



# Hydraulics Basics

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



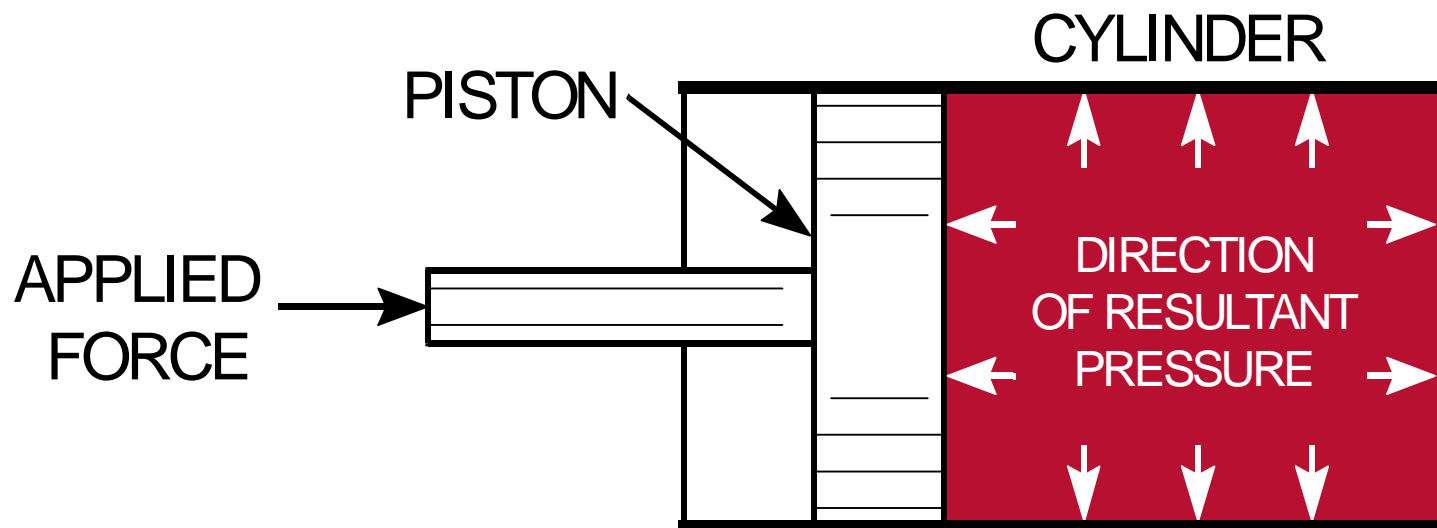
## Agenda

- Hydraulic concepts
- Hydraulic system components
  - Hydraulic pumps
- Hydraulic fluid applications
- Hydraulic fluids



Blaise Pascal

## Basic Hydraulics – Pascal's Law

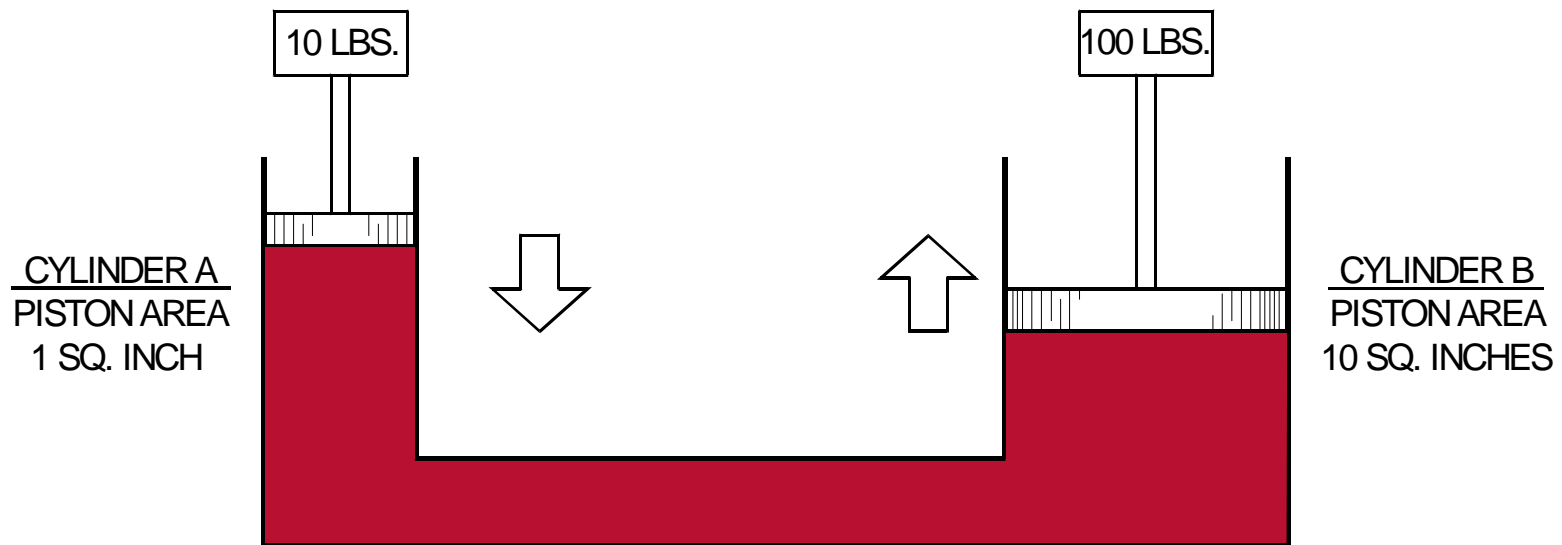


$$\Delta P = \rho g(\Delta h)$$

## Pascal's Law in a Hydraulic System

Converts a small force into  
a much larger one

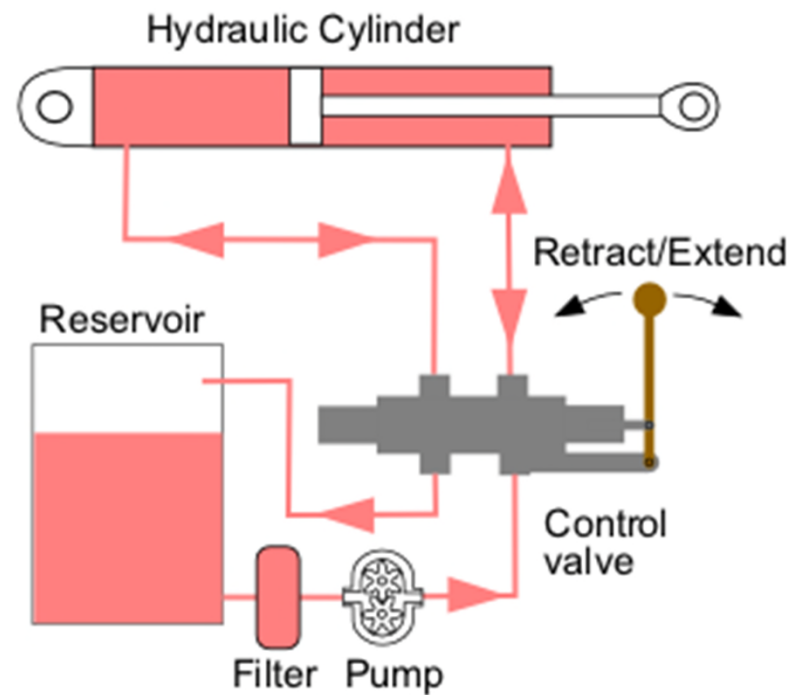
Uses a liquid to transfer energy  
to move or drive a load



## Simple Hydraulic Circuit

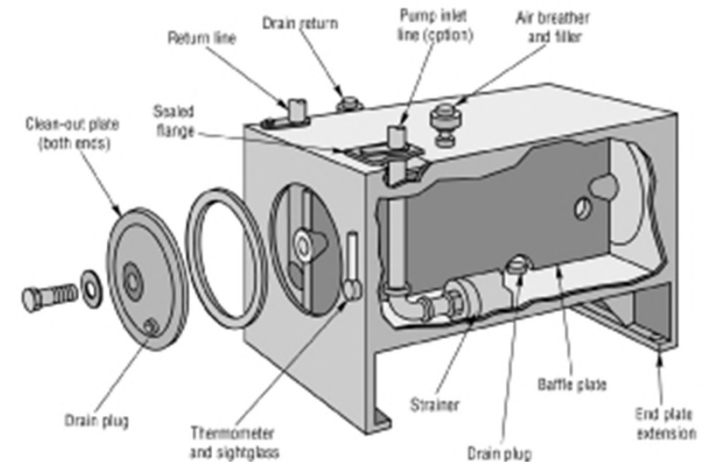
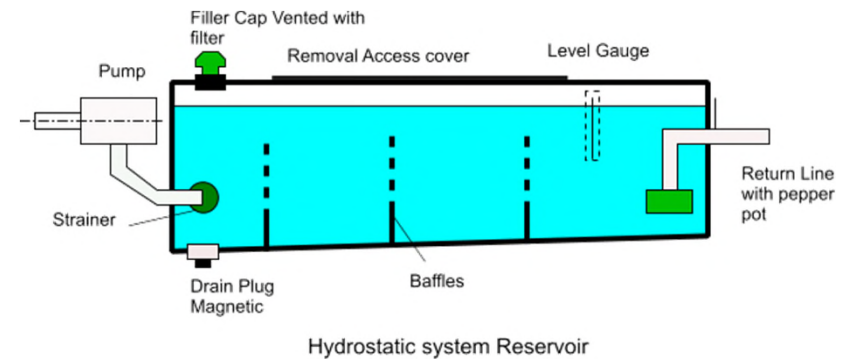
Components:

- Fluid Reservoir
- Filter
- Pump
- Directional Control Valve
- Hydraulic Cylinder



## Hydraulic System Reservoir

- Different Designs Possible
- Atmospheric / Pressurized
- Raised Suction
- Suction Strainer
- Baffle(s)
- Return Line Below Liquid Level
- Desiccant Filter Breather
- Level Indicator
- Temperature Indicator
- Bottom Drain Point
- Access Ports



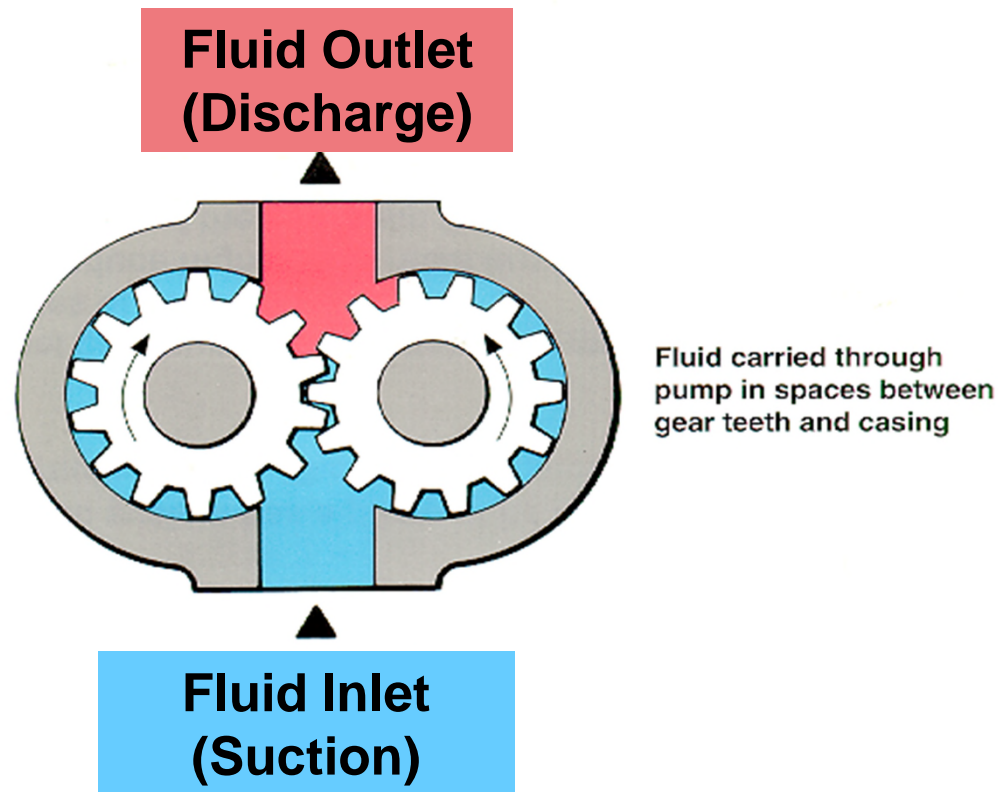
## Hydraulic Fluid Filters

- Hydraulic systems must have filters to protect system components
- Strainer on pump suction
- Fine filter on return line
- Spin-on or cartridge type
- Typically 3 – 10  $\mu$  with a  $\beta$  ratio of 1000
- Sample port should be on return line before filter





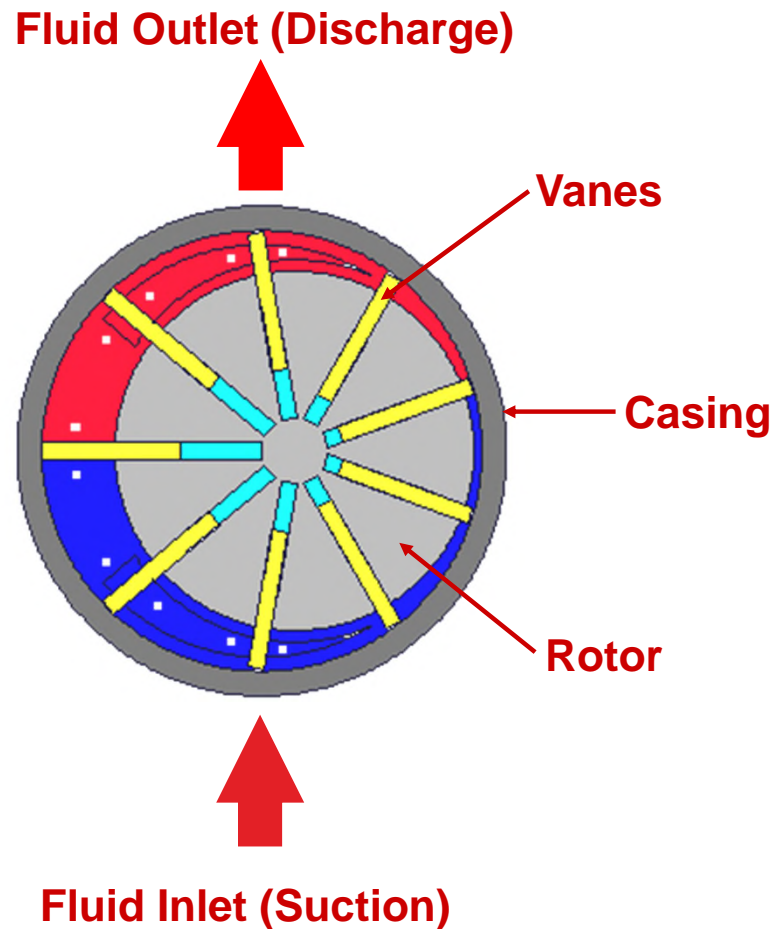
## Hydraulic Gear Pump



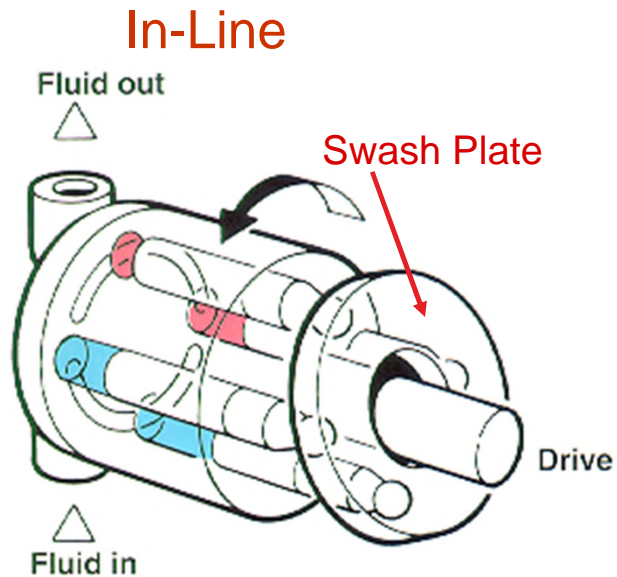
## Axial Vane Pump

Fluid is carried through the pump in the spaces between the vanes and the casing.

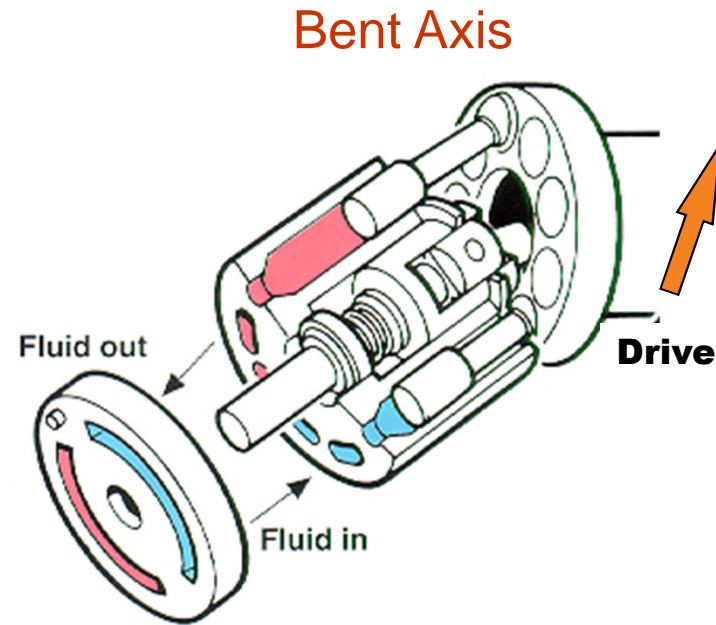
-AW additive is mandatory to prevent wear of vanes.



# Hydraulic Piston Pump



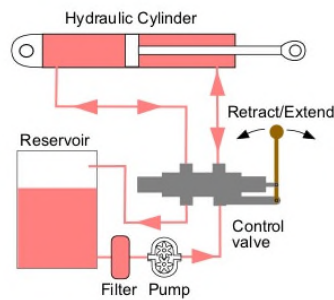
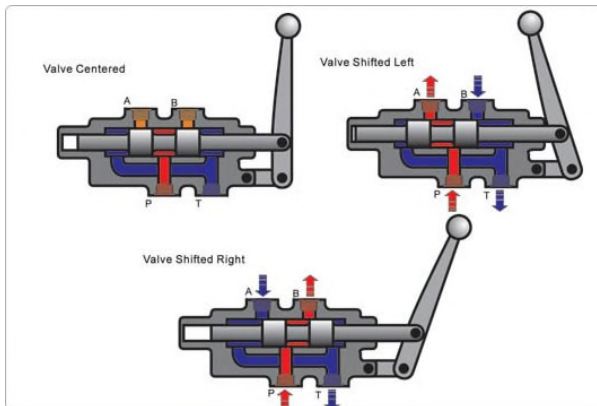
Reciprocation of pistons provided by angled swash plate



Reciprocation of pistons due to rotation of angled shaft

# Hydraulic Components - Valves

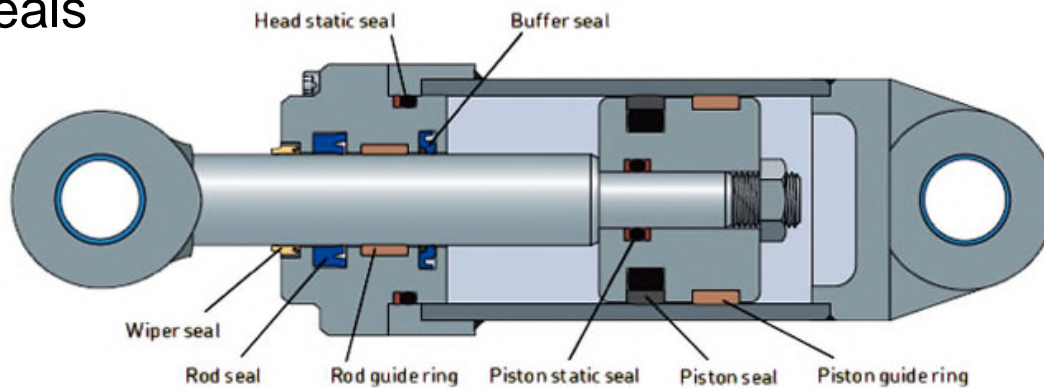
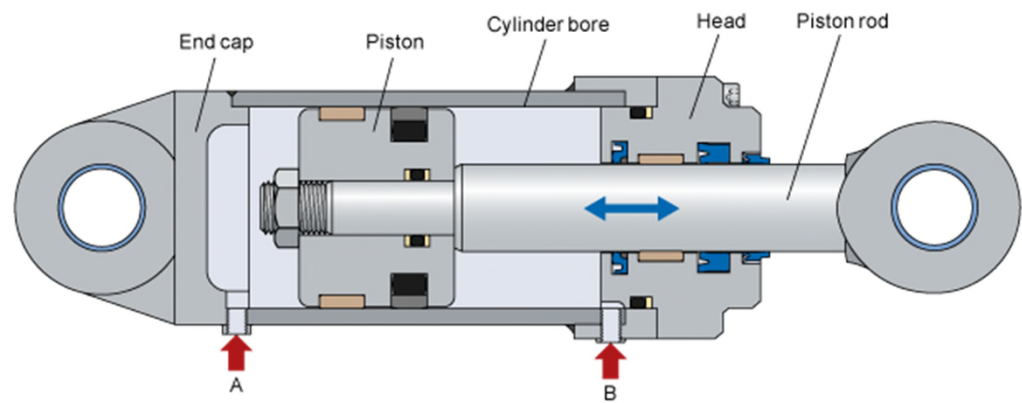
- Spool valve is used to control direction of motion
- Varnish on spool valve is a major issue in hydraulic control system operation



# Hydraulic Cylinder – Linear Motion

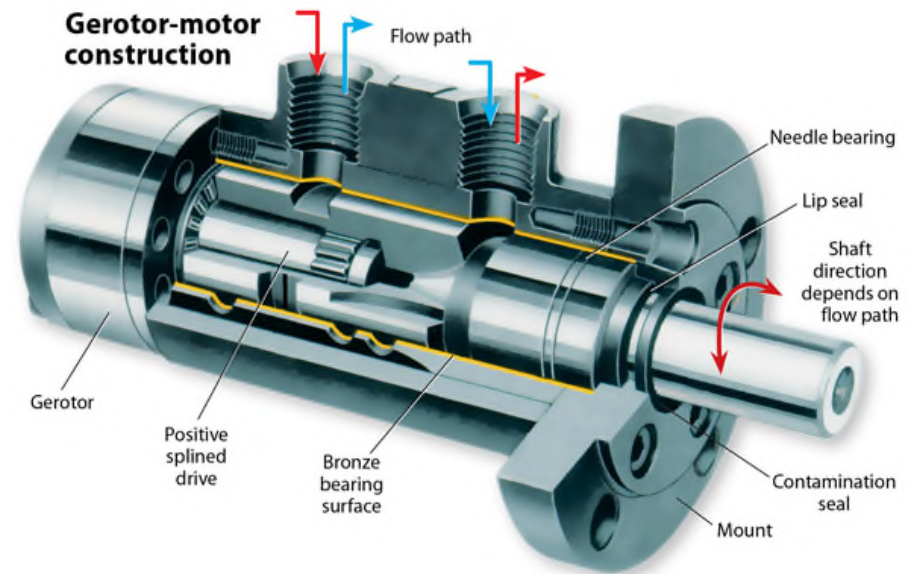
- Main Components:

- Head
- Cylinder
- End Cap
- Piston
- Piston Rod
- Seals



## Hydraulic Motor – Rotary Motion

- Main Components:
  - Housing
  - Drive
  - Bearings
  - Seals
  - Output Shaft



# Hydraulic System Symbols

Hydraulics  
ONLINE

## Graphical Symbols for Hydraulic Circuits

Basic Symbols	Spool Controls	Energy Transformations	Energy Control	Fluid Treatment	
PRESSURE OR RETURN LINE	GENERAL SYMBOL	FIXED DISPLACEMENT PUMP	ADJUSTABLE 3-WAY FLOW CONTROL WITH REVERSE FLOW CHECK (e.g. TVCR...3/2VCR)	SOLENOID OPERATED 4-PORT DIVERTER/CHECK/OVER VALVE (e.g. M270)	
PILOT LINE	PUSH KNOB	SINGLE ACTING HAND PUMP (e.g. 370)	ADJUSTABLE 3-WAY FLOW CONTROL WITH REVERSE FLOW CHECK (e.g. TVCR...3/2VCR)	SOLENOID DIVERTER VALVE WITH EXTERNAL DRAIN (e.g. M84...)	
TWO OR MORE FUNCTIONS IN ONE UNIT	PUSH-PULL KNOB	DOUBLE ACTING HAND PUMP (e.g. 3700)	ADJUSTABLE 3-WAY FLOW CONTROL	DIRECT ACTING SOLENOID DIRECTIONAL VALVE (e.g. 3VFD...)	
FLEXIBLE HOSE	LEVER	FIXED DISPLACEMENT REVERSIBLE PUMP WITH DRAIN	FLOW DIVIDER	DIRECT ACTING SOLENOID DIRECTIONAL VALVE (SPOOL PORT) (e.g. 3VFD...)	
UNION	SINGLE ACTING PEDAL	FIXED DISPLACEMENT REVERSIBLE PUMP WITH DRAIN	SPOOL TYPE FLOW DIVERTER (e.g. 3VCR...3/2)	WATER/OIL COOLER	
CROSS	DOUBLE ACTING PEDAL	FIXED DISPLACEMENT REVERSIBLE PUMP WITH DRAIN	LEAK FREE SEQUENCE VALVE WITH EXTERNAL DRAIN (e.g. 3V40)	AIR/OIL COOLER	
CLOSED CONNECTION	PLUNGER	ROTARY ACTUATOR (e.g. 1A7...)	BILGE/UNLOADING VALVE WITH EXTERNAL HYDRAULIC PILOT AND EXTERNAL DRAIN (e.g. 3V30...)	HEATER	
DIRECTION OF MOVEMENT	PLUNGER WITH STROKE LIMITATION	SINGLE ACTING CYLINDER	REDUCING VALVE (e.g. 3V8...)	TEMPERATURE CONTROLLER	
DIRECTION OF ROTATION	SPRING	DOUBLE ACTING CYLINDER	ELECTRICAL UNLOADING VALVE (e.g. 3V30...)	<b>Measuring Instruments &amp; Indicators</b>	
REGULATION POSSIBLE	ROLLER	DOUBLE ACTING CYLINDER WITH VARIABLE DAMPING AT BOTH ENDS	ELECTRICAL PROPORTIONAL SOLENOID DIRECTIONAL VALVE (e.g. 3V30...)	PRESSURE INDICATOR	
ELECTRIC	LEVER WITH ROLLER	DOUBLE ACTING CYLINDER WITH VARIABLE DAMPING AT BOTH ENDS	ELECTRICAL PROPORTIONAL SOLENOID DIRECTIONAL VALVE (e.g. 3V30...)	PRESSURE TRANSDUCER	
SOLENOIDS WORKING IN OPPOSITE DIRECTIONS	SINGLE SOLENOID	DOUBLE ACTING CYLINDER WITH VARIABLE DAMPING AT BOTH ENDS	PILOT OPERATED CHECK VALVE WITH DRAIN (e.g. 3V85...)	PRESSURE GAUGE (e.g. 3V2...)	
DIRECTION OF ROTATION LOOKING AT SHAFT	PUSH/PULL SOLENOID	DOUBLE ACTING TELESCOPIC CYLINDER	PILOT OPERATED CHECK VALVE WITH DRAIN (e.g. 3V85...)	DIFFERENTIAL PRESSURE GAUGE	
PNEUMATIC	DIRECT PILOT OPERATED	SINGLE ACTING TELESCOPIC CYLINDER	OPEN CENTRE VALVE (e.g. 3V20...)	FLUID LEVEL GAUGE	
HYDRAULIC	PNEUMATIC/HYDRAULIC OPERATED	DOUBLE ACTING TELESCOPIC CYLINDER	RELIEF VALVE/HYDRAULIC LOWERING VALVE (e.g. 3V8...)	FLUID LEVEL TRANSDUCER	
TEST POINT	ELECTRIC MOTOR	DOUBLE ACTING TELESCOPIC CYLINDER	NORMALLY OPEN SOLENOID CHECK VALVE (e.g. 3V20...)	THERMOMETER	
SPRING	OTHER CONTROL UNIT (NOT ELECTRIC MOTOR)	DOUBLE ACTING TELESCOPIC CYLINDER	NORMALLY CLOSED SOLENOID CHECK VALVE (e.g. 3V20...)	FLOW INDICATOR	
THROTTLE	INTERMEDIATE POSITION	DOUBLE ACTING TELESCOPIC CYLINDER	PRIORITY VALVE (e.g. 3V20...)	FLOW METER	
PUGGED PORT	PROPORTIONAL SPOOL	DOUBLE ACTING TELESCOPIC CYLINDER	STEERING UNITS	TACHOMETER	
ROTARY UNION	COUPLING	DOUBLE ACTING TELESCOPIC CYLINDER	OPEN CENTRE	TORQUE METER	
DETENT	INTERNAL PILOT	DOUBLE ACTING TELESCOPIC CYLINDER	CLOSED CENTRE	PRESSURE SWITCH	
RETURN ABOVE/BELow FLUID LEVEL	EXTERNAL PILOT	DOUBLE ACTING TELESCOPIC CYLINDER	CLOSED CENTRE WITH 3-POSITION	MICRO SWITCH	
CHECK VALVE		ACCUMULATOR WITH GAS PRE-CHARGE			
SHUT-OFF VALVE					

If it's hydraulic we can design it, supply it, solve it or repair it... HydraulicsOnline.com

# Hydraulic Power - Applications

## Advantages of hydraulic power:

- ✓ power and precision to move heavy loads with fine control
- ✓ reliability
- ✓ compact, economical systems

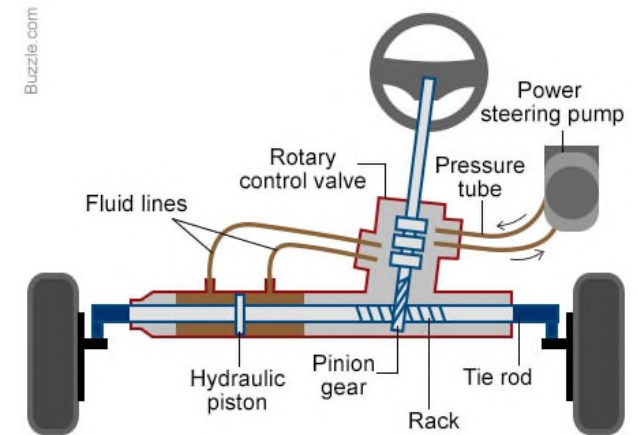
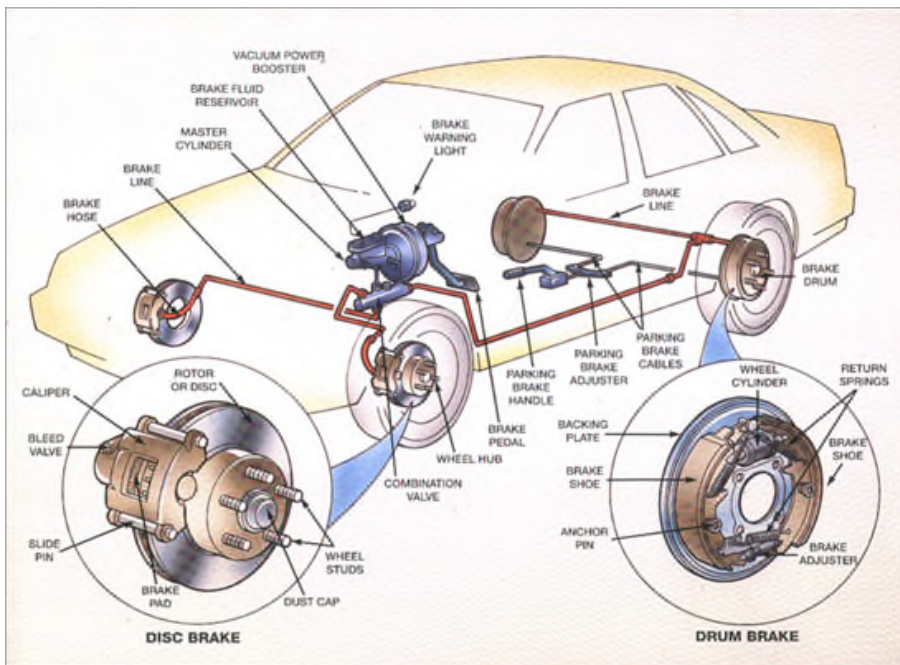
## Hydraulic systems are found in all industrial sectors:

- ✓ manufacturing (e.g. injection moulding machines, presses, metalworking)
- ✓ mobile equipment (e.g. construction equipment, agricultural machinery, utility equipment)
- ✓ mining, oil rigs, bridge and lock gate machinery, rescue equipment





# Hydraulic Power - Applications





## Hydraulic Fluid Functions

- Primary Function
    - Transmit Power
  - Secondary Functions
    - Lubricate / Prevent Wear
    - Transfer Heat
    - Protect System Components
    - Seal Out Contaminants
  - Other Functions
    - Fire Resistance
    - Low Toxicity
    - Biodegradability
-



# Hydraulic Fluid Properties

Function: **Transmit Power**

- Required Properties:
    - Non-compressible (High Bulk Modulus)
    - Fast Air Release
    - Low Foaming Tendency/Stability
    - Low Volatility
-



# Hydraulic Fluid Properties

Function: **Lubricate and Prevent Wear**

- Required Properties:
    - Proper Viscosity
    - Low Temperature Fluidity
    - Thermal Stability
    - Oxidative Stability
    - Hydrolytic Stability
    - Water Separability / Demulsibility
    - Filterability (dry and wet)
    - Antiwear Characteristics
-



## Hydraulic Fluid Properties

Function: **Transfer Heat**

- Required Properties:
    - Good Heat Capacity
    - Good Thermal Conductivity
-



# Hydraulic Fluid Properties

Function: **Protect System Components**

- Required Properties:
    - Proper Viscosity
    - Viscosity Index
    - Shear Stability
    - Rust Prevention
    - Corrosion Prevention
    - Resistance to Deposit Formation
    - Antiwear Characteristics
    - Material Compatibility
-

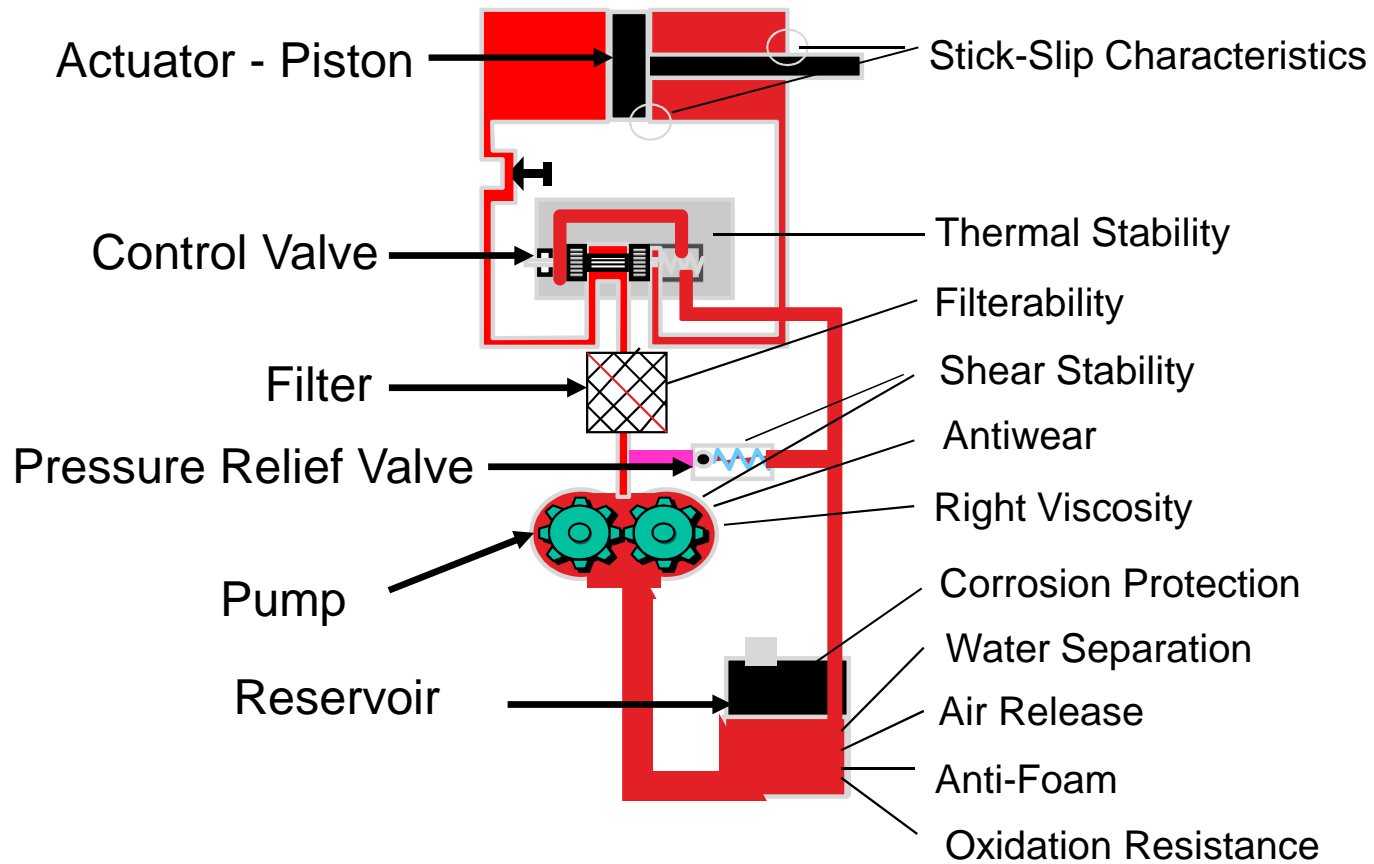


## Hydraulic Fluid Properties

Function: **Seal Out Contaminants**

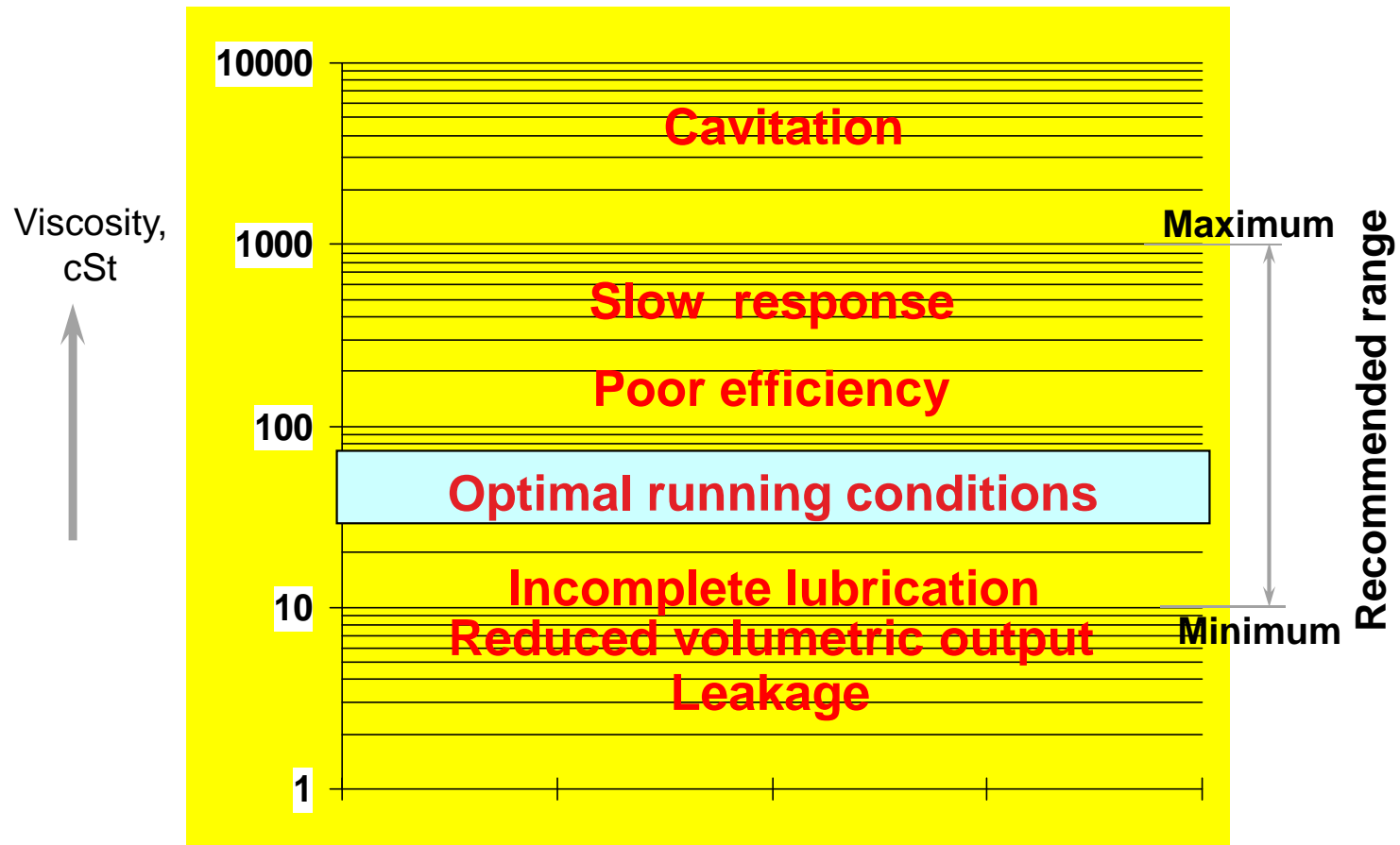
- Required Properties:
    - Proper Viscosity
    - Viscosity Index
    - Shear Stability
-

# Oil Properties Protect the Hydraulic System

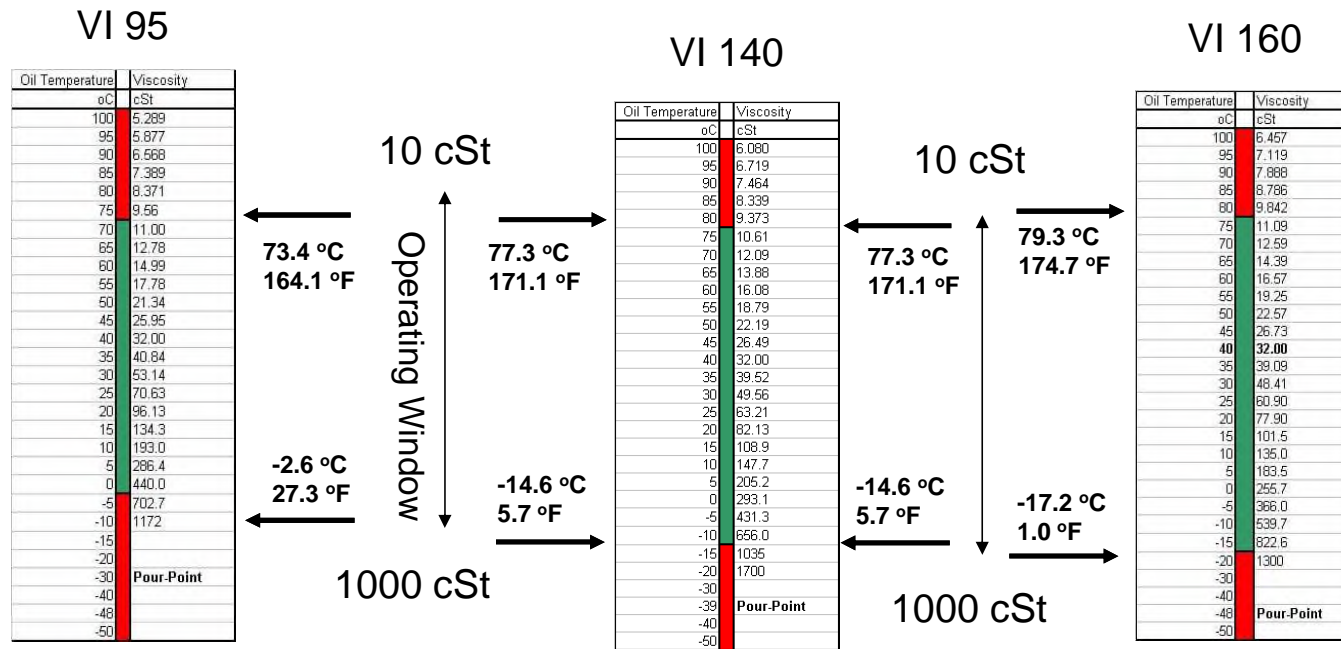




# Viscosity – Temperature Operating Window (TOW)



# Temperature Operating Window – Effect of VI



**10 cSt is the minimum recommended viscosity to secure lubrication**  
**1000 cSt is the maximum recommended viscosity to secure pumpability**

## CITGO Hydraulic Fluids

<b>3 Common Types of Hydraulic Fluids</b>		
<b>Mineral-based</b>	Widely used Low cost High quality	Additives: R&O, AW, VI improvers, defoamants, anticorrosion
<b>Water-based</b>	Fire-resistance is needed. Systems should be monitored closely.	Available as water glycol blends.
<b>Synthetic</b>	Man-made lubricants	Offer performance benefits in high pressure and high temperature systems: thermal stability, fire resistance, lower friction.

# CITGO Hydraulic Fluids



## CITGO HyDurance™ AW Synthetic Fluids

- Fully synthetic, zinc free, extended life
- Extreme high and low temperature performance
- ISO 46 and 68



## CITGO HyDurance™ AW Fluids

- Premium performance
- Long life
- ISO 22, 32, 46, 68, 100, and 150
- All Temp fluids available in ISO 32, 46, and 68



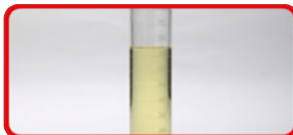
## CITGO HyDurance™ AW NZ Fluids

- Zinc-free formulation for low aquatic toxicity per LC50 for environmentally sensitive applications
- Long life
- ISO 32, 46, and 68
- All Temp fluids available in ISO 32, 46, and 68



## CITGO HyDurance™ AW CP Fluid

- High Dielectric Strength for applications such as Cherry Picker lifts
- Low temperature performance



## CITGO A/W Hydraulic Oils

- Standard life
- No marketing programs
- ISO 32, 46, and 68, Bulk only

## CITGO HyDurance AW Synthetic Fluids

### Synthetic PAO based

- Ashless anti-wear package, Zinc-free
- Maximum service life in vane, piston, and gear pumps
- Excellent thermal and oxidative stability
- Excellent corrosion protection
- Excellent demulsibility characteristics
- High viscosity index
- Wide temperature range performance
- Available in ISO 46 and 68



## CITGO HyDurance AW Fluids

### Mineral oil based

- Blended with API Group II base oils
- Excellent wear protection
- Thermal and oxidative stability
- Excellent rust and corrosion protection
- Anti-foaming performance
- Demulsibility
- ISO 22, 32, 46, 68, 100, and 150



Rexroth Internal Gear Pump



Rexroth Fixed Displacement Motor



Rexroth Variable Vane Pump



Rexroth Fixed Displacement Bent Axis Pump

# CITGO HyDurance AW All Temp Fluids

## Mineral oil based

- Blended with API Group II base oils
- High viscosity index
- Wide temperature range operation
- Excellent wear protection
- Thermal and oxidative stability
- Excellent rust and corrosion protection
- Anti-foaming performance
- Demulsibility
- ISO 32, 46, and 68



## CITGO A/W Hydraulic Oil Super MV

### Very High Viscosity Index Fluid

- Multi-grade hydraulic fluid
  - 202 Viscosity Index
- Formulated with high quality mineral base stocks
- Zinc based
- Provides:
  - Oxidation stability
  - Rust protection
  - Foam resistance
  - Wear protection
- Wide temperature range
- Low pour point, -54°F
- Contains seal conditioner







## CITGO HyDurance AW/AL 100 Fluid

### Mineral oil based

- Blended with API Group II base oils
  - Seal conditioner for longer seal life
  - High viscosity index
  - High dielectric strength – 35 kV
  - Wide temperature range operation
  - Excellent wear protection
  - Thermal and oxidative stability
  - Excellent rust and corrosion protection
  - Anti-foaming performance
  - Demulsibility
  - ISO 100
-

## CITGO HyDurance AW CP Fluid

- 35 KV dielectric strength
- Multi-grade performance (high viscosity index)
- Wide temperature range performance
- Applications:
  - Tree trimming, fruit picking mobile equipment
  - Firefighting lift trucks, buckets, etc.
  - Aerial lift buckets
  - Mobile hydraulic systems
  - Garbage collection equipment
  - Public utility vehicles
  - Construction equipment in colder services



## CITGO HyDurance AW NZ Fluids

- Zinc free, ashless additive system
- Less environmental impact
- Non-toxic in LC-50 acute aquatic toxicity test per OECD TG 203 test limit
- Inherently biodegradable
- Premium antiwear protection for pumps, motors, and other hydraulic components
- Extended service life
- Excellent thermal stability
- Outstanding rust and corrosion protection
- Readily separates water
- Foam resistant
- ISO 32, 46, and 68



## CITGO HyDurance AW All Temp NZ Fluids

- Zinc free, ashless additive system
- Less environmental impact
- Inherently biodegradable and low acute aquatic toxicity
- High viscosity index for wide temperature range operation
- Premium antiwear protection for pumps, motors, and other hydraulic components
- Extended service life
- Excellent thermal stability
- Outstanding rust and corrosion protection
- Readily separates water
- Foam resistant
- ISO 32, 46, and 68



## CITGO HyDurance AW Super NZ Fluid

- Zinc free, ashless anti-wear additive
- Less environmental impact
- Suitable for high pressure piston pumps
- High viscosity index – 177- for wide temperature range (ISO 32 / ISO 68)
- Excellent shear and thermal stability
- Readily separates from water
- Premium rust and corrosion protection
- Excellent foam resistance
- Dyed blue for easy identification
- Recommended for use in Hitachi excavators



# CITGO Fire Resistant Hydraulic Fluids

## CITGO FR WG-40XD<sup>®</sup> Hydraulic Fluid

- Premium water-glycol type fire-resistant fluid
- Provides optimum performance in hydraulic systems
- Protects against wear, foam, and corrosion
- 40 cSt @ 40°C

## CITGO Glycol FR-5046HP

- High pressure polymer thickened water-glycol fluid
- Can be used in high pressure systems
- ISO 46
- Applications:
  - Environmentally sensitive areas
  - Mobile or stationary equipment



CITGO FR WG-40XD WATER ADJUSTMENT CHART						
BRIX	VISCOSITY (SUS) AT 100°F	VISCOSITY (cSt) AT 40°C	PERCENT WATER IN UNADJUSTED FLUID	GALLONS OF WATER NEEDED PER 100 GALLONS OF UNADJUSTED FLUID IN SYSTEM	CONDITION	
50.0	412	82.5	28.4	18.1	SEVERE	
48.5	394	78.8	29.3	17.1		
49.0	377	75.0	30.2	15.8		
48.5	358	71.2	31.2	14.4		
48.0	342	67.9	32.2	13.0		
47.5	324	64.3	33.3	11.5		
47.0	309	61.3	34.2	10.2		
46.5	294	58.4	35.3	8.8		MODERATE
46.0	280	55.6	36.5	7.3		
45.5	266	52.7	37.7	5.8		
45.0	253	50.1	38.8	4.5		
44.5	241	47.7	40.0	3.0		
44.0	228	45.0	41.5	1.5	NORMAL	
43.5	217	43.0	42.7	0.0		
43.0	207	41.0	43.9	0.0		
42.5	197	38.9	44.5	0.0		
42.0	187	37.0	45.5	0.0		
41.5	177	34.5	-	Excess Water		
40.0	153	30.0	-	Excess Water		

## Mystik JT-9 LeakShield AW Hydraulic Oils

- Premium quality anti-wear, anti-leak, and anti-foam hydraulic oils formulated for use in modern high- and low-pressure industrial and mobile hydraulic systems
- Provides proven protection for seals, pumps, and other critical components against water, contaminants, oxidation, and corrosion



## Mystik JT-9 LeakShield AW Hydraulic Oils

- Blended with API Group II base oils
- Excellent wear protection
- Thermal and oxidative stability
- Excellent rust and corrosion protection
- Anti-foaming performance
- Demulsibility
- Contain seal conditioner, dyed green
- ISO 32, 46, 68, and 100

### Mystik AW/AL HVI-32 and HVI 68

- High viscosity index
- Wide temperature range
- Contain seal conditioner, dyed green
- High dielectric strength – 35 kV





# Mystik JT-9 LeakShield AW Hydraulic Oil

## Packaging





## Mystik Anti-Leak Industrial Oil

- High viscosity index for multi-grade performance
  - Can replace ISO 46, 68 and 100 monograde hydraulic fluids
  - Antioxidant, antirust, antiwear, and antifoam additives
  - Anti-spatter additive for splash resistance and slower drip-off rate
  - May also be used as a medium viscosity way oil, winter grade rock drill oil, circulating oil for low to moderately loaded gears and bearings, and a “non-drip” general purpose shop oil
  - Dyed aqua-blue
-

## Mystik Hydraulic Jack Oil

- For use in hand or foot operated hydraulic jacks
- Low viscosity – ISO 22
- Antiwear, antioxidant, antirust, and antifoam additives
- Low pour point
- Natural seal swell property to retard leakage
- Convenient 1-quart bottles
- Dyed red



## Clarion Food Grade Hydraulic Fluids

### Clarion Food Machinery AW Oils

- Based on white mineral base oils
- NSF HX-1 additives
- NSF H1 for incidental food contact
- ISO 32, 46, 68, and 100 grades

### Clarion Food Grade FR Fluid

- For high-temperature hydraulic applications where there is a risk of fire
- Contains propylene glycol
- Excellent heat transfer properties
- NSF H1 for incidental food contact

Clarion CompressorGard products can be used where a synthetic food grade hydraulic fluid is needed.



# Clarion Green Hydraulic Fluids

## Clarion Green AW Oils

- White mineral oil based
- Inherently biodegradable
- ISO 32, 46, and 68 grades

## Clarion Green Synthetic Fluids

- Synthetic ester based
- **Readily biodegradable**
- Meet EPA 2013 VGP requirements
- ISO 22, 32, 46, and 68 grades

## Clarion Green Bio fluids

- Natural ester based (vegetable oil)
- **Readily biodegradable**
- Meet EPA 2013 VGP requirements
- ISO 32, 46, and 68 grades



# Product Application Guide for Hydraulic Fluids

CITGO® Hydraulic Fluids—Properties and Specifications Chart																
HYDRAULIC FLUIDS	KEY PROPERTIES						MEETS OR EXCEEDS									
	Viscosity Grades (ISO)	Fire Resistant	High Efficiency/ Energy Saving	Dielectric Strength**	Wide Temperature Range	Reduced Leakage	Low Temperature Properties	High Viscosity Index	Lower Toxicity Zinc Free Formulation	Readily Bio-degradable (meets VGP EAL requirements)	Parker Hannifin HF-O	DIN 51524	Eaton Brochure	Fives Cincinnati	NSFH-1	Bosch Rexroth
<b>CITGO</b>																
HyDurance® AW Fluids	22, 32, 46, 68, 100, 150										*	*	*	*		*
HyDurance AW CP Fluids	26*			*	*		*	*			*	*	*			
HyDurance AW Synthetic Fluids	46, 68				*		*	*			*	*	*	*		
HyDurance AW All Temp Fluids	32, 46, 68		*		*		*	*			*	*	*			*
HyDurance AW/AL HVI 100	100		*	*	*	*	*	*			*	*	*			*
HyDurance AW NZ Fluids	32, 46, 68							*			*	*	*	*		
HyDurance AW All Temp NZ Fluids	32, 46, 68		*		*		*	*	*		*	*	*			
HyDurance AW Super NZ Fluids	32, 53*		*		*		*	*	*		*	*	*	*		
FRWG-40XD Hydraulic Fluid	40*	*					*	*	*							
Glycol FR-5046 HP	46	*					*	*	*	*						
<b>MYSTIK®</b>																
JT-9™ LeakShield® AW Hydraulic Oils	32, 46, 68, 100				*	*					*	*	*	*		*
JT-9 LeakShield AW Hydraulic Oils - HVI	32, 68		*	*	*	*	*	*			*	*	*	*		*
<b>CLARION®</b>																
Green Bio	32, 46, 68			*				*	*	*			*			
Green Synthetic Fluids	22, 32, 46, 68		*	*	*		*	*	*	*						
Green AW Fluids	32, 46, 68							*								
CompressorGard®	32, 46, 68		*		*		*	*	*							*
SynBar® Fluid 22	22		*				*	*	*							*
Food Machinery AW Fluids	32, 46, 68, 100							*								*
Food Grade FR Fluid	46	*						*								*

\* Value shown is cSt @ 40°C, not an ISO viscosity grade.

\*\* Dielectric strength is extremely sensitive to humidity and contamination. Once the containers are opened, the dielectric strength cannot be expected to remain at its original value. Containers should be kept tightly sealed and stored in a dry environment.



## 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](mailto:lubeshelp@citgo.com)
    - Available 24/7
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## Future Webinars

June 10, 2022

Low Viscosity HD Engine Oils and Fuel Efficiency  
-Steve Bowles

June 24, 2022

Water, Water, Everywhere

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