International Standard 6303

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Pressure vessel steels not included in ISO 2604, Parts 1 to 6 — Derivation of long-time stress rupture properties

Produits en acier pour récipients à pression ne figurant pas dans l'ISO 2604, Parties 1 à 6 — Dérivation des propriétés de rupture sous contrainte prolongée

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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 6303 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in November 1979.

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

Australia	India	Romania
Austria	Italy	South Africa, Rep. of
China	Japan	Spain
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The member body of the following country expressed disapproval of the document on technical grounds :

Belgium

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0 Introduction

In the ISO rules for the construction of stationary boilers (ISO/R 831) and the draft rules for the construction of unfired pressure vessels, mean stress for rupture in 100 000 h is listed as an alternative design criterion.

International Standards for pressure vessel steels contain mean values for stress to give rupture in 100 000 h and longer times which have been internationally agreed. For products supplied to these International Standards or national standards conforming with the relevant International Standards, the stress rupture values given in the International Standards are valid provided that

a) the product has been manufactured strictly in accordance with the technical requirements of the relevant International Standard;

b) the manufacturer supplies a statement to this effect.

In all other cases, it is necessary to assure the manufacturer of the vessel that the product supplied is capable of meeting the values given in a national standard or other specification

a) by adequate records of test results on the type of steel concerned, and

b) by a statement that the manufacturing processes have remained equivalent to those of the steel for which the test results were obtained.

A method of extrapolation used in analyses of creep rupture data is given in the annex.

1 Scope and field of application

This International Standard defines a procedure for obtaining and for assessing the data necessary to establish long-time stress rupture values of steels for pressure purposes

a) for a steel not included in ISO 2604, Parts 1 to 6;

b) where properties different from those internationally agreed are being claimed (for example, in instances where a standard specifies a restricted or extended composition or heat-treatment range).

The purpose of specifying a standard procedure is to minimize any differences in long-time estimates obtained in different countries due to

a) differences in the quantity and duration of the data used to establish the estimates;

b) differences in the method of analysing the data.

Details of the method of extrapolation used in the analysis of creep rupture data are given in the annex.

2 References

ISO/R 206, *Creep stress rupture testing of steel at elevated temperatures.*

ISO/R 831, *Rules for construction of stationary boilers.*

3 General

The stress rupture strength of a steel depends upon various factors, including the thermal history and the chemical composition, which includes residual and trace elements. Consequently, a number of samples have to be tested in order to estimate both the average stress rupture strength and the scatter in results.

The accuracy to which estimates of scatter and of average stress rupture strengths are made, depend in turn upon the number of samples tested; the manner in which samples are selected for testing, in relation to permitted heat treatment and compositional ranges in specifications; the influence of testing technique and the extent and method of extrapolation. It is necessary, therefore, to give attention to these factors when considering the validity of data and long-time estimates.

4 Procedure

4.1 Selection of samples

4.1.1 Except as provided in 4.1.2, test samples shall be taken from finished products manufactured and heat treated commercially and shall be representative of the material as specified and supplied. It is preferable for the programme to include samples in the condition in which the product goes into service.

4.1.2 If circumstances are such that the above conditions cannot be complied with in part or in full (for example, in the case of a new steel), then this shall be made clear and full details of the manufacturing processes and heat treatment, including cooling rates, shall be recorded. An adequate supply of the material selected shall be held in reserve to enable further tests and/or metallographic investigations to be made at some time in the future, if desired.

It is important to ensure that the test programme as a whole produces data that are representative of the major metallurgical variables allowed for in the specification for the steel concerned. Test samples shall therefore be selected to take account of the following variables.

a) Chemical composition : The effects of variations in chemical composition with respect to the limits permitted by the specification(s), taking account of those elements known to be important. Consideration shall also be given to those elements which are known to be important, but which are not specified.

b) Heat treatment : The effects of variations in heat treatment, including austenitising temperature and tempering, with respect to the limits permitted by the materials specification(s). Consideration should also be given, where applicable, to variations in the rate of cooling from the austenitising temperature.

c) Room temperature tensile properties : The samples tested shall cover the range of tensile strengths permitted for the steel in the specification(s). It is likely that this requirement may be satisfied by those samples meeting the requirements of a) or b).

It is recognized that a) and b) may not require equal emphasis, and that the factors requiring the most attention may depend upon the type of steel.

4.2 Number of samples

Samples are required from a minimum of three casts from each manufacturer.

An individual manufacturer may include two or more suppliers provided that

a) they have a common relationship, i.e. are part of the same commercial organization or technical association;

b) each supplier has contributed to the pool of data.

4.3 Test conditions

4.3.1 Method of test

Stress rupture tests shall be carried out in accordance with the requirements of ISO/R 206.

4.3.2 Duration of test

At each temperature of testing, test pieces from each cast shall be tested at constant loads chosen to cause rupture at times approximating to those shown in table 1.

Table 1

Test series	Approximate test duration h
A	1 000 3 000 10 000
B	30 000
C	50 000

4.3.3 Temperatures of test

At least three test temperatures shall be chosen covering the temperature range within which the stress rupture properties are likely to be the main basis of design. The temperatures of testing shall be multiples of 25 °C or 50 °C, preferably the latter.

4.4 Long-term values

Available test results shall be assessed in accordance with the procedure given in the annex.

The initial assessment shall be made after series A has been completed and assessments made on completion of test series B and C of 4.3.2.

4.5 Validity of estimates

4.5.1 The extent to which test data can be reliably extrapolated depends on the number and duration of the tests. Three basic factors are involved : temperature, time and stress.

4.5.2 Estimates shall be regarded as tentative until data are available on the appropriate numbers of casts and durations required by 4.5.3 and 4.5.4.

4.5.3 Experience suggests that reliable extrapolations may be made, covering a range of ± 25 °C about each test temperature, on the basis of a series of tests from at least five casts of steel, the longest test of each series exceeding a certain minimum duration. A proportion of these five casts shall satisfy the requirements of 4.1.1.

4.5.4 The confidence which can be placed upon such properties will be related to the extent of extrapolation and, for the purpose of this International Standard, extrapolations exceeding approximately three times the above minimum duration are described as "extended time extrapolations". Stress rupture properties are normally listed at the time-intervals shown in table 2, which defines where "extended time extrapolation" shall be applied.

Values which have involved "extended time extrapolation" are marked with an asterisk in the tables of estimated average rupture stresses. Such values are recommended, but their use should take account of the quantity and duration of the test data on which they are based.

4.5.5 "Extended stress extrapolation" shall apply where values have been obtained by extending the parametric master curve to stresses beyond the range for which tests were carried out. Such values, which are subject to greater uncertainty compared with other values, are shown in parentheses ( ).

4.5.6 A scatter of greater than ± 20 % in the test results indicates that the specification to which the samples have been supplied is not sufficiently precise.

4.6 Presentation of results

The results of the stress rupture tests shall be recorded and, in addition, the report on each series of tests shall contain details of

a) steelmaking processes, including deoxidation practice;

b) chemical analysis, including residuals and trace elements;

c) the form of product with details of sizes;

d) heat treatment, temperatures, times and cooling rates;

e) position and orientation of test samples in relation to the component;

f) tensile properties at room temperature.

Table 2

Values in hours

Test duration exceeded by data points from 5[1)] casts at temperatures within 25 °C of that specified	80 000	70 000	50 000	30 000	20 000	10 000
Durations beyond which the term "extended time extrapolation" shall be applied	250 000	200 000	150 000	100 000	50 000	30 000

1) Unbroken points may be included if above the lower 20 % scatter band limit at the appropriate duration.

Annex

Method of extrapolation used in analyses of creep rupture data[1]

(This annex forms part of the Standard.)

The method makes use of a modified form of the generalized form of the time-temperature parameter due to Manson.[2]

$$P = \frac{\sigma^{-q} \log t - \log t_a}{(T - T_a)^r} \qquad \dots (1)$$

It involves the use of a computer programme for the optimization of parameter constants by a least-squares technique devised by Mendelson, Roberts and Manson[3], modified by setting the stress exponent $q = 0$ and the temperature exponent $r = +1$ or -1.

The procedure follows the following steps :

a) Log stress/log time graphs are plotted for individual test samples and mean isothermal curves are constructed through the data points at each temperature, but not extrapolated beyond the range of data. Any apparently erroneous data for which there is no satisfactory explanation may be eliminated at this stage.

b) Values of stress for rupture in specific times ranging from 100 h or 300 h at roughly equal logarithmic time increments up to the maximum possible are determined from the isothermal curves and recorded. Such values are the most convenient form of creep rupture data for any statistical studies that may be necessary.

c) Preliminary examinations of scatter in creep rupture properties are made, where appropriate, with the objective of subgrouping. Multiple regression analysis is one of the techniques used, the response variables studied being 1 000 and 10 000 h creep rupture strengths, usually obtained from step b).

d) For each sub-group of the steel resulting from step c), log stress/log time scatter band graphs are plotted. Mean isothermal curves are then fitted through, but not beyond, the test data, the objective being to extrapolate these using a time-temperature parameter. There are two alternative methods of deriving mean isothermal curves.

1) Mean values of stress for rupture in 100, 300, 1 000, 3 000, 10 000 and 20 000 h (or higher) at each temperature, are calculated from the distribution of these values, obtained from step b). The values so determined are used as a basis for constructing a series of isothermal curves.

2) By the method of least-squares fitting, curves of the following general form, and examining up to fourth degree polynomials.

$$\log t = b_0 + b_1 \log \sigma + b_2 (\log \sigma)^2 + \dots + b_n (\log \sigma)^n$$

The problem of weighting, which can be important with data of the kind being considered, can be dealt with much more effectively by method 1). It is mainly for this reason that method 1) is preferred.

e) For most steels it is found that tests have been made (collectively) at several temperatures, so that step d) may produce several mean isothermal curves. It is frequently found that there are large discrepancies in the amounts of data at different temperatures. These influence the relative accuracies of estimates of the true, population means and influence the accuracy of estimation of parameter constants. Whilst it is not possible to eliminate this problem, certain minimum requirements are imposed on the isothermal data to be used for extrapolation purposes .

1) The range of rupture times (i.e. minimum to maximum) shall be at least 5 000 h.

2) The number of casts tested shall be at least 3.

3) Rupture times shall extend to at least 5 000 h.

4) The number of data points shall be 10 or more.

f) From each of the isothermal curves obtained from step d) and meeting the selection requirements of step e), a series of log stress/log time values are determined at log time intervals of not greater than 0,25 along the curves.

g) The values derived from step f) are used to compute optimized values of constants T_a and $\log t_a$. The computer programme used is a modification of that used by Mendelson, Roberts and Manson.[3] Use of the system has been described by Harvey and May.[5] The stress and temperature exponents are set at $q = 0$ and $r = \pm 1$ and a series of trial values of T_a ranging from 0 to 600 °K in steps of 50 are considered. If the chosen value of T_a is zero, then it is most likely that the associated value of r is -1, i.e. Larson-Miller. If it is $+1$, then the standard deviation for this estimate shall be compared with the standard deviation for Larson-Miller. If these are similar, i.e. within 20 %, Larson-Miller shall be chosen.

If the chosen value of T_a is 600, the range shall be extended up to the value to T_a which causes $(T - T_a)$ to go negative. If the standard deviation achieves a minimum before $(T - T_a)$ becomes negative, then this can be used for a Manson-Haferd form of the equation.

h) The output from the computer will include optimized values of constants, parameter values for the stress and time-temperature data used and the coefficients of the equation relating stress with parameter.

The master curve is constructed from the output of the computer programme as a graph of log stress against the parameter value. Each data point used in developing the master curve is plotted on this graph along with the curve, in order to assess the degree of fit.

NOTE — The data obtained in accordance with clause 3 will normally be few in number and are unlikely to require sub-grouping, so that the initial procedure in stages a) to f) may be omitted. The data may then be used directly to calculate optimized values of the constants and master curve following g) and h).

Where computer facilities are not available, it will generally be sufficient to use one of the standard forms of the parameter, the simplest being the Larson-Miller method.

Bibliography

[1] ISO/TC 17/SC 10/ETP N 58, *Method of extrapolation used in recent analyses of ISO creep rupture data.*

[2] MANSON, S. S., James Clayton Lecture, *I. Mech.E.Proc.* Vol. 178, Part 3A, 1963-64.

[3] MENDELSON, A., ROBERTS, E., and MANSON, S. S., Aug. 1965, NASA-TN-D-2975.

[4] MANSON, S. S., *ASM Materials Engineering Congress*, 1968, ASM Publication No. D8-100.

[5] HARVEY, R. P., and MAY, M. J., *ASM Materials Engineering Congress*, 1968, ASM Publication No. D8-100.