International Standard ISO 6073

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Hydraulic fluid power — Petroleum fluids — Prediction of bulk moduli

Transmissions hydrauliques — Huiles minérales — Détermination des modules de compressibilité volumique

First edition — 1980-11-01

UDC 665.767 : 621.22 : 532.12 **Ref. No. ISO 6073-1980 (E)**

Descriptors : hydraulic fluid power, petroleum products, liquids, mineral oils, hydrocarbons, physical properties, compressibility, bulk modulus, computation.

Price based on 9 pages

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 6073 was developed by Technical Committee ISO/TC 131, *Fluid power systems and components*, and was circulated to the member bodies in November 1978.

It has been approved by the member bodies of the following countries :

Austria	Germany, F. R.	Romania
Belgium	Hungary	Spain
Chile	India	Sweden
China	Italy	United Kingdom
Czechoslovakia	Japan	USA
Egypt, Arab Rep. of	Korea, Rep. of	USSR
Finland	Netherlands	Yugoslavia
France	Norway	

The member body of the following country expressed disapproval of the document on technical grounds :

Australia

Hydraulic fluid power — Petroleum fluids — Prediction of bulk moduli

0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Bulk modulus measures the fluid resistance to volume reduction by pressure.

1 Scope

This International Standard specifies a procedure for predicting the bulk moduli of a petroleum or hydrocarbon oils used as fluids (in the absence of air bubbles) in hydraulic fluid power systems and for other purposes.

The standard provides graphical techniques to obtain moduli of these fluids without extended calculations and with such accuracy as would be required for the practical calculation of hydraulic system parameters.

2 Field of application

2.1 The useful temperature range is from 0 to 270 °C, with a pressure range from atmospheric to 7 000 bar (700 000 kPa)[1].

2.2 Select the appropriate bulk modulus according to the problem and conditions of operation. (See clause 4).

2.3 Refer to annex A for range of measurement.

2.4 Refer to annex B for sample calculations.

3 References

ISO 91/1, *Petroleum measurement tables — Part 1 : Tables based on reference temperature of 15 °C and 60 °F.*[2]

ISO 3658, *Crude petroleum and liquid petroleum products — Determination of density or relative density — Graduated bicapillary pyknometer method.*[3]

ISO 3675, *Crude petroleum and liquid products — Laboratory determination of density or relative density — Hydrometer method.*

ISO 3838, *Crude petroleum and liquid or solid petroleum products — Determination of density or relative density — Capillary-stoppered pyknometer method.*[3]

ISO 5598, *Hydraulic and pneumatic fluid power — Vocabulary.*[3]

4 Definitions

4.1 bulk modulus : The measure of resistance to compressibility of a fluid. It is the reciprocal of the compressibility.

4.2 isothermal bulk modulus : Modulus data based on equilibrium conditions and constant temperature.

4.2.1 isothermal secant bulk modulus (B_T) : The bulk modulus, resulting from pressure change from atmospheric to the pressure of interest.

$$B_T = -V_0 [p - p_0)/(V_0 - V)]_T$$

4.2.2 isothermal tangent bulk modulus (K_T) : The bulk modulus, representing the true rate of change at the pressure of interest.

$$K_T = -V(\partial p/\partial V)_T$$

$K_T > B_T$ except at atmospheric pressure, where $K^0_T = B^0_T$.

4.3 isentropic bulk modulus : The volumetric modulus of elasticity under conditions of constant entropy. It applies under conditions where pressure changes are rapid and there is no opportunity for the temperature to reach equilibrium.

4.3.1 isentropic secant bulk modulus (B_S) : Defined as

$$B_S = -V_0 [(p - p_0)/(V_0 - V)]_S$$

4.3.2 isentropic tangent bulk modulus (K_S) : Defined as

$$K_S = -V(\partial p/\partial V)_S$$

1) 1 Pa = 1 N/m²; 1 bar = 100 kPa (≈ 14,5 lbf/in²).

2) At present at the stage of draft. (Revision of ISO/R 91-1970.)

3) At present at the stage of draft.

5 Symbols and units

p = gauge pressure, bar

p_0 = atmospheric pressure = 0 bar

V = volume, m^3

V_0 = volume at atmospheric pressure and temperature (t_0)

t = Celsius temperature, °C

T = thermodynamic temperature, K

S = entropy, J/K

ϱ = density, corresponding to a given pressure, kg/l or g/cm^3 *

ϱ_0 = density at atmospheric pressure, kg/l or g/cm^3

κ_T = isothermal coefficient of compressibility = $1/K_T$

κ_S = adiabatic coefficient of compressibility = $1/K_S$

B_T = isothermal secant bulk modulus, bar

B_T^0 = isothermal secant bulk modulus at atmospheric pressure, bar

B_S = isentropic secant bulk modulus, bar

K_S = isentropic tangent bulk modulus, bar

K_T = isothermal tangent bulk modulus, bar

c_p = specific heat capacity at constant pressure, J/(kg.K)

K_T^0 = isothermic tangent bulk modulus at atmospheric pressure, bar

NOTE — It should be noted that $K_T^0 = B_T^0$.

K_S = isentropic tangent bulk modulus

6 General procedure

6.1 Isothermal secant bulk modulus (B_T)

6.1.1 Estimate density at desired temperature and atmospheric pressure, by taking data at 15 °C and using ISO 91/1 tables.

6.1.2 Use ISO 3675 for direct determination at 15 °C.

6.1.3 Refer to ISO 3658 and ISO 3838 for pyknometer determinations of density at various temperatures.

6.1.4 Locate, in figure 1, the point representing density at desired temperature.

6.1.5 Read the isothermal secant bulk modulus (B_T) in bars, from the scale on the ordinate. The value found represents the modulus at a reference pressure of 1 500 bar (150 000 kPa) and at the selected temperature.

6.1.6 Transfer the value of isothermal secant bulk modulus (B_T) to the ordinate of figure 2.

6.1.7 Move horizontally to the right until the line for 1 500 bar (150 000 kPa) is intersected.

NOTE — Find the value of B_T for any other pressure by moving vertically through this point of intersection to the line representing the desired pressure; move horizontally to read the value B_T at the new pressure from the scale on the ordinate. Find the bulk modulus for atmospheric pressure (B_T^0) by dropping vertically from the starting point to the line representing zero gauge pressure.

6.2 Isothermal tangent bulk modulus (K_T)

6.2.1 Find the isothermal secant moduli values at the desired pressure (B_T) and atmospheric pressure (B_T^0) as described in 6.1.

6.2.2 Calculate the relative isothermal secant bulk modulus by B_T/B_T^0.

6.2.3 Enter the value of B_T/B_T^0 on the abcissa of figure 3.

NOTE — The inset curve is an enlarged scale for lower values.

6.2.4 Find the point of intersection of B_T/B_T^0 with the line.

6.2.5 Move horizontally and read the value of the relative isothermal tangent bulk modulus (K_T/B_T^0) on the ordinate scale.

6.2.6 Calculate the isothermal tangent bulk modulus (K_T) by multiplying the value of relative isothermal tangent bulk modulus (K_T/B_T^0) by B_T^0.

* 1 kg/l = 1 g/cm^3 = 1 000 kg/m^3

6.2.7 The K_T value thus determined is at the same pressure and temperature for which the value of B_T was determined.

6.3 Isentropic tangent bulk modulus (K_S)

NOTE — The determination of B_T and K_T required only a knowledge of fluid density and temperature of interest because chemical structure considerations had no affect on the modulus.

The isentropic bulk modulus (K_S) is considered to be essentially adiabatic and does become involved in structural differences.

Specific heat capacities are required in the calculation of K_S, and these are a function of chemical structure and density.

6.3.1 Determine or estimate the specific heat capacity at constant pressure c_p, assuming that it does not vary with pressure.

6.3.2 Find the rate of change of density with temperature from the bulk modulus data calculations.

6.3.3 Calculate the isentropic tangent bulk modulus from the equation :

$$K_S = \frac{1}{(1/K_T) - [T(\partial \varrho/\partial T)^2/\varrho^3 c_p]}$$

6.4 Density or volume under pressure

6.4.1 Determine the isothermal secant bulk modulus (B_T) as in 6.1.

6.4.2 Obtain the value of the density at atmospheric pressure and the same temperature.

6.4.3 Calculate density or volume in terms of the ratios (ϱ_0/ϱ) or (V/V_0) where

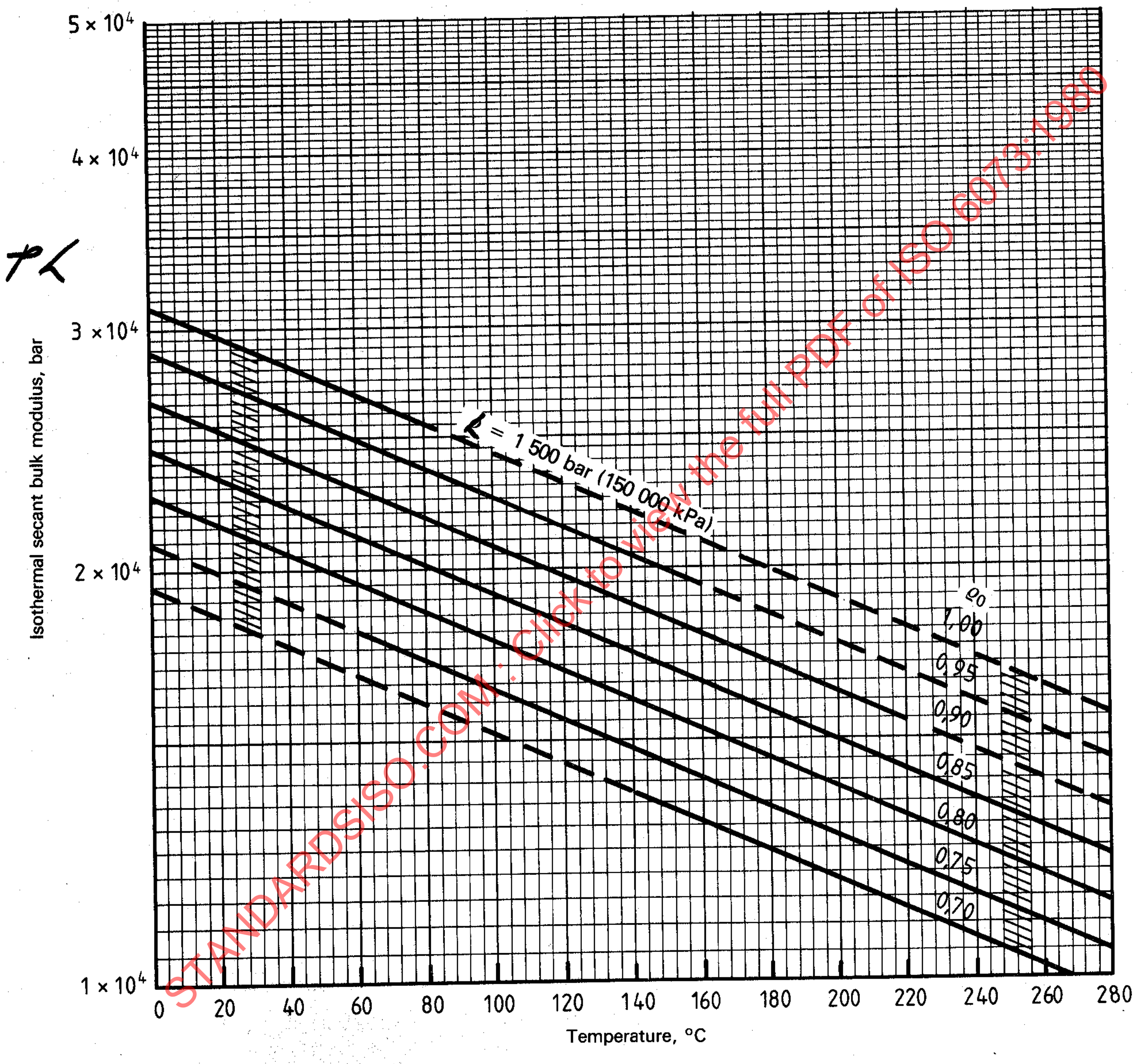
$$(\varrho_0/\varrho) = (V/V_0) = 1 - (p/B_T)$$

6.4.4 Use volume as the reciprocal of density ($V = 1/\varrho$), to calculate the volume under pressure.

7 Identification statement (Reference to this International Standard)

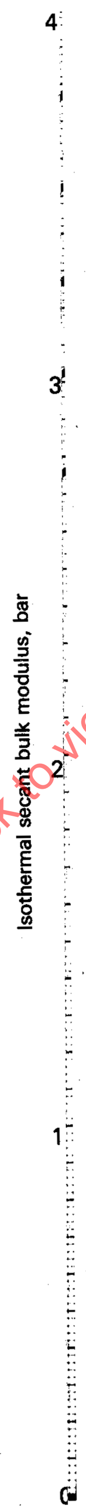
Use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard :

"Bulk moduli for petroleum fluids conforms to ISO 6073, *Hydraulic fluid power — Petroleum fluids — Prediction of bulk moduli*".



NOTE — Dotted lines indicate areas of less well defined relationship

Figure 1 — Secant bulk modulus at 1 500 bar (150 000 kPa) gauge pressure versus temperature and density for petroleum oils


4
3
2
1
0
Isothermal secant bulk modulus, bar

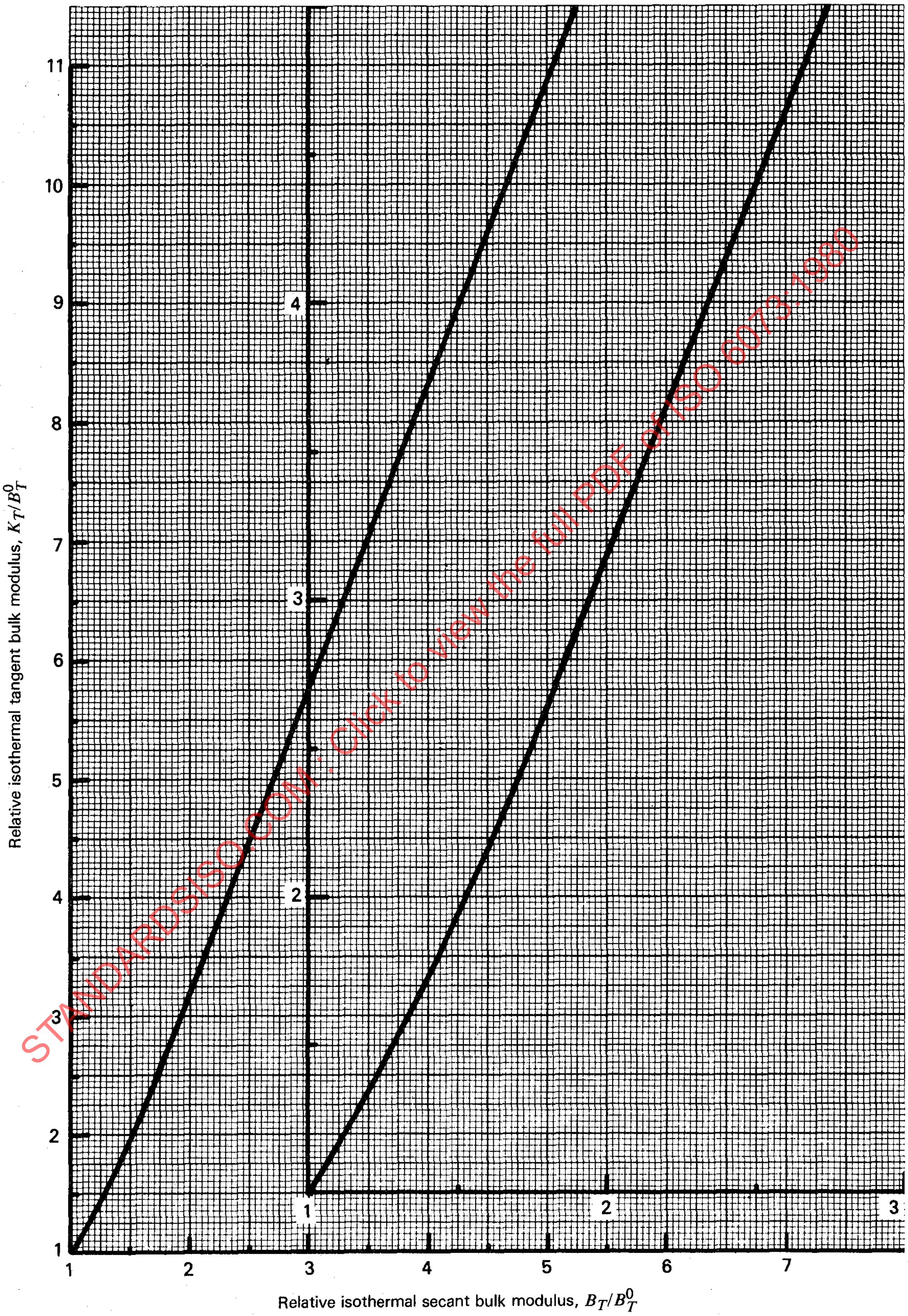


Figure 3 — Relation between isothermal secant and isothermal tangent bulk moduli for petroleum oils