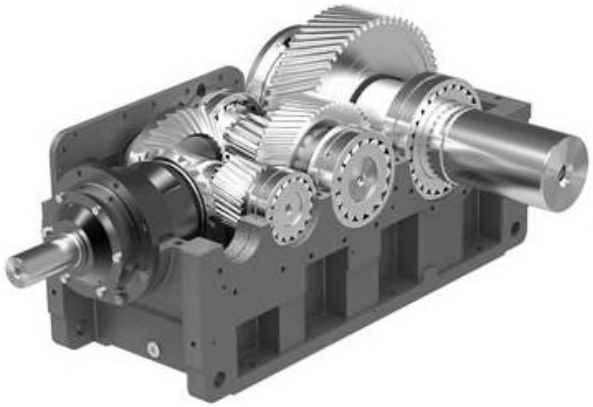
Industrial Gears and Gear Lubricants

The webinar will begin in less than 10 minutes.

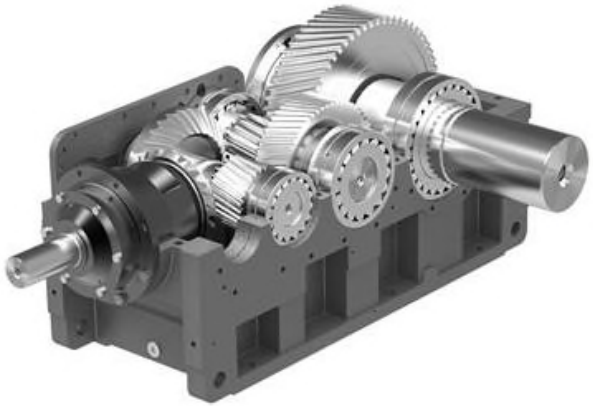
David Turner, CLS, OMA-I, CLGS



Industrial Gears and Gear Lubricants

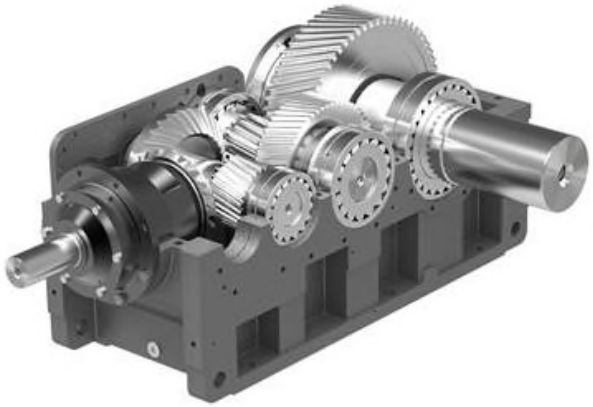
The webinar will begin in less than 5 minutes.

David Turner, CLS, OMA-I, CLGS



Industrial Gears and Gear Lubricants

David Turner, CLS, OMA-I, CLGS



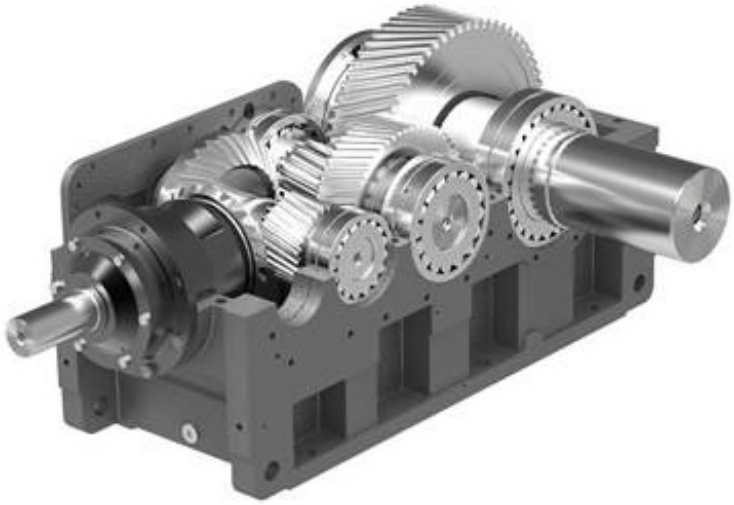
David Turner, CLS, OMA-I, CLGS

- CITGO Sr. Technical Services Representative
- BS, Chemical Engineering
- 40+ Years Experience in Lubricants
- STLE Certified
  - Certified Lubrication Specialist
  - Oil Monitoring Analyst I
- NLGI Certified
  - Certified Lubricating Grease Specialist
- Active in STLE, NLGI, and ASTM

Agenda

- Basics – Functions of gears and gear lubricants
- Gear types
- Gear lubricant selection factors
- Gear lubricant properties
- Gear lubricant specifications
- CITGO industrial gear lubricant portfolio
- Industrial gear lubrication trends

Salisbury Cathedral Clock, 1386



ISL
INDUSTRIAL SYNTHETIC LUBRICANTS

Industrial Gear Basics

Functions of Gears and Gear Lubricants

Gear Functions

- Means of transmitting power
- For altering speed (Usually speed reducer)
- For altering torque (Usually torque increaser)
- Changing direction of rotation

Gear Basics

- What is a pinion gear?

Gear Basics

- What is a pinion gear?

➢ A pinion gear is the high speed or input mounted gear

Gear Basics

- What is a pinion gear?

➢ A pinion gear is the high speed or input mounted gear

- What is the bull gear?

Gear Basics

- What is a pinion gear?

➢ A pinion gear is the high speed or input mounted gear

- What is the bull gear?

➢ The bull gear is the slower speed or output mounted gear

Gear Basics

- How do you determine gear ratio?

Gear Basics

- How do you determine gear ratio?

➢ Gear ratio = The number of teeth on the bull gear divided by the number of teeth on the pinion gear

Gear Basics

- How do you determine gear ratio?

➢ Gear ratio = The number of teeth on the bull gear divided by the number of teeth on the pinion gear

- What is the final gear ratio of a **double** 5:1 reduction gearbox?

Gear Basics

- How do you determine gear ratio?

➢ Gear ratio = The number of teeth on the bull gear divided by the number of teeth on the pinion gear

- What is the final gear ratio of a **double** 5:1 reduction gearbox?

➢ Double 5:1 reduction is 5 X 5 = 25:1 final reduction

Gear Basics

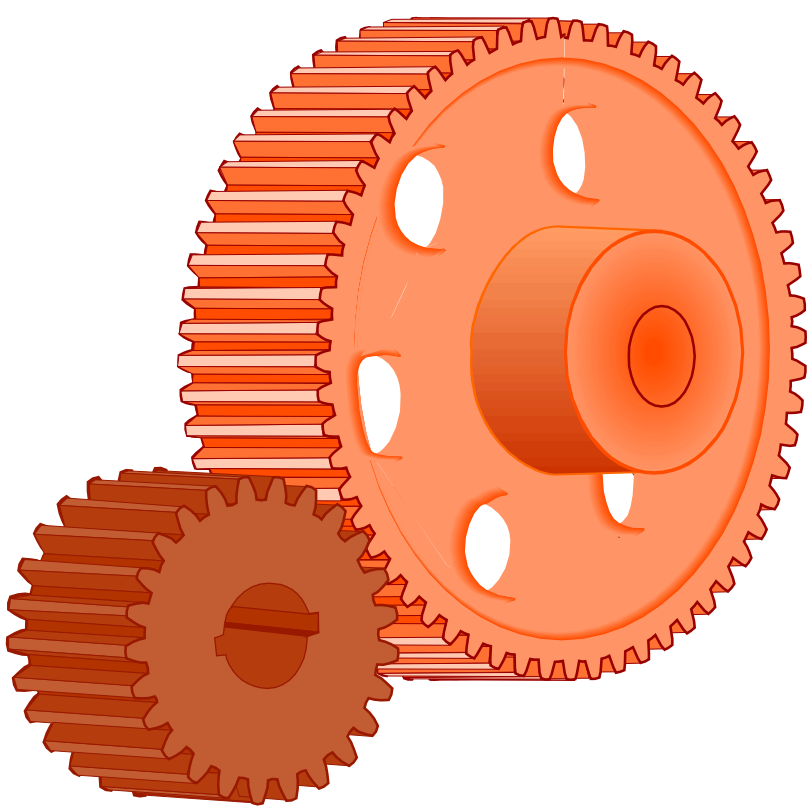
- How is input speed to output speed related to gear ratio?
- Input speed divided by gear ratio = output speed
- What is relationship of speed reduction to torque?
- Decrease in speed yields equivalent increase in torque
  - Decrease speed by 5 times = Increase in torque 5 times

Gear Lubricant Functions

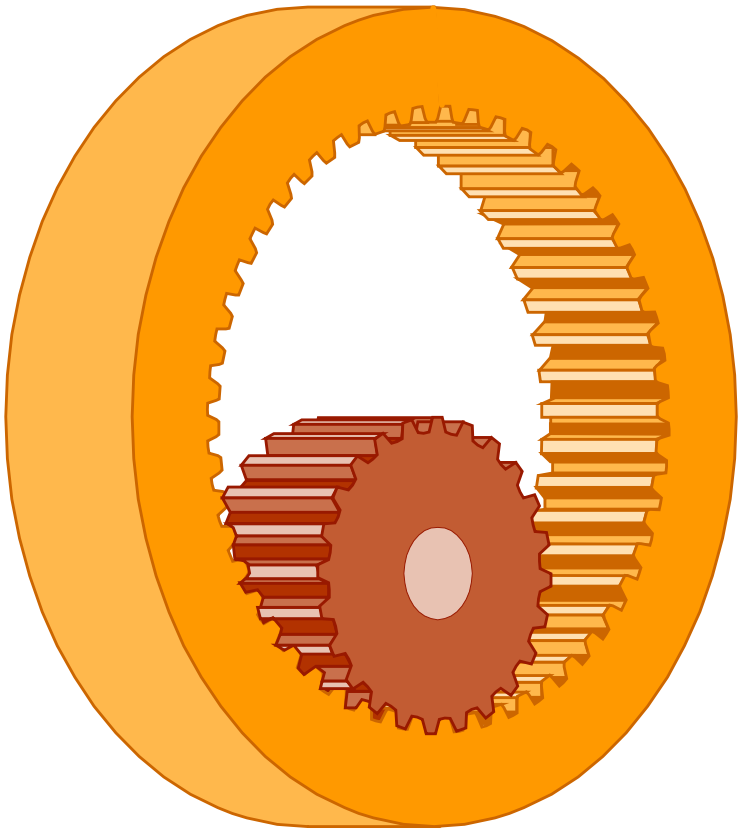
- Provide fluid film to adequately separate components (i.e. gear sets and bearings)
  - Control friction
  - Minimize wear
- Resist oxidation, rust, and corrosion
- Act as a heat transfer medium
- Dampen shock loads, reduce noise
- Seal against contaminants
- Compatibility with seals, elastomers, paints, and coatings
- Remove wear metal particles
- Shed water and resist emulsion formation
- Resist foaming and release air

Gear Types

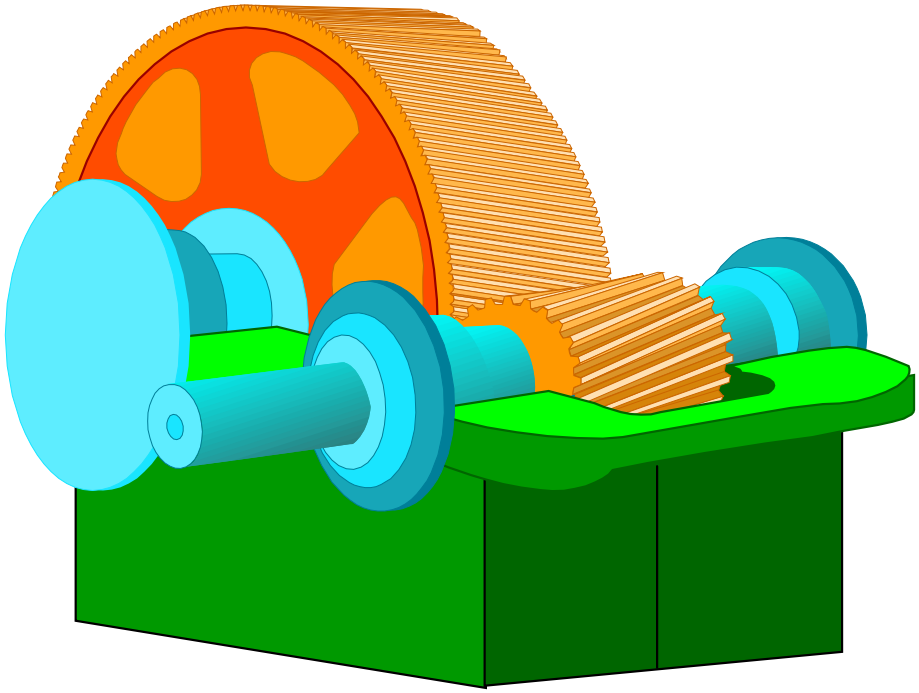
Gear Types – Spur Gear

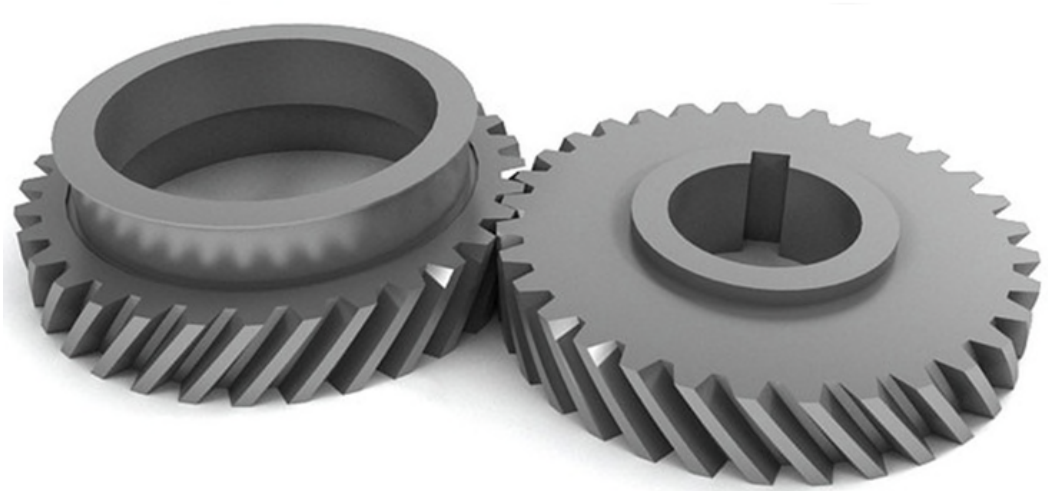


Gear Types – Internal Spur Gear and Pinion

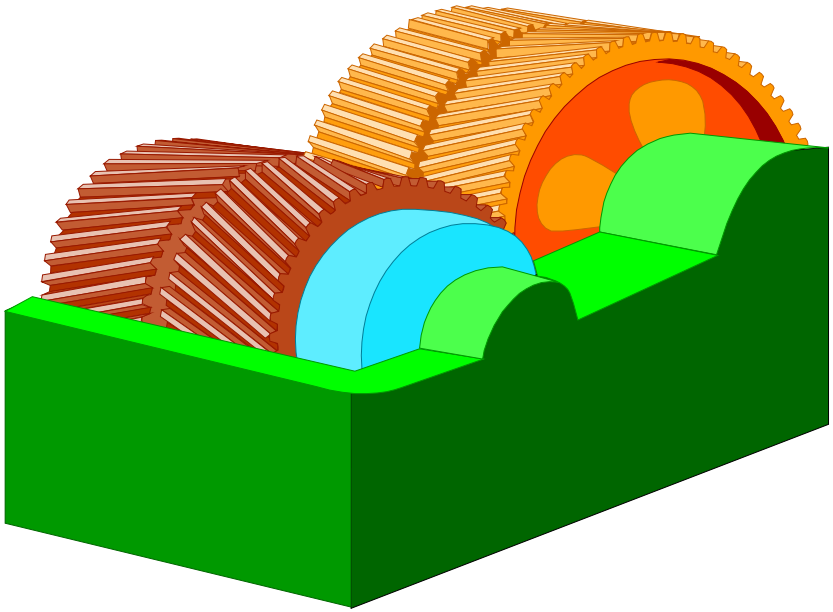


Gear Types – Helical Gear



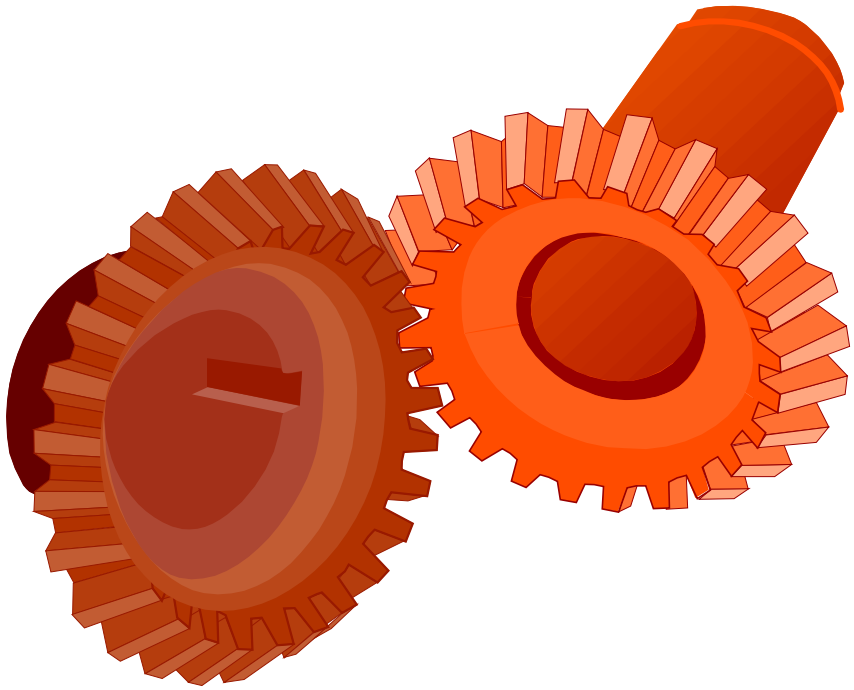


Gear Types – Double Helical Gear



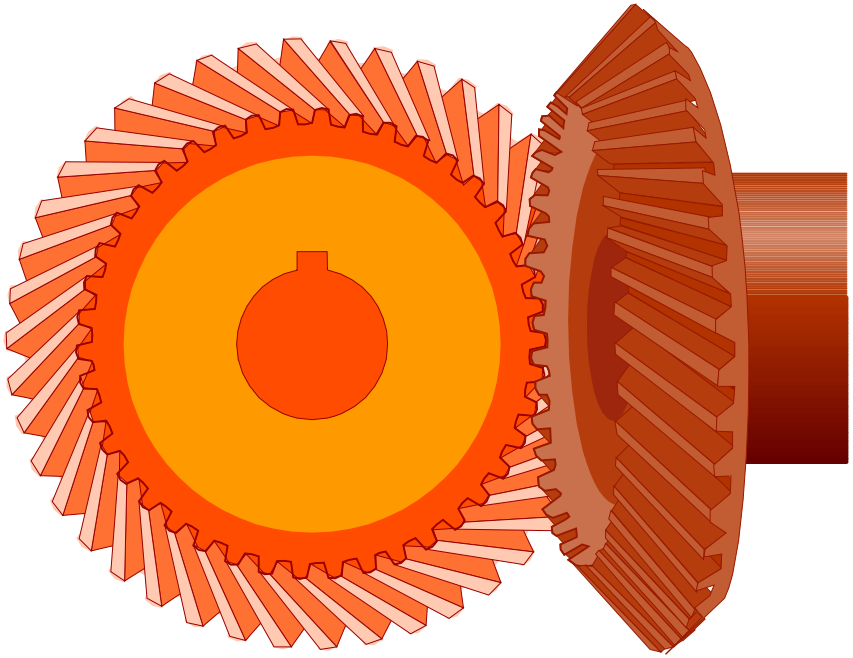
Gear Types – Straight Bevel Gear

Right angle – Input to output shaft



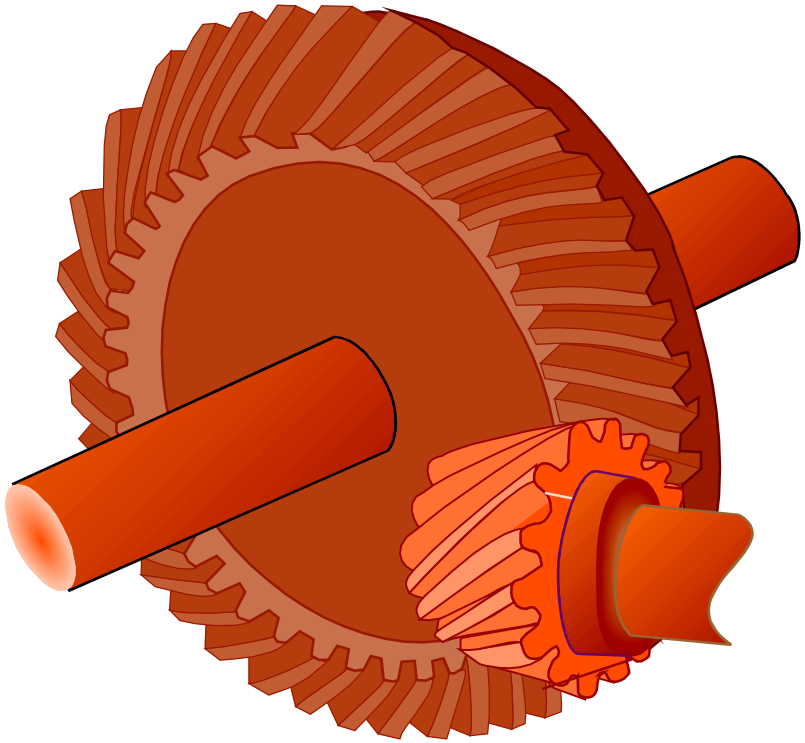
Gear Types – Spiral Bevel Gear

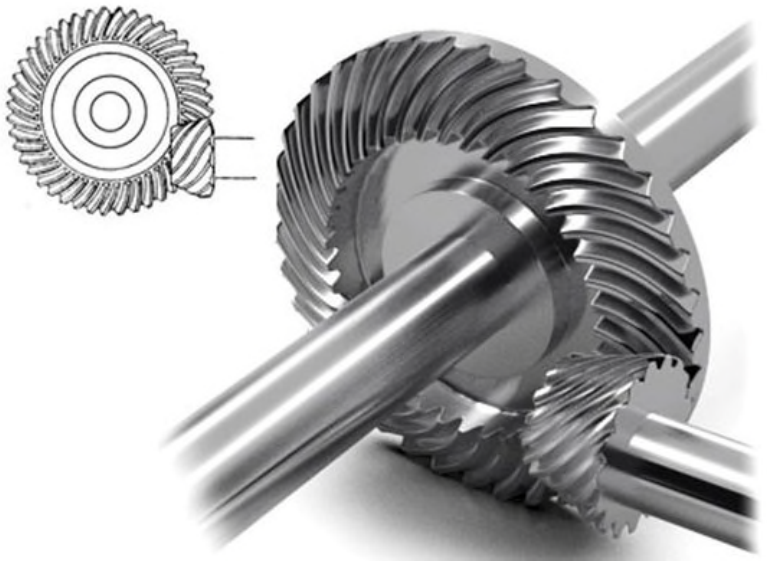
Right angle – Input to output shaft



Gear Types – Hypoid Gear

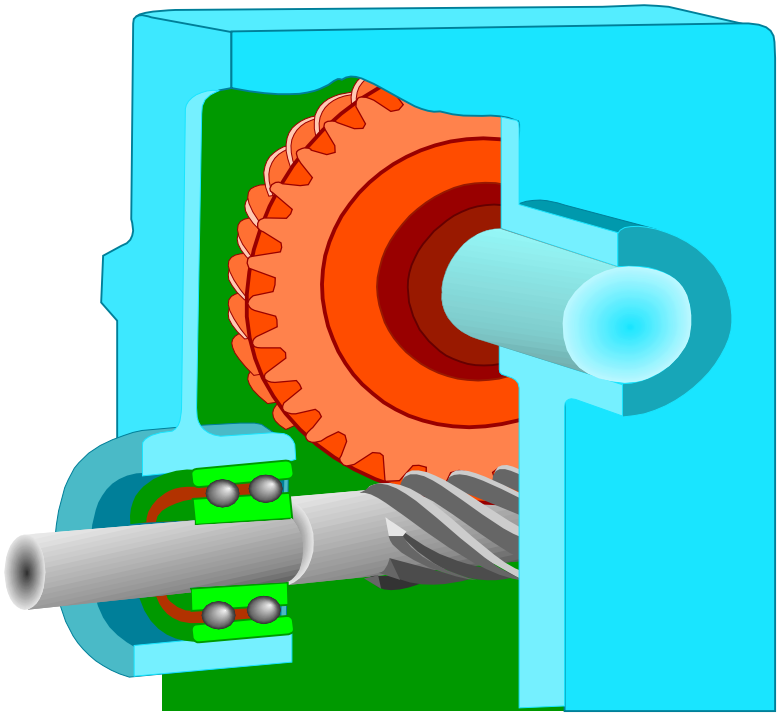
Right angle – Shaft centerlines off-set





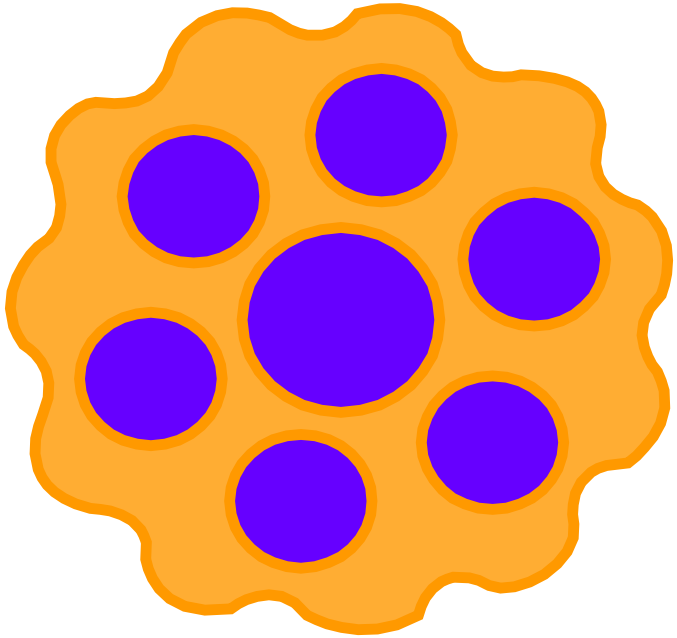
Gear Types – Worm Gear

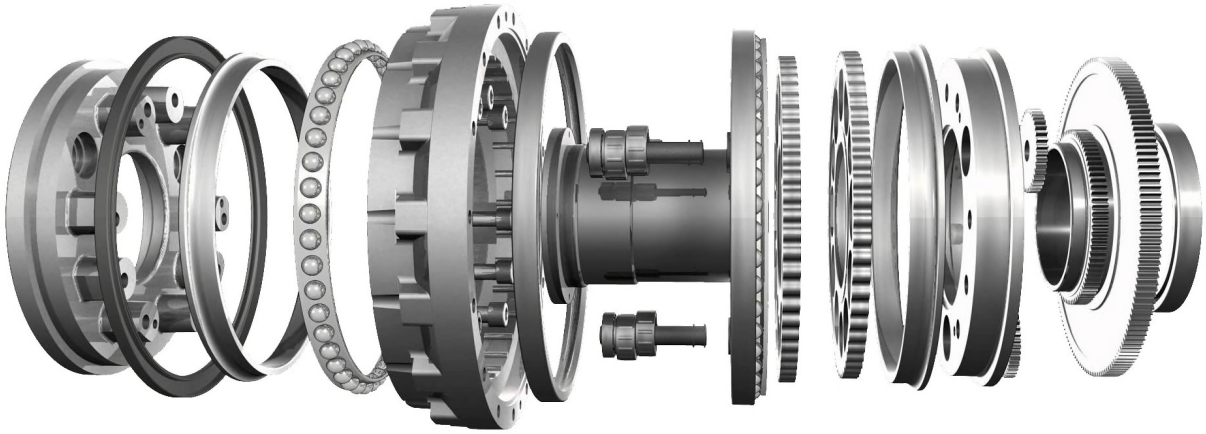
Right angle – Maximum shaft off-set



Gear Types – Cycloid Disc Gear Set

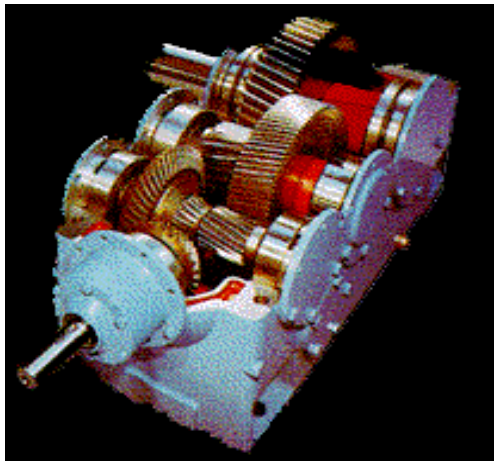
No gear teeth – All rolling motion; pins and lobes



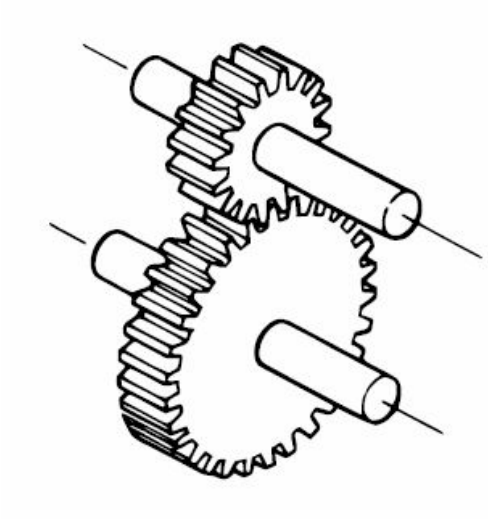


Enclosed Gears

Spur, helical (and related) types



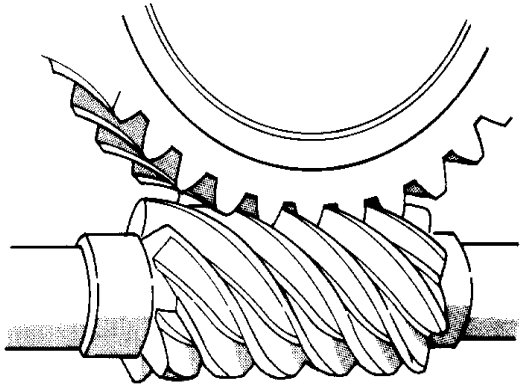
- Generally steel gears, “steel-on-steel”
- Used for small speed reductions, typically with parallel input/output shafts
- Teeth are heavily line or point loaded
  - tooth contact is mixture of rolling and sliding
  - little energy dissipation (good efficiency) (typically 2.5% per gear set)



Enclosed Gears

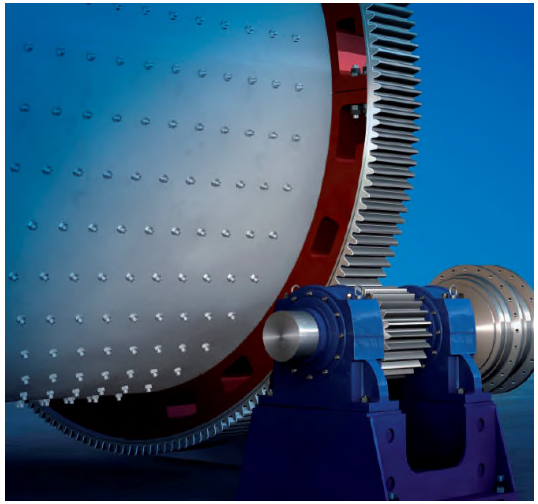
Worm gears

- Usually a steel worm and bronze wheel, “steel-on-bronze”
- Used for high reductions, Right angle input/output shafts (up to 100:1)
- Tooth loadings relatively light, with a large area of sliding contact
  - contact pressures low compared with steel/steel
  - **energy dissipation high because of sliding motion – loss of power (typically 10 to 50%)**



Open Gears

- Typically steel-on-steel
- Commonly spur or helical gears
- Usually very high speed reduction ratio
- Often very large bull gear
- Require special lubricants that stay on the gears



Where Gear Lubricants Are Used

- Packaged gear boxes
  - 40% of oil volume; typically used in process drives (anything that moves), conveyors, materials handling
  - helical 40%, geared motors (mostly helical) 20%, worm boxes 16%, others 24% (spur, bevel, cycloid)
- Metal production
  - 40% of oil volume, steel industry, for rolling mill drives lubricated by circulating systems
- Mines and quarries
  - 8% of volume, enclosed gear boxes (may be standard package), open gears, also sliding components, wire ropes, etc.
- High speed drives
  - small volume of specialized gear oils, drives for high speed rotating equipment, turbines, centrifugal compressors, generally using common system lubricant

Gear Lubricant Composition

- Base Stocks (95-98%)
  - Mineral or Synthetic
- Gear Oil Additive (2-5%)
- Other
  - Pour Point Depressant
  - Foam Inhibitor
  - Friction Modifier
  - Viscosity Modifier
  - Tackifier

Gear Lubricants

Selection Factors

Gear Lubricant Selection Factors

- Speed, Load, Operating Temperature
- Gear Type, including Open or Enclosed
- Gear Metallurgy and Surface Finish
- Shock Loading or Vibration
- **OEM Recommendation**

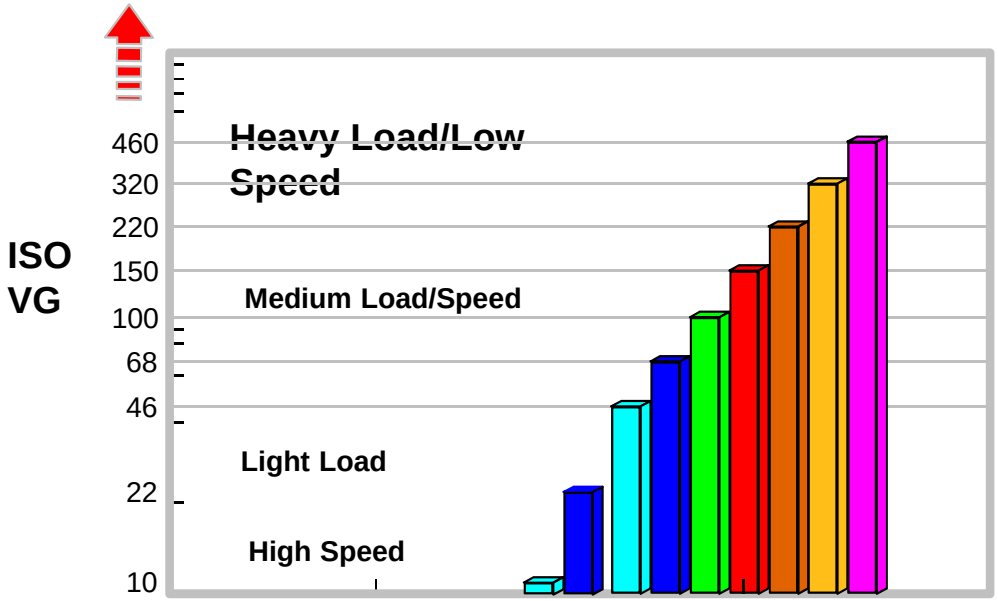
Lubricant	Spur	Helical	Worm	Bevel	Hypoid
Rust and oxidation inhibited	Normal loads	Normal loads	Light loads and slow speeds only	Normal loads	Not recommended
EP gear lube	Heavy or shock loading	Heavy or shock loading	Satisfactory for use in most applications	Heavy or shock loading	Required or specified for most applications
Compounded	Not normally used	Not normally used	Preferred for use by most OEMs	Not normally used	For lightly loaded applications
Synthetics shock loading	Heavy or shock loading	Heavy or use by most OEMs, especially at operating temperatures exceeding 180°F (82°C)	Preferred for shock loading	Heavy or must contain extreme pressure additives	Gear lubricant

Factor	Requirement
Gearing type • Spur and bevel • Helical and spiral bevel • Hypoid • Worm	 Low slide, low speed Moderate slide, moderate to high loading High slide, high loading Excessive sliding, moderate to high loading
Loading	Highly loaded industrial gear drives require the use of extreme pressure gear lubricants.
Surface finish	Rougher surfaces require high-viscosity oils, smoother surfaces can use lower viscosity oils.
Transmitted power	As load is increased, viscosity must be increased.
Gear speed	The higher the speed of the gear drive, the lighter the viscosity needs to be.
Materials compatibility	Some types of extreme pressure additives can attack yellow metals such as brass and bronze.
Temperature	The industrial gear lubricant's viscosity must be used must be selected based on the lowest and highest operating and/or ambient temperature experienced.

Source: Machinery Lubrication

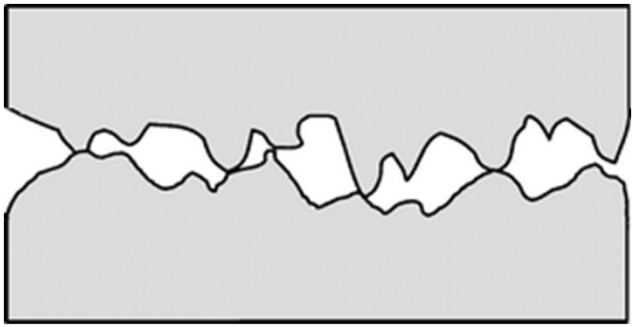
Viscosity Requirements

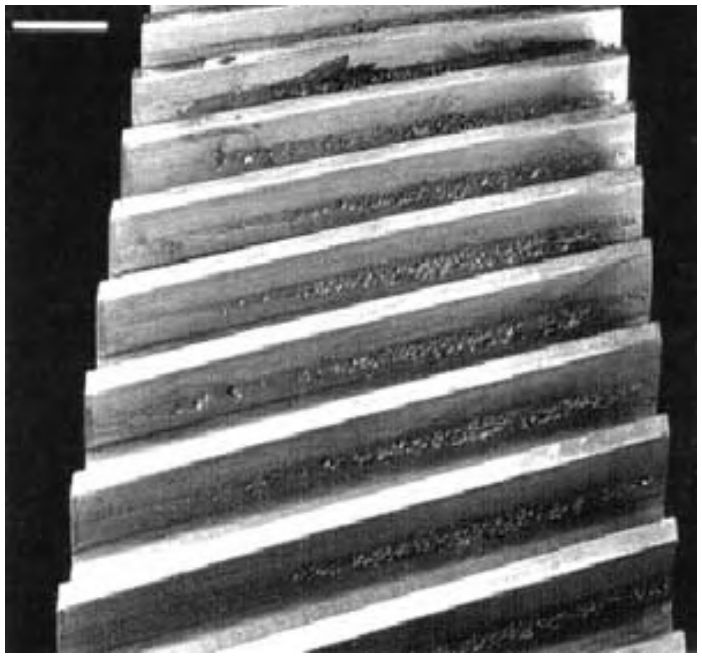
- Higher Loads Require Higher Viscosity
- Higher Temperatures Require Higher Viscosity
- Higher Speeds Require Lower Viscosity



Effects of Low Viscosity

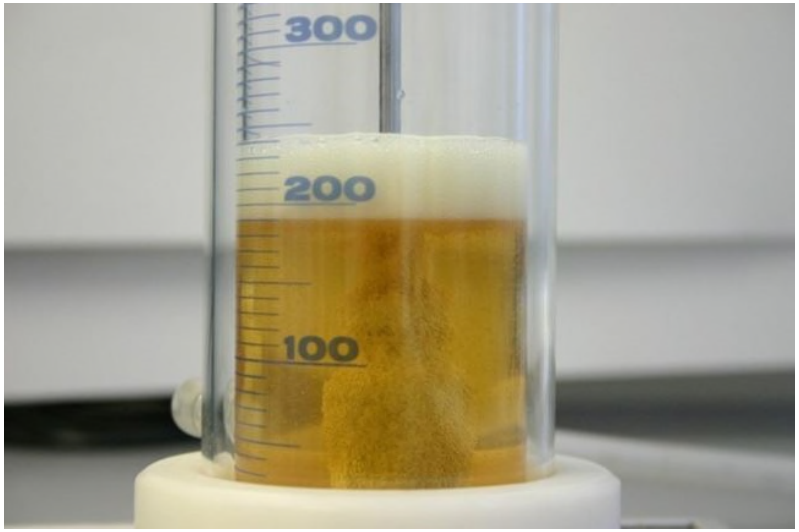
- Increased Temperature and Asperity Contact
- Wear
- Decreased Load Carrying Ability





Effects of High Viscosity

- Increased Temperature from Fluid Friction
- Increased Power Consumption from Fluid Friction
- Increased Foaming from Churning
- Lubricant May Not Flow to Critical Parts



Viscosity – General Rule

- It is very important to have an oil with the proper viscosity to prevent wear.
- It is better to recommend an oil that is one viscosity grade too high than one that is one viscosity grade too low.
- If in doubt, use the higher viscosity oil.

AGMA – American Gear Manufacturers Association

- AGMA is the global network for technical standards, education, and business information for manufacturers, suppliers, and users of mechanical power transmission components
- Founded in 1916
- Currently over 400 member companies
- Produces standards for all aspects of gear technology
- Many technical committees
- Education courses
- Annual meeting in May

Pre-2005 AGMA Gear Lubricant Classifications

- Numbers designate the Viscosity and Letters designate the Additives in the AGMA Grade Gear Oil.

- R&O = Rust and Oxidation Inhibited, No EP additives
  (Spur, Bevel, and most Helical)

- EP = Extreme Pressure (common Sulfur and Phosphorus)
  (Now known as Anti-Scuff - AS) – steel-on-steel gears

- S = Synthetic (PAO, PAG, Esters, type of fluid is unclassified)

- Comp = Compounded
  (Petroleum oils with Fatty Oil additive to provide lubricity)

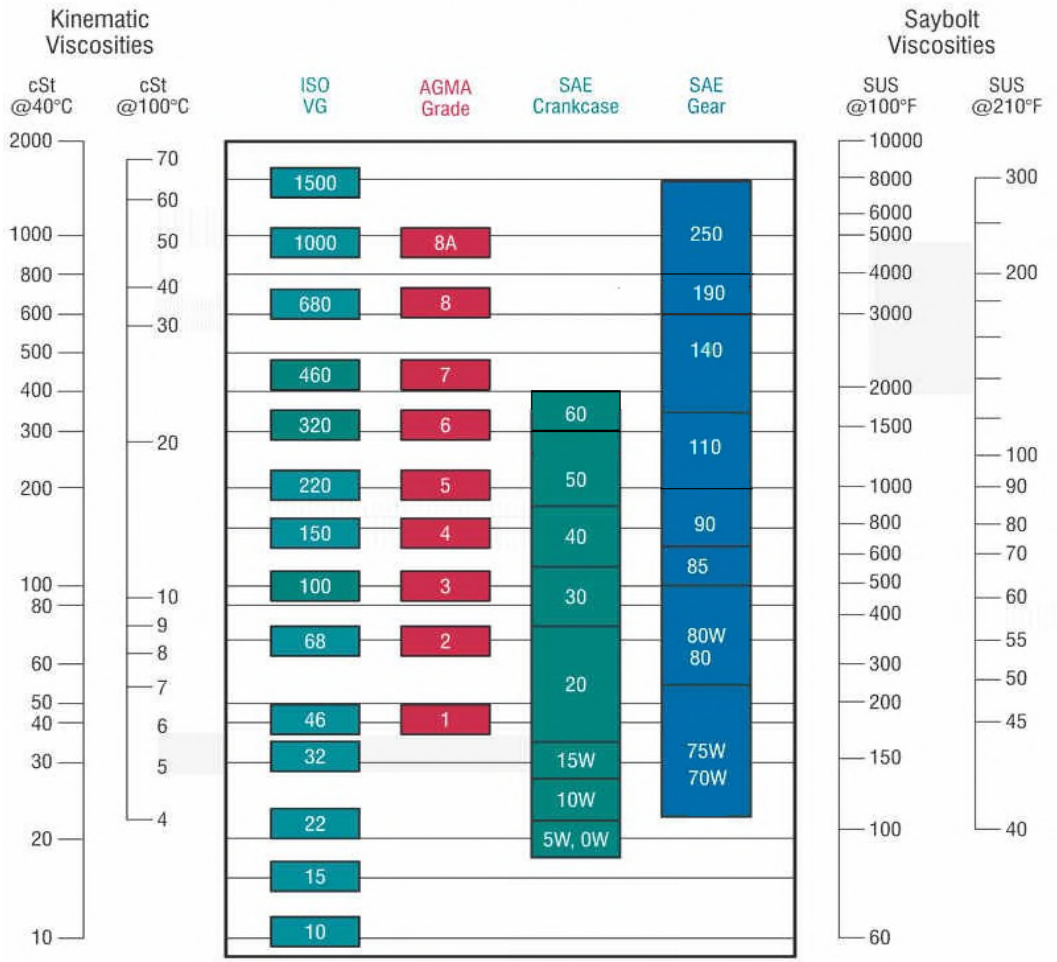
- Res = Residual
  (Heavy Asphaltic Type Oils Normally for Large Open Gears)

Pre-2005 AGMA Gear Lubricant Viscosity Classification

ISO Grade	AGMA Grade
32	0 (R&O, S)
46	1 (R&O, S)
68	2 (R&O, EP, S)
100	3 (R&O, EP, S)
150	4 (R&O, EP, S)
220	5 (R&O, EP, S)
320	6 (R&O, EP, S)
460	7 (EP, COMP, S)
680	8 (EP, COMP, S)
1000	8A (EP, COMP, S)
1500	9 (EP, S)
2200	10 (EP, S)
3200	11 (EP, S)
	14R, 15R (Residual)

ISO and AGMA Gear Lubricant Viscosity Classifications

Table 2. Comparative Viscosity Classifications



Post-2005 AGMA Gear Lubricant Viscosity Classification

Table 4 - Viscosity grade requirements

ISO viscosity grade	Mid-point viscosity at 40°C mm^2/s [1]	Kinematic viscosity limits at 40°C mm^2/s [1]		Former AGMA grade equivalent [2]
		min	max	
ISO VG 32	32	28.8	35.2	0
ISO VG 46	46	41.4	50.6	1
ISO VG 68	68	61.2	74.8	2
ISO VG 100	100	90.0	110	3
ISO VG 150	150	135	165	4
ISO VG 220	220	198	242	5
ISO VG 320	320	288	352	6
ISO VG 460	460	414	506	7
ISO VG 680	680	612	748	8
ISO VG 1000	1000	900	1100	8A
ISO VG 1500	1500	1350	1650	9
ISO VG 2200	2200	1980	2420	10
ISO VG 3200	3200	2880	3520	11

NOTES:

1) The preferred unit for kinematic viscosity is mm^2/s, commonly referred to as centistoke (cSt).

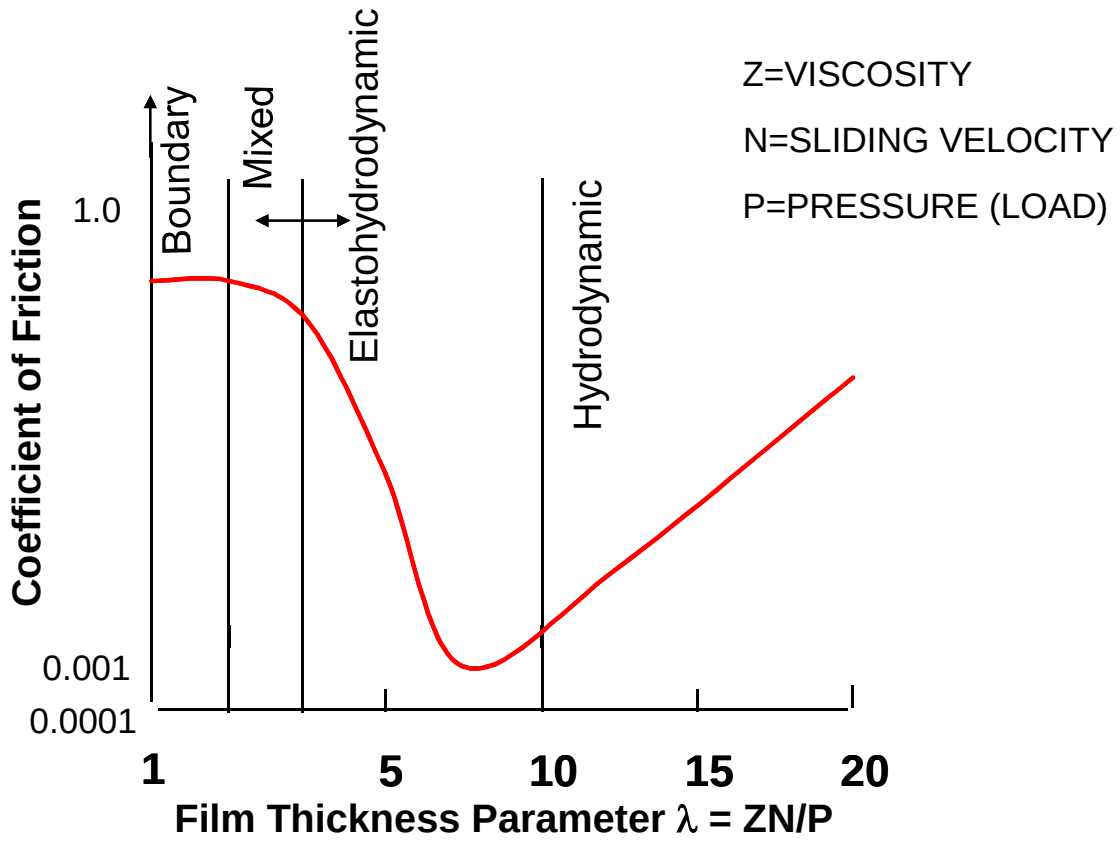
2) With the change from AGMA viscosity grade equivalents to ISO viscosity grade classifications, the designations S, EP, R and COMP will no longer be used as part of the viscosity grade nomenclature.

Source: AGMA 9005-E02 (2002)

Selecting the Right Gear Lubricant Viscosity

- Remember ZN/P
- Speed – in gears, measured as the pitch line velocity
- Temperature – ambient
  - Gear “box” designed to dissipate heat – maximum temperature rise is 40°F over ambient
- Load is restricted to bending fatigue of the steel teeth

Stribeck Curve

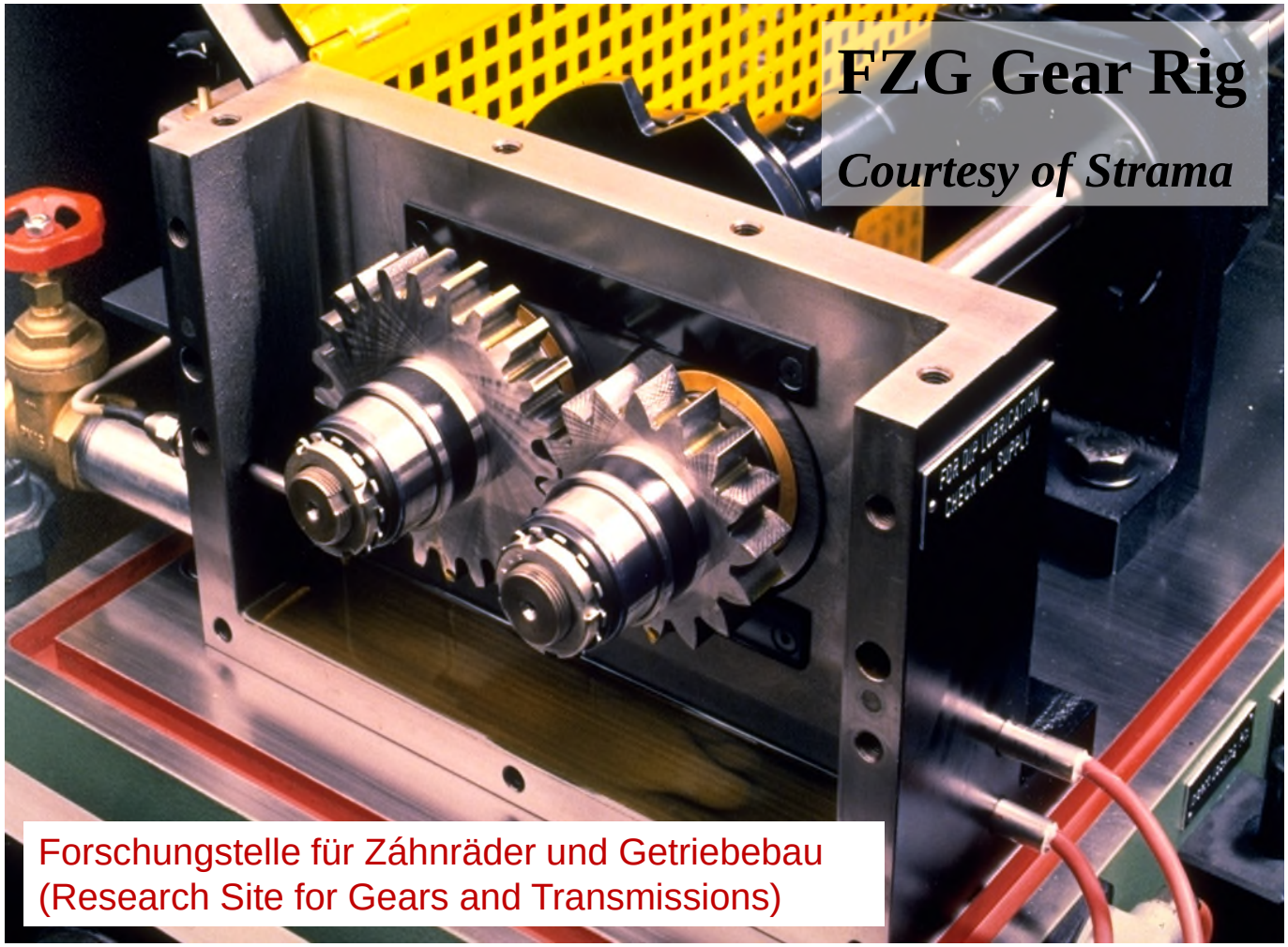


Gear Lubricant Properties

Gear Lubricant Properties

- Viscosity and Viscosity Index – D445, D2270
- Water Shedding and Demulsibility – D1401, D2711
- Oxidation Stability – D2893
- Thermal Stability – D2070
- Rust Prevention – D665A/B
- Corrosion Prevention – D130
- Foaming Resistance – D892
- Air Release – D3427
- Wear Prevention – D4172 (4-Ball), D4998 (FZG)
- EP Performance – D2782 (Timken), D2783 (4-Ball), D5182 (FZG)

ASTM D5182 FZG Gear Test Rig



Forschungstelle für Záhnräder und Getriebebau
(Research Site for Gears and Transmissions)

Gear Lubricant Specifications

Gear Lubricant Specifications

- Industry Organizations
  - ANSI/AGMA 9005-F16
  - DIN 51517 Part 3
  - ISO 12925-1
- OEMs
  - Flender
  - David Brown
  - Falk
  - Fives Group
- Users
  - US Steel 224

CITGO Industrial Gear Lubricant Portfolio

CITGO Industrial Gear Lubricant Portfolio

- CITGO Cylinder Oils
- CITGO EP Compounds
- CITGO CITGEAR® Synthetic HT Lubricants
- CITGO CITGEAR® Synthetic EP Lubricants
- CITGO CITGEAR® Synthetic PAG Gear Fluids
- CITGO CITGEAR® WT 320
- CITGO Pacemaker® SD Oils
- CITGO CITGEAR® XCO Oils
- CITGO CITGEAR® MGM-OGL
- Mystik® Open Gear #1.5 Grease
- Clarion® Food Machinery Gear Oils and Synthetic Gear Fluids
- Clarion® Green Gear Lubes and Green Synthetic Gear Fluids

CITGO Industrial Gear Lubricants

- **CITGO Cylinder Oils**
  - Specific use in steam cylinders, gas compressor cylinders, and worm gear drives
  - Compounded oil
  - 220-5 (ISO 220, 5% fat)
  - 400-5 (400 cSt at 40C, 5% fat), AGMA 7C
  - 680-7 (ISO 680, 7% fat), AGMA 8C

- **CITGO EP Compounds**
  - Can be used in mist lubrication systems
  - Recommended for plain and antifriction bearings and gear drives operating under heavy conditions
  - ISO 68, 100, 150, 220, 320, 460, 680, 800
  - Meet: DIN 51517 part 3, US Steel 224

CITGO Industrial Gear Lubricants

- **CITGO CITGEAR® Synthetic HT Lubricants**
  - For operations at severe high or low temps
  - Non EP AGMA Lubricants
  - Can be used in worm gears and industrial blowers
  - Can be used in compressor applications (higher P, check downstream catalysts if used in compressor)
  - ISO 68, 100, 150, 220, 320, 460, 680

- **CITGO CITGEAR® Synthetic EP Lubricants**
  - Intended for severe temperature applications (wide ranges)
  - Compatible with most seals – nitrile, Buna N, Viton, Teflon, Polyethylene
  - ISO 68 and 100 meet GL-4 requirements for manual transmission/transaxles
  - ISO 100, 150, 220, 320, 460, 680

CITGO Industrial Gear Lubricants

- **CITGO CITGEAR® Synthetic PAG Gear Fluids**
  - PAG (polyalkylene glycol) Gear Fluids
  - Gear boxes, worm gears, bearings, blowers, reciprocating compressors, and hydraulic systems
  - High Viscosity Index and low pour point
  - Heat transfer ability
  - Hygroscopic
  - Not compatible with mineral oils
  - ISO 100, 150, 220, 320, 460
  - Multipurpose industrial equipment capability

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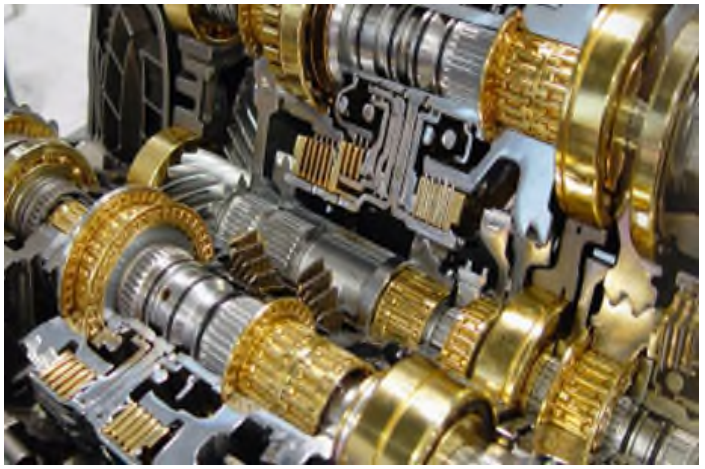

CITGO Industrial Gear Lubricants

- **CITGO CITGEAR® WT 320**
  - Synthetic gear lubricant designed for wind turbine gears
  - Industrial gear applications that require EP protection
  - Wear protection for gears and bearings
  - Wide temperature range performance
  - Seal compatibility
  - Siemens MD (Rev. 15) - Flender gear unit approval
  - ISO 320

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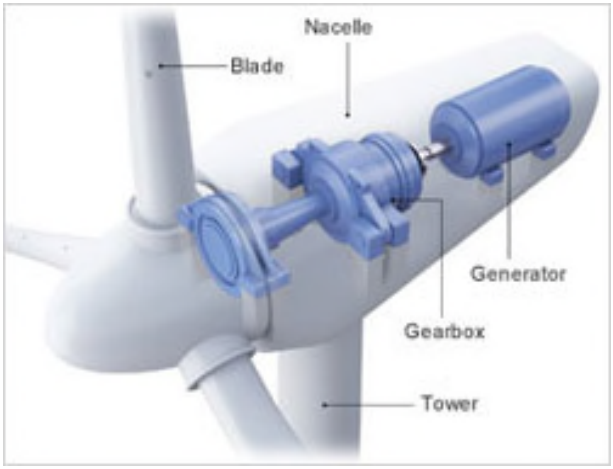
INDUSTRIAL SYNTHETIC LUBRICANTS



CITGO Industrial Gear Lubricants

- **CITGO Pacemaker® SD Oils**
  - High quality R&O inhibited circulating oils
  - “Super Demulsible”
  - Bearing applications where Super Demulsible oils are called for such as Morgoil systems
  - Lubricate both gears and bearings
  - ISO 150, 220, 320, 460, 680

- **CITGO CITGEAR® XCO**
  - Provide excellent performance in high speed no twist rod mills such as those mfg. by Danieli and Morgan.
  - Excellent demulsibility, antiwear additive system
  - ISO 100, 220, 320, 460

CITGO Industrial Open Gear Lubricants

- **CITGO CITGEAR® MGW-OGL**
  - Asphaltic open gear lubricant
  - Protect heavily loaded open gears
  - EP additive
  - Grinding mill gear and pinion, cement kiln open gears
  - 1600 cSt @ 100 C
  - Solvent cut-back for easy application

Mystik Industrial Open Gear Lubricants

- **Mystik Open Gear #1.5 Grease**
  - Lithium soap grease
  - NLGI 1.5
  - Smooth, stringy, tacky
  - Water resistant, protects against corrosion
  - High EP and antiwear properties
  - Molybdenum disulfide and graphite
  - No solvent

Clarion Food Grade Gear Lubricants

- **Clarion® Food Machinery Gear Oils**
  - Based on white mineral oil
  - NSF H1 registered
  - Kosher and Halal certified
  - ISO 150, 220, 320, 460
  - ISO 220 is NSF/ANSI Standard 60/61 certified

- **Clarion® Synthetic Gear Fluids**
  - Based on PAO synthetic fluid
  - NSF H1 registered
  - ISO 150, 220, 320, 460
  - High viscosity index
  - Low pour point

ISL
INDUSTRIAL SYNTHETIC LUBRICANTS

Clarion Environmentally Friendly Gear Lubricants

Clarion® Green Gear Lubes

- Based on white mineral oil
- Inherently biodegradable
- Pass the US Coast Guard Static Sheen Test
- Ashless, non-toxic to aquatic life
- ISO 220, 320, 460

Clarion® Green Synthetic Gear Fluids

- Based on PAO synthetic fluid
- Readily biodegradable
- Ashless, non-toxic to aquatic life
- Meet 2013 VGP EAL requirements
- ISO 150, 220, 320
- High viscosity index, low pour point

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INDUSTRIAL SYNTHETIC LUBRICANTS

Application Guide for Industrial Gear Lubricants

CITGO Gear Lubricant Options	AGMA EP	AGMA Non EP	Open Gear	Compounded	Morgan/Danieli Super Demulsible	Morgan/ Danieli No Twist Rod Mill	Extra Long Life	Wide Temp Operating Range	Synthetic	Low Pour PT	LC 50 Toxicty	Zinc Free	LubeAlert CPM	Food Grade	Coast Guard Static Sheen Pass
Clarion Food Machinery Gear															
Clarion Synthetic Gear															
Clarion Green Gear Lube															
CITGO EP Compound															
CITGO CITGEAR Synthetic Gear EP															
CITGO CITGEAR Synthetic Gear HT															
CITGO CITGEAR Synthetic Gear PAG															
CITGO Pacemaker															
CITGO Pacemaker SD															
CITGO CITGEAR XCO															
CITGO Cylinder Oils															
CITGO MGW-OGL															

Industrial Synthetic Gear Lubricants

The following products are part of the Industrial Synthetic Lubricants portfolio:

- CITGO CITGEAR® Synthetic HT Lubricants
- CITGO CITGEAR® Synthetic EP Lubricants
- CITGO CITGEAR® Synthetic PAG Gear Fluids
- CITGO CITGEAR® WT 320
- Clarion® Synthetic Gear Fluids
- Clarion® Green Synthetic Gear Fluids

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These products qualify for the SwiftShip program.

swiftship

SwiftShip can get product delivered directly to your customer in two to four days. No need to stock expensive synthetic products.

Industrial Gear Lubrication Trends

Industrial Gear Lubrication Trends

Global/OEM Industry Trends	Fluid Requirements
Clean gear concept	Less sludge formation
Improved micro-pitting performance	Less corrosive EP and balanced friction performance
Smaller sump sizes	Improved foam and air release
Higher operating temperatures	Improved oxidation and thermal stability
Extended oil drain	Improved overall performance
Reduced energy consumption	Improved friction

Common Gear Lubrication Problems

- Thickening / Thinning
  - Contamination, e.g. incorrect oil viscosity / lubricant
  - Oxidation
    - Sludge formation
    - System cleanliness
- Foaming and Demulsibility
  - Incorrect oil level, Additive interactions, Contaminants – e.g. water, dirt, cement dust
- Corrosion
  - Ferrous and Non-Ferrous
- Noise
  - Improper design, faulty installation (alignment of equipment)
  - Foaming
  - Pour point - low temperature start-up, fluid circulation problems
  - Gear wear, micro-pitting
- High energy consumption

Questions

- Please post your questions using the Q&A function.

How to Contact Us

- Lubes Answer Line

800-248-4684

8:00 AM - 12:00 PM, 1:00 PM – 5:00 PM CT
Monday through Thursday

8:00 AM - 12:00 PM, 1:00 PM – 4:30 PM CT
Friday

lubeshelp@citgo.com

Future Webinars

To be Announced