DRAFT AMENDMENT

ISO 1217:2009/DAM 1

ISO/TC **118**/SC **6**

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Displacement compressors — Acceptance tests

AMENDMENT 1: Calculation of isentropic efficiency and relationship with specific energy

Compresseurs volumétriques — Essais de réception

AMENDEMENT 1: .

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Foreword

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The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

Amendment 1 to ISO 1217:2009 was prepared by Technical Committee ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 6, *Air compressors and compressed air systems*.

Introduction

Compressor performance can be expressed and compared in different ways. The most simple and precise but limited method is to compare the power requirement of different compressors fulfilling the same compression task at the same inlet conditions. If part load volume flow rates at constant outlet pressure and constant inlet conditions have to be considered as well, the use of specific power requirement (also denoted as specific energy requirement SER) is quite common, mainly in the area of standard air (industrial compressed air, compressors with atmospheric inlet, air in contact with oil) where constant outlet pressure is typical. Outside the area of standard air the application of isentropic efficiency to express performance is widely used.

Isentropic efficiency is an additional, widespread measure to judge the quality of thermodynamic processes, e.g. compression. It is a dimensionless number and will typically have values between 0 and 1 (0% and 100%), which eases assessment of compressor performance.

The need for a definition of the boundaries for the measurement of P_{real} is always present, regardless if specific energy requirement or isentropic efficiency is to be calculated.

Annex H
(informative)
Isentropic efficiency and its relation to specific energy requirement

(When amalgamated into ISO 1217)

H.1 Scope

This amendment provides general derivation of isentropic power and calculations for the relationship between isentropic efficiency as defined in this annex and specific energy requirement in accordance with ISO 1217.

No additional data or measurements are required for the calculation of isentropic power and isentropic efficiency.

This amendment provides calculations for the relative tolerances between specific power and isentropic efficiency.

H.2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

H.2.1

isentropic power

power that is theoretically required to compress an ideal gas under constant entropy, from given inlet conditions to a given discharge pressure

Note 1 to entry the term 'ideal gas' is used to indicate any gas in a condition or state so that it follows closely the ideal gas law.

H.2.2

isentropic efficiency

ratio of the required isentropic power to measured power for the same specified boundaries with the same gas and the same operating conditions

$$\eta_{isen} = \frac{P_{isen}}{P_{real}}$$

Note 1 to entry examples of specified boundaries may be shaft power of bare compressor or motor power of the package or total input power of the package.

Note 2 to entry In many turbo compressor textbooks, the stage gas power $P_i = \Delta h \cdot q_m = (h_2 - h_1) \cdot q_m$ is taken as P_{real}. Isentropic efficiency is than defined as: $\eta_{isen} = \frac{P_{isen}}{\Delta h \cdot q_m} = \frac{\Delta h_{isen}}{\Delta h}$.

H.3 Symbols and subscripts

Symbol	Term	SI unit	Other practical units
c_p	specific heat at constant pressure	J/(kg·K)	-
h	specific enthalpy	J/kg	kJ/kg
Δh	specific enthalpy difference	J/kg	kJ/kg
P	power	W	MW, kW
p	pressure	Pa	MPa, bar, mbar
Δp	pressure difference	Pa	MPa, bar, mbar
R	gas constant	J/(kg·K)	
T	absolute temperature	K	
q_m	mass rate of flow	kg/s	kg/h
q_V	volume flow rate	m^3/s	m^3/h, m^3/min, L/s
K	isentropic exponent (ratio of specific heats)		min^{-1}
L	lower limit		
η	efficiency		
ρ	density	kg/m^3	
U	upper limit		

Subscript	Term	Remark
isen	isentropic	
η	efficiency	
m	mass	Characterizes the mass-specific rates of flow, energies and volumes
P	power	
$real$	real	
$spec$	specific	
V	volume	Characterizes the volume-specific rates of flow and energy
$1,2$	states	

H.4 Derivation of isentropic power

The power required for isentropic compression can be derived from basic relationships:

$$P_{isen} = \Delta h_{isen} \cdot q_m \qquad \text{with} \qquad q_m = q_V \cdot \rho = \frac{p_1}{RT_1} \quad \text{(ideal gas)} \tag{3}$$

Isentropic enthalpy difference:

$$\Delta h_{isen} = c_p \cdot \left[T_{2,isen} - T_1\right] \qquad \text{(ideal gas)} \tag{4}$$

with

$$c_p = R \cdot \frac{K}{(K-1)} \tag{5}$$

follows:

$$\Delta h_{isen} = \frac{K}{(K-1)} RT_1 \cdot \left[\frac{T_{2,isen}}{T_1} - 1\right] \tag{6}$$

With the isentropic relation $\frac{T_{2,isen}}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{K-1}{K}}$ follows

$$\Delta h_{isen} = \frac{K}{(K-1)} RT_1 \cdot \left[\left(\frac{p_2}{p_1}\right)^{\frac{K-1}{K}} - 1\right] \tag{7}$$

and for the power required for isentropic compression:

$$P_{isen} = q_m \Delta h_{isen} = q_{V1} \cdot \frac{p_1}{RT_1} \Delta h_{isen}$$

$$P_{isen} = q_{V1} \cdot \frac{p_1}{RT_1} \frac{K}{(K-1)} RT_1 \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{K-1}{K}} - 1 \right]$$

$$P_{isen} = q_{V1} \cdot p_1 \frac{K}{(K-1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{K-1}{K}} - 1 \right] \qquad (8)$$

which is the most widely used version of the formula for isentropic power.

The equation above shows that no additional data has to be measured for the calculation of isentropic power and isentropic efficiency.

H.5 Relationship between isentropic efficiency and specific energy requirement

"Specific energy requirement" (SER) or more precisely "specific power requirement" is defined as:

$$P_{spec} = \frac{P_{real}}{q_{V1}} \qquad (9)$$

The relation of "isentropic efficiency" to "specific power requirement" can be derived using

$$\frac{1}{\eta_{isen}} = \frac{P_{real}}{P_{isen}} \qquad \text{and} \qquad P_{isen} = q_{V1} \cdot p_1 \frac{K}{(K-1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{K-1}{K}} - 1 \right] \qquad (10)$$

to build

$$\frac{1}{\eta_{isen}} = \underbrace{\left(\frac{P_{real}}{q_{V1}} \right)}_{P_{spec}} \cdot \frac{1}{p_1 \frac{K}{(K-1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{K-1}{K}} - 1 \right]} \qquad (11)$$

$$\frac{1}{\eta_{isen}} = P_{spec} \cdot \frac{1}{p_1 \frac{K}{(K-1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{K-1}{K}} - 1 \right]} \qquad (12)$$

or alternatively

$$\eta_{isen} = \frac{1}{P_{spec}} \cdot p_1 \frac{K}{(K-1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{K-1}{K}} - 1 \right] \qquad (13)$$

Therefore, if the operating conditions are known, the calculation of isentropic efficiency from specific energy requirement and vice versa is unambiguous.

H.6 Tolerances

As isentropic efficiency can be calculated from specific power requirement without additional data to be measured and vice versa (see above), their relative tolerances are directly related as well. As isentropic efficiency is proportional to the reciprocal of specific power requirement (see Equation 11 or 12), the algebraic signs of the tolerance values change and the values have to be converted.

Let P_{spec} have a lower limit L_P and an upper limit U_P, both given as relative values in per cent.

Then, P_{spec} can have values between

$$\frac{(100 - (L_P\,[\%]))}{100} \times P_{spec} \qquad \text{and} \qquad \frac{(100 + (U_P\,[\%]))}{100} \times P_{spec} \qquad (14)$$