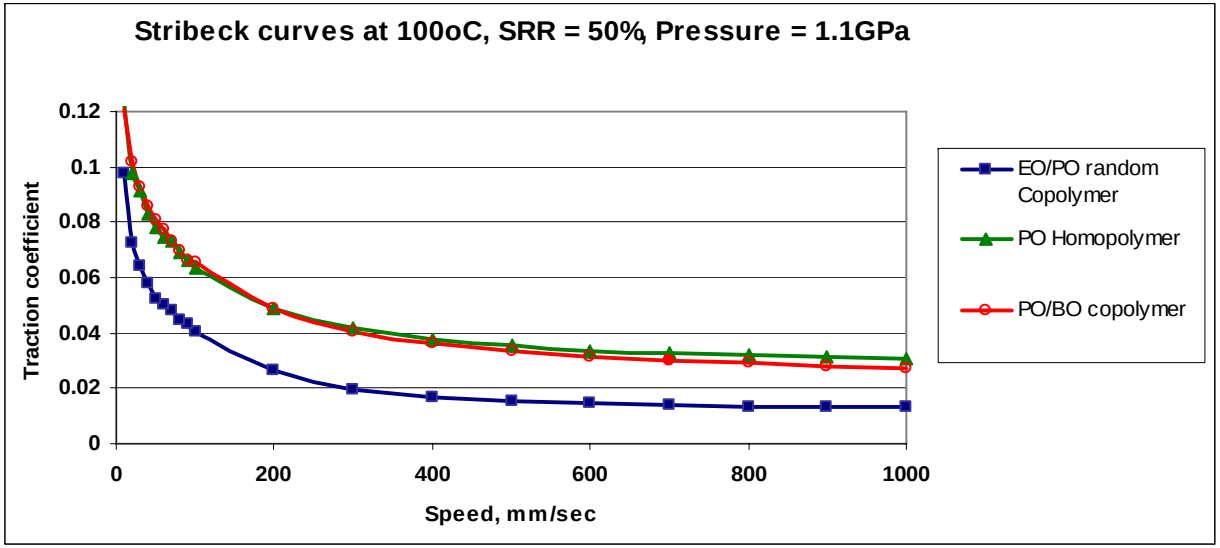
Chemistry	OSP/Base Oil 10/90 w/w	OSP/Base Oil 50/50 w/w	OSP/Base Oil 90/10 w/w
Group I Mineral oils	Miscible	Miscible	Miscible
Group II and III Mineral oils	Miscible	Miscible	Miscible
PAO-4, 6, 8	Miscible	Miscible	Miscible
PAO-40	Partial Miscible	Partial Miscible	Partial Miscible
Diesters & Polyol esters	Miscible	Miscible	Miscible
Naphthenics	Miscible	Miscible	Miscible
PAG's - PO homo-polymers	Miscible	Miscible	Miscible

Miscibility defined as clear homogeneous solutions before and after storing at ambient temperature and 80°C for 168 hours

- Example above shows specifically OSP-46 / OSP-36 fully miscible with PAO-40
- Miscibility improvements ongoing with higher viscosity PAOs

Stribeck Curves of OSPs versus Conventional PAGs (ISO VG-46)



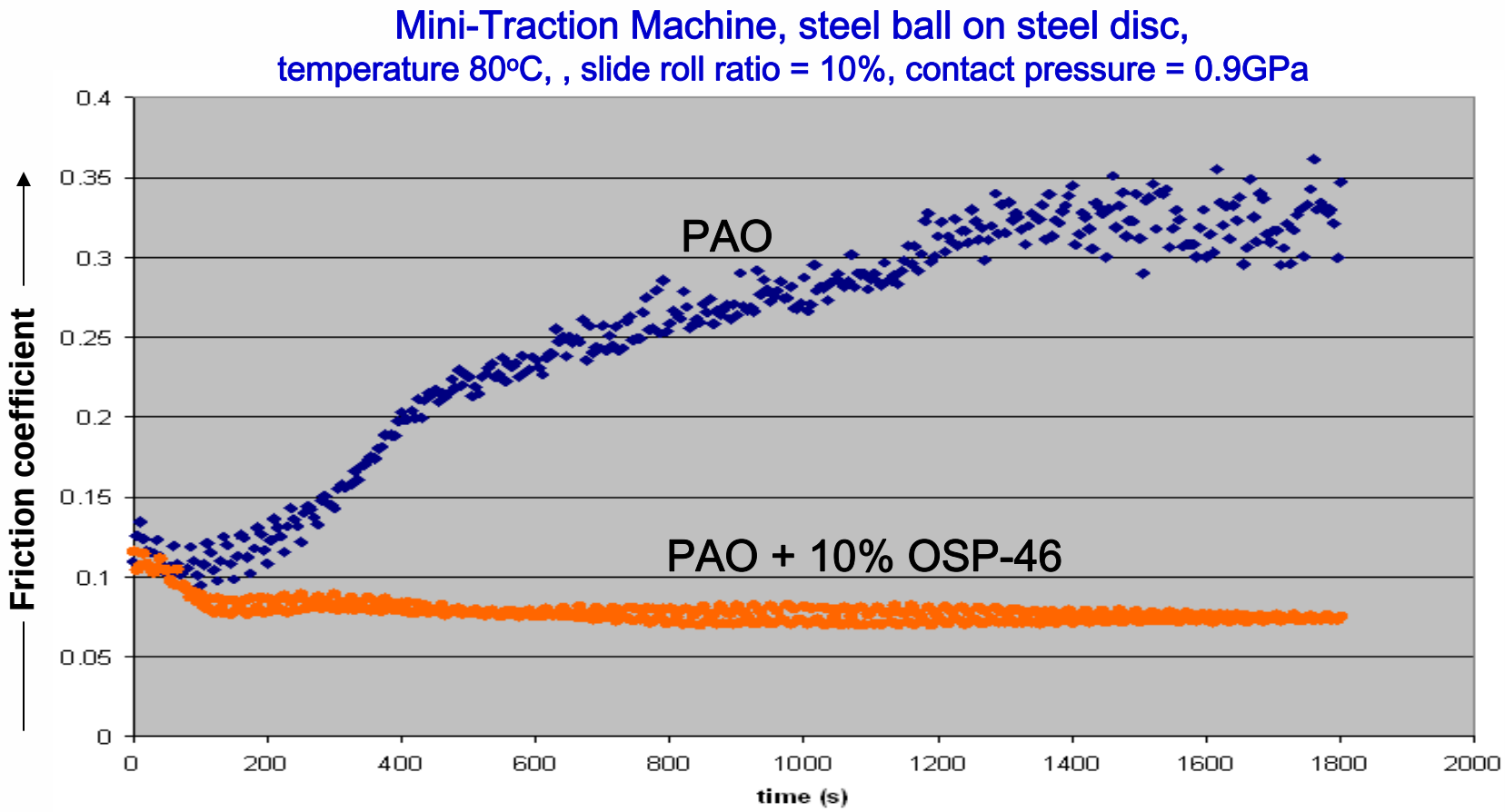


Traction coefficients were measured on a Mini Traction Machine with a ¾ inch steel ball rotating on a steel disk

Directly comparing alkoxide chemistries

Friction coefficients
EO/PO< PO/BO < PO

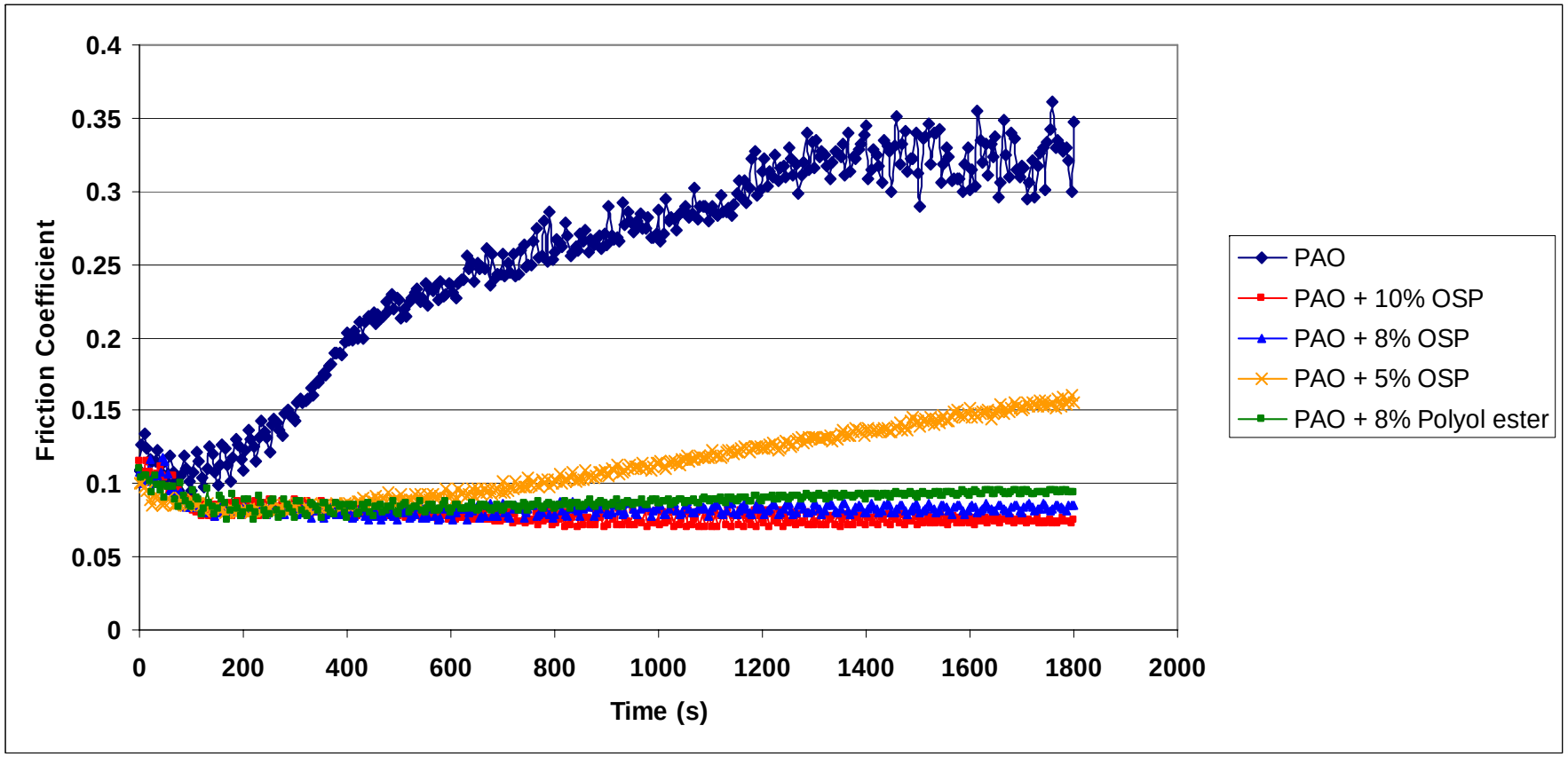
Friction Performance of OSPs as Additives



Under high contact pressures, OSPs impart friction reducing properties in hydrocarbon base stocks. The polar nature of PAGs helps migration to the metal surface. Mechanism of action is being studied

Friction Performance of OSPs as Additives in PAO

Mini-traction machine, steel ball on steel disc, temperature 80°C, , SRR = 10%, Pressure = 0.9GPa



Polyalphaolefin is a PAO-8 base oil (un-additized)

OSP's may offer another choice to esters and other film forming additives

Deposit Control : Extended ASTM D2893 at 120°C

Group I Mineral Oil

0d

50d

Deposit formation

Group I Mineral Oil + OSP-46 (5%)

0d

50d

Deposit free

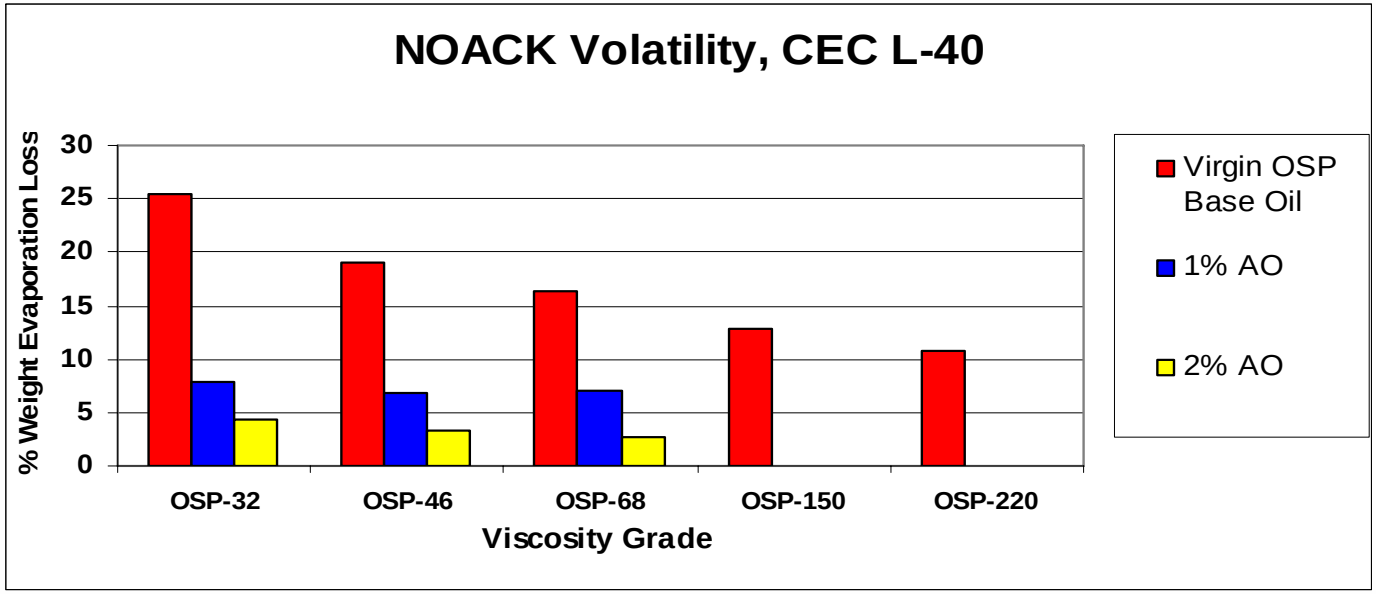
Oxidation Stability Using RPVOT Method

Oil Soluble PAG Base Oil (ISOVG-46) with 2% anti-oxidant

Formulation	Phenolic AO 1 %	Phenolic AO 2 %	Aminic AO 3 %	Aminic AO 4 %	RPVOT (min)
A (Base Oil)	0	0	0	0	15
B	2	0	0	0	70
C	0	2	0	0	60
D	0	0	2	0	935
E	0	0	0	2	966
F	0	1	1	0	440
Proprietary (2%)					1530

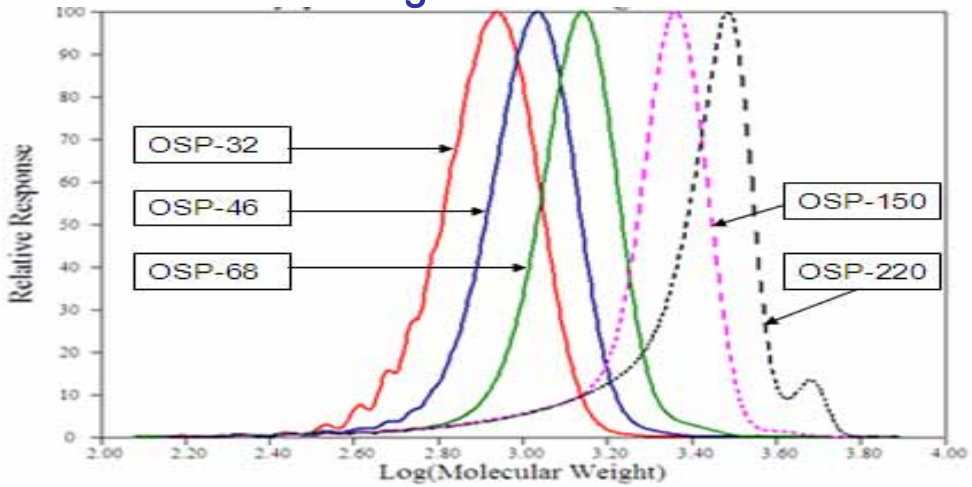
Method used was ASTM D2272 Rotary Pressure Vessel Oxidation Test

NOACK Volatility



Test Duration 60 minute, Temperature = 250°C

GPC – Mol. Weight Distribution



OSP polymerization technology produces a broad molecular weight distribution

UCON OSP Recommended Applications & Uses

Base Oil Uses

	OSP-32	OSP-46	OSP-68	OSP-150	OSP-220	OSP-320	OSP-460	OSP-680
Hydraulics	x	x	x					
Gas Compressors	x	x	x	x				
Industrial Gas Turbines	x	x						
Industrial Gears				x	x	x	x	
Auto Engine Oils	x	x						
Metal Deformation				x	x	x	x	x
Greases			x	x	x	x	x	x

Selection criteria's based on typical viscosity requirements for specific applications

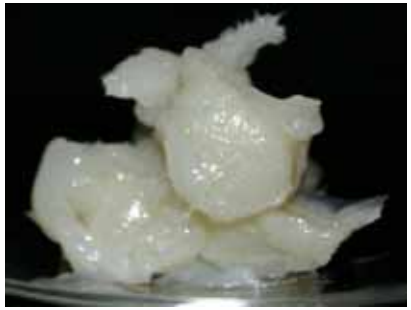
Additive Uses

	OSP-32	OSP-46	OSP-68	OSP-150	OSP-220	OSP-320	OSP-460	OSP-680
Friction Modifier	x	x						
Viscosity Modifier							x	x
Deposit Control Additive	x	x	x					

PAGs are being used in grease formulations. OSP 220 has been used for Li complex grease formulation.

Conclusions

- The formulators and researchers have another option for using PAGs as a “tool” for solving some of our industry problems.
- Formulators can now use Oil Soluble PAGs as a primary base oil, a co-base oil or as an additive in formulations
- Equipment conversions from hydrocarbon oils to Oil Soluble PAGs is simpler and less problematical
- OSPs offer options to upgrade hydrocarbon oils to boost viscosity index and improve deposit control
- OSPs can provide improved friction control when used as an additive. They may provide an alternative to synthetic esters as friction modifiers.
- The flexibility of PAG chemistry provides a huge amount of space for innovation and providing solutions to specifications and standards of the future



THANK YOU

Questions:
gvkhemchandani@dow.com

Tel:979-238-4045