Comparison of extrapolation methods

for creep rupture stresses of 12Cr and 18Cr10NiTi steels

information nr 130-1979

STYRELSEN FÖR TEKNISK UTVECKLING

Comparison of extrapolation methods

for creep rupture stresses of 12Cr and 18Cr10NiTi steels

Bo Ivarsson,
Swedish Institute for Metals Research

STU-information nr 130-1979

ISSN 0347-8645
LF/ALLF 222 79 020
Offsetcenter ab, Uppsala 1979

COMPARISON OF EXTRAPOLATION METHODS FOR CREEP RUPTURE STRESSES OF 12Cr AND 18Cr10NiTi STEELS

Bo Ivarsson
Swedish Institute for Metals Research, Stockholm, Sweden

ABSTRACT

As a part of a Soviet-Swedish research programme the creep rupture properties of two heat resisting steels namely a 12% Cr steel and an 18%Cr12%Ni titanium stabilized steel have been studied. One heat from each country of both steels were creep tested. The strength of the 12% Cr steels was similar to earlier reported strength values, the Soviet steel being somewhat stronger due to a higher tungsten content. The strength of the Swedish 18/12 Ti steel agreed with earlier results, while the properties of the Soviet steel were inferior to those reported from earlier Soviet creep testings.

Three extrapolation methods were compared on creep rupture data collected in both countries. Isothermal extrapolation and an algebraic method of Soviet origin gave in many cases rather similar results, while the parameter method recommended by ISO resulted in higher rupture strength values at longer times.

CONTENTS

1. INTRODUCTION

The need of extrapolation methods for creep rupture strength predictions for rupture times exceeding 100 000 hours has increased during the last years due to longer desired life times for plants working at high temperatures. A number of different extrapolation methods have been proposed in the literature. They can be devided into three groups: graphical, analytical and parametric methods.

One of each of these methods has been studied in this project, which has been a part of a Soviet-Swedish cooperative research programme for materials research and technology. The Soviet part of this project has been carried out at The Department of Boiler and Turbine Materials at the Central Research Institute for Machinery (CNIITMASH), and will be reported elsewhere. The Swedish part has been performed by the Swedish Creep Committee at The Swedish Institute for Metals Research.

2. RESEARCH PROGRAMME

The programme consisted of two parts:

A. Comparison of creep rupture properties of related Soviet and Swedish heat resisting steels

The purpose of this part was to examine the results of creep rupture tests of the same heats of steels to reveal eventual differences, which can later affect the extrapolated strength values.

B. Comparison of different methods for extrapolation

In this part the results of the different extrapolations have been compared to the experimental values used, to enable an evaluation of the accuracy and applicability of the methods.

In both parts the following steel types have been studied:

- a 12% Cr steel (Soviet: ЭИ 756, Sweden: Sandvik HT9)
- a titanium-stabilized 18%Cr12%Ni steel (Soviet: OX18H12T, Sweden: SIS 2337)

Both parts have been carried out using all four steels.

3. MATERIALS AND EXPERIMENTAL PROCEDURES

3.1 Comparison of creep rupture properties

The composition, heat treatment and room temperature properties of the four steels studied are shown in Tables 1 and 2. The testing temperature was chosen to 600°C. At least five different stress levels with predicted rupture times up to 20 000 hours have been used.

The specimens, 10 mm in diameter and 45 mm in gauge length, were tested in Bofors single specimen creep testing machines (1). No strain measurements during testing were made. The accuracy of the temperature regulation was ±1°C. Besides time to rupture, total elongation and reduction of area were measured for each specimen.

Since no Soviet data have been reported yet, no comparison can be made of results from testing the same steels at the two laboratories. The results of these comparisons will be reported separately.

However, the properties of the Soviet and Swedish variants of the two steel grades have been compared.

3.2 Comparison of different extrapolation methods

Creep rupture data for the Soviet and Swedish steels have been exchanged and evaluated at CNIITMASH and IM, each laboratory using its own extrapolation method.

The ranges of compositions and heat treatments are shown in Tables 3 and 4. The number of rupture times reported for each temperature are shown in Table 5. All data on the Swedish 12% Cr steel are from one manufacturer, Sandvik, while the 18/12 Ti steel data originate from Avesta, Bofors, Sandvik and Uddeholm.

The Soviet evaluations have been made by fitting the following expression to the experimental values (2,3).

$$t_R = \exp(a) \cdot T^2 \cdot \sigma^{-2} \cdot \exp(\frac{b-c\cdot\sigma}{T})$$

t_R = time to rupture, T = temperature and σ = rupture stress. a, b and c are constants that are varied to get the best fit.

At The Swedish Institute for Metals Research two methods have been used.* The most straight forward approach is graphical extrapolation in a $\log\sigma$-$\log t_R$ diagram for constant temperature. The $\log\sigma$-$\log t_R$ curves have been obtained by up to fourth degree polynomial regression analysis. The degree giving the best fit was chosen, provided the coefficient of the highest degree term was negative. This method, later referred to as "the isothermal method" is in fact the first step of the second method used, namely the parameter method, recommended by ISO (4,5).

In this method interpolated isothermal values are used to construct a master curve, $\log\sigma$-P, where P is Manson's generalized time-temperature parameter

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

T_a, t_a, r, q are constants that are varied to get the best fit of the master curve to the experimental values. Values recommended by ISO are q=0, r=±1 and T_a=0-600 K. Extrapolations with a factor of three are regarded as accurate, but extrapolations with a factor of ten give acceptable results only in special cases (6,7,8).

4. RESULTS

4.1 Comparison of creep rupture properties

The results of the Swedish tests are presented in Fig. 1 for the 12% Cr steels and in Fig. 2 for the 18/12 Ti steels. The experimental values have been fitted to second degree polynomials for the 12% steels and to straight lines for the 18/12 Ti steels.

In Tables 6 and 7 the stress, time to rupture, elongation and reduction of area for every specimen are tabulated.

4.2 Comparison of different extrapolation methods

The extrapolations are extended at most to 200 000 hours or to about ten times the maximum experimental rupture time. E.g. for the steel 0X18H12T the extrapolations are limited to 50 000 hours.

In Figs. 3-16 all experimental data points are shown for rupture times exceeding 3 000 hours (0X18H12T: 1 000 h) together with the results from the three different extrapolation methods. For the steels [illegible]-756, HT 9 and SIS 2337 the results of the creep rupture testing are plotted in Figs. 4, 8 and 13 respectively. The results for 0X18H12T are plotted in Fig. 17 together with the calculated strengths values at 600°C, according to the Soviet and the ISO methods. The master curves and the interpolated values used in the ISO evaluation are plotted in Figs. 18-21.

Since the data of the Swedish steel are from one manufacturer, Sandvik, the strength values extrapolated by Sandvik at 550 and 600°C are plotted in Figs. 7 and 8. The extrapolation method used is isothermal linear $\log t_R$-$\log\sigma$ regression for data with rupture times exceeding 5000 hours. However, the data used by Sandvik are not identical to those used in the present investigation so the results can not be used to compare the different isothermal extrapolation methods.

In Figs. 22 and 23 the evaluated rupture stresses at 600°C according to the Soviet and the ISO methods are plotted to enable comparison between the two variants of the same steel. The evaluated values are tabulated in Table 8, together with the evaluated strength of steel 0X18H12T at 610°C.

In Figs. 22 and 23 ISO data for the corresponding steels (steel 40 and 53) are also plotted. In the ISO analysis both steels are divided into two categories, depending on room temperature tensile strength and heat treatment. The steels used in this investigation correspond most closely to the weaker category of both steels. The amount of data used by ISO is somewhat larger than that of the present investigation. Unfortunately their data are concentrated to rupture times shorter than 10 000 hours.

5. DISCUSSION

5.1 Comparison of creep rupture properties

As can be seen from Fig. 1 the creep rupture strength of the Soviet 12% Cr steel is higher than that of the Swedish one. This is probably due to the higher tungsten content of the Soviet steel, since W favours the formation of stable carbides of type M_2C and V_4C_3 (10).

The higher nickel content of the Swedish steel may contribute to some extent to its lower creep rupture strength, since higher nickel content reduces the stability of the carbides and thus also the creep strength of the material (11).

The difference in heat treatments used is not likely to be of importance in this context. Although it affects the room temperature yield stress, this has been reported to have a negligible influence on the creep rupture stress at 600°C (12).

The same strength relationship between the Soviet and Swedish steels is also found for the steels used for the comparison of extrapolation methods. Table 3 shows that the differences in chemical composition are about the same as for the creep rupture tested steels.

Table 6 indicates that the ductility of the Swedish steel is somewhat higher, but the results are within experimental scatter.

Of the 18/12 Ti steels the Swedish one shows the greatest strength, especially at shorter rupture times. The ductility of the Soviet steel is also inferior (cf. Table 1). Figs. 13 and 17 indicate that the difference mainly depends on the subnormal strength of the Soviet steel.

Since the poor strength could not be explained by differences in chemical composition or heat treatment, a microscopic examination was made of the two steels in their heat treated condition. This examination revealed that the grain structure of the Soviet steel was irregular and much coarser than that of the Swedish steel. This also explains the low ductility of the Soviet steel.

5.2 Comparison of different extrapolation methods

Figs. 13-16 indicate that the extrapolation curves in many cases have a poor fit to the experimental values for longer rupture times.

ЭИ756

The Soviet method results in much too low values at 585°C and 630°C. The 600°C curve lies a bit below the experimental values. The isothermal curves give, as can be expected, a good fit within the interval with experimental points but drops in an unreasonable way beyond it. The ISO curve yields too low values at 585°C, somewhat too high ones at 600°C and much too high ones at 630°C.

HT 9

At 500°C the three curves almost coincide and represent a good fit to the experimental values. The fit is almost equally good at 550°C, except that the results of the Soviet evaluation are somewhat low. At 600°C the Soviet and the isothermal curves are almost identical, but the ISO curve lies too high. This is also the case at 650°C, where the isothermal and especially the Soviet curves are too low, when compared to the experimental values.

0X18H12T

At both 610 and 660°C the ISO curves are concave upwards which is physically unrealistic and results in too high extrapolated values in spite of the good fit to experimental values. The Soviet and the isothermal curves agree with the experimental values at 610°C but at 660°C they both seem to be strongly influenced by the single value at 10 MPa, so that the Soviet curve is too low in almost the whole interval, while the isothermal curve falls rapidly when extrapolated beyond the experimental interval.

SIS 2337

The ISO curves are possibly somewhat too high at all temperatures except at 800°C, while the results from the Soviet evaluation are too low except at 550°C and 800°C. The fit of the isothermal curves is satisfactory.
Comparisons with the values evaluated by ISO (cf. Figs. 22 and 23) show that these values are lower than those evaluated in the present investigation for the 12% Cr steels. For the 18/12 Ti steels the ISO values agrees with the Soviet evaluation of the Soviet steel, and falls between the Soviet and the ISO evaluation of the Swedish steel.

Naturally the isothermal curves in general give the best fit to experimental values, but single values at either end of the interval of experimental rupture times seem to influence the curves strongly and make them drop rapidly with increasing rupture times.

The isothermally extrapolated values are also dependent on the degree of the polynomial used in the regression analysis. Though the decrease of the residual sum of squares is very small (only a few percent) when increasing the degree of the polynomial, the extrapolated values are strongly affected. This is clearly in Figs. 24 and 25 where the curves corresponding to the four polynomials are shown together with the experimental values for steel HT9 at 600°C and steel 0X18H12T at 660°C. In Fig. 24 the fourth degree polynomial and Fig. 25 the second degree polynomial are rejected due to positive highest degree term coefficients, which results in curves that are concave upwards.

The Soviet method, on the other hand, often results in too low values in the experimental interval, but the values do not decrease with increasing rupture time as fast as those of the isothermal extrapolation. The rupture strengths predicted by the Soviet method are in general larger than the isothermally extrapolated ones at rupture times over 100 000 hours.

The curves of the ISO method often fit the experimental values reasonably well, but the extrapolated values are consistently appreciably higher than those predicted by the isothermal extrapolation and in most cases also than those of the Soviet method. The reason for this can easily be seen from the master curves, Figs. 18-21. From these curves it is obvious that an extrapolation of the isothermally interpolated points used when constructing the master curves, will result in a lower strength value than that derived from the master curve for the same P value.

In order to reduce the incompatibility between the curvatures of the isothermal curves and the master curve, evaluations have been made with other values for q and r than those recommended by the ISO. These trials resulted in somewhat improved fits, but far from satisfactory.

Difficulties in using the ISO method for the steels investigated in the present paper have been reported earlier (7,8).

As has been mentioned earlier the results of the Sandvik extrapolation plotted in Figs. 7 and 8 have been achieved using a different set of data than that used in this investigation. Thus, the results can not be used for comparison to the other extrapolation methods, but they show how strongly the extrapolated strengths are affected by the use of different data sets.

6. CONCLUSIONS

6.1 Comparison of creep rupture properties

The results of the creep rupture testing did not deviate from earlier findings except for the Soviet 18/12 Ti steel, which had lower strength than expected. This was due to a coarse and irregular grain structure, possibly the result of an improper heat treatment.

6.2 Comparison of different extrapolation methods

The results of the extrapolations show that an extrapolation factor of 10 can not be allowed. In most cases even an extrapolation by a factor of 2 or 3 leads to considerable scatter in predicted strength.

None of the methods investigated can be regarded as entirely satisfactory, since they all yield results that either deviate from experimental values or are somewhat unrealistic physically.

The Soviet extrapolation represents a poor fit of the extrapolation curves to the experimental values. The isothermal extrapolation, on the other hand, results in curves with a good fit to experimental data but the extrapolated values depend on the chosen degree of the polynomial. They are also influenced by single experimental values at large times. For the ISO method it is obvious from the master curves that the extrapolated values overestimate the strength of the materials.

REFERENCES

1. ALDÉN, G., The Creep Testing Laboratory at the Swedish Institute for Metals Research. (In Swedish) IM-802, October 1971.

2. TRUNIN, I.I., LOGINOV, E.A., A Method of Predicting the Creep Rupture Strength of Metals and Alloys. (In Russian) Machinovedenie 2 (1971) 66-73.

3. TRUNIN, I.I., An Estimation of Creep Ductility Characteristics of Steel. (In Russian) Machinovedenie 4 (1973) 68-73.

4. Method of Extrapolation Used in Recent Analysis of ISO Creep Rupture Data. ISO/TC17/WG10/ETP-SG, 58.

5. HARVEY, R.P., MAY, M.J., The Application of Time-Temperature Parameters for the Prediction of Long Term Elevated Temperature Properties Using Computerized Techniques. Time-Temperature Parameters for Creep-Rupture Analysis. ASM Publication No. D8-100, 277-310.

6. GLEN, J., Properties in Relation to Design and Modern Codes. Keynote Lecture. Creep and Fatigue in Elevated Temperature Applications. Proceedings of an International Conference in Philadelphia 1973. Sheffield 1974, Volume 2, 1-13.

7. MURRY, G., Extrapolation of the Results of Creep Tests by Means of Parametric Formulae. Joint International Conference on Creep, New York, London, 1963, Paper 73, (6-87)-(6-100).

8. Draft ISO Proposal for a Procedure for Deriving Long Time Stress Rupture Properties of Steel Products for Pressure Vessels.
ISO/TC17/WG10/ETP-SG, 61.

9. Summary of Average Stress Rupture Properties for Pressure Vessel Steels for Times of 10 000 Hours to 250 000 Hours and Master Curves.
ISO/TC17/WG10/ETP-SG, 53.

10. KOUTSKÝ, J., JEZEK, J., High-Temperature Properties of 12% Cr Steels Alloyed with Tungsten, Molybdenum and Vanadium.
JISI 203 (1965), 707-14.

11. MARRISON, T., HOGG, A., Influence of Nickel Content on the Structure and High-Temperature Properties of a 12% Cr-Mo-V-Nb Steel.
Creep Strength in Steel and High Temperature Alloys. Proceedings of a Conference in Sheffield 1972, 242-48.

12. ZSCHOKKE, H., STAUFFER, W., FELIX, W., Evaluation of the Results of Creep Tests on High-Temperature 12 Per Cent Cromium Steel.
Joint International Conference on Creep, New York, London, 1963, Paper 45(2), (5-25)-(5-28).

Table 1

12% Cr - Material Characterization

1a Chemical composition

Steel	C	Si	Mn	Cr	Ni	Mo	W	V	Cu
Soviet	0,12	0,30	0,50	10,08	0,10	0,70	1,75	0,30	0,14
Swedish	0,21	0,37	0,50	11,8	0,48	0,99	0,51	0,29	-

1b Heat treatment

Steel	Annealing	Tempering
Soviet	1020-1050°/1h, AC	720-750°C/3h, AC
Swedish	1050°C/0,5h, AC	780°C/2,5h, AC

1c Product forms

Steel	Product form	Dimension
Soviet	Tube	426x60 mm
Swedish	Cylindrical bars	φ 19 mm

1d Mechanical properties at room temperature

Steel	Proof stress $R_{p0,2}$ (MPa)	Tensile strength Rm (MPa)	Elongation A_5 (%)	Reduction of area Z (%)
Soviet	608	790	19,8	-
Swedish	522	775	18,0	60

Table 2

18/12 Ti - Material characterization

1a Chemical composition

Steel	C	Si	Mn	Cr	Ni	Ti	N
Soviet	0,07	0,53	1,42	17,66	11,83	0,48	-
Swedish	0,062	0,66	1,78	17,6	10,6	0,43	0,017

1b Heat treatment

Steel	Annealing	Tempering
Soviet	1060°C, WQ	800°C, WQ
Swedish	1130°C/0,3h, AC	-

1c Product forms

Steel	Product form	Dimensions
Soviet	Tubes	560x32 mm
Swedish	Plates	960x18 mm

1d Mechanical properties at roomtemperature

Steel	Proof stress $R_{p0,2}$ (MPa)	Tensile strength R_m (MPa)	Elongation A_5 (%)	Reduction of area Z (%)
Soviet	275	549	49,8	61,0
Swedish	200	560	38	72

Table 3

12% Cr - Actual minimum and maximum values of composition of materials analysed. Heat treatments.

3a Chemical composition

Steel		C	Si	Mn	Cr	Ni	Mo	W	V
Soviet	Min	0,10	0,23	0,55	10,7	0,08	0,67	1,82	0,21
	Max	0,14	0,49	0,76	11,7	0,25	0,82	2,20	0,30
Swedish	Min	0,18	0,23	0,42	11,3	0,42	0,97	0,46	0,27
	Max	0,20	0,46	0,76	12,3	0,57	1,06	0,57	0,40

3b Heat treatment

Steel	Annealing	Tempering
Soviet	1020-1050°C/0,5-1,0h	720-780°C/3h
Swedish	1050°C/0,5h	750-780°C/2-2,5h

Table 4

18/10 Ti - Actual minimum and maximum values of composition of materials analysed. Heat treatments.

4a Chemical composition

Steel		C	Si	Mn	Cr	Ni	Ti
Soviet	Min	0,04	-	-	17,12	11,64	0,12
	Max	0,12	-	-	19,03	13,68	0,62
Swedish	Min	0,04	0,42	0,58	17,2	8,5	0,31
	Max	0,07	0,80	1,62	18,6	11,7	0,68

4b Heat treatment

Steel	Annealing
Soviet	Not reported
Swedish	1050-1160^{o}C/0,17-1,0h

Table 5

Number of creep rupture values/temperature.

Steel	Temperature	Number of values
ЭИ-756	585 °C	103
	600 °C	61
	630 °C	103
HT 9	500 °C	14
	550 °C	60
	600 °C	88
	650 °C	38
OX 18H12T	610 °C	109
	660 °C	51
SIS 2337	550 °C	33
	575 °C	3
	600 °C	135
	650 °C	48
	700 °C	56
	800 °C	37

Table 6

Results from creep rupture tests 12% Cr. 600°C.

6a 3M-756

Stress (MPa)	Time to rupture (h)	Elongation (%)	Red. of Area (%)
196	288	21,8	80,6
177	1152	23,6	82,8
167	2760	23,6	76,9
157	3864	18,3	68,5
147	3864	25,2	73,1
137	5736	16,6	62,8
118	13080	22,8	58,3

6b HT 9

Stress (MPa)	Time to rupture (h)	Elongation (%)	Red. of Area (%)
180	264	27,3	83,7
171	456	33,0	86,9
160	984	28,9	85,5
140	2160	25,2	75,7
127	2928	20,0	68,2
115	3480	34,5	89,0
104	6648	21,1	70,5
95	10632	17,3	61,3

Table 7

Results from creep rupture tests.
18/12 Ti. 600°C.

7a OX18H12T

Stress (MPa)	Time to rupture (h)	Elongation (%)	Red. of Area (%)
177	432	6,4	9,2
167	744	7,9	12,7
157	1392	9,4	7,6
147	1848	5,4	7,8
137	3024	4,5	0,2
118	11304	3,8	0,3

7b SIS 2337

Stress (MPa)	Time to rupture (h)	Elongation (%)	Red. of Area (%)
260	624	11,8	17,7
235	720	11,6	20,2
220	1464	7,0	16,2
190	2856	9,2	16,4
172	3024	10,5	15,3
155	7896	16,0	21,5

Table 8

Extrapolated creep rupture strengths.

Steel	Method	Evaluated Strength (MPa)				
		1000h	10000h	50000h	100000h	200000h
ЭИ 756 600°C	Soviet	164	119	92	81	71
	Isothermal	176	133	95	78	63
	ISO	180	128	100	92	86
HT 9 600°C	Soviet	152	106	78	67	57
	Isothermal	154	106	76	66	55
	ISO	148	110	86	77	68
0X18H12T 600°C	Soviet	209	141	103	-	-
	ISO	221	156	128	-	-
0X18H12T 610°C	Soviet	196	130	94	-	-
	Isothermal	208	132	85	-	-
	ISO	208	144	121	-	-
SIS 2337 600°C	Soviet	211	131	89	74	62
	Isothermal	209	152	102	84	63
	ISO	199	150	115	105	89

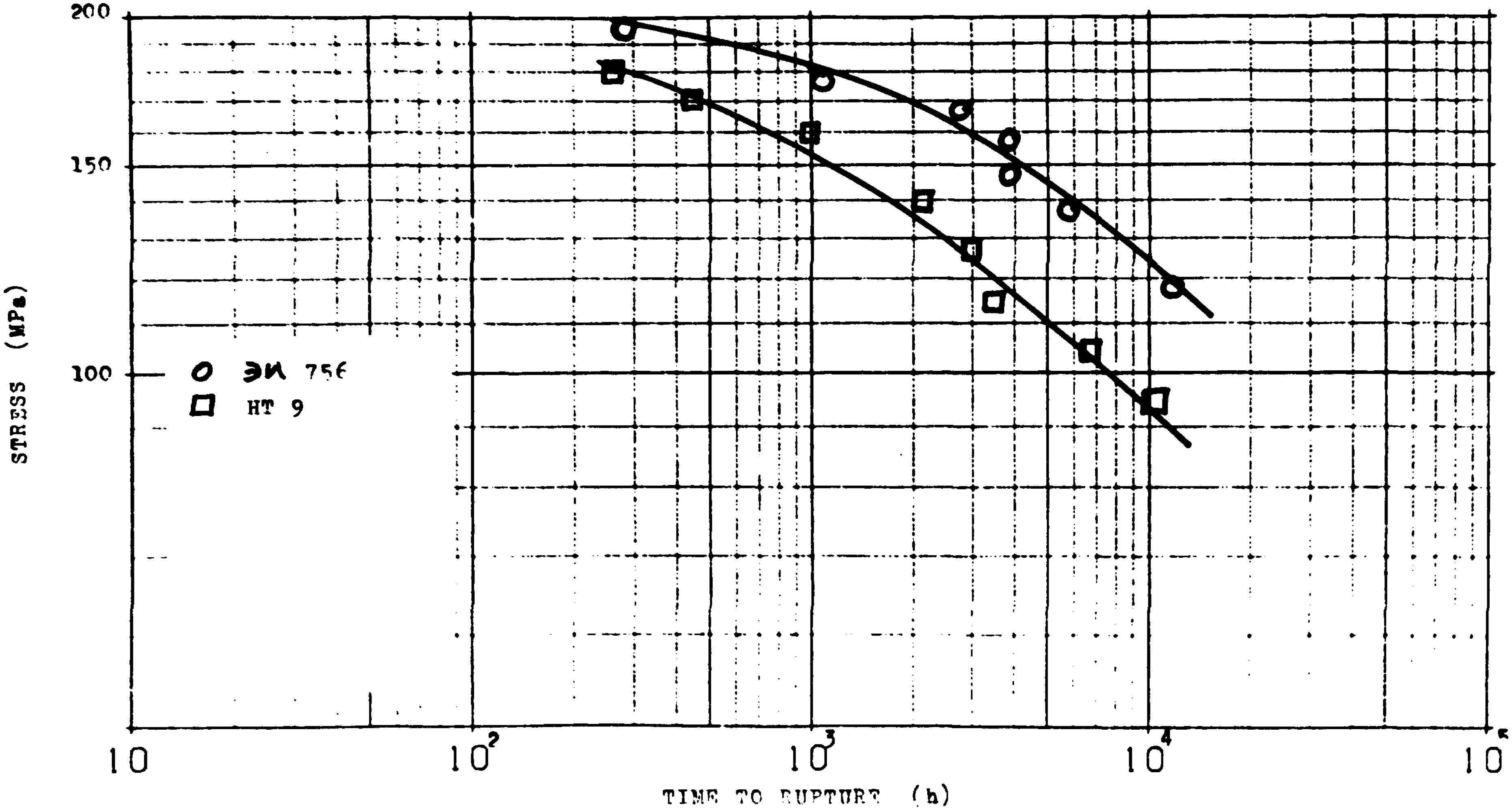

Fig 1. Results from the creep rupture testing of 12 % Cr steels

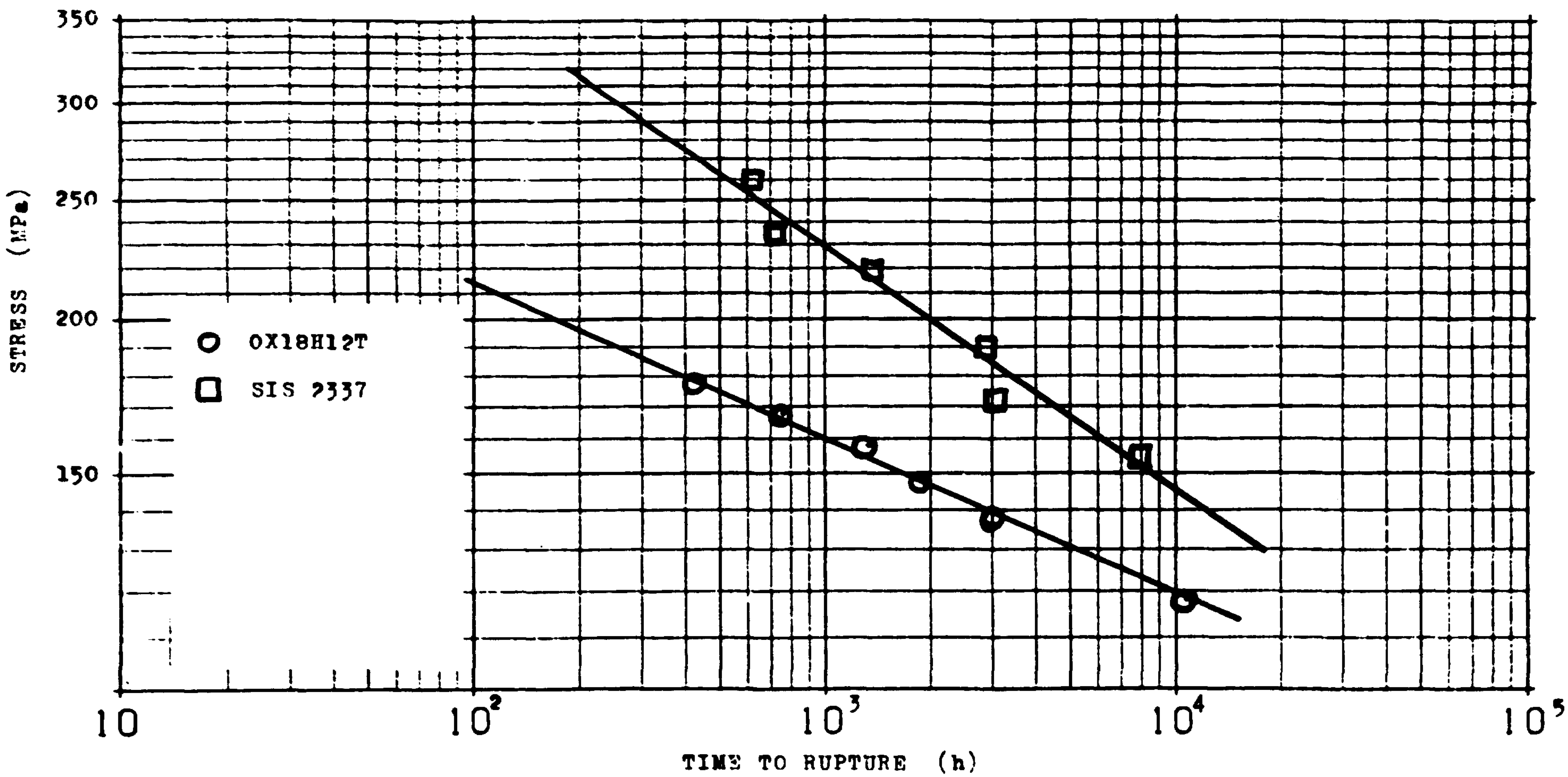

Fig 2. Results from the creep rupture testing of 18/12 Ti steels

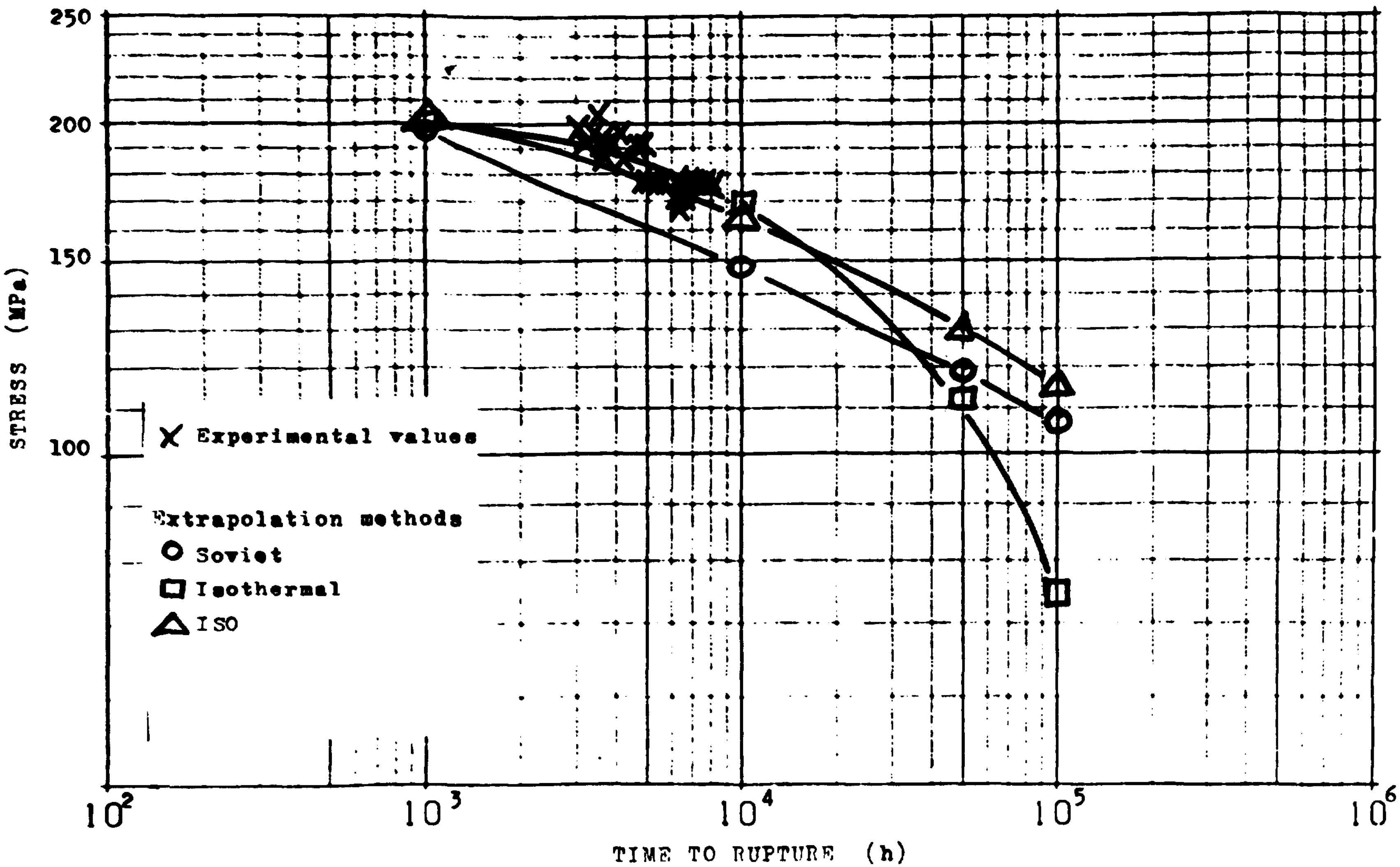

Fig 3. Extrapolation for steel ЭИ 756 at 585 °C

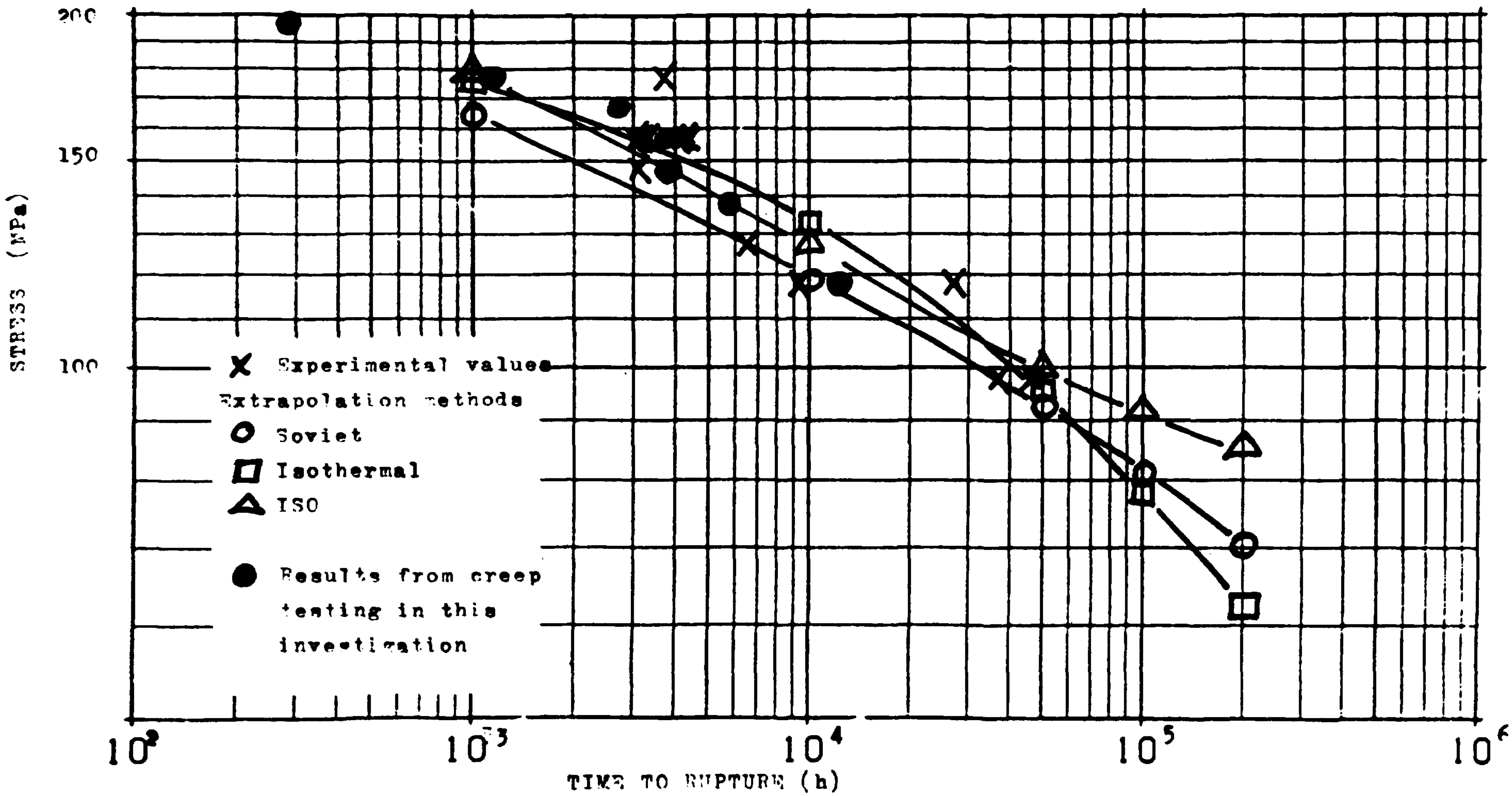

Fig 4. Extrapolation for steel ЭИ 756 at 600 °C

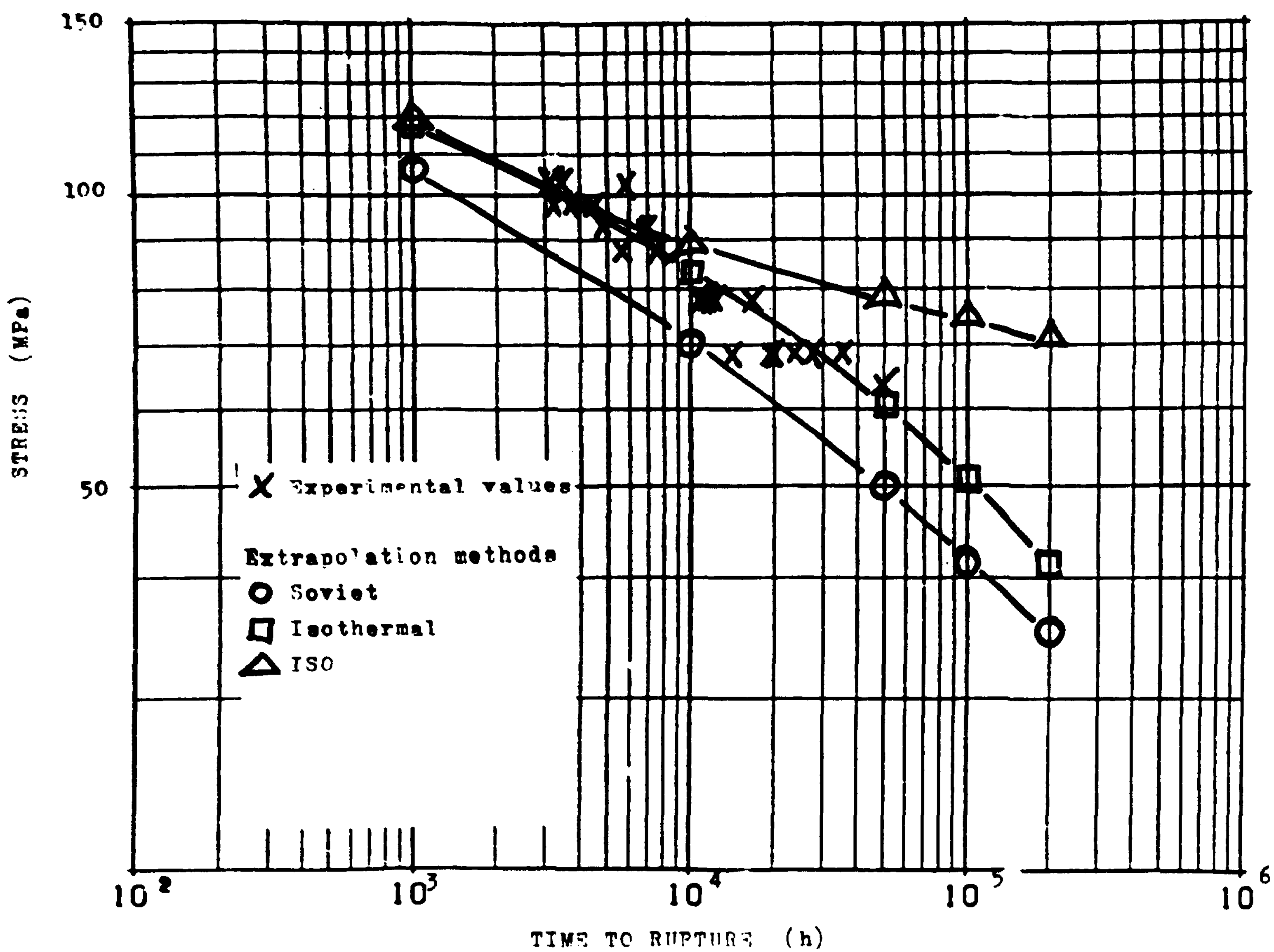

Fig 5. Extrapolation for steel ЭИ 756 at 630°C

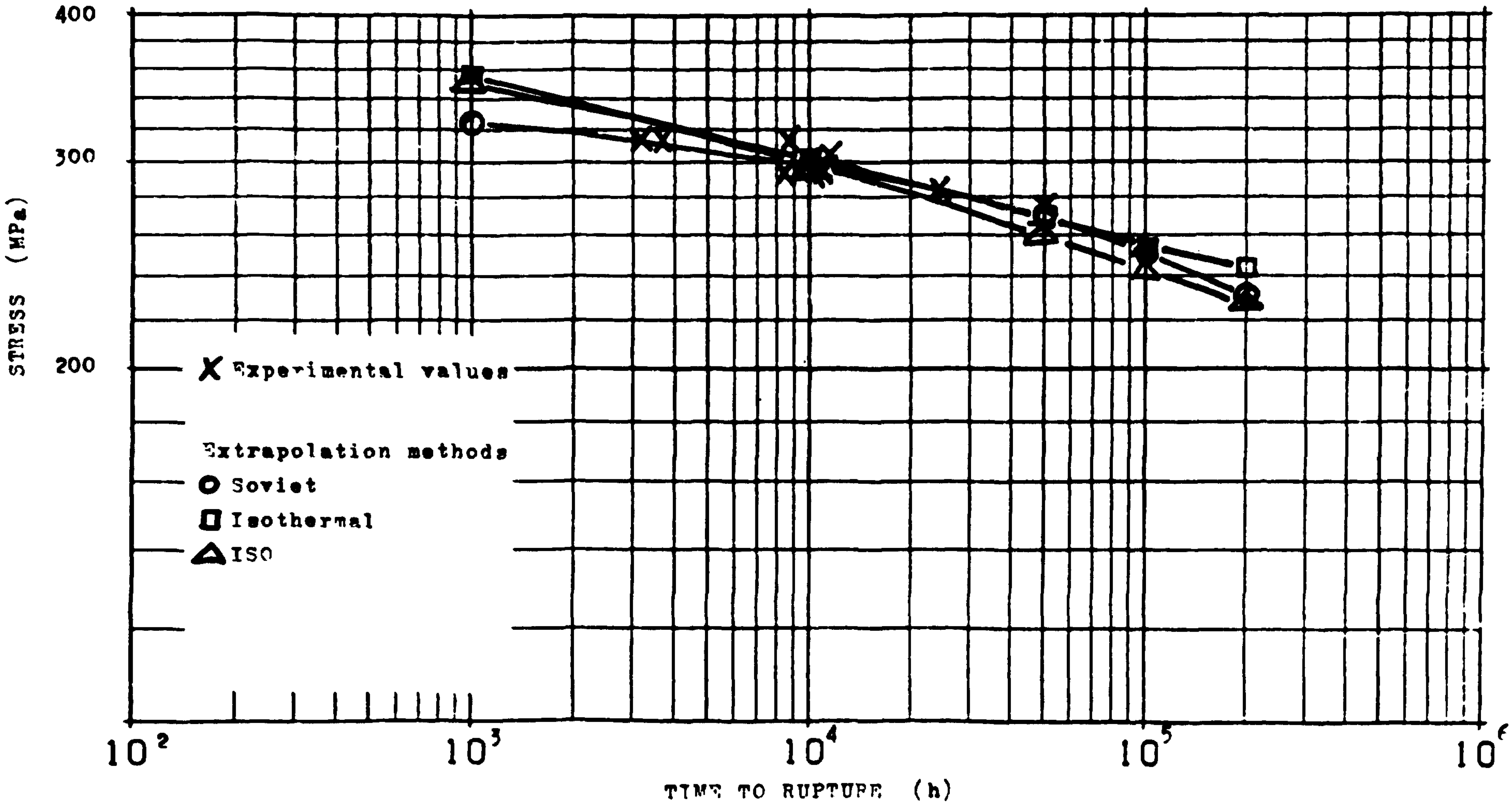

Fig 6. Extrapolation for steel HT 9 at 500 °C

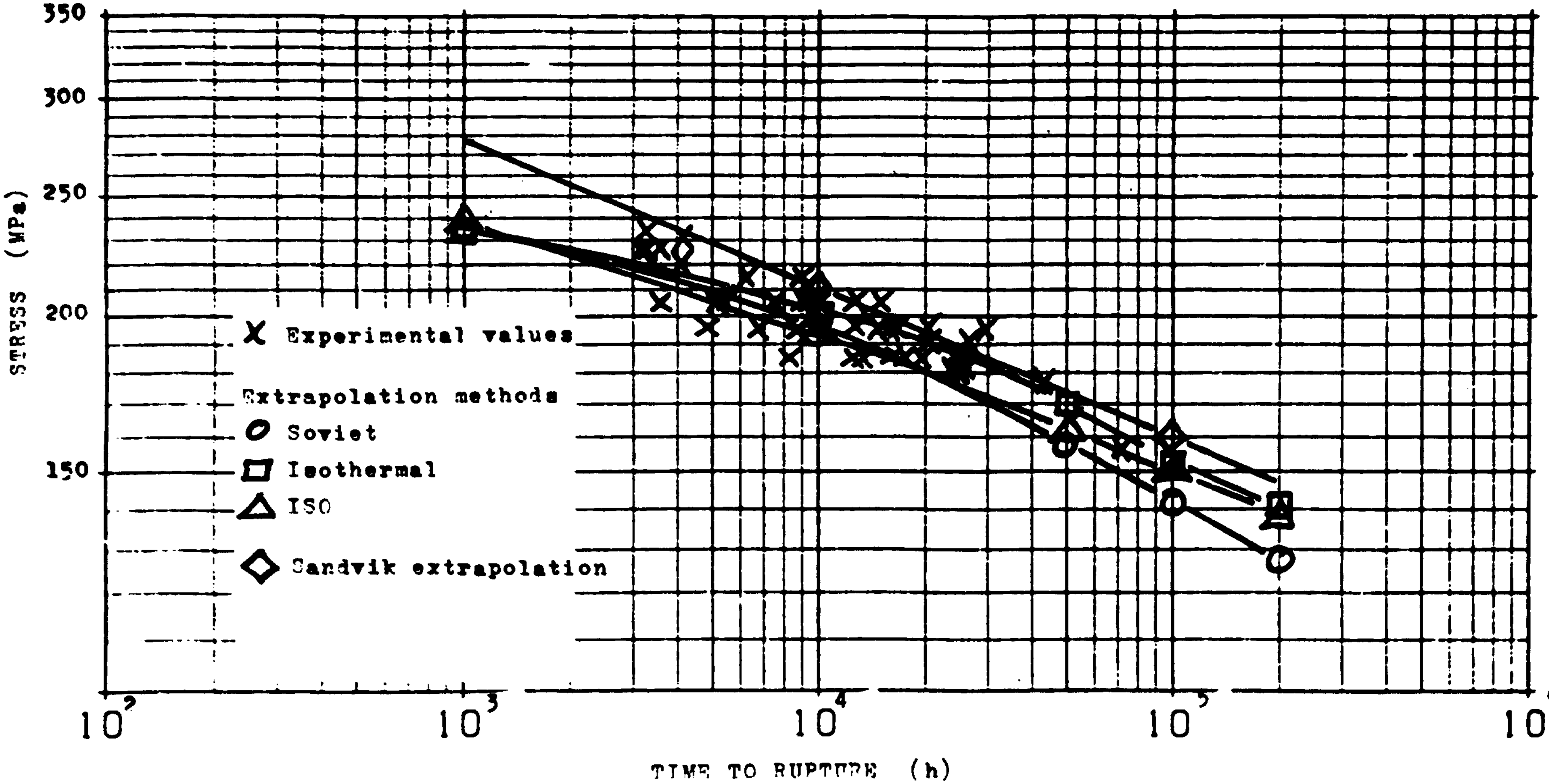

Fig 7. Extrapolation for steel HT 9 at 550 °C

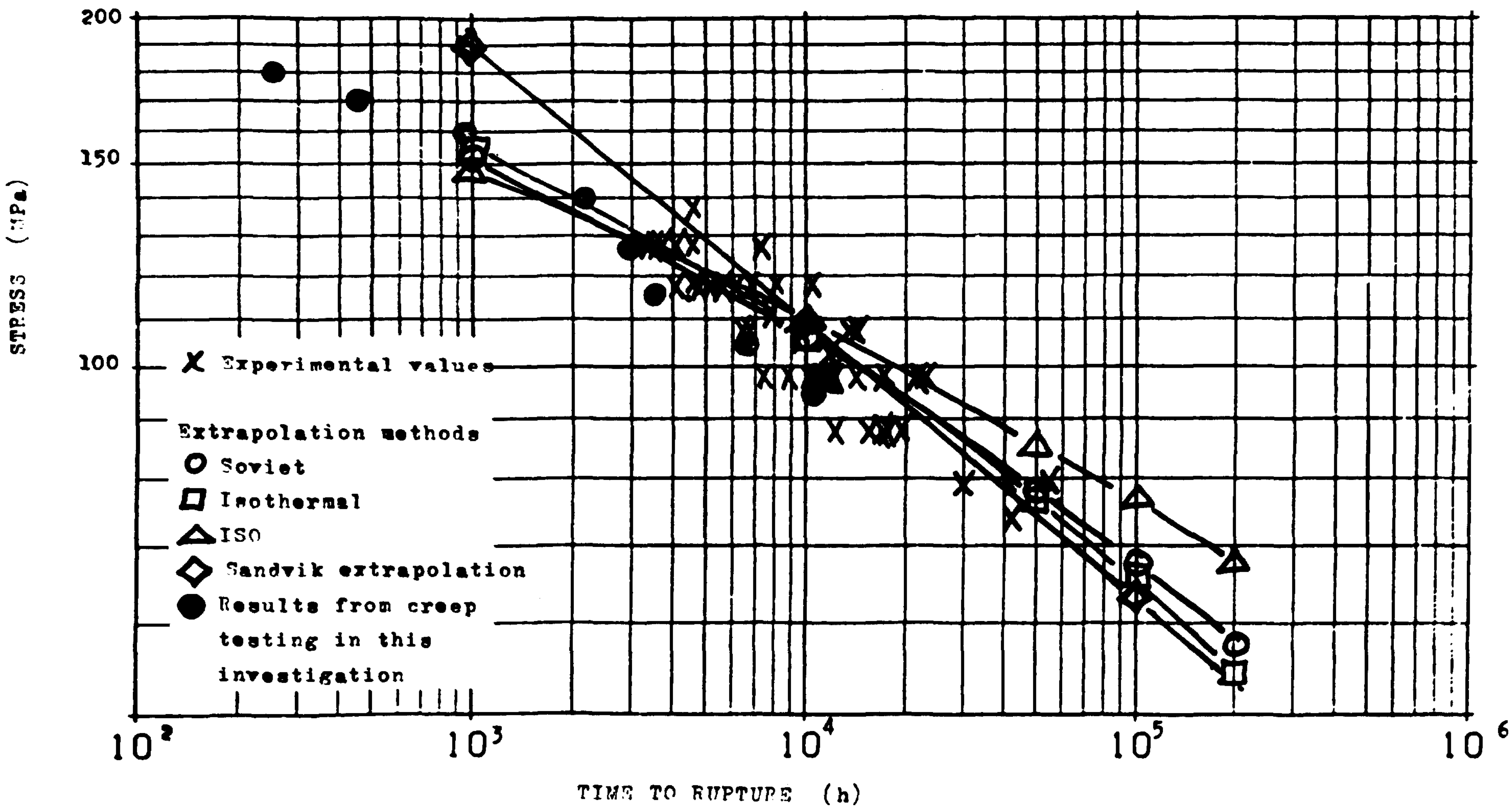

Fig 8. Extrapolation for steel HT 9 at 600 °C

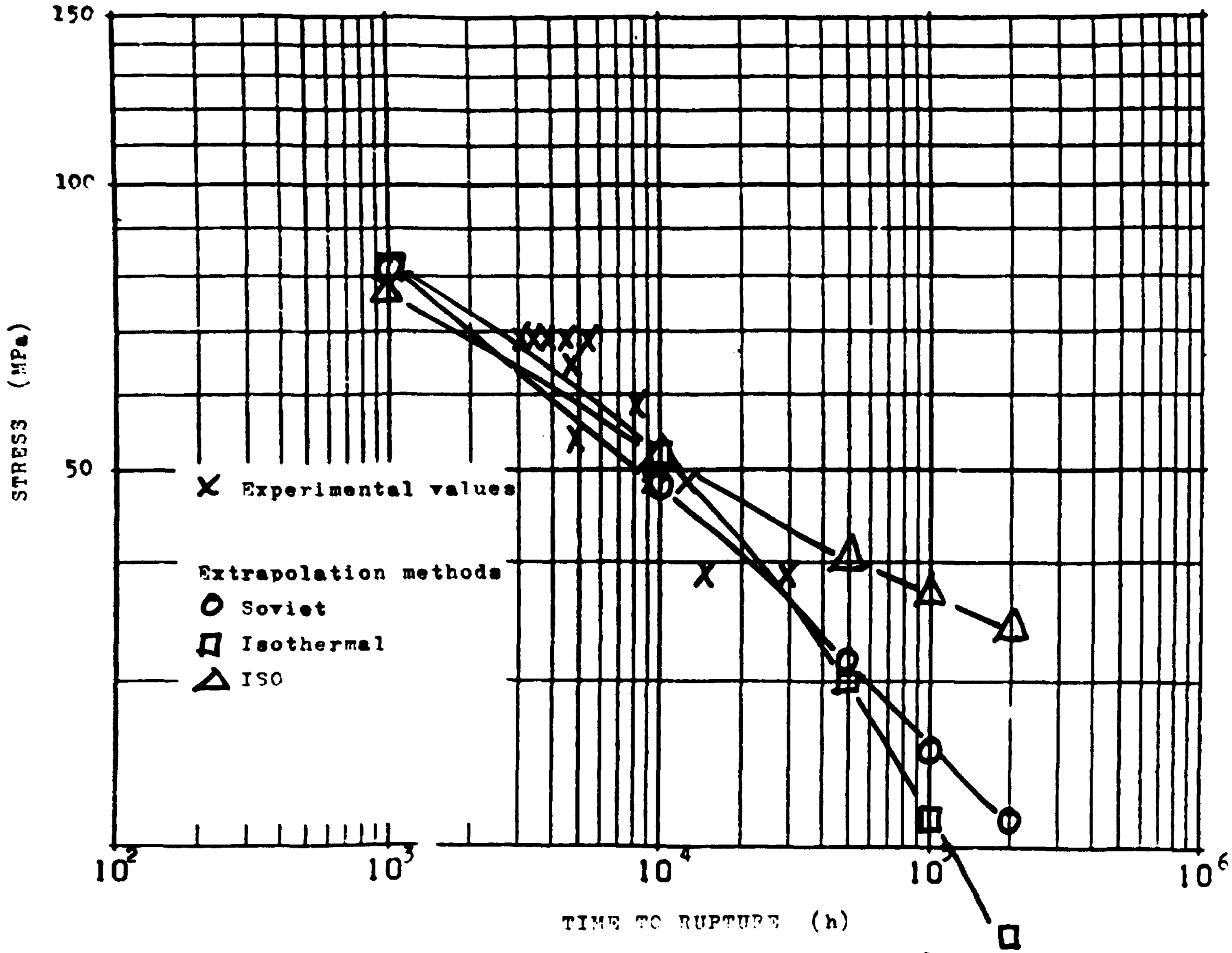

Fig 9. Extrapolation for steel HT 9 at 650 °C

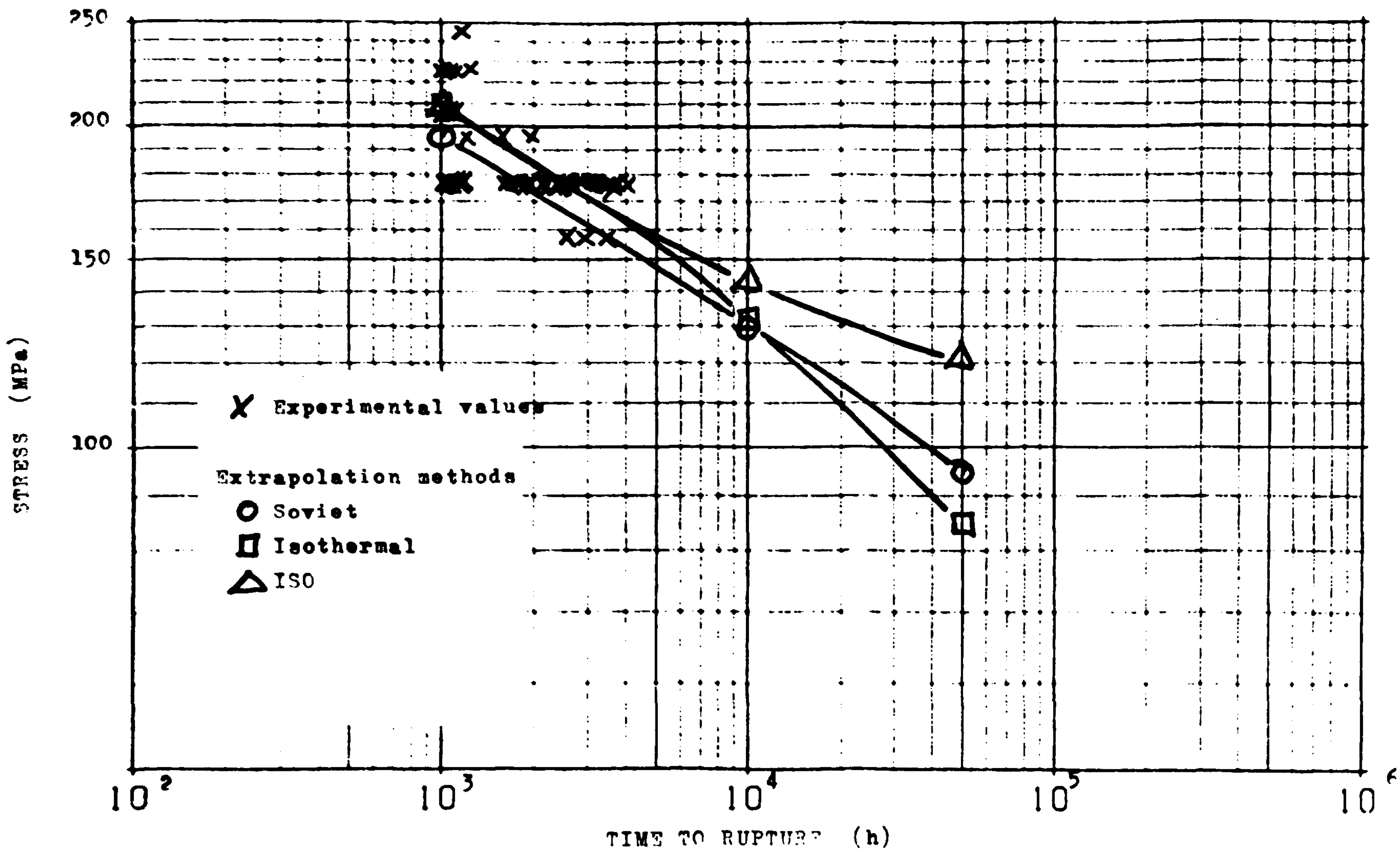

Fig 10. Extrapolation for steel 0X18H12T at 610 °C

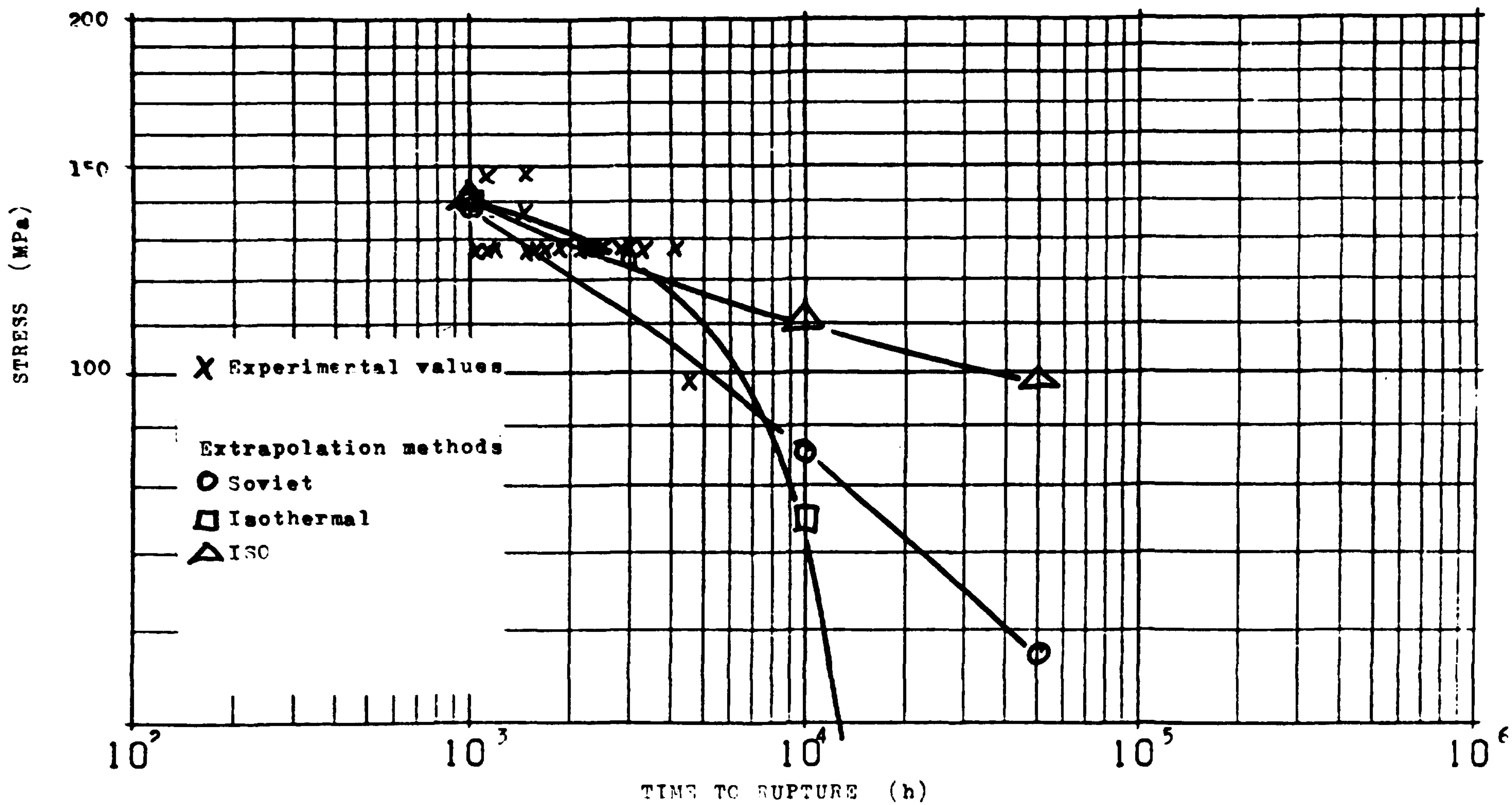

Fig 11. Extrapolation for steel OX18H12T at 660 $^{\circ}$C

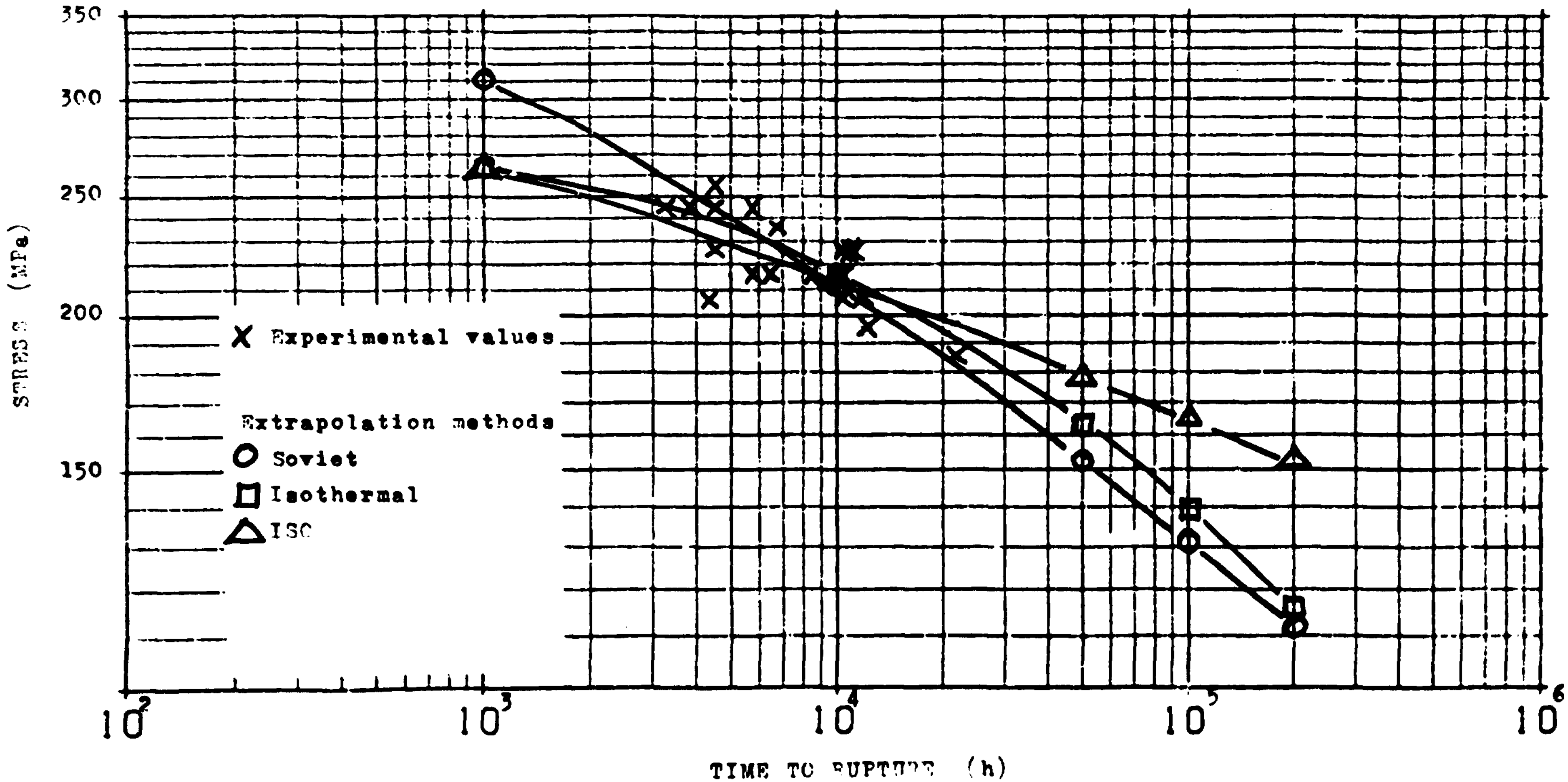

Fig 12. Extrapolation for steel SIS 2337 at 550 °C

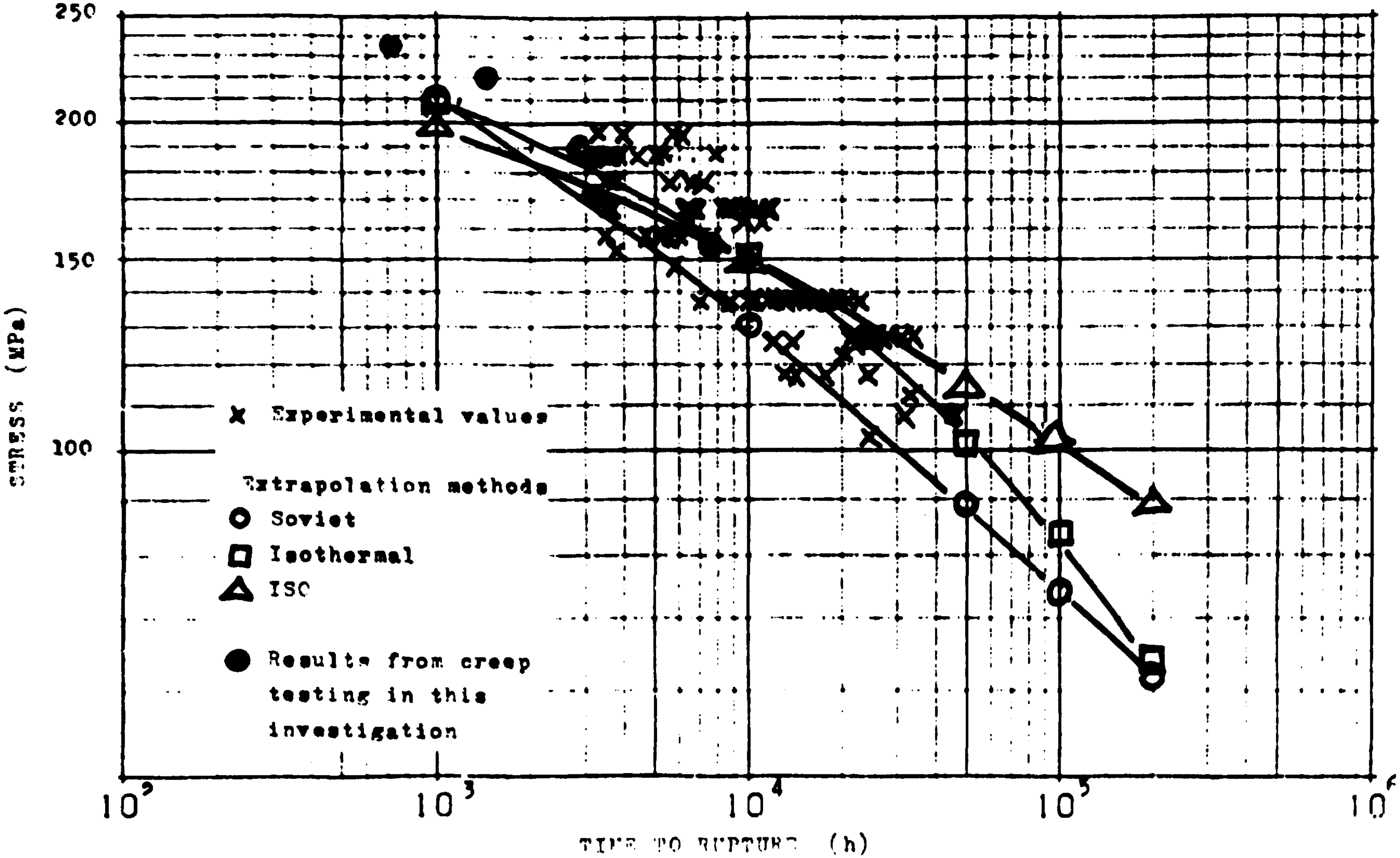

Fig 13. Extrapolation for steel SIS 2337 at 600 °C

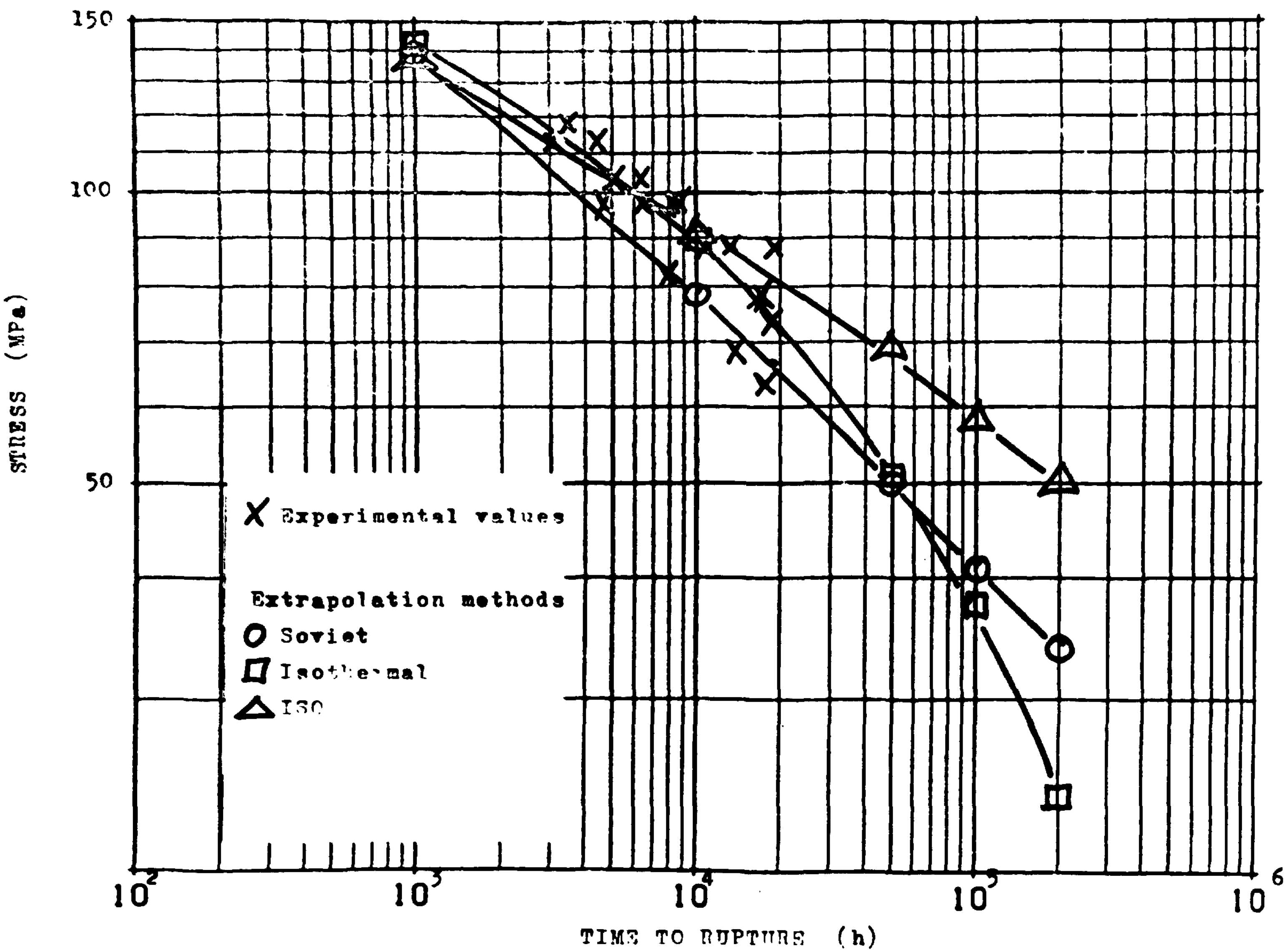

Fig 14. Extrapolation for steel SIS 2337 at 650 °C

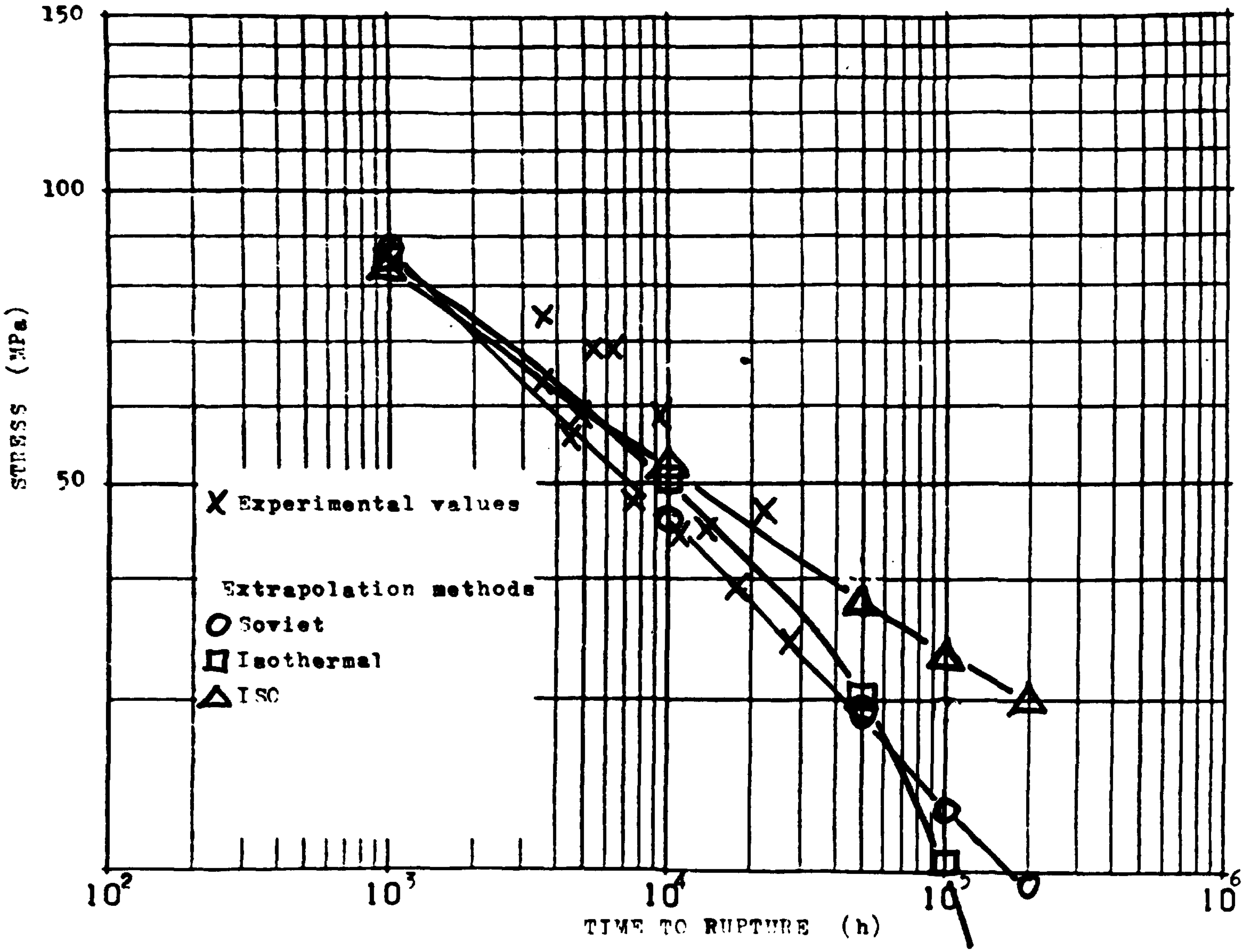

Fig 15. Extrapolation for steel SIS 2337 at 700 °C

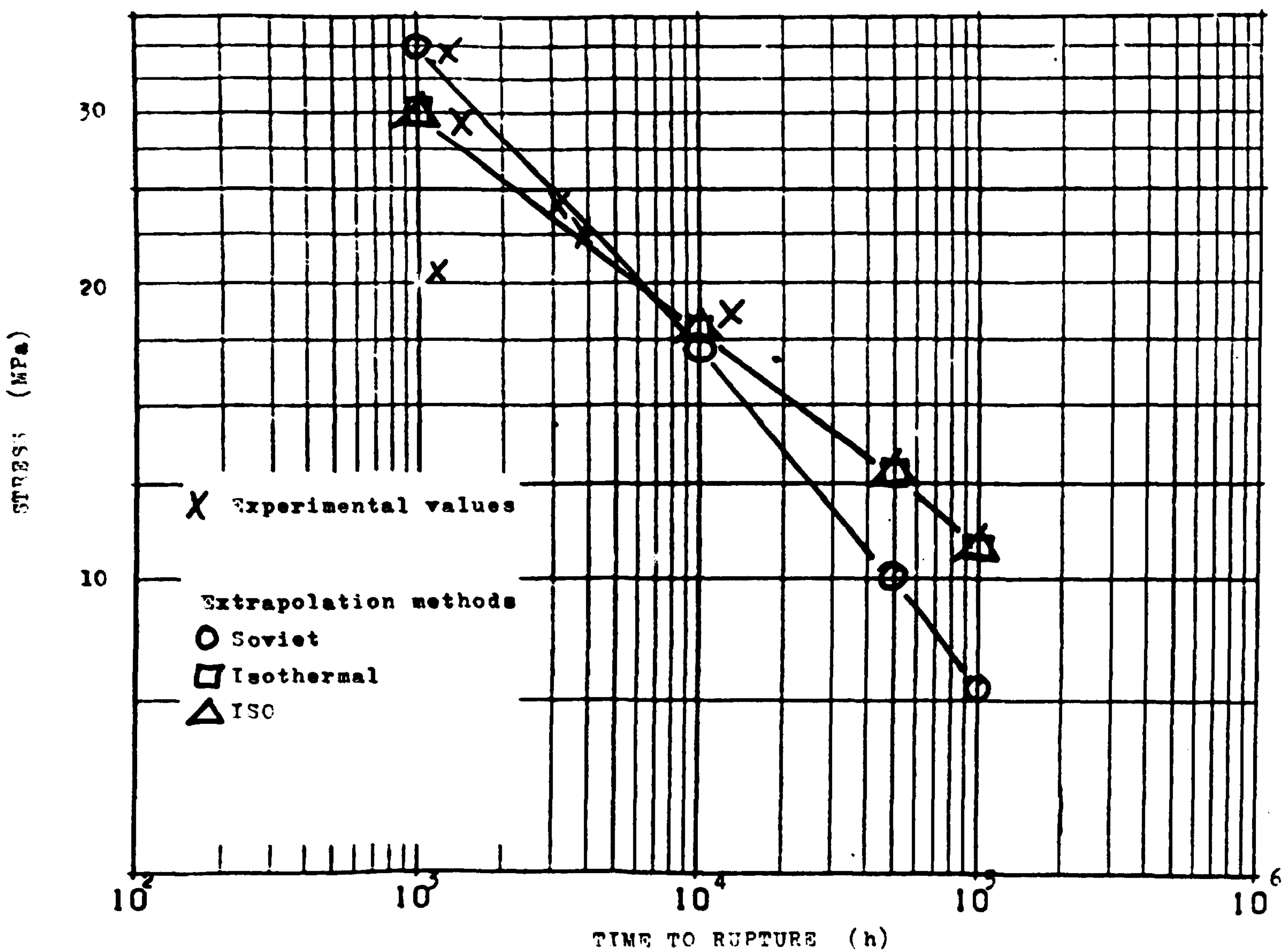

Fig 16. Extrapolation for steel SIS 2337 at 800 °C

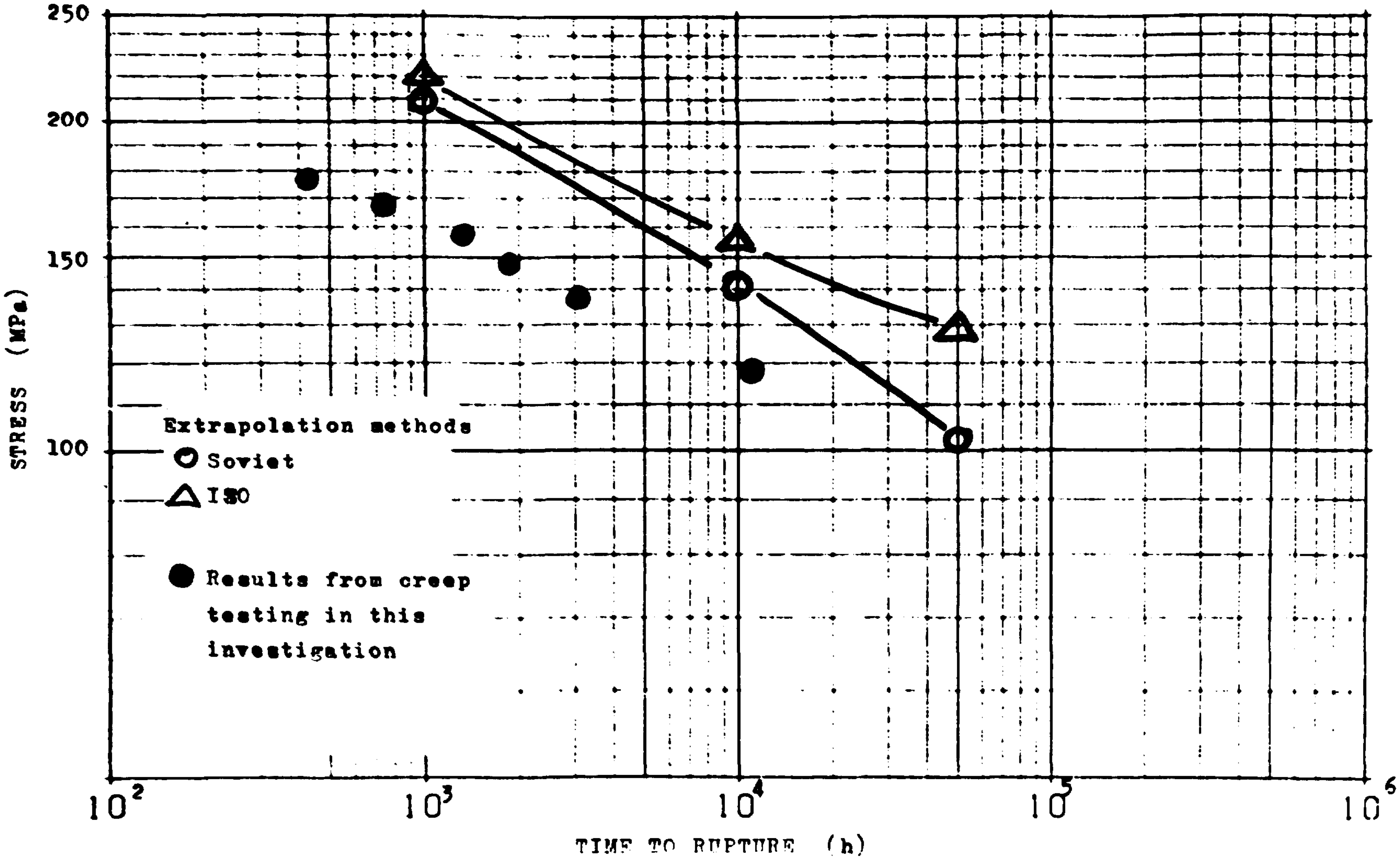

Fig 17. Extrapolation for steel OX18H12T at 600 °C

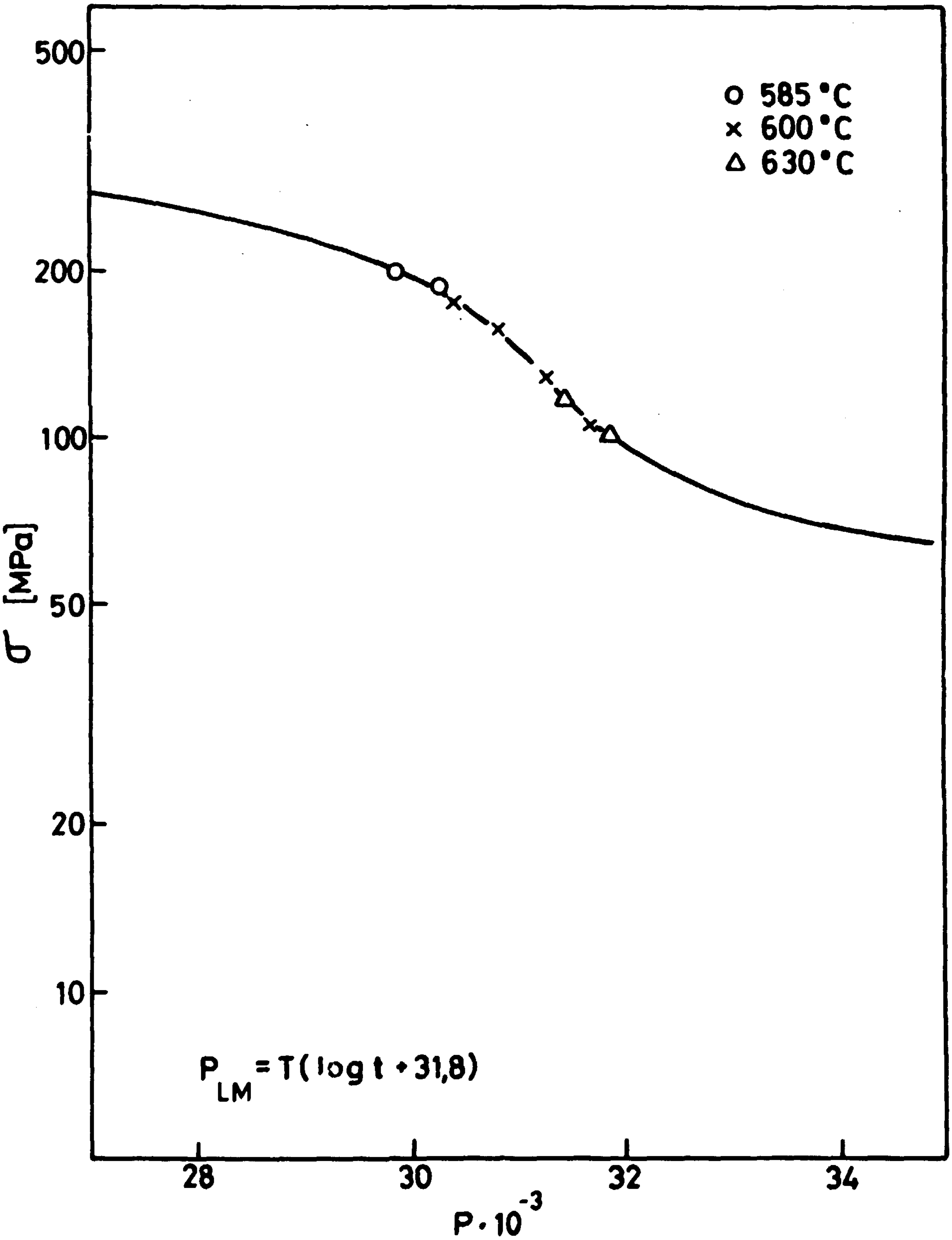

Fig 18. Master curve for steel ЭИ 756

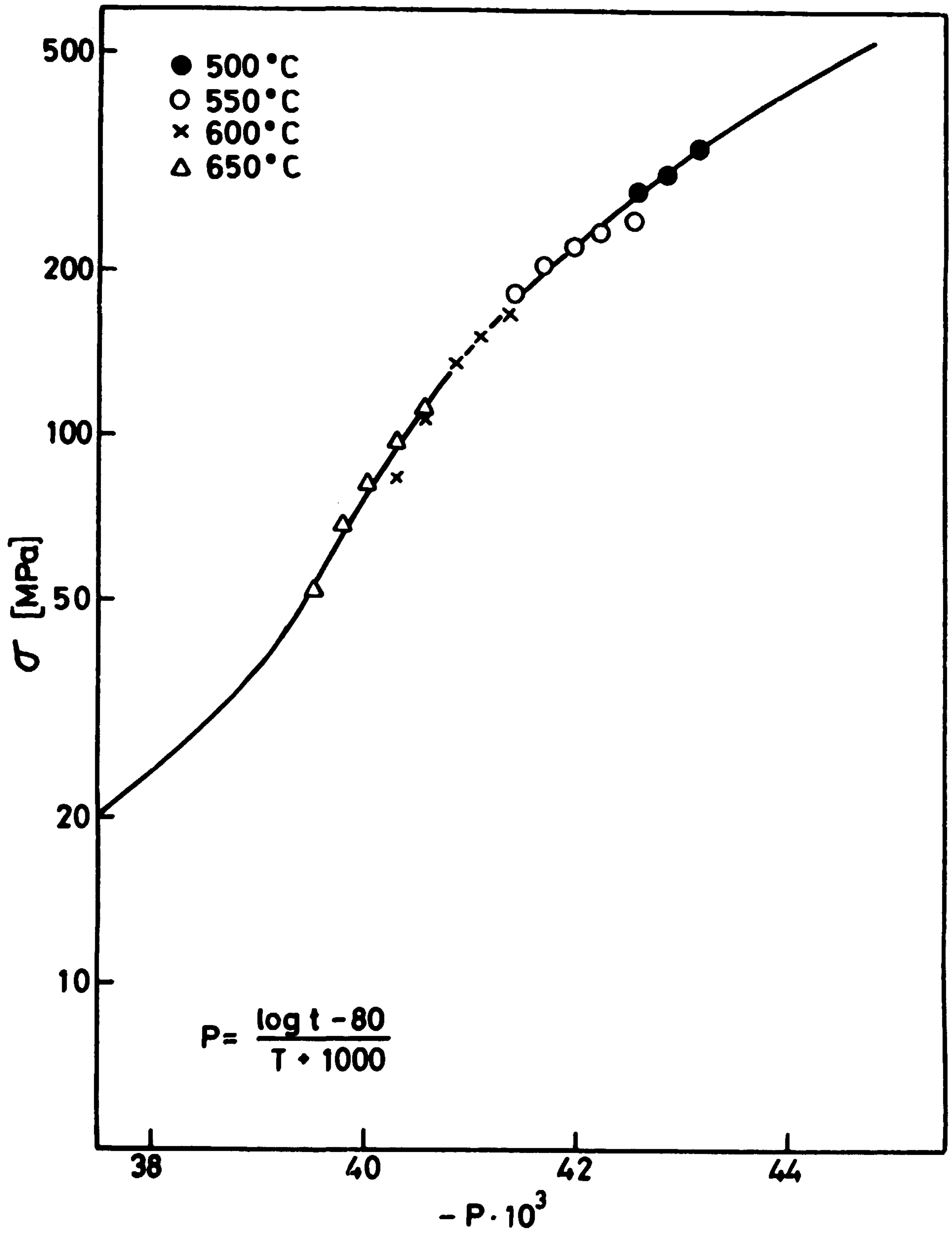

Fig 19. Master curve for steel HT 9

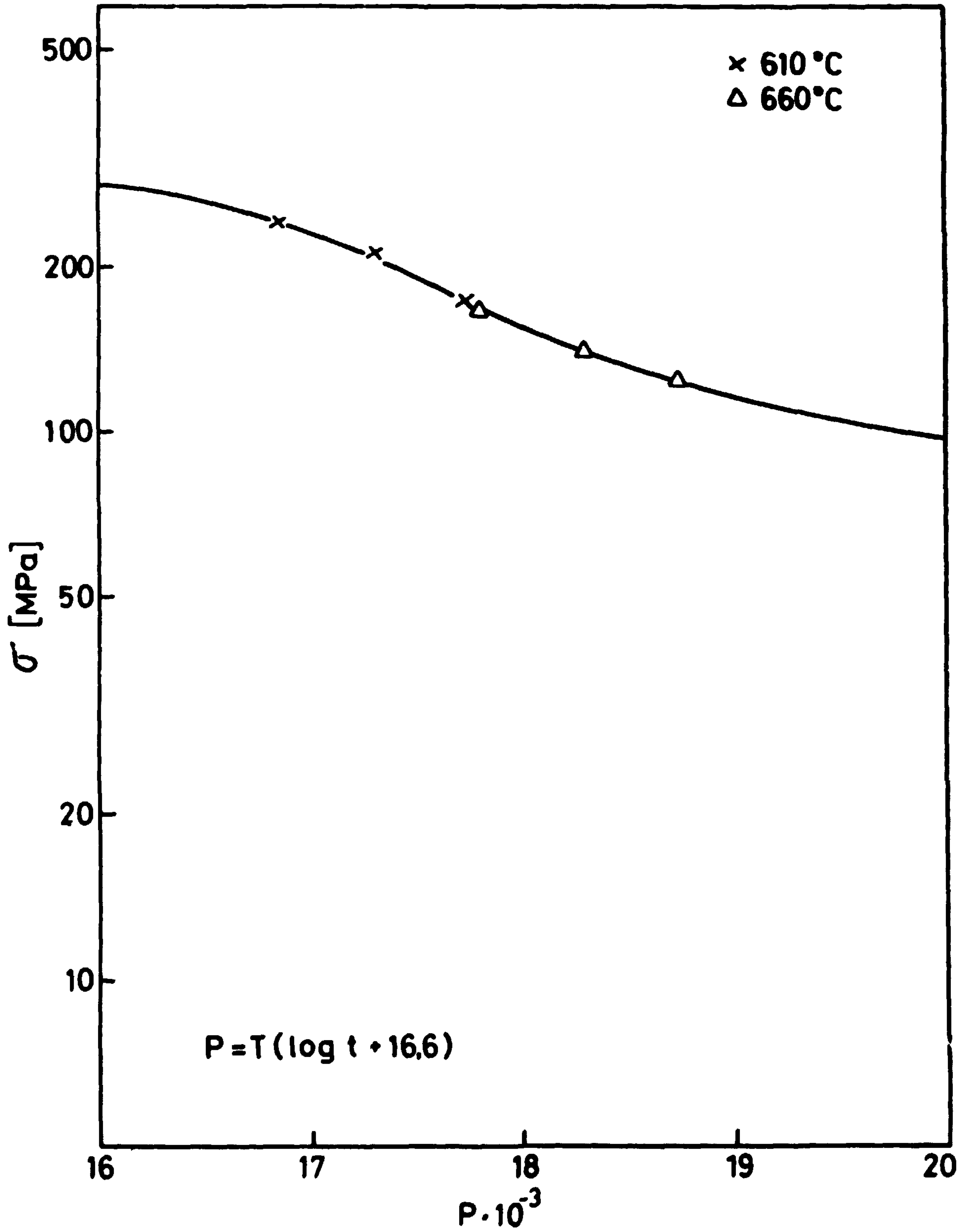

Fig 20. Master curve for steel 0X18H12T

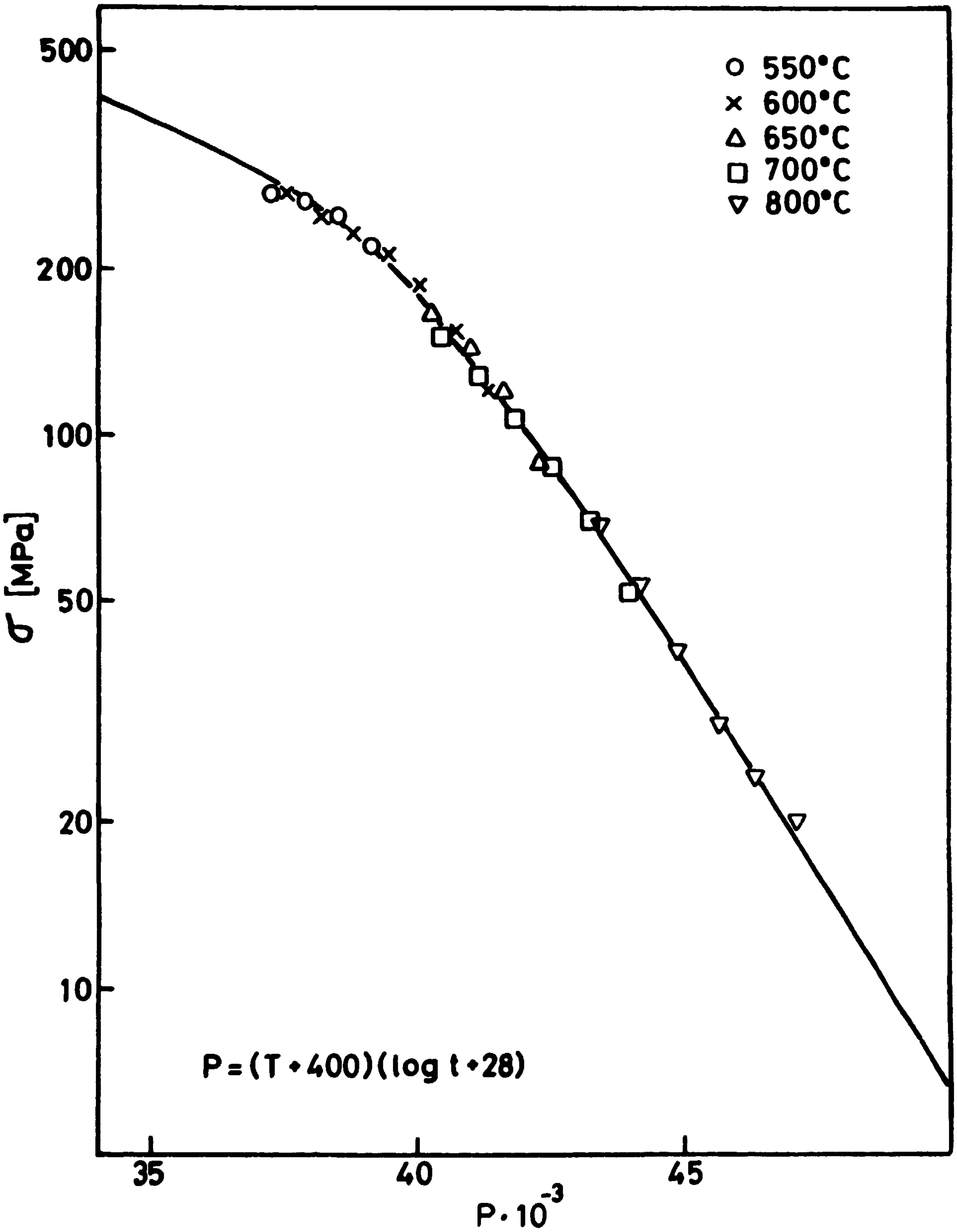

Fig 21. Master curve for steel SIS 2337

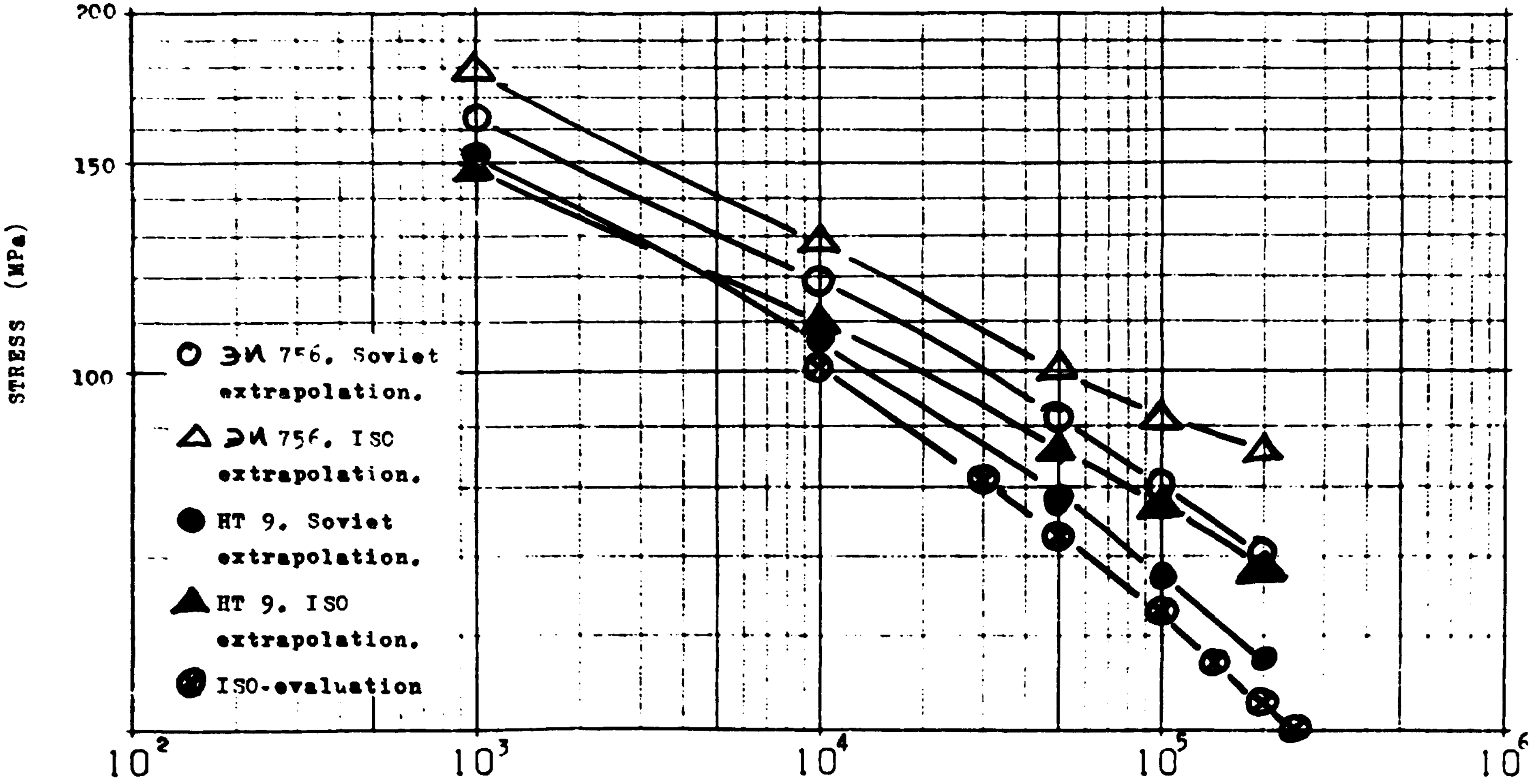

Fig 22. Extrapolated rupture stresses at 600 °C for 12 % Cr steels

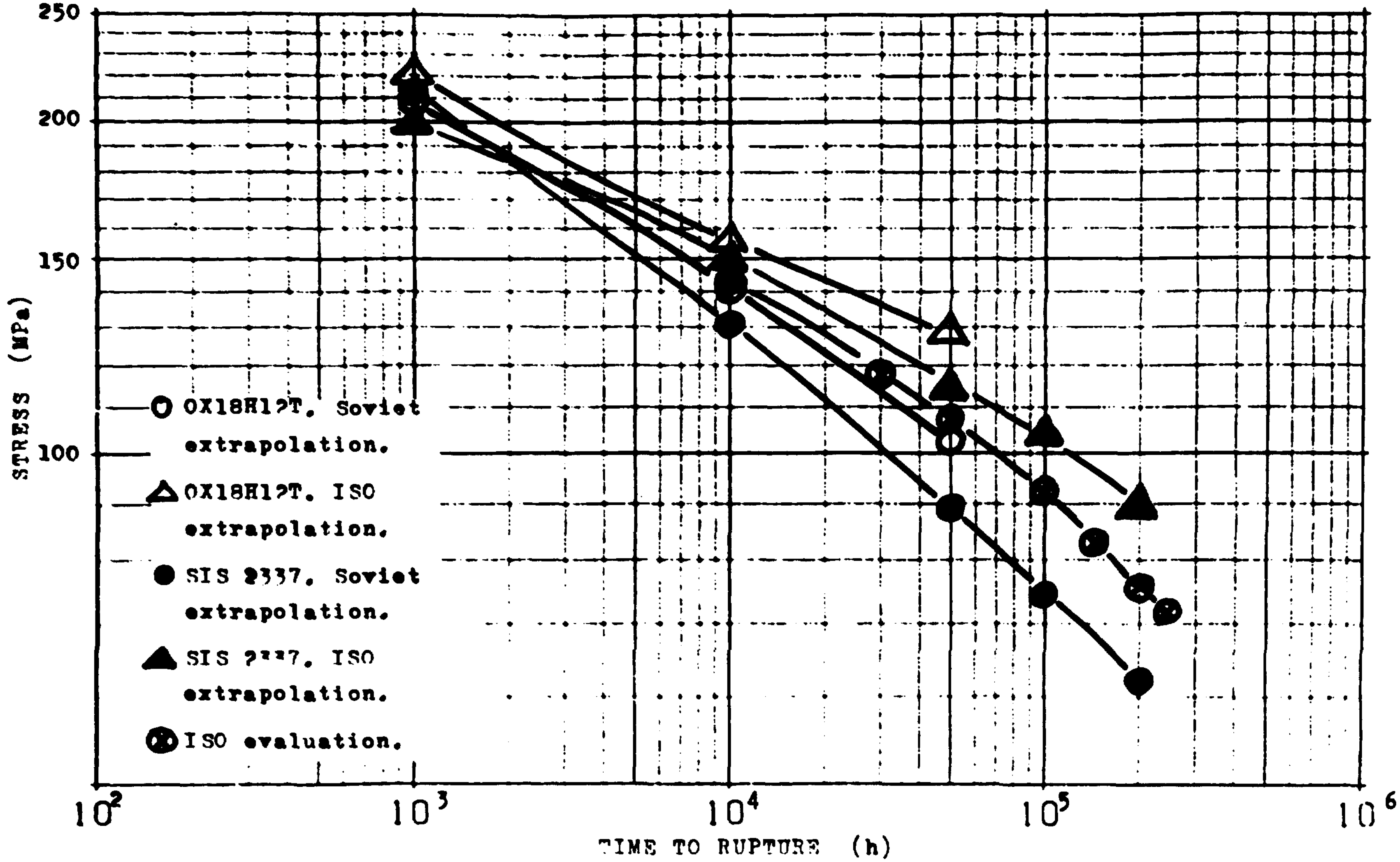

Fig 23. Extrapolated rupture stresses at 600 °C for 18/12 Ti steels

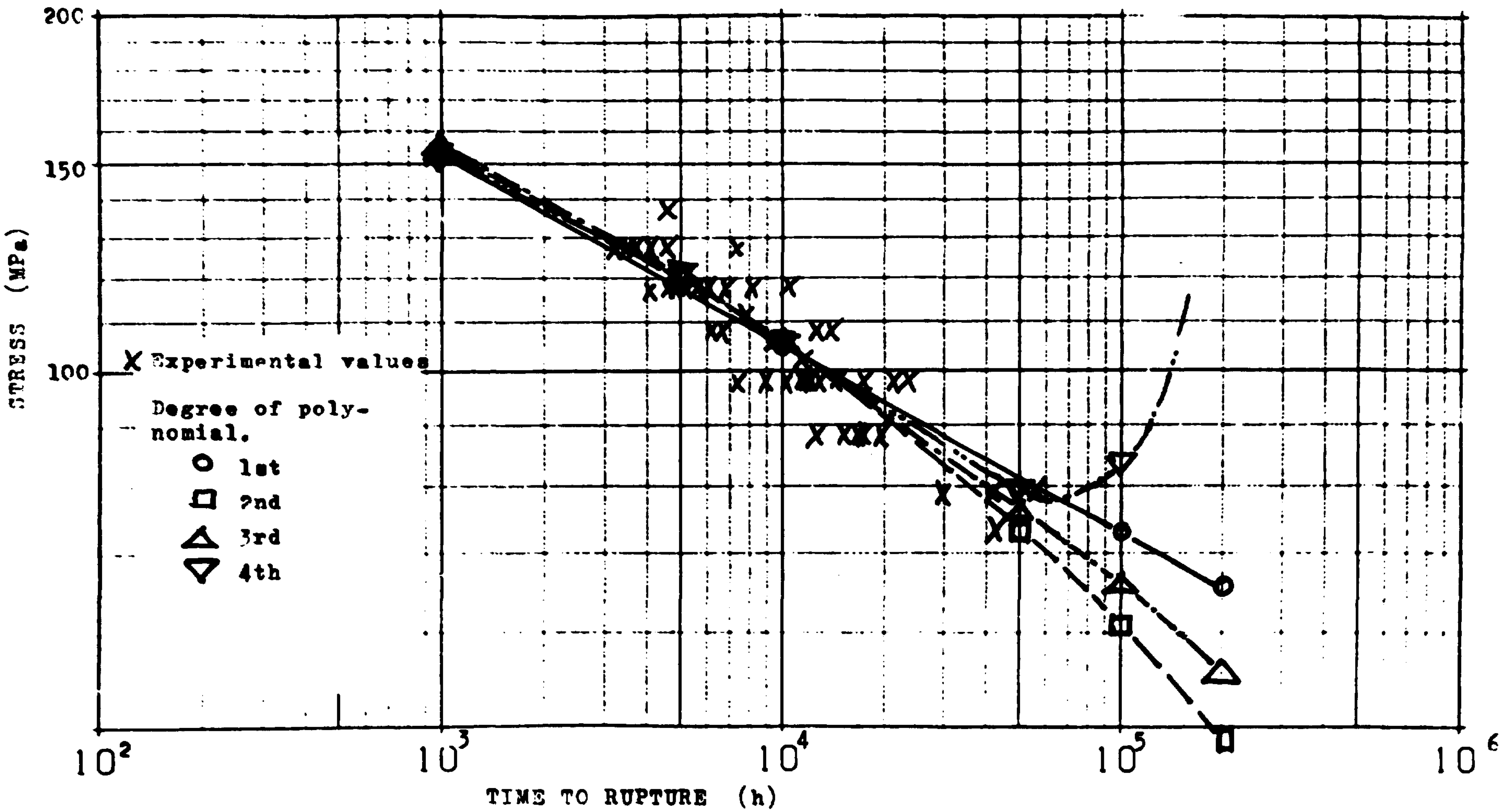

Fig 24. Isothermal extrapolation for steel HT 9 at 600 °C.

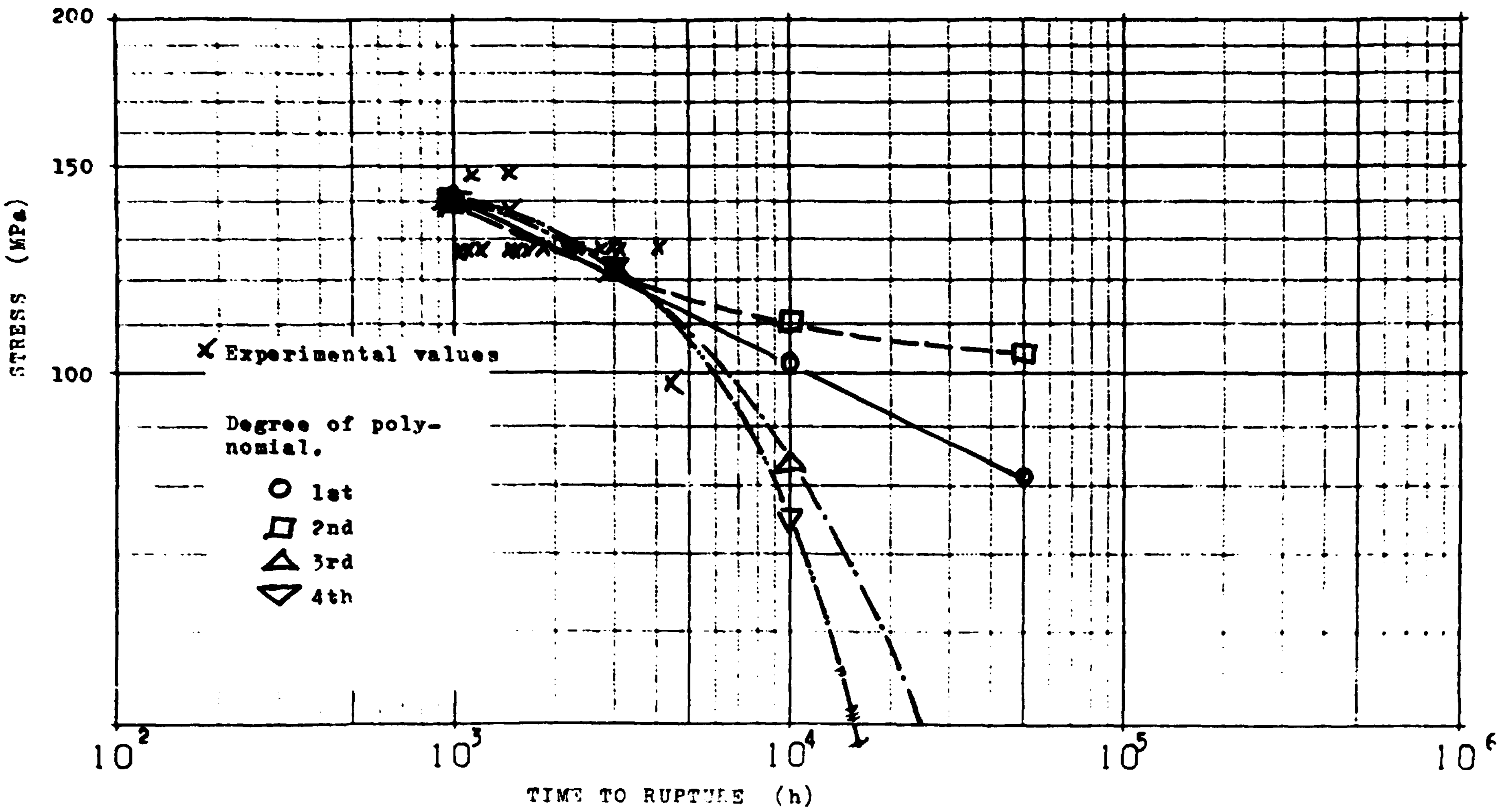

Fig 25. Isothermal extrapolation for steel 0X18H12T at 660 °C.

Comparison of extrapolation methods

for creep rupture stresses of 12Cr and 18Cr10NiTi steels

STU

Styrelsen för teknisk utveckling
Informationssektionen
Fack, 10072 STOCKHOLM
Telefon 08/744 51 00
Telex 10840 swedstus

ISSN 0347-8645
LF/ALLF 222 79 020
Offsetcenter ab, Uppsala 1979