TECHNICAL INFORMATION

CONVERSION FACTORS

TORQUE

ft-lb	in-lb	daN-m	N-m	kg-m
1	12	.13556	1.356	.1382
.08333	1	.01130	.1130	.01152
7.376	88.51	1	10	1.019
.7376	8.851	.1	1	.102
7.2359	86.80	.9806	9.806	1

PRESSURE

psi	MPa	bar	kPa	kg/mm²	kg/cm²
1	.006895	.06895	6.895	.0007031	.07031
145	1	10	1000	.102	10.20
14.50	.1	1	100	.0102	1.02
.145	.001	.01	1	.000102	.0102
1422	9.807	98.07	9807	1	100
14.22	.09807	.9807	98.07	.01	1

1 Atmosphere = 14.7 lb/in²
1 Atmosphere = 29.92 inches of Mercury
1 Atmosphere = 33.96 ft of water
1 inch of Mercury = 0.491 lb/in² = 13.6 inches of water
1 psi = 2.0416 inches of Mercury at 62°F

ENERGY

ft-lb	kg-m	kW-hr	hp-hr	in-lb	J
1	.1383	.0016	.002	12	1.356
7.233	1	.011	.015	86.80	9.806
634.1	87.69	1	1.341	7609.7	859.9
472.9	65.39	.7457	1	5675.7	641.2
.0833	.01152	.00013	.00017	1	.113

1 Btu = British thermal unit = heat required to raise temperature of 1 lb of water 1°F
1 Btu = 778.57 ft-lb

VELOCITY

m/s	ft/s	km/hr	mph	ft/min
1	3.281	3.6	2.237	196.85
.3048	1	1.097	.6818	60
.2778	.9113	1	.6214	54.68
.4470	1.467	1.609	1	88
.00508	.01667	.01829	.01136	1

LENGTH

cm	in	ft	m	km	mi
1	.3937	.03281	.01	.00001	.000006
2.54	1	.08333	.02778	.000027	.000017
30.48	12	1	.3048	.0003	.000186
100	39.37	3.281	1	.001	.000621
100,000	39,370	3281	1000	1	.6214
160,934	63,360	5280	1609	1.609	1

VOLUME

in^3	cm^3	L	qt
1	16.39	.01639	.0173
.06102	1	.0001	.0010
61.02	1000	1	1.05
57.75	947	.9463	1

1 U.S. gallon = 231 in^3
1 U.S. gallon = 0.13368ft^3
1 gpm = 3.85 in^3/s
1 gpm = 3.79 L/min (liquid)

FORCE AND WEIGHT

N	kg	lb
1	.1020	.224
10	1.020	2.24
9.807	1	2.20
4.4482	.4536	1

ACCELERATION

ft/s^2	in/s^2	m/s^2	cm/s^2
1	12	.3048	30.48
.08333	1	.0254	2.54
3.281	39.37	1	100
.03281	3937	.01	1

AREA

in^2	cm^2	mm^2
1	6.452	645.2
.1550	1	100
.001550	.01	1

POWER

hp	kW	met-hp
1	.7457	1.014
1.341	1	1.360
.9863	.7355	1

1 hp = 550 ft-lb/s
1 hp = 33,000 ft lb/min
1 hp = 42.44 Btu/min

TEMPERATURE

$^{o}F = (^{o}C \times 1.8) + 32$
$^{o}C = (^{o}F - 32) \div 1.8$

HYDRAULIC FORMULAE

FOR HYDRAULIC PUMPS

$$\text{Input Power (kW)} = \frac{\text{Flow (L/min)} \times \text{Pressure (Bar)}}{600}$$

$$\text{Output Flow (L/min)} = \frac{\text{Displacement (cm}^3\text{/rev)} \times \text{Speed (rpm)}}{1000}$$

FOR HYDRAULIC MOTORS

$$\text{Output Power (kW)} = \frac{\text{Torque (Nm)} \times \text{Speed (rpm)}}{9549}$$

$$\text{Shaft Torque (Nm)} = \frac{\text{Pressure (Bar)} \times \text{Displacement (cm}^3\text{/rev)}}{62.8}$$

$$\text{Shaft Speed (rpm)} = \frac{\text{Flow (L/min)} \times 1000}{\text{Displacement (cm}^3\text{/rev)}}$$

FOR HYDRAULIC CYLINDERS

$$\text{Force (N)} = \frac{\text{Area (mm}^2\text{)} \times \text{Pressure (Bar)}}{10}$$

$$\text{Speed (mm/sec)} = \frac{\text{Flow (L/min)} \times 21{,}220}{\text{Diameter}^2\text{ (mm}^2\text{)}}$$

$$\text{Where Area (mm}^2\text{)} = \text{Diameter}^2\text{ (mm}^2\text{)} \times 0.7854$$

RECOMMENDED CLEANLINESS CODE CHART

PUMPS

Pressure	<2000	2000-3000	3000+
Fixed Gear	20.18.15	19.17.15	
Fixed Vane	20.18.15	19.17.14	18.16.13
Fixed Piston	19.17.15	18.16.14	17.15.13
Variable Vane	18.16.14	17.15.13	
Variable Piston	18.16.14	17.15.13	16.14.12

VALVES

Pressure	<3000	3000+
Directional (solenoid)	20.18.15	19.17.14
Pressure Control (modulating)	19.17.14	19.17.14
Flow Controls (standard)	19.17.14	19.17.14
Proportional Directional (throttle valves)	17.15.12	15.13.11*
Check Valves	20.18.15	20.18.15
Servo Valves	16.14.11*	15.13.10*
Cartridge Valves	18.16.13	17.15.12
H.R.C	18.16.13	17.15.12
Proportional Pressure Controls	16.14.12*	15.13.11*
Flow Controls (pressure compensating)	17.15.13	17.15.13
Proportional Cartridge Valves	17.15.12	16.14.11*

ACTUATORS

Pressure	<2000	2000-3000	3000+
Cylinders	20.18.15	20.18.15	20.18.15
Vane Motors	20.18.15	19.17.14	18.16.13
Axial Piston Motors	19.17.14	18.16.13	17.15.12
Gear Motors	21.19.17	20.18.15	19.17.14
Radial Piston Motors	20.18.14	19.17.13	18.16.13
Cam Wave Motors	18.16.14	17.15.13	16.14.12*

HYDROSTATIC TRANSMISSIONS

Pressure	<3000	3000-4000	4000+
Hydrostatic Transmissions (in-loop fluid)	17.15.13	16.14.12*	16.14.11*

BEARINGS

Ball Bearing Systems	15.13.11*
Roller Bearing Systems	16.14.12*
Journal Bearings (high speed)	17.15.13
Journal Bearings (low speed)	18.16.14
General Industrial Gearboxes	17.15.13

* Requires precise sampling practices to verify cleanliness levels.

Note: The above cleanliness codes are only to be used as a guide. Cleanliness codes may vary depending on component application requirements.

How to Set a Target Cleanliness Level

Step One

Using the Recommended Cleanliness Code Chart, determine the cleanest fluid (lowest code) required by any component in the system. All components that draw fluid from a common reservoir should be considered to be part of the same system even if their operations are independent or sequential (i.e. a central power unit running several different machines). The pressure rating for the system is the maximum system pressure achieved by the machine during a complete cycle of operation.

Step Two

For any system where the fluid is not 100% petroleum oil, set the target one Range Code cleaner for each particle size. Example: If the cleanest code required was an 17.15.13 and water glycol is the system fluid, the target becomes 16.14.12.

Step Three

If any two of the following conditions are experienced by the machine or system, set the target cleanliness one level lower for each particle size.

- Frequent cold starts at less than 0ºF (-18ºC)
- Intermittent operation with fluid temperatures over 160ºF (71ºC)
- High vibration or high shock operation
- Critical dependence on the system as part of a process operation
- Personal safety of the operator or others in the area could be put at risk by a system malfunction

Again, looking at the example above, if this system was expected to cold start in Alaska and a failure could cause personal injury, the target cleanliness would become 15.13.11.

Using this three step procedure the system target cleanliness code for the system is now set.

Test Stands

Target cleanliness level for test stands should be one range code cleaner, for each particle size, than the code for each particle size, than the code for the most sensitive condition and component to be tested. Example: Variable piston pump tested at 2500 psi cleanliness level should be 17.15.13 so the TEST STAND cleanliness level should be at least 16.14.12.

Fluid Conditioning

Proper fluid condition is essential for long and satisfactory life of hydraulic components and systems. Hydraulic fluid must have the correct balance of cleanliness, materials and additives for protection against wear of components, elevated viscosity and inclusion of air.

PIPE PRESSURE RATINGS

Pipes Currently are Sized by Schedule Number

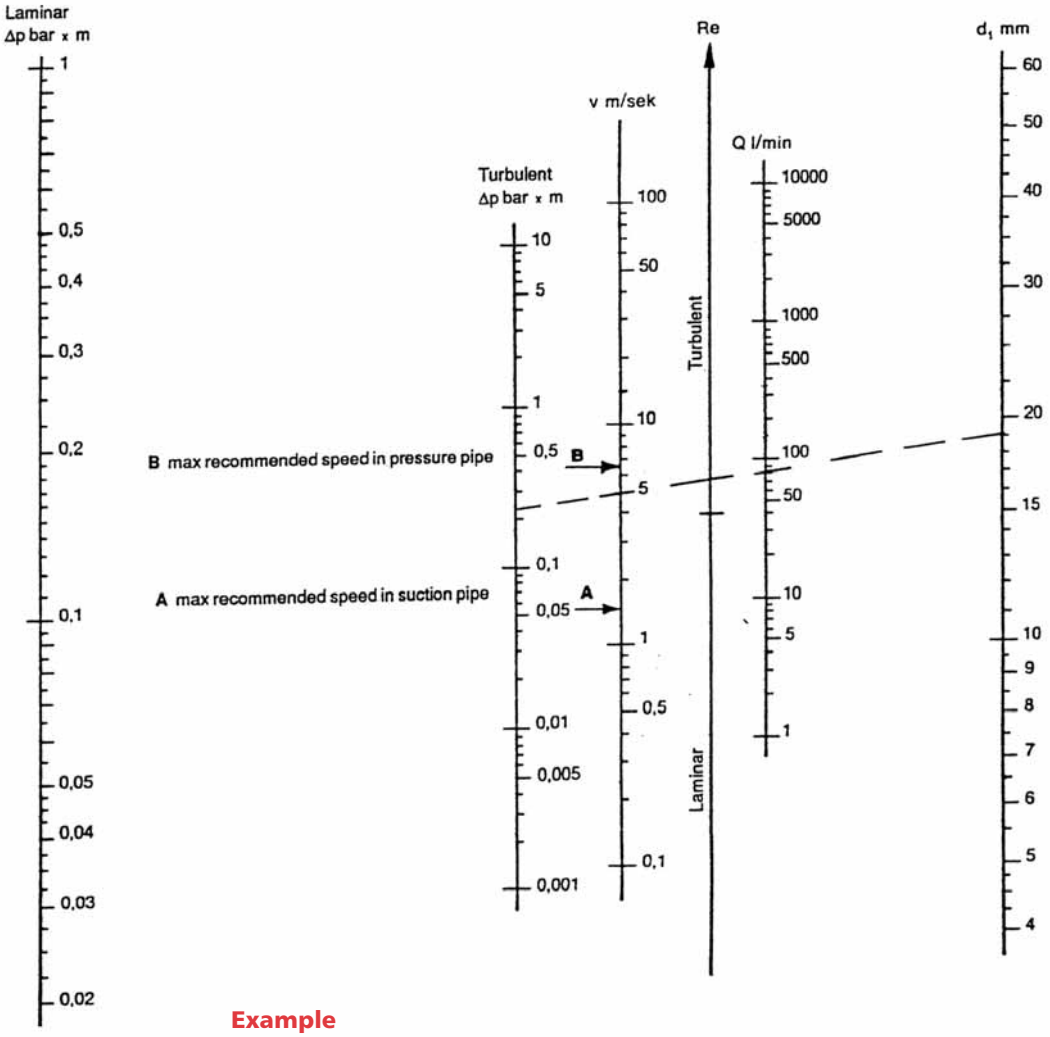
Nom. Size	Pipe O.D.	Inside Diameter Schedule 40 Standard	Schedule 80 Extra Heavy	Schedule 160	Double Extra Heavy
1/8	.405	.269	.215		
1/4	.540	.364	.302		
3/8	.675	.493	.423		
1/2	.840	.622	.546	.466	.252
3/4	1.050	.824	.742	.614	.434
1	1.315	1.049	.957	.815	.599
1 1/4	1.660	1.380	1.278	1.160	.896
1 1/2	1.900	1.610	1.500	1.338	1.100
2	2.375	2.067	1.939	1.689	1.503
2 1/2	2.875	2.469	2.323	2.125	1.771
3	3.500	3.068	2.900	2.624	
3 1/2	4.000	3.548	3.364		
4	4.500	4.026	3.826	3.438	
5	5.563	5.047	4.813	4.313	4.063
6	6.625	6.065	6.761	5.189	
8	8.625	7.981	7.625	6.813	
10	10.750	10.020	9.564	8.500	
12	12.750	11.934	11.376	10.126	

Pressure Rating of Pipes

Nominal Pipe Size in.	Outside Diameter Pipe in.	Number of Threads per Inch	Lenght of Effective Threads in.	Schedule 40 Standard Pipe ID in	Schedule 40 Standard Burst Press psi	Schedule 80 Extra Heavy Pipe ID in.	Schedule 80 Extra Heavy Burst Press. psi	Schedule 160 Pipe ID in.	Schedule 160 Burst Press. psi	Double Extra Heavy Pipe ID in.	Double Extra Heavy Burst Press. psi
1/8	0.405	27	0.26								
1/4	0.540	18	0.40	.364	16,000	.302	22,000				
3/8	0.675	18	0.41	.493	13,500	.423	19,000				
1/2	0.840	14	0.53	.622	13,200	.546	17,500	.466	21,000	.252	35,000
3/4	1.050	14	0.55	.824	11,000	.742	15,000	.614	21,000	.434	30,000
1	1.315	11 1/2	0.68	1.049	10,000	.957	13,600	.815	19,000	.599	27,000
1 1/4	1.660	11 1/2	0.71	1.380	8,400	1.278	11,500	1.160	15,000	.896	23,000
1 1/2	1.900	11 1/2	0.72	1.610	7,600	1.500	10,500	1.338	14,800	1.100	21,000
2	2.375	11 1/2	0.76	2.067	6,500	1.939	9,100	1.689	14,500	1.503	19,000
2 1/2	2.875	8	1.14	2.469	7,000	2.323	9,600	2.125	13,000	1.771	18,000
3	3.500	8	1.20	3.068	6,100	2.900	8,500	2.634	12,500		

Working pressures for various schedule pipes are obtained by dividing burst pressure by the safety factor.

PRESSURE DROP IN PIPES



Example

Q = 80 l/min, pipe 22/19

Pressure drop per meter pipeline is searched for.
A line is drawn from d_1 - 19mm through Q = 80 l/m
It crosses the Re-line in the turbulent area, and the result can be read on the turbulent scale.
Δp = 0.23 bar x m
(If the Re-line is in the laminar area, the result is to be read on the laminar scale).
The nomographic chart applies to the viscosity
25 cSt ÷ 3.5°E and the density 900 kg/m³
At another viscosity a correction is to be made as follows:-

Turbulent flow:

$$\Delta p = \sqrt{\frac{v}{Vnomogr}} \times \Delta p \text{ nomogr}$$

Laminar flow:

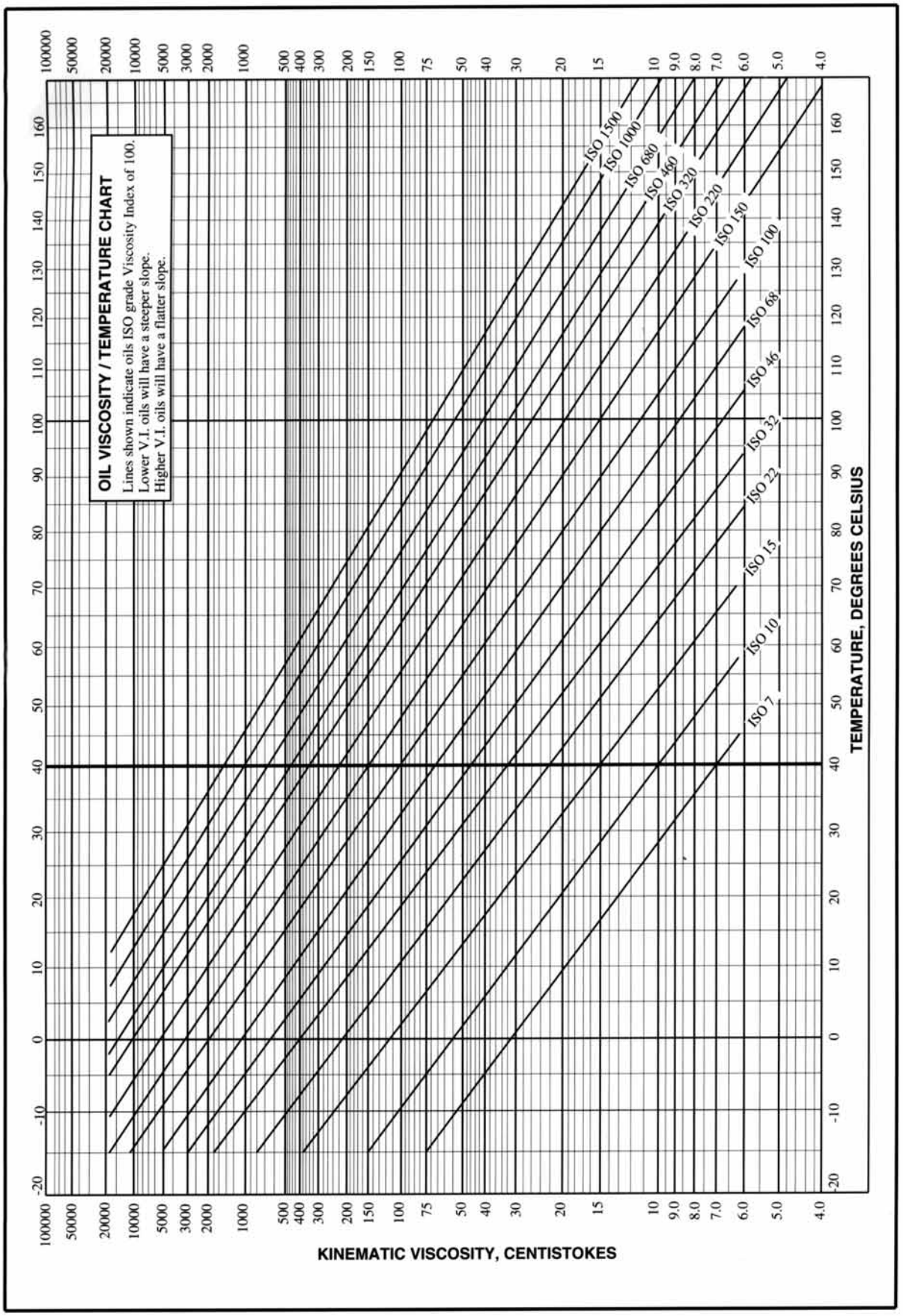
$$\Delta p = \frac{v}{Vnomogr} \times \Delta p \text{ nomogr}$$

v = the oil viscosity in cSt
At another density a correction is to be made as follows:

$$\Delta p = \frac{\rho}{\rho nomogr} \times \Delta p \text{ nomogr}$$

ρ = the oil density in kg/m³

OIL VISCOSITY / TEMPERATURE CHART



Notes:

Notes:

Notes: