Aalto University
School of Engineering

MEC-E5003

FLUID POWER BASICS

Study Year 2019 - 2020

Hydraulic fluids

- Overview of effects/tasks/requirements of the fluid
- Classification of hydraulic fluids
- Viscosity (recap) and viscosity index (VI)
- Fluid selection and viscosity grades
- Handling of hydraulic fluids

Effects of the fluid

Properties (and use and maintenance) of fluid will influence:

- operational characteristics (efficiency)
- operational age
- reliability of operation of the system

www.indiamart.com

www.insanehydraulics.com

www.flightglobal.com

Tasks in the system

- conveying of energy/power

- lubrication
- cooling
- inhibition of corrosion and rust
- carrying away impurities

hydraulicspneumatics.com

Requirements

www.oilman.com.au

Operating conditions:
- pressure range (pressure resistance)
- temperature range (heat resistance)
  - viscosity
  - lubrication ability
  - etc.

Special demands:
  - non-toxicity
  - incombustibility
  - etc.

Several base fluids

Mineral oils
Vegetable oils
Water
Emulsions
Synthetic fluids

www.acculube-store.com

haldimandsyntheticoil-wboil.com

www.nbk-ukr.com

www.ocsoil.fi

www.princessauto.com

The base fluid is usually not good enough.

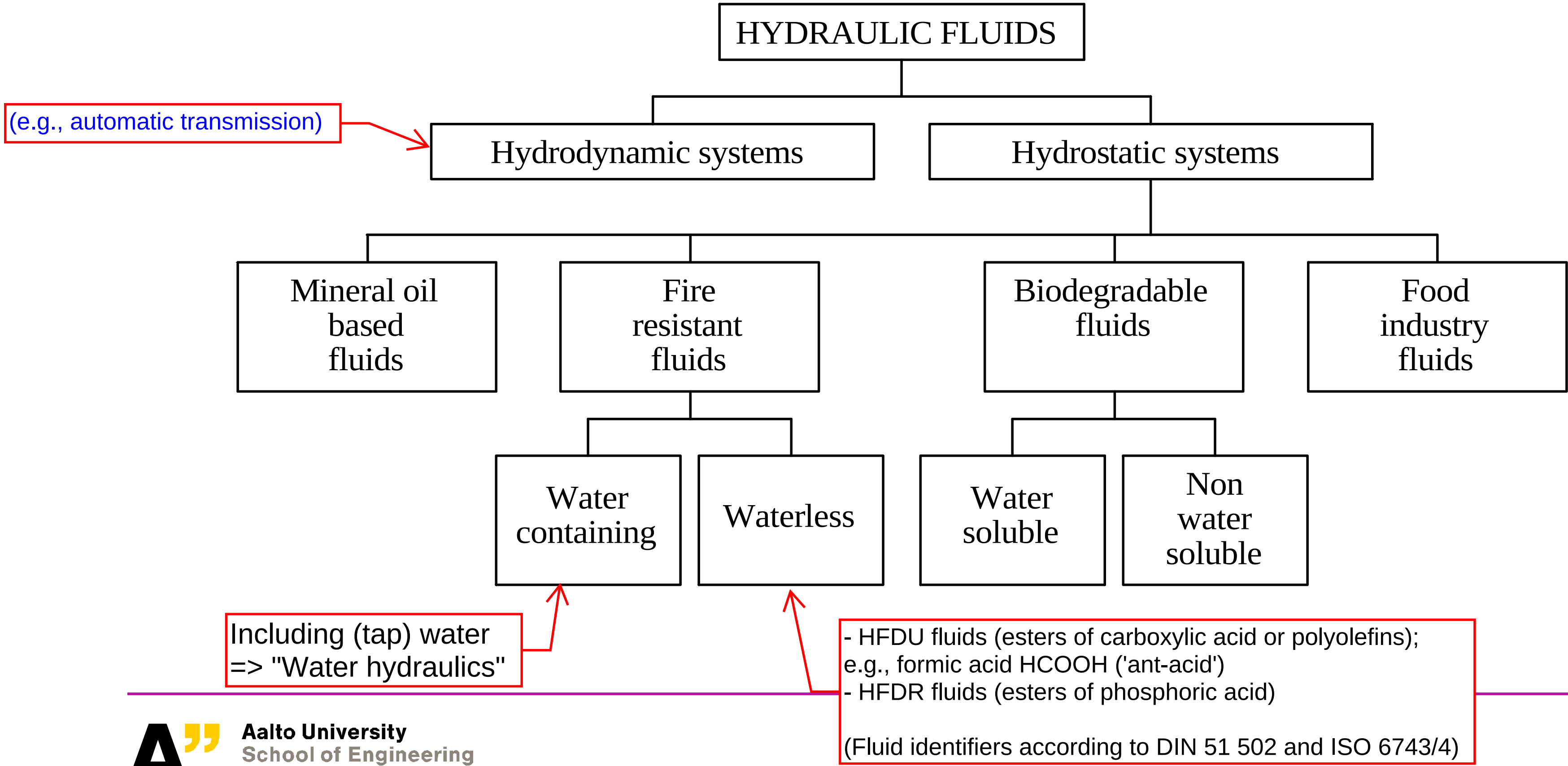
Fluid additives

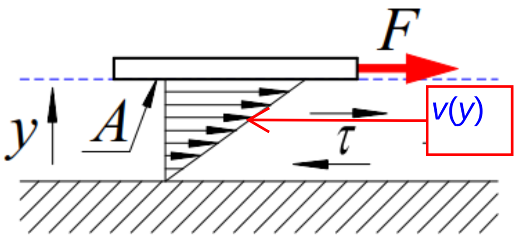
Improving the properties of base fluids

- lubrication ability
- pressure resistance
- viscosity, viscosity index
- inhibition of corrosion and rust
- inhibition of chemical reactions
- etc.

www.tradekeyindia.com

Classification of fluids





Recap
$\tau = \eta\,(dv/dy)$; shear stress in fluid flow [Pa]
η **= dynamic viscosity** [Poise] = [Pa s]
dv/dy = shear rate [1/s]

The **kinematic viscosity** ν is
$\nu = \eta / \rho$; the units are [m^2/s]
ρ = density of the fluid

Commonly used units of viscosity:
1 cP = mPa s (water at 20 deg C: 1.002 cP)
1 cSt = 1 mm^2/s = 1E-6 m^2/s (water@20C: 1 cSt)

Characteristic values of fluids

Viscosity

	$\times 10^{-6}$ m^2/s [cSt]
Ideal viscosity range [(a)]	~ 15 - 100
Upper viscosity limit in cold start (cavitation risk)	~ 500 - 1000
Lower viscosity limit (lubrication ability limit)	~ 10

Generally recommended viscosity range ν = 16 - 36 cSt
(Note: in normal operating temperature)

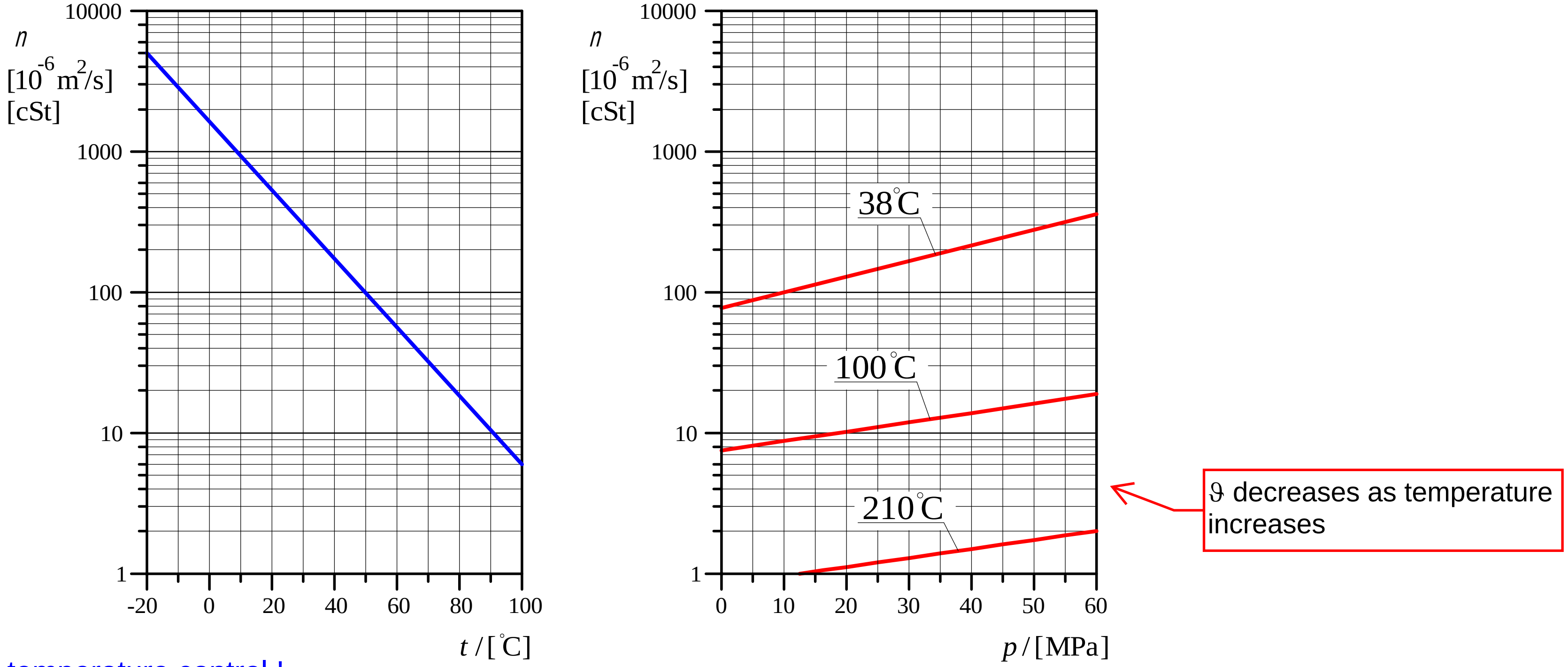
Standardized Viscosity grades (VG)

ISO viscosity grades => p. 16

[(a)] see also p. 15, p. 17

Pressure dependence:
$\eta = \eta_0 e^{\vartheta p}$
η_0 = dyn. visc. at atmospheric pressure [Pa s] ϑ = viscosity-pressure coefficient [1/Pa]
(e.g., 1.7×10^{-8} 1/Pa for HLP mineral oil *))
p = system pressure [Pa]
($\nu = \eta/\rho$ = kin. visc.)

Temperature and pressure dependence of viscosity

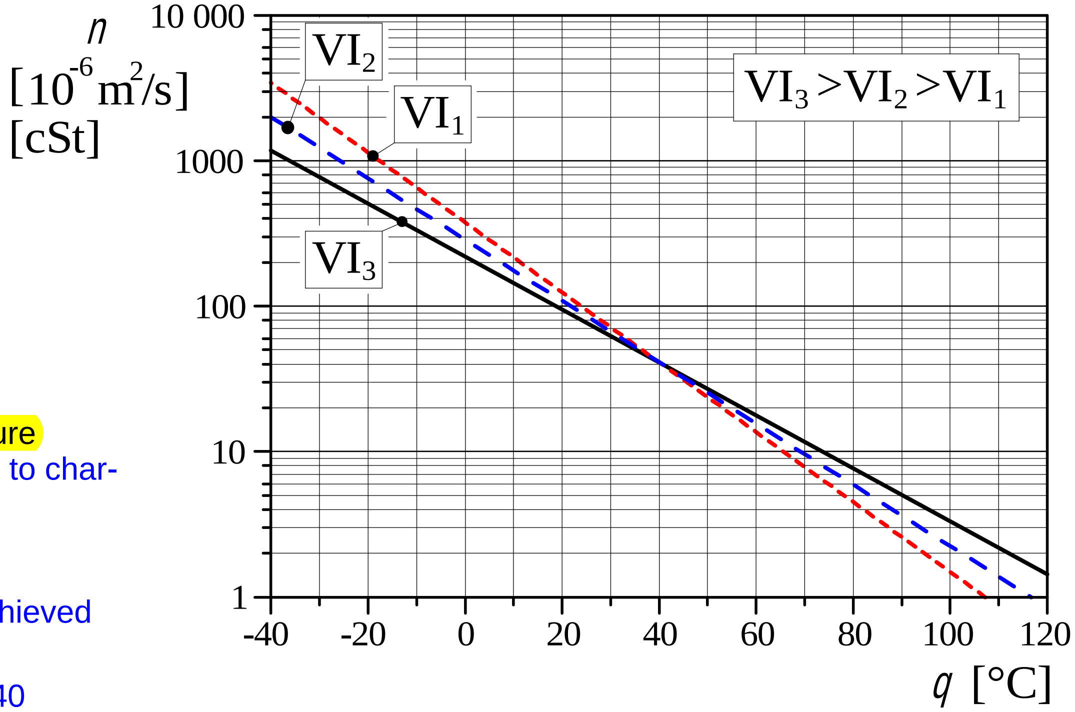


=> Importance of temperature control !

*) HLP (DIN 51 502 classification):
- Typical/common hydraulic mineral oil
- Contains additives to increase pressure resistance

Viscosity index VI

Represents temperature dependence of viscosity



- Increased VI => decreased dependence on temperature
- Originally (around 1929) two reference oils were used to characterize the temperature dependence:
  -- Gulf Coast crude => VI = 0
  -- Pennsylvania crude => VI = 100
- For modern oils or hydraulic fluids VI > 100 can be achieved
- Typically for mineral oils => VI = 95 ... 100
- Using better base oil or additives => VI can exceed 140 (HVLP type fluids [DIN 51 502] or HV type fluids [ISO 6743/4])

Properties of fluids

- Density
- Lubrication characteristics
- Pressure resistance characteristics
- Oxidation resistance characteristics
- Deaeration and anti-foaming characteristics
- Water separation characteristics
- Corrosion and rust inhibition characteristics
- Shear strength characteristics
- Specific heat and thermal conductivity
- Pour point, flash point and ignition point
- Filtration characteristics
- Dissolving characteristics
- Environmental impacts

Aging of the fluid:
For over 60 °C, every 10 °C increase in temperature will double the oxidation rate.

- The fluid (when not water-based) should not form an emulsion with water.
- Instead, water should separate from the fluid, e.g., in the tank when the system is not used. The water will then collect at the bottom from where it can be removed.

- Ability to form & maintain a lubricating film between moving parts during the operating conditions.

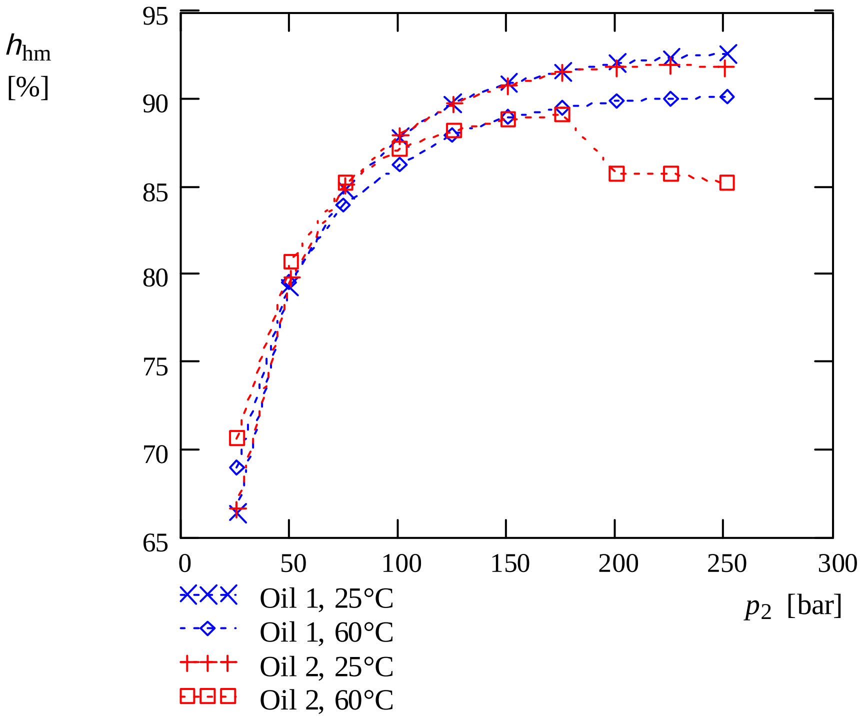
- Air in the fluid will increase compressibility => decreased accuracy of drives and actuators, as well as increased response times.
- Dissolved air vs. undissolved air = bubbles.
- Danger of cavitation and 'diesel effect' (very hot air bubbles due to rapid compression of the air)

High specific heat [J/(kg K)] and high thermal conductivity [W/(m K)] are helpful in controlling system temperature.

Example: Pressure resistance characteristics

Hydro-mechanical efficiency

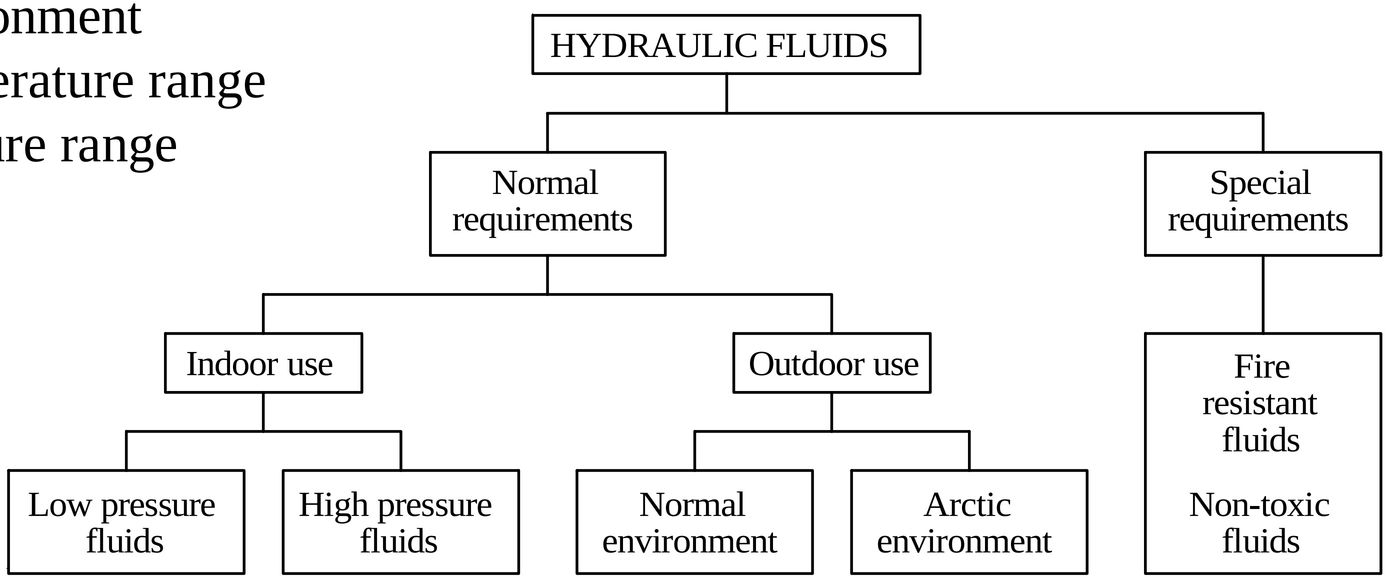
(when losses are due to hydraulic and mechanical friction)



Fluid selection

Impact of operating condition

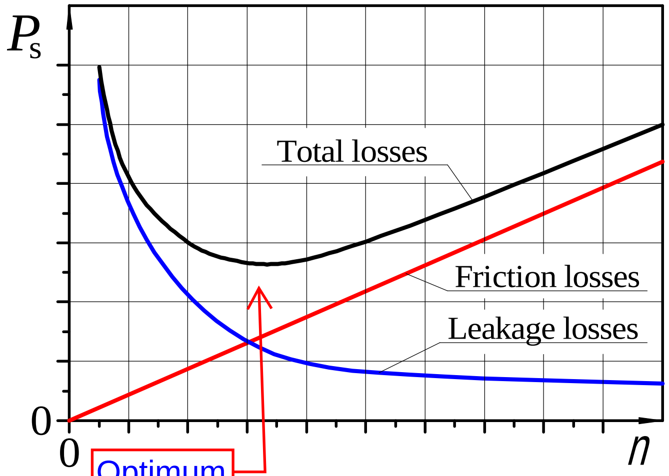
Environment
Temperature range
Pressure range



Impact of viscosity / viscosity grade

P_s = power loss, dissipation power

"q_V x Δp" [W]

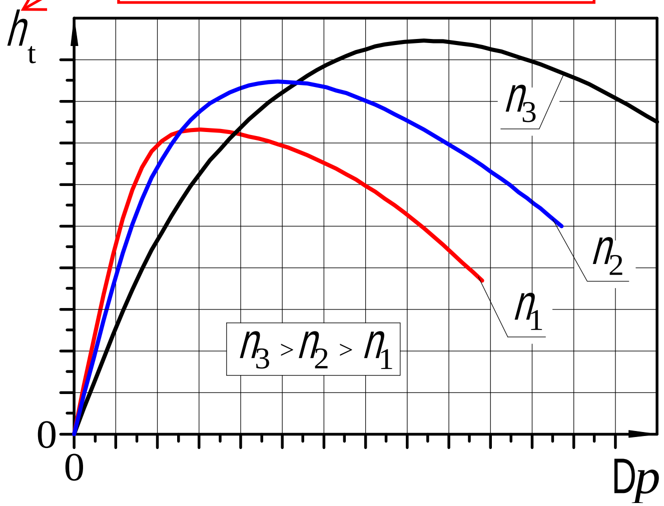


Optimum

Viscosity affects friction and leakage losses

Too high => excessive fluid friction losses and possible cavitation
Too low => high leakage losses and weak lubrication film

Total efficiency ($\eta_t = \eta_v \times \eta_{hm}$) [-]



At higher pressure levels a higher viscosity grade (higher base viscosity) has to be selected

Otherwise => excessive leakage losses

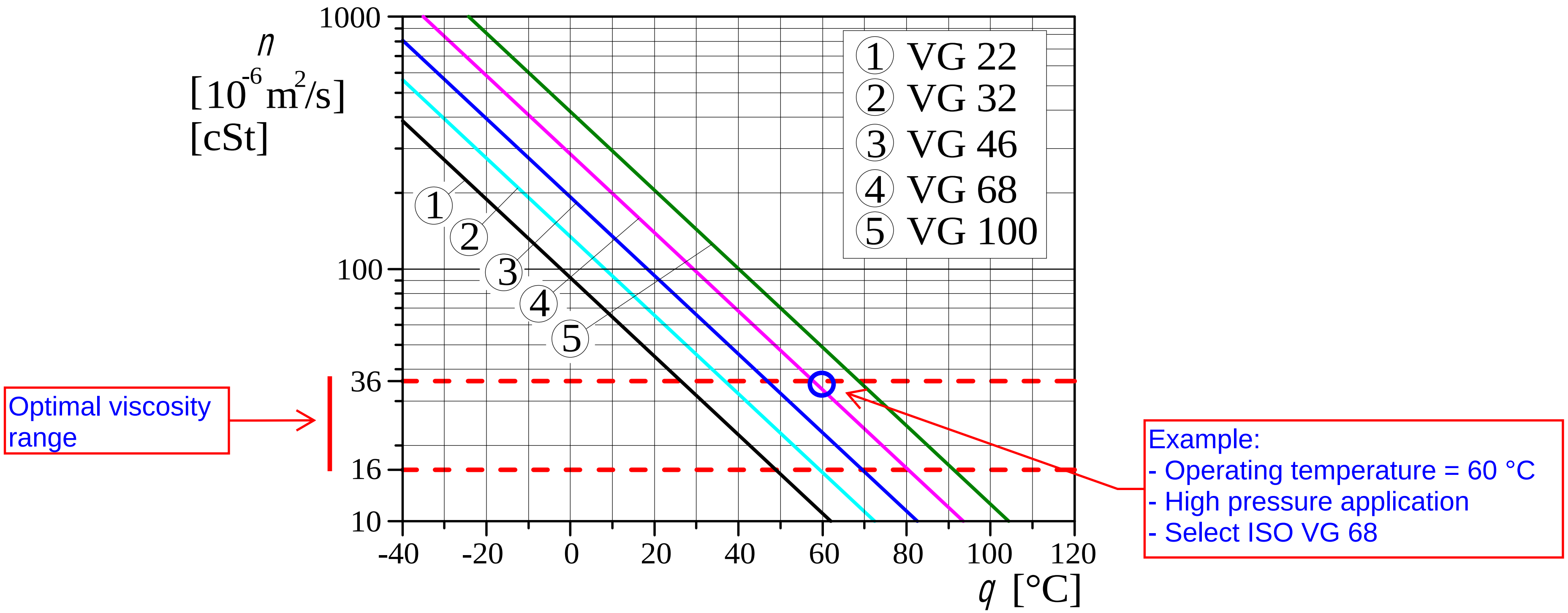
Viscosity grades

Determined at 40°C (ISO/DIN)

ISO VG -class (Viscosity Grade)	Mid-point $\times 10^{-6}$ m²/s [cSt]	Minimum $\times 10^{-6}$ m²/s [cSt]	Maximum $\times 10^{-6}$ m²/s [cSt]
2	2,2	1,98	2,42
3	3,2	2,88	3,52
5	4,6	4,14	5,06
7	6,8	6,12	7,48
10	10	9,00	11,0
15	15	13,5	16,5
22	22	19,8	24,2
32	32	28,8	35,2
46	46	41,4	50,6
68	68	61,2	74,8
100	100	90,0	110
150	150	135	165
220	220	198	242
320	320	288	352
460	460	414	506
680	680	612	748
1000	1000	900	1100
1500	1500	1350	1650
2200	2200	1980	2420
3200	3200	2880	3520

+/- 10 %
deviation allowed

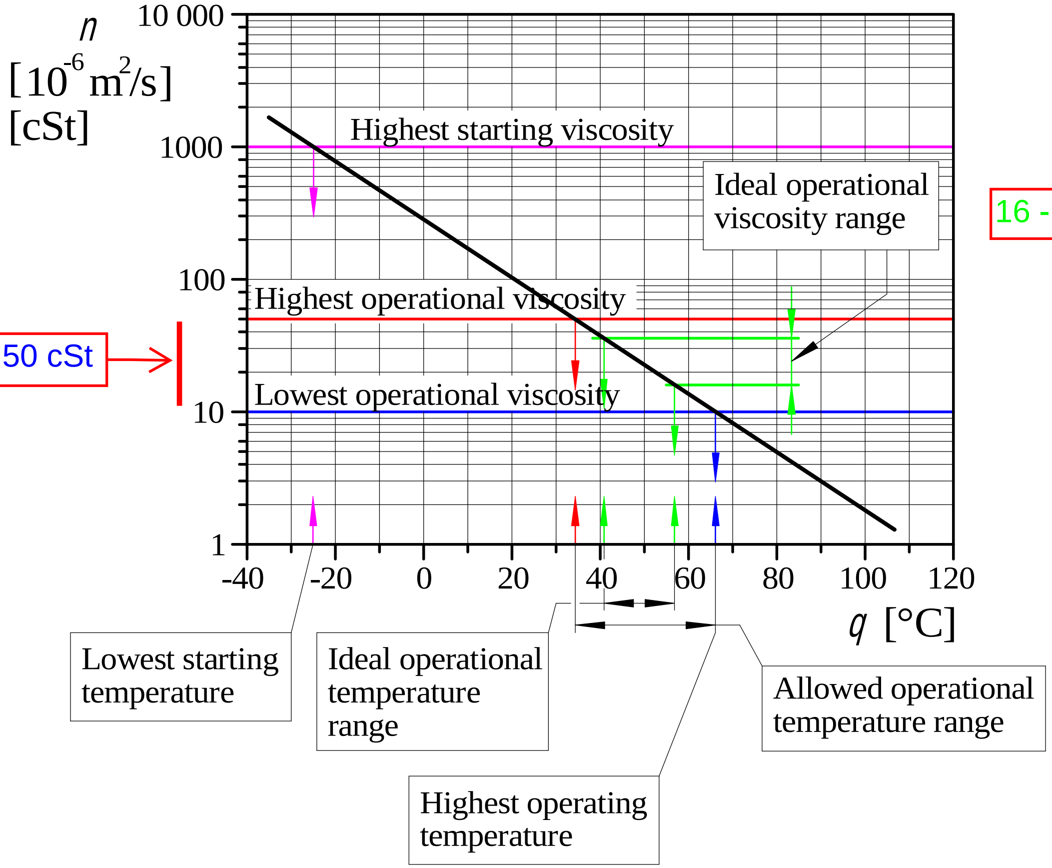
Selection of viscosity grade



Selection of viscosity grade

If we have
- the viscosity-temperature data for a candidate fluid and
- our selection criteria (from system component specifications)
- we can determine the temperature (range) requirements

e.g., 10 - 50 cSt



16 - 36 cSt

Note that the VI should be high enough, such that viscosity requirements are fulfilled at the extremes of the temperature range

Effect of fluid type on price

Hydraulic fluid	Price in relation to mineral oil
Oil in water -emulsion	0,3- 0,5
Mineral oil	**1**
Water in oil –emulsion	1,2- 1,5
Vegetable oil	1,5- 2,0
Polyglycol-water -emulsion	3,0- 4,0
Synthetic fluids	4,0- 20,0

Example fluid type designations:

HFA (HFAE); 1-10 % oil

H, HL, HLP, HVLP, HLPD (DIN 51 502)

HFB; 40-60 % oil

HETG; canola, rapeseed, etc. oil plants

HFC; 35-50 % water
HEPG; insensitive to water contamination

HFD (HFDU & HFDR); often for high temp
HEPR; biocompatible synthetic fluid

Demand for special properties?

Properties of fluids

A directive comparison

Mineral oil → HLP; Oil-in-water → HFA; Synthetic waterless → HFD; Vegetable → HETG

Property	HLP	HFA	HFD	HETG	
Density (15 °C)	870	1000	1150	920	[kg/m3]
Kinematic viskosity (40 °C)	10- 100	1	15- 70	32- 48	[$\times 10^{-6}$ m^2/s] [cSt]
Viscosity Index	100	-	< 200	210	
Bulk modulus	2	2,5	2,3- 2,8	2,5	[$\times 10^{9}$ N/m^2]
Specific heat (20 °C)	2,1	4,2	1,3- 1,5	2,1	[kJ/kgK]
Thermal conductivity (20 °C)	0,14	0,6	0,11	0,17	[W/mK]
Coefficient of thermal expansion	7	1,8	7	7,5	[$\times 10^{-4}$ 1/K]
Normal tempera-ture range	-10- 80	5- 50	10- 70	0- 70	[°C]
Max temperature range	-40- 120	0- 55	-20- 150	-20- 90	[°C]
Flash point	210	-	245	315	[°C]
Ignition point	310- 360	-	500	350- 500	[°C]
Pour point	-18	0	-24- 6	-25	[°C]
Vapour pressure (20 °C)	10^{-9}	10^{-2}	10^{-6}	3×10^{-7}	[MPa]

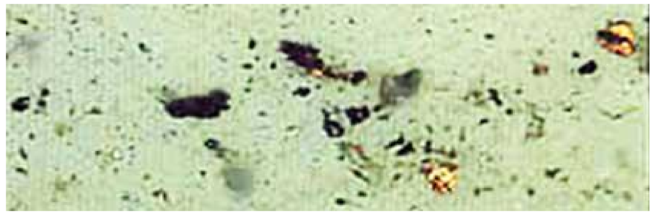
(vapour pressure for water 0.02 bar)

Handling of hydraulic fluids

- Use dedicated filling gear
- Fill through filter

Appropriate/responsible handling:
- in storage
- in filling/transfer
- in use
- in disposal

www.descase.com



www.ntz-filters.co.uk

Hydraulic fluids are almost without exception toxic waste
- appropriate disposal

yle.fi

hydraulicoilflushing.com

Lecture themes - Recap

Is fluid only for energy/power transfer?

Significance of hydraulic fluid?

Selection of fluid – How?

Carefree/careless?