INTERNATIONAL STANDARD

ISO 6073

Second edition
1997-12-15

Petroleum products — Prediction of the bulk moduli of petroleum fluids used in hydraulic fluid power systems

Produits pétroliers — Détermination des modules de compressibilité volumique des fluides pétroliers pour systèmes de transmission hydraulique

ISO 6073:1997(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 6073 was prepared by Technical Committee ISO/TC 28, *Petroleum products*.

This second edition cancels and replaces the first edition (ISO 6073:1980), which has been technically revised.

Annexes A and B of this International Standard are for information only.

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Printed in Switzerland

Petroleum products — Prediction of the bulk moduli of petroleum fluids used in hydraulic fluid power systems

1 Scope

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

This International Standard provides graphical techniques to obtain moduli of such fluids without using extended calculations and with the accuracy that would be required for the practical calculation of hydraulic system parameters. The useful temperature range is from 0 °C to 270 °C, with a pressure range of approximately 100 kPa to 700 MPa. Annex A gives some example calculations.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 91-1:1992, *Petroleum measurement tables - Part 1: Tables based on reference temperatures of 15 degrees C and 60 degrees F.*

ISO 3675:1993, *Crude petroleum and liquid petroleum products - Laboratory determination of density or relative density - Hydrometer method.*

ISO 3838:1983, *Crude petroleum and liquid or solid petroleum products - Determination of density or relative density - Capillary-stoppered pyknometer and graduated bicapillary pycnometer methods.*

ISO 12185:1996, *Crude petroleum and petroleum products - Determination of density - Oscillating U-tube method.*

3 Principle

A bulk modulus is selected according to the problem and conditions of operation, and the predicted value is obtained from the determination of density and reference to one or more of the nomographic figures provided.

4 Definitions

For the purposes of this International Standard, the following definitions apply:

4.1 bulk modulus: The measure of resistance to compressibility of a fluid taken as 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 working pressure.

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

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

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

$K_T > B_T$ except at atmospheric pressure, where $K_T^0 = B_T^0$

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

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

5 Symbols and units

The following symbols are used in the text and figures of this International Standard. The units shown are those preferred; if other units are used, the outcome of some multiples will be affected.

Symbol	Designation	Unit
B_S	Isentropic secant bulk modulus	MPa
B_T	Isothermal secant bulk modulus	MPa
B_T^0	Isothermal secant bulk modulus at atmospheric pressure	MPa
c_p	Specific heat capacity at constant pressure	J/(kg·K)
k_S	Adiabatic coefficient of compressibility	MPa^{-1}
k_T	Isothermal coefficient of compressibility	MPa^{-1}
K_S	Isentropic tangent bulk modulus	MPa
K_T	Isothermal tangent bulk modulus	MPa
K_T^0	Isothermal tangent bulk modulus at atmospheric pressure	MPa
p	Gauge pressure	kPa or MPa
p_0	Atmospheric pressure	kPa
S	Entropy	J/K
T	Temperature	K
V	Volume	m^3
V_0	Volume at atmospheric pressure and temperature	m^3
θ	Temperature	°C
ρ	Density at a given pressure	kg/m^3
ρ_0	Density at atmospheric pressure	kg/m^3

6 Determinations

6.1 Determine the density at 15 °C in accordance with ISO 3675, ISO 3838 or ISO 12185.

6.2 Determine the density at the required temperature in accordance with ISO 91-1.

NOTE — The densities determined above are at atmospheric pressure.

7 Predictions

7.1 Isothermal secant bulk modulus

7.1.1 From figure 1, read off the isothermal secant bulk modulus at a reference pressure of 150 MPa.

7.1.2 Transfer the figure obtained in 7.1.1 to the ordinate of figure 2, and move horizontally until this value intersects with the 150 MPa line. A line drawn vertically from this point gives values of the isothermal secant bulk modulus at other pressures. Read off the appropriate values on the ordinate.

7.2 Isothermal tangent bulk modulus

7.2.1 Calculate the relative isothermal secant bulk modulus at the desired pressure, B_T/B_T^0 and enter this value on the abscissa of figure 3.

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

7.2.2 Find the point of intersection of this value with the line, and read horizontally on the ordinate, the value of the relative isothermal tangent bulk modulus, K_T/B_T^0.

7.2.3 Calculate the isothermal tangent bulk modulus by multiplying the value obtained in 7.2.2 by B_T^0.

NOTE — The value determined in 7.2.3 is at the same pressure and temperature as that for which the value of B_T was determined.

7.3 Isentropic tangent bulk modulus

NOTE — The determination of isothermal bulk moduli only requires a knowledge of density and the temperature in question, since these are independent of chemical structure. For isentropic bulk moduli however, which are considered to be essentially adiabatic, the chemical structure does have an effect. It is therefore necessary to obtain a figure for the specific heat capacity at constant pressure, c_p, which is a function of density and chemical structure.

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

7.3.2 Calculate the rate of change of density with temperature in accordance with ISO 91-1 or using figure 1.

7.3.3 Calculate the isentropic tangent bulk modulus using the following equation:

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

7.4 Density or volume under pressure

7.4.1 Determine the isothermal secant bulk modulus (B_T) as in 7.1.

7.4.2 Obtain the value of density at atmospheric pressure and the temperature used for the bulk modulus calculations.

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

$$(\rho_0/\rho) = (V/V_0) = 1 - (p/B_T)$$

7.4.4 Use volumes as the reciprocal of density (V=1/ρ) to calculate the volume under pressure.

8 Expression of results

Report the predictions of bulk moduli to the nearest 100 kPa or 0,1 MPa.

9 Precision

The precision of this International Standard has not been determined according to ISO 4259 since the formulae have been derived by regression analysis of several hundred refined experimental data points on a wide variety of petroleum fluids and pure hydrocarbons. Precision will depend to some extent on the precision of the density method chosen (see 6.1) and the accuracy and interpretation of the figures.

An estimate of accuracy of prediction has been made using a matrix of 200 data points, on 10 fluids over the temperature range of approximately 40 °C to approximately 200 °C, and a pressure range of atmosphere up to 690 MPa. The bulk moduli of these fluids under these conditions ranged from 900 MPa to 3 500 MPa. This matrix had an average error of ± 0,84 % and a standard deviation of 10,07 MPa.

10 Test report

The test report shall contain at least the following information:

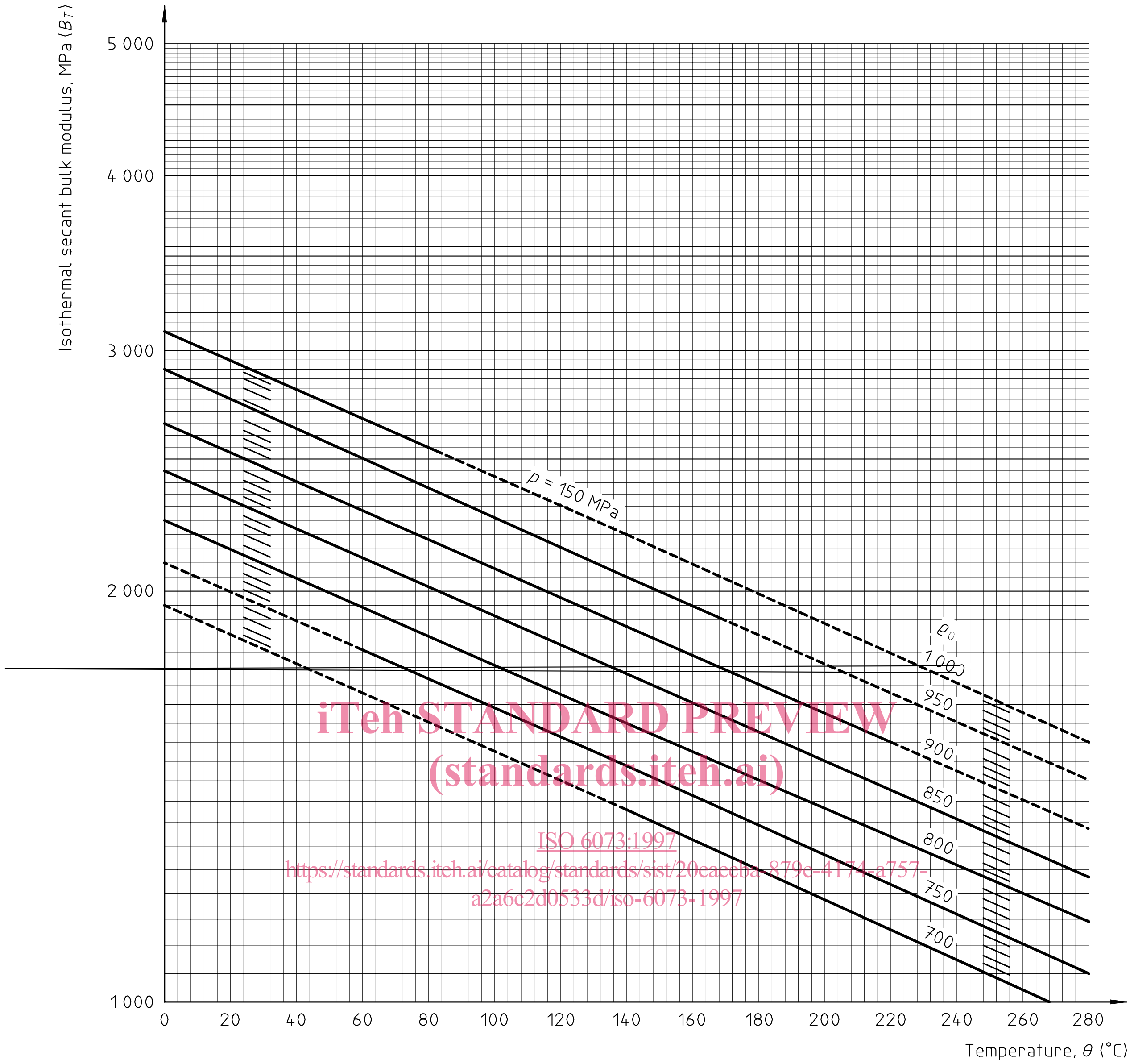
a) a reference to this International Standard, i.e. ISO 6073:1997;

b) the type and complete identification of the product tested;

c) the results of the test (see clause 8);

d) any deviation, by agreement or otherwise, from the standard procedures specified;

e) the date of the test.



NOTE — Dotted lines indicate areas of less well defined relationship

Figure 1 — Secant bulk modulus at 150 MPa gauge pressure versus temperature and density for petroleum oils

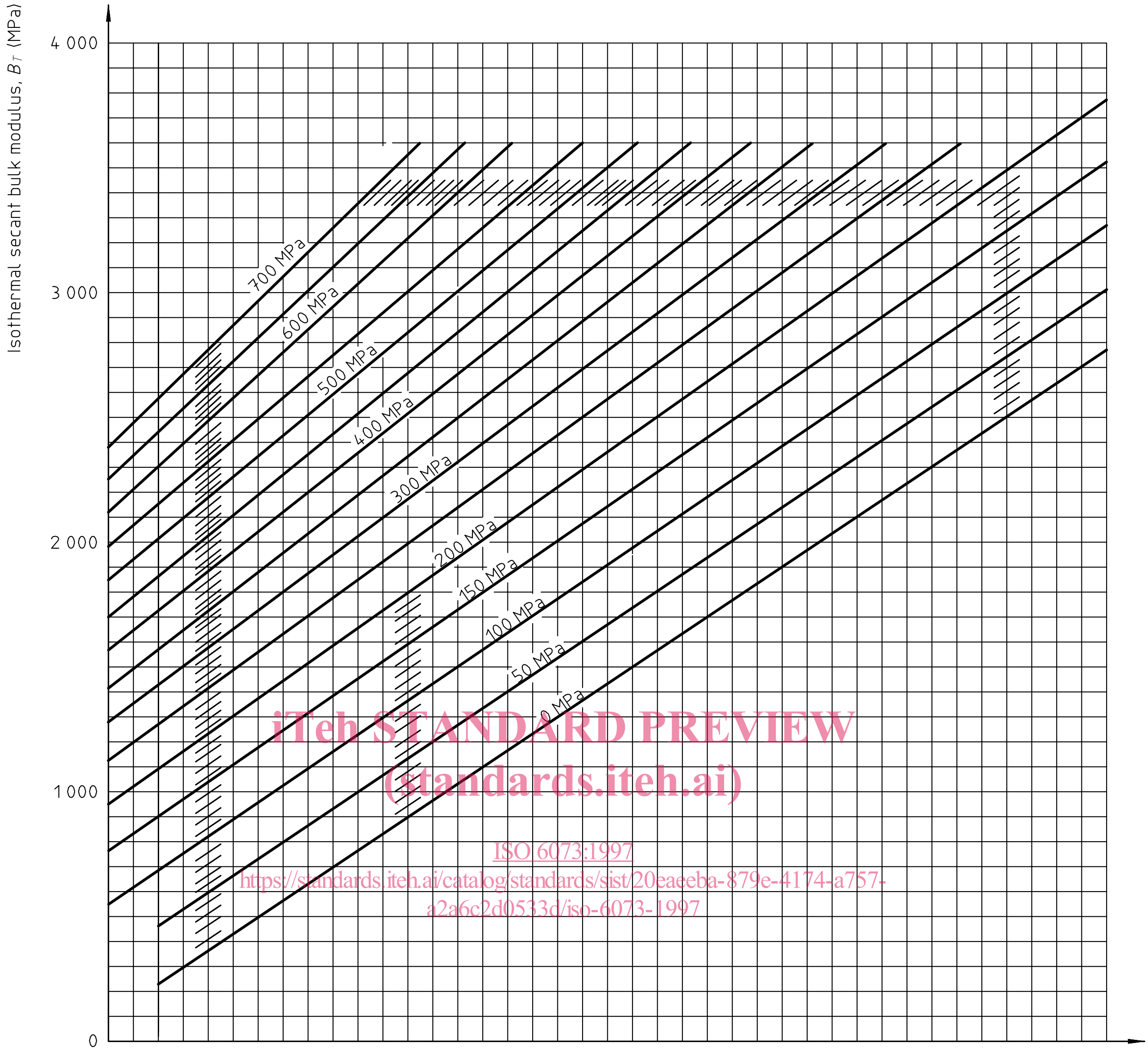


Figure 2 — Secant bulk modulus versus pressure for petroleum oils