

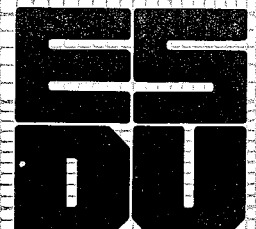
92073

92015

Issued May 1992

Guide to the effect of shot peening on fatigue strength

Endorsed by



ESDU DATA ITEM No.92015

ESDU DATA ITEMS

Data Items provide validated information in engineering design and analysis for use by, or under the supervision of, professionally qualified engineers. The data are founded on an evaluation of all the relevant information, both published and unpublished, and are invariably supported by original work of ESDU staff engineers or consultants. The whole process is subject to independent review for which crucial support is provided by industrial companies, government research laboratories, universities and others from around the world through the participation of some of their leading experts on ESDU Technical Committees. This process ensures that the results of much valuable work (theoretical, experimental and operational), which may not be widely available or in a readily usable form, can be communicated concisely and accurately to the engineering community.

THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item was monitored and guided by the Fatigue Committee, which first met in 1955 and now has the following membership:

Chairman	
Dr R.N.Wilson	— Royal Aerospace Establishment, Farnborough
Members	
Mr D.Brazington	— Dowty Aerospace, Gloucester, Ltd
Mr K.E.Cheverton	— Independent
Mr D.Crouch	— British Aerospace Dynamics
Dr M.S.G.Cullimore	— Independent
Dr P.R.Edwards	— P.P.Data Ltd
Dr J.M.Finney*	— Aeronautical Research Laboratories, Melbourne, Australia
Mr A.Humble	— British Aerospace (Military Aircraft) Ltd
Dr M.Miller*	— Boeing Commercial Airplane Co, Seattle, USA
Mr D.Painter	— Westland Helicopters Ltd
Mr A.R.Simpson	— British Aerospace (Commercial Aircraft) Ltd
Mr T.Swift*	— Federal Aviation Administration, USA
Dr R.J.Wanhill*	— National Aerospace Laboratory, NLR, The Netherlands.

The work on this Item was carried out in the Strength Analysis Group of the Engineering Sciences Data Unit under the supervision of Mr M.E.Grayley, Group Head. The member of staff who undertook the technical work involved in the initial assessment of the available information and the construction and subsequent development of the Item was

Mr C.O'Neill — Engineer.

(Continued on inside back cover)



GUIDE TO THE EFFECT OF SHOT PEENING ON FATIGUE STRENGTH

CONTENTS		Page
1.	INTRODUCTION	1
2.	THE SHOT PEENING PROCESS	1
	2.1 Types of Shot	1
	2.2 Control of Shot Peening Intensity	2
3.	EFFECTS OF SHOT PEENING	2
	3.1 Plastic Deformation of the Surface	2
	3.2 Residual Stresses due to Shot Peening	3
	3.3 The Effects of Shot Peening on Surface Finish	4
4.	NOTES ON DESIGNING FOR SHOT PEENING	4
5.	NOTES ON FIGURES	5
6.	DERIVATION AND REFERENCES	6
	6.1 Derivation	6
	6.2 References	7
	TABLES AND FIGURES	8 to 41

GUIDE TO THE EFFECT OF SHOT PEENING ON FATIGUE STRENGTH

1. INTRODUCTION

Shot peening is widely used in both mechanical and aeronautical engineering. It is primarily used to give improvements in fatigue strength but is also used to improve surface conditions and as a forming method. Components such as welded joints, torsion shafts, propeller blades and wing skins are often shot peened.

This Data Item presents fatigue strength data which demonstrate the effects of shot peening on a range of materials. The data are taken from constant amplitude tests and the specimen types are shown on the figures. Other details are provided in the accompanying tables. It should be noted that no data from variable amplitude tests are presented.

2. THE SHOT PEENING PROCESS

The shot peening process is a cold working process and consists of propelling small particles (shot) at high speed against the surface to be treated. The impacts of the shot cause local deformation beyond the elastic limit. The deformed surface layer of material is constrained by the bulk material. This results in compressive stresses at the surface balanced by tensile stresses below. The compressive residual stresses act in a small volume of material near the surface and tend to be large, typically in the region of 80 per cent of the tensile strength of the material. The depth of the compressive layer is typically in the region of 0.5 - 1.0 mm (0.02 - 0.04 in). The tensile stresses act over a large volume in the bulk of the material and consequently are normally negligible in magnitude in comparison with the compressive stresses. The residual compressive stresses are largely responsible for improvements in fatigue strength. They retard crack growth in the material near the surface where the majority of fatigue failures originate. Shot peening of components can result in substantial increases in fatigue life and can also increase resistance to mechanical or chemical damage, such as fretting and stress corrosion cracking.

There are many parameters to be controlled in shot peening. The major parameters are:

- the type of shot (material, shape and dimensions),
- the shot velocity,
- the exposure time of the component to the shot peening and
- the degree of coverage of specific areas of the component.

2.1 Types of Shot

Cast steel shot is widely used. It is particularly useful when high shot peening intensities are required. However, some component materials may require further treatment to remove any embedded steel. Cast iron shot is now rarely used owing to its tendency to shatter which makes it uneconomical in many situations. Shot manufactured from other metallic materials such as aluminium is also used. Shot manufactured from wire stock is commonly used and maintains its physical properties well during shot peening. Glass shot and refractory electro-cast balls tend to be used for operations on particularly thin or delicate components because of their lower density. Refractory electro-cast balls are a more recent development and have the advantage of lasting longer than glass shot.

It is normal practice to recycle shot to reduce costs. It is vital that if the shot is recycled during shot peening it is filtered so as to remove broken shot and associated debris. If this filtering is not undertaken it is possible to damage the surface being treated and significantly reduce the fatigue strength.

2.2 Control of Shot Peening Intensity

The effects of shot peening result from the transfer of kinetic energy from the particles to the surface. The intensity of the shot peening is a measure of the transferred kinetic energy. The intensity of shot peening is usually controlled and measured using the Almen test (following, for example, the US military standard MIL S-13165 B) where a standardised metal strip (Almen strip) is fastened to a metal block and the strip shot peened. On removal from the block the strip will be arched towards the shot peened side. The arc height is related to the intensity of shot peening and is measured using an Almen gauge.

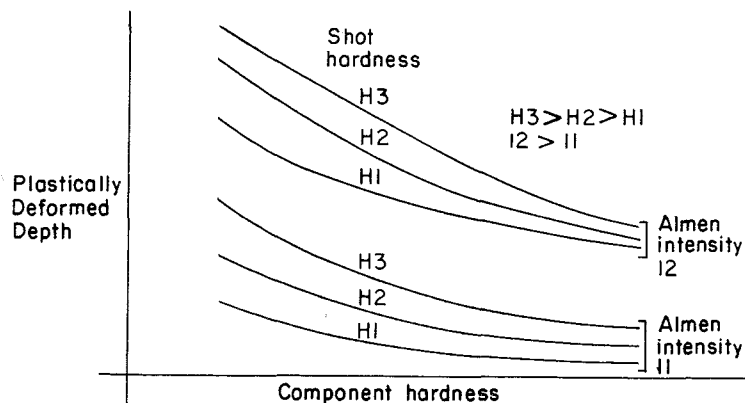
There are several types of Almen strip having different dimensions which cater for different intensity ranges. The most common are the 'A' strip, the 'C' strip and the 'N' strip. These are shot peened to a condition defined as saturation when doubling the exposure time of the strip to the shot peening will produce less than a 10 per cent increase in arc height. The Almen intensity is not a direct measure of intensity but is a measure of deformation which varies with the intensity of the shot peening. The usual approach is to quote the arc height in either millimetres or hundredths of millimetres (inches where lbf in units are used) followed by a letter (and number if necessary) designating the type of Almen strip. Some sources do not quote the actual arc height but instead quote a multiple of the arc height. All Almen intensities quoted in this Item appear as they are quoted in the relevant derivations. It should be noted that it is possible to obtain different depths of plastically deformed material and residual stress distributions in components which have been shot peened to the same Almen intensity. Therefore, the Almen number is not of itself necessarily indicative of fatigue benefits.

3. EFFECTS OF SHOT PEENING

3.1 Plastic Deformation of the Surface

Shot peening causes plastic deformation in the surfaces of treated components and in many cases will increase the surface roughness. The depth of plastically deformed material, the residual compressive stresses and the surface roughness must be properly controlled to obtain worthwhile improvement in fatigue strength from shot peening. It is difficult to alter one of these without affecting the others because they are all interrelated.

The depth of the plastically deformed material is largely determined by the hardness of the component material, the shot hardness and the Almen intensity (see Sketch 3.1.1). For a given shot type and velocity, the depth of plastically deformed material is less for harder component materials. The depth of plastically deformed material in harder components is less sensitive to changes in the shot peening parameters.



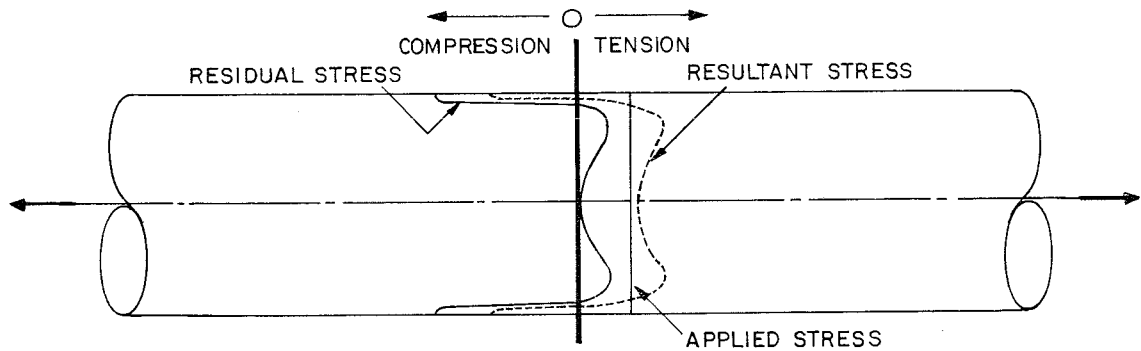
SKETCH 3.1.1 Effect of component hardness on plastically deformed depth for different values of shot hardness and different Almen intensities (Derivation 11)

Harder shot tends to increase the depth of material deformed plastically but differences due to shot hardness can be reduced by increasing the Almen intensity (for example, by increasing shot velocity). Increasing the shot diameter also increases the depth of plastically deformed material, but increasing the diameter beyond a certain point will result in a negligible increase in the depth of this layer. Increasing the Almen intensity also results in an increase in the depth of plastically deformed material.

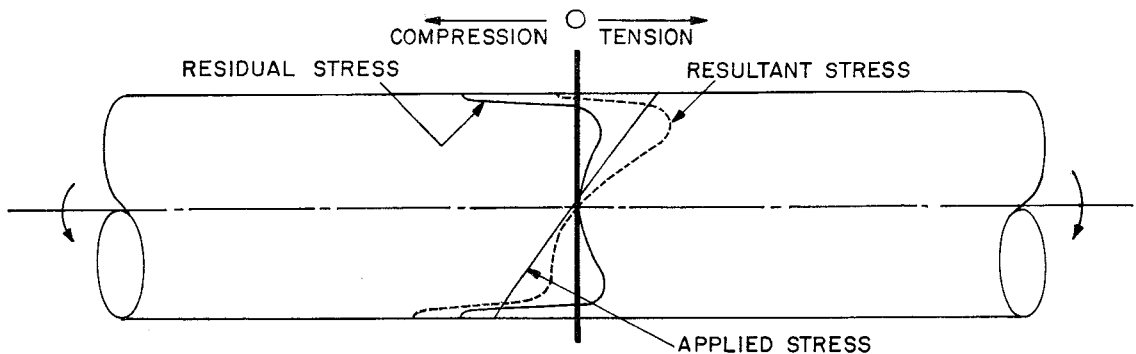
3.2. Residual Stresses due to Shot Peening

The magnitude and depth of the residual compressive stresses caused by shot peening are the most important factors in increasing the fatigue strength of a component. Sketch 3.2 shows how in principle these residual stresses reduce the tensile stresses at the surface of a component subject to axial loading or bending. It is important that the established compressive stresses are relatively stable during the working life of the component if shot peening is to produce maximum improvements in the fatigue strength. The service loading of a component can diminish or completely remove the residual compressive stresses thus reducing any fatigue strength benefits. This is particularly likely to happen if the component is subjected to large compressive loads. Heat treatment after shot peening can also cause stress relaxation which will reduce the benefits obtained from the shot peening process. To obtain optimum fatigue life it is usually better to carry out any heat treatments prior to shot peening (see Derivation 8).

There is no simple relationship between Almen intensity and maximum compressive stress. However, larger shot (which produces higher Almen intensities) tends to produce greater compressive stresses in hard materials.



(a) Applied tensile load



(b) Applied bending moment

Sketch 3.2 Interaction of residual and applied stresses

3.3. The Effects of Shot Peening on Surface Finish

Shot peening will usually increase the surface roughness of a treated component. This increase in surface roughness can aid the initiation of fatigue cracks. For a given component material and shot type, increasing the Almen Intensity will increase the surface roughness. When high projectile speeds are used small changes in the speed may produce larger changes in the surface roughness than would be produced by similar changes at lower speeds. In some situations the surface roughness may be unacceptable and the component may have to be treated again by polishing or by shot peening at a significantly lower intensity.

Shot size is a particularly important parameter in terms of achieving a good surface finish. The size of shot which will give the optimum surface finish, for a given set of conditions, will vary with the hardness of the treated material. Using a shot size significantly larger or smaller than the optimum can result in considerably poorer surface finish and consequently poorer fatigue performance, particularly in soft materials.

4. NOTES ON DESIGNING FOR SHOT PEENING

Shot peening can produce large increases in fatigue strength and increased resistance to stress corrosion cracking and other forms of chemical/mechanical attack. If in the production of a component the effects of a shot peening operation are quantifiable and reproducible, the designer may be able to increase allowable loads and/or reduce weight by reducing critical dimensions, regulations permitting. This is the situation for some components such as springs in the automotive industry. However, in the design of many components, data are unavailable and without substantial testing programmes it would not be advisable to rely on the benefits of the shot peening.

To obtain the above benefits from a shot peening operation it is necessary that it establishes stable compressive surface stresses. To establish such stresses in a component, the component must have a sufficient local elastic mass, that is, the volume of material in the region of interest must be much greater than the volume of material which will be subject to compressive stresses.

Selective shot peening of only a particular area of a component will introduce tensile residual stresses in the immediately adjacent areas of the component thus increasing the risk of cracking in these areas. If the designer wishes to shot peen only a particular area, the shot peening should run out in a less stressed area to allow for these residual tensile stresses. A reassessment of inspection procedures may be required. Shot peening can mask defects and therefore it is usually necessary to inspect the surfaces of components prior to the shot peening process.

Shot peening produces the largest increases in fatigue strength in situations where the loading and geometry produce high stress gradients with the maximum tensile stress at the surface. Components subject to bending with stress concentrations at any exterior surface are particularly suitable for shot peening. Shot peening is unlikely to produce significant increases in fatigue strength in components with plain surfaces subjected to axial loading.

It is important to note that inappropriate shot peening or the use of fragmented shot can cause serious damage to the surface of a component and lead to premature fatigue failure. The optimum shot peening intensity in terms of fatigue strength tends to be in a narrow band of intensities (see Figure 1). Coverage is defined as the ratio of the area which has been deformed by the impact of shot to the entire surface area to be treated. Coverage is usually quoted as a percentage. To achieve substantial benefits from a shot peening process a minimum of one hundred per cent coverage of the treated area is usually needed. Although portable equipment is available for on-site use, it is recommended that the shot peening process is automated wherever possible to ensure accurate control and repeatability.

The designer should ensure that any shot peening process is fully specified. The use of a suitable standard such as US Military Standard MIL S-13165 B is recommended.

5. NOTES ON FIGURES

This Item presents fatigue strength data for various materials tested in a variety of situations. These data are intended to provide guidance on the effects of shot peening on fatigue endurance. However, it is advisable to carry out tests, even when the design situation is very similar to that of the test for which data are presented in this Item.

Unless otherwise stated the data presented in the figures are from fatigue tests in air. All the data are from constant amplitude tests. The test details in each case are presented in the accompanying tables. Material data are given in Table 1 on Page 8. The stress ratio (minimum stress/maximum stress) is quoted if it is given in the relevant derivation. Figures 1 to 12 present data for aluminium alloys, Figures 13 to 16 for steels and Figure 17 for titanium alloy.

Figure 2 shows an increase in fatigue strength and an increased fatigue limit owing to shot peening for 7075 over the entire range of the data. From Figures 3, 4 and 5 it is clear that shot peening can give substantial benefits in terms of fatigue strength. However, if the component is stretched (which relieves the compressive residual stresses) the benefits of the shot peening can be negated and the fatigue strength may even be reduced below the level of an unpeened component (see Figure 4 curve 4). Polishing a shot peened component can give further increases in fatigue strength but may reduce fatigue strength slightly where the surface is subject to fretting. However, different combinations of fretting severity and Almen intensity may produce different results.

Figures 6 and 7 show that at low cycles, in either fatigue or fretting fatigue tests, the longest fatigue endurance are obtained by the highest levels of shot peening. At high cycles the benefits of shot peening are lessened if the peening is excessive (see also Figure 1).

The relative benefits in terms of endurance for various combinations of heat treatment and shot peening are shown in Figures 8 and 9. The figures indicate that shot peening after heat treatment is usually better, particularly where there is no fretting. Shot peening an aged component before final ageing (curve 5 in both figures) gives poor results compared to the other combinations.

Data for aluminium alloy load carrying fillet welds are presented in Figure 10. There is little difference between the endurance of the shot peened and the unpeened specimens in this figure. In Figure 11 aluminium alloy transverse butt welds, which have been shot peened, show an increase in fatigue strength over the unpeened specimens over the complete range of data.

Figure 12 presents data for welded Al-5Zn-2Mg specimens tested in salt water. All the peened specimens show significant increases in fatigue strength over the unpeened specimens. There is little difference between the fatigue strength of the specimens peened to different intensities.

The data for medium carbon steel specimens in Figure 13 show that fatigue strength is increased as a result of shot peening. Shot peening of the maraging steel butt welds for which data appear in Figure 14 produces large increases in fatigue strength. However, the increases in fatigue strength due to shot peening of the maraging steel transverse load carrying fillet welds, in Figure 15, are much smaller than those shown in Figures 13 and 14.

Figure 16 illustrates the benefits of shot peening for a steel subject to fretting fatigue. It also shows the reduction in fatigue strength benefits that can occur when a steel is stretched after being shot peened.

Figure 17 shows that under conditions of fretting the fatigue strength benefits of shot peening on Ti-6Al-4V can be maintained at elevated temperatures.

6. DERIVATION AND REFERENCES

6.1 Derivation

This section lists selected sources that have been of assistance in the preparation of this Data Item.

1. BRINE, F.E.
WEBBER, D.
BARON, H.G. Effect of shot peening on the fatigue properties of maraging steel and Al-Zn-Mg alloy. *British Welding Journal*, pp. 541-546, UK, November 1968.
2. WATERHOUSE, R.B.
NOBLE, B.
LEADBEATER, G. The effect of shot peening on the fretting fatigue strength of an age hardened aluminium alloy (2014A) and an austenitic stainless steel (En 58A). *Journal of Mechanical Working Technology*, Part 8, pp. 147-153. Elsevier Science Publishers, The Netherlands, 1983.
3. FAIR, G.
NOBLE, B.
WATERHOUSE, R.B. The stability of compressive stresses induced by shot peening under conditions of fatigue and fretting fatigue. In: *Advances in Surface Treatments*, Vol. I, Pergamon Press, UK, 1984.
4. LEADBEATER, G.
NOBLE, B.
WATERHOUSE, R.B. The fatigue of an aluminium alloy produced by fretting on a shot peened surface. In: *Proceedings of 6th International Conference on Fracture*, New Delhi, 4-10 December 1984, Vol. 3, Pergamon Press, UK, 1984.
5. SIMPSON, R.S. Development of a mathematical model for predicting the percentage fatigue life increase resulting from shot peened components. Phase 1. US Air Force Wright Aeronautical Laboratories, AFWAL-TR-84-3116, Wright-Patterson Air Force Base, USA, 1984.
6. DIEPART, C.P. Controlled shot peening used in the original design life of critical parts. In: *Conference Proceedings: Fatigue Prevention and Design*. April 1986, Amsterdam. pp. 373-384, Engineering Materials Advisory Services Ltd, UK, 1986.
7. KOEHLER, W. Influence of different peening media on the stress corrosion and corrosion fatigue behaviour of a welded AlZnMg-Alloy. In: *Advances in surface treatment: Technology - applications - effects*. Vol. 3, Pergamon Press, UK, 1986.
8. FAIR, G.
NOBLE, B.
WATERHOUSE, R.B. The initiation and propagation of fatigue cracks in the shot-peened surface of two high strength aluminium alloys. In: *Proceedings of the International Conference on Fatigue of Engineering Materials and Structures*, Sheffield, UK, 15-19 September 1986.
9. LUO, W.
NOBLE, B.
WATERHOUSE, R.B. The interaction between shot peening and heat treatment on the fatigue and fretting fatigue properties of the high strength aluminium alloy 7075. In *Proceedings 2nd International Conference on Impact Treatment Procedure*, Cranfield, UK, 22-26 September, 1986.
10. MÜSGEN, B.
HOFFMAN, K. Improvement of the fatigue strength of welded high-strength steels. *Thyssen Technische Berichte*, Heft 1/87, pp. 67-79, Germany, 1987.

11. NIKU-LARI, A. Overview on the shot peening process. In: Proceedings of AST World Conference - Advances in Surface Treatments and Surface Finishing, Vol. 5, pp. 155-170, Pergamon Press, UK, 1987.
12. LUO, W.
NOBLE, B.
WATERHOUSE, R.B. The effect of shot-peening intensity on the fatigue and fretting fatigue behaviour of an aluminium alloy. In: Proceedings of AST World Conference - Advances in surface treatments and surface finishing, Volume 5, pp. 145-153, Pergamon Press, UK, 1987.
13. DIEPART, C.P. Improved performance of turbomachinery components through controlled shot peening. ASME: International Gas Turbine Institute (publication) IGTI, Vol. 3, pp. 91-95, USA, 1988.
14. SCHÄFER, R.
SCHÜLTZ, W. Fretting fatigue strength of Ti-6Al-4V at room and elevated temperatures and ways of improving it. In: High Temperature Surface Interactions, AGARD-CP-461, 1989.
15. HAMMOND, D.W.
MEGUID, S.A. Crack propagation in the presence of shot-peening residual stresses. *Engineering Fracture Mechanics*, Vol. 37, part 2, pp. 373-387, UK, 1990.

6.2 References

The references given are recommended sources of information supplementary to that in this Item.

16. REDFERN, A.K. The use of shot peening for the fatigue enhancement of aluminium alloy aircraft parts. British Aerospace Report No. BAe-MSM-R-GEN-0549, UK, March 1983.
17. KUMAR, D.
DAS, S.
RADHAKRISHNAN, V.M. Effect of shot peening on fatigue of a Ni-based superalloy. *Scandinavian Journal of Metallurgy*, Vol. 16, part 6, pp. 253-256, 1987.
18. GREGSON, P.J.
NEWMAN, J.
GRAY, A. Effect of surface treatment on fatigue properties of Al-Li-Cu-Mg-Zr and Al-Zn-Mg-Cu-Zr plate. *Materials Science and Technology*, Vol. 5, part 1, pp. 65-70, 1989.
19. O'HARA, P. Controlled shot peening to prevent fatigue and stress corrosion cracking. *Trans. Inst. Metal Finish.*, Vol. 68, part 3, pp. 87-91. UK, 1990.
20. MEGUID, S.A. Effect of partial coverage on the fatigue fracture behaviour of peened components. *Fatigue Fract. Engng Mater. Struct.*, Vol. 14, No.5, pp. 515-530, 1991.
21. ECKERSLEY, J.S.
CHAMPAIGNE, J. *Shot peening: theory and application*. Institute for Industrial Technology Transfer, France, 1991.

TABLE 1 Guide to Materials

<i>Alloy</i>	<i>Composition*</i>	<i>Heat treatment*</i>	<i>Figure number</i>
<i>Aluminium Alloys</i>			
7075	no details are given	T6	1
7075	no details are given	T73	1
7075	5.98Zn -1.28Cu-2.5Mg- 0.2Cr-0.19Fe-0.1Si- 0.054Ti-0.05Zr-remainder Al	T7351	2
2014 A (fully aged)	4.2Cu-0.7Mg-0.7Si- remainder Al	solution heat treated at 505 °C (941°F), aged for five hours at 185°C (365°F)	3, 4
2014 A (age hardened)	4Cu-0.7Mg-0.7Si-remainder Al	quenched from 505 °C (941°F) and aged for five hours at 185 °C (365°F)	5
2014 A	4.48Cu-0.7Mg-0.55Si- 0.35Fe-0.7Mn-remainder Al	solution heat treated, water quenched and fully aged at 185 °C (365°F)	6, 7
7075	1.76Cu-2.65Mg-0.145Si- 0.21 Fe-0.03Mn-0.03Ni- 5.40Zn-remainder Al	solution heat treated at 460 °C (860°F), water quenched and aged, see Tables 7 and 8 for ageing details	8, 9
Al-5 Zn-1 Mg	5.0Zn-1.2Mg-0.3Mn- 0.2Cr-remainder Al	solution heat treated and fully aged	10, 11
Al-5 Zn-2 Mg	4.5Zn-2Mg-remainder Al	T6	12
<i>Steels</i>			
080M 40 medium carbon steel (En 8)	0.43C-0.79Mn-0.012S- 0.20Si-0.022P-remainder Fe	no details are given	13
18% Ni maraging steel	18Ni-8.5Co-3.2Mn-0.2Ti- 0.1Al-remainder Fe	maraged for three hours at 480 °C (896°F)	14, 15
En 58A austenitic stainless steel	no details are given	annealed	16
<i>Titanium Alloys</i>			
Ti-6Al-4V	6.2Al-4.0V-0.16Fe-0.014C- remainder Ti	annealed	17

* As quoted in the derivations

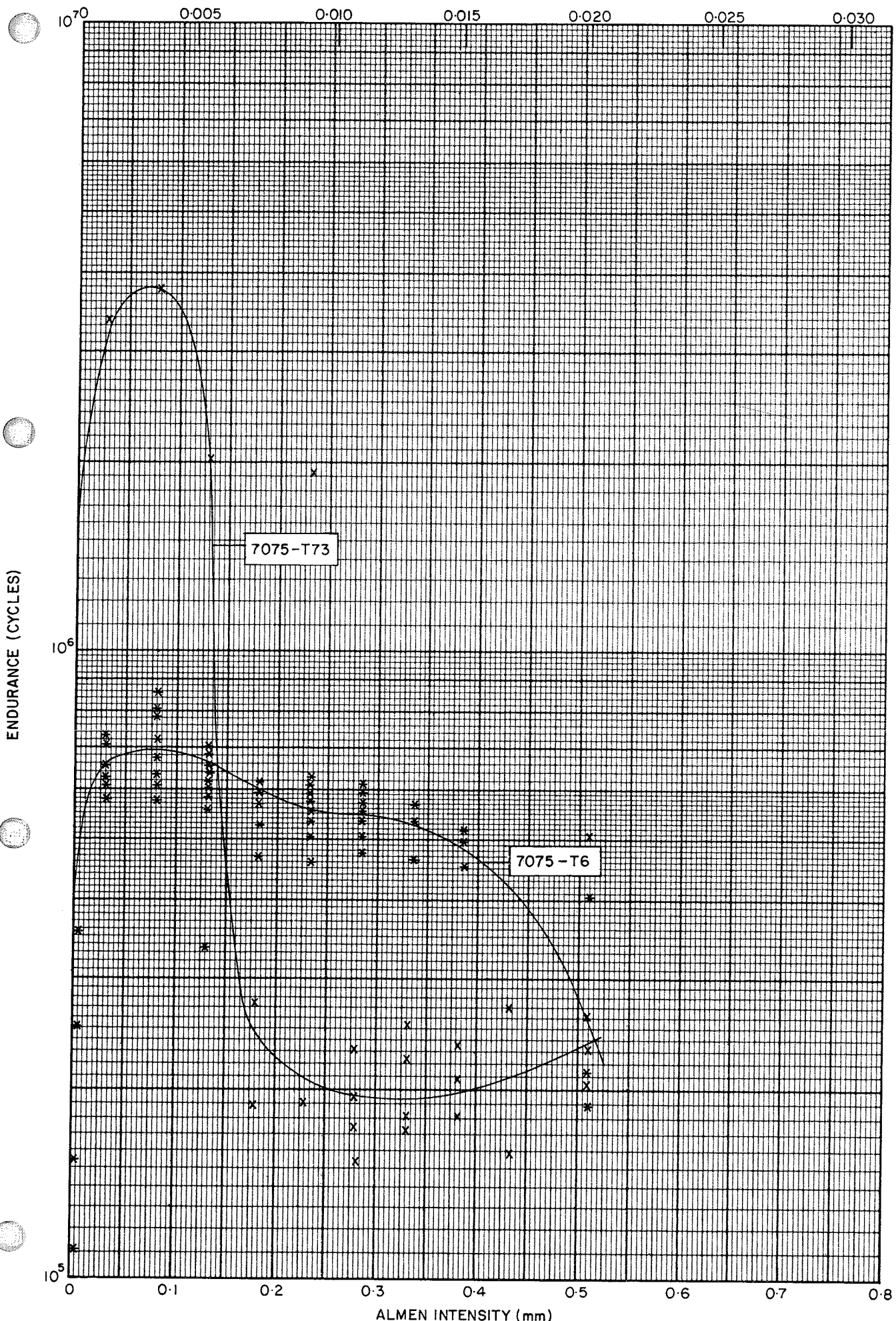


FIGURE I. ENDURANCE VERSUS ALMEN INTENSITY FOR 7075-T73 AND 7075-T6

TABLE 2 Guide to Figure 2

The effects of shot peening on the fatigue strength of an aluminium alloy tested in rotating bending.				
Alloy : 7075-T7351				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	15	rotating bending	unpeened
2	○	15	rotating bending	shot peened (0.25-0.40 mm (0.010-0.015 in) on A strip (0.010-0.016 A))

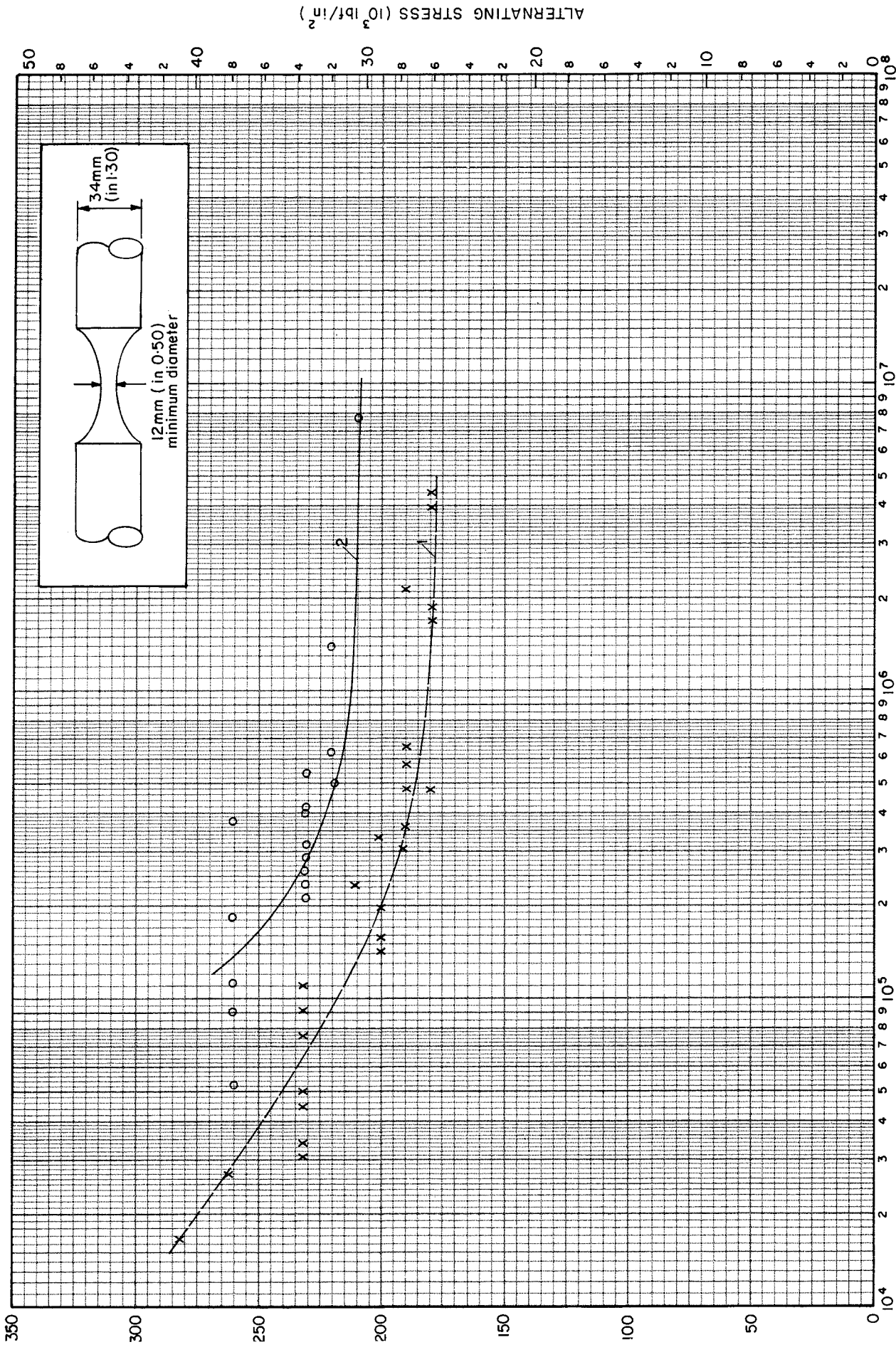
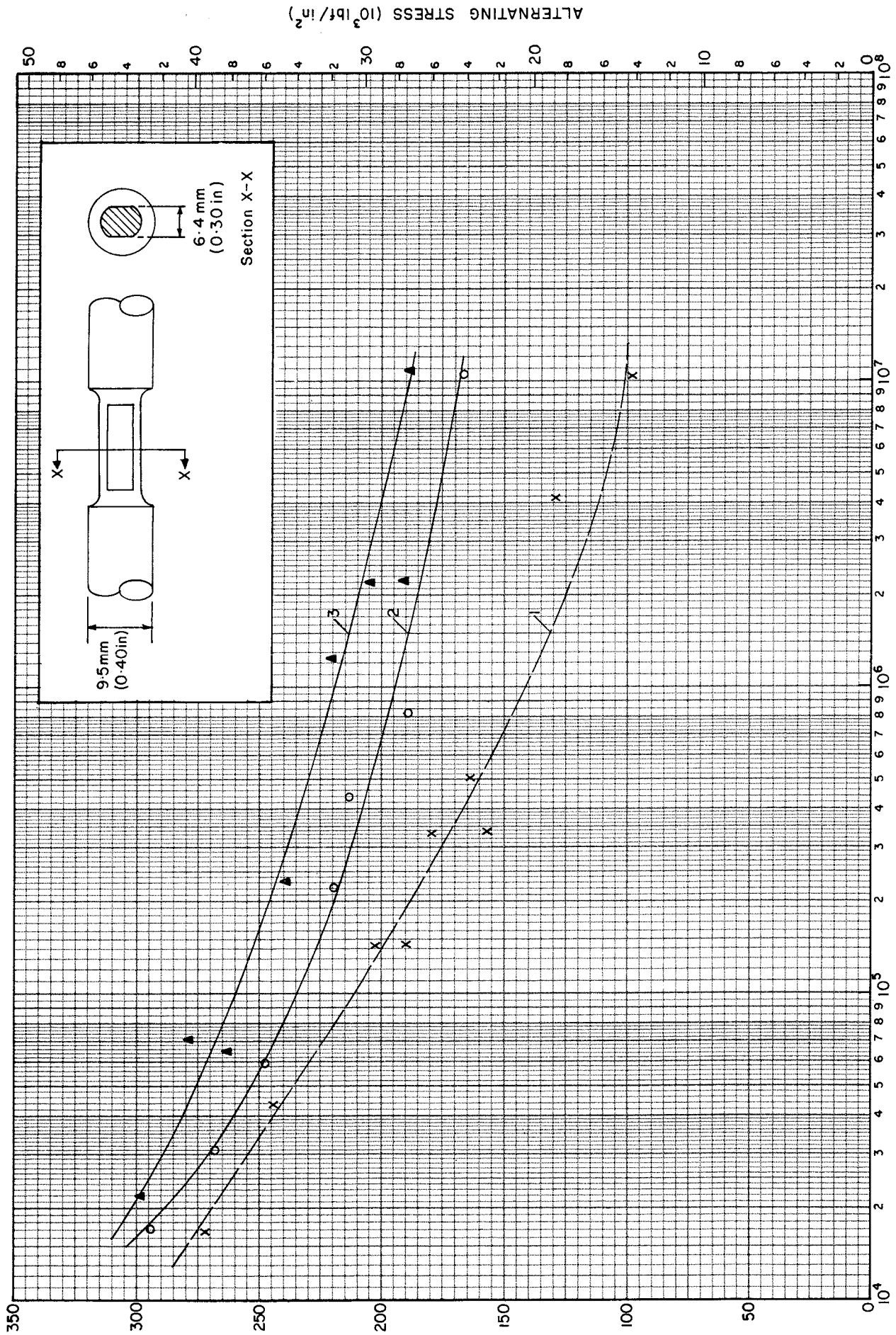


FIGURE 2. ENDURANCE (CYCLES)

FIGURE 2.

TABLE 3 Guide to Figure 3

The effects of shot peening and shot peening followed by polishing on fatigue strength of an aluminium alloy tested in rotating bending.				
Alloy : 2014A (fully aged)				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	×	4	rotating bending	unpeened
2	○	4	rotating bending	shot peened (0.30 - 0.40 mm (0.010-0.015 in) on A strip)
3	▲	4	rotating bending	shot peened (0.30 - 0.40 mm (0.010-0.015 in) on A strip) and polished



ENDURANCE (CYCLES)

FIGURE 3.

TABLE 4 Guide to Figure 4

The effects of shot peening, shot peening followed by polishing, and shot peening followed by stretching on the fatigue strength of an aluminium alloy tested in rotating bending with fretting.				
Alloy : 2014A (fully aged)				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	4	fretting fatigue, rotating bending	unpeened
2	○	4	fretting fatigue, rotating bending	shot peened (0.30 - 0.40 mm (0.01-0.015 in) on A strip)
3	▲	4	fretting fatigue, rotating bending	shot peened (0.30 - 0.40 mm (0.01-0.015 in) on A strip) and polished
4	▷	4	fretting fatigue, rotating bending	shot peened (0.30 - 0.40 mm (0.01-0.015 in) on A strip) and stretched either 0.5% or 1.0%

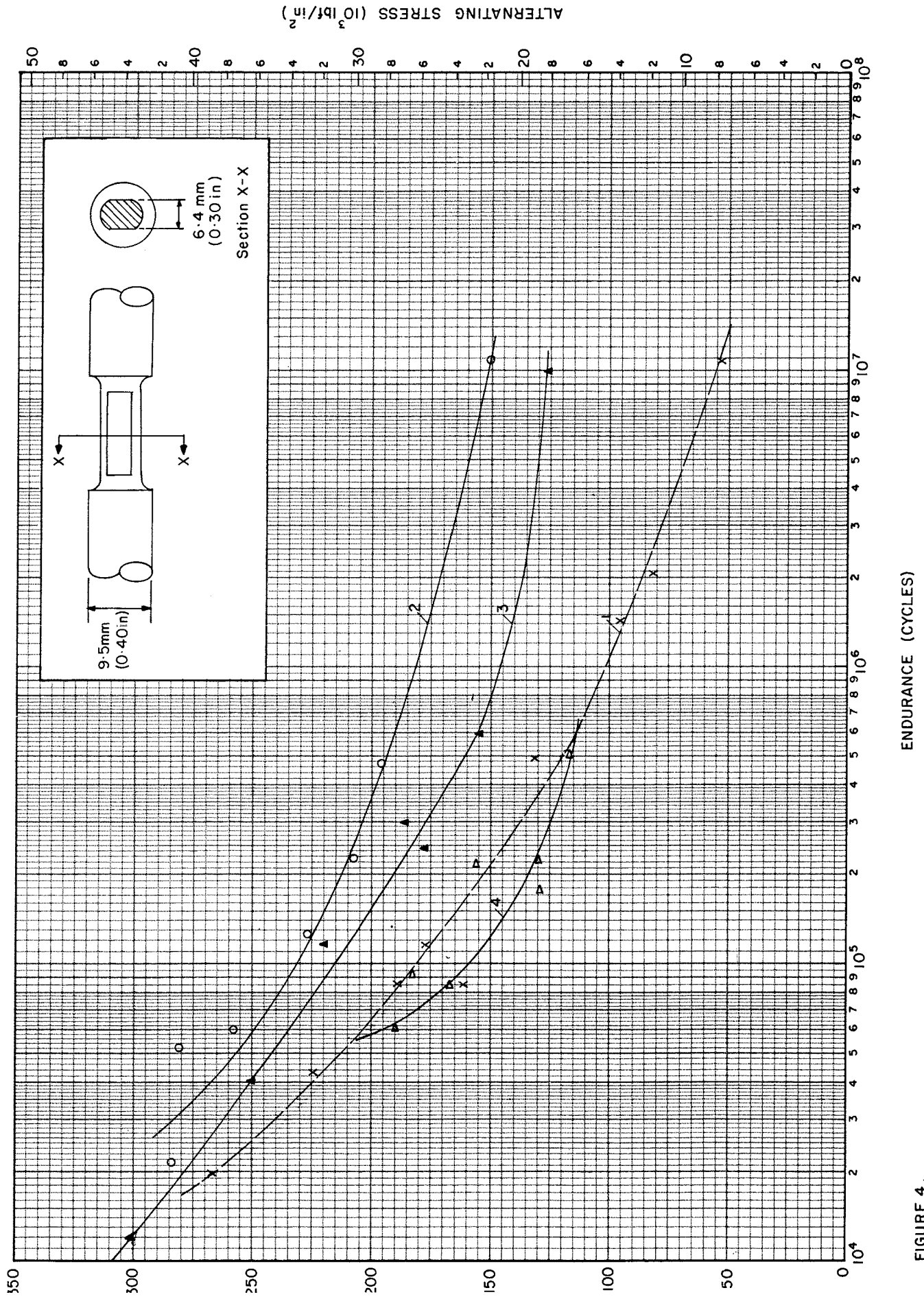


FIGURE 4.

ENDURANCE (CYCLES)

ALTERNATING STRESS (10^3 lbf/in^2)

TABLE 5 Guide to Figure 5

The effects of shot peening, shot peening followed by stretching and shot peening before ageing on fatigue strength of an aluminium alloy tested in rotating bending and with fretting (except for curve 5).				
Alloy : 2014A (age hardened)				
<i>Curve number</i>	<i>Symbol</i>	<i>Deviation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	2	fretting fatigue, rotating bending	unpeened
2	○	2	fretting fatigue, rotating bending	shot peened (0.012-0.016 A)
3	▲	2	fretting fatigue, rotating bending	shot peened (0.012-0.016 A) and then stretched to 0.5% strain
4	▷	3	fretting fatigue, rotating bending	shot peened (0.012-0.016 A) before ageing
5	●	3	rotating bending	shot peened (0.012-0.016A) before ageing

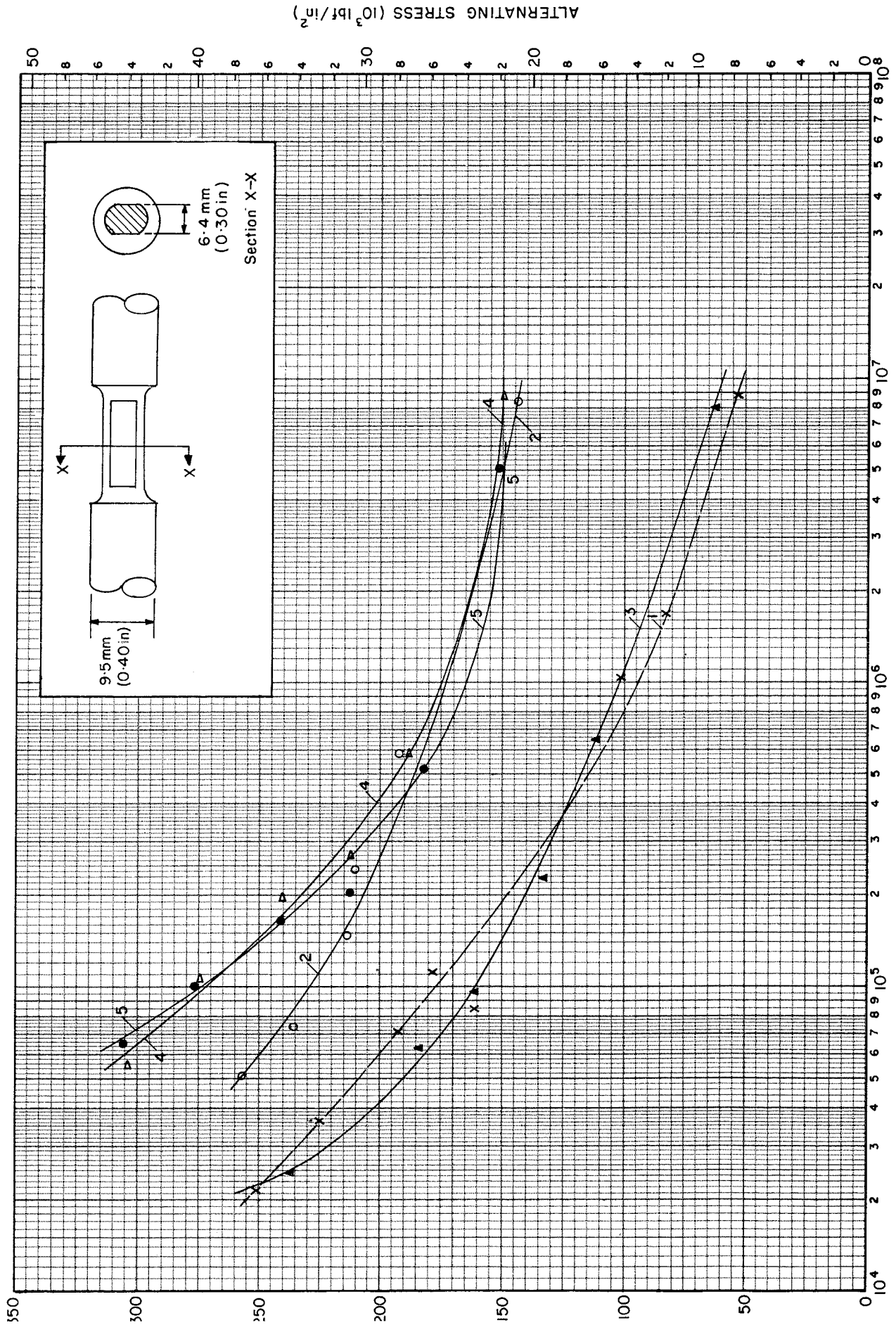


FIGURE 5.

TABLE 6 Guide to Figure 6

The effects of different shot peening intensities on the fatigue strength of an aluminium alloy tested in rotating bending.				
Alloy : 2014A				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	12	rotating bending	unpeened
2	○	12	rotating bending	shot peened (12-16 A)
3	▲	12	rotating bending	shot peened (16-20 A)
4	▷	12	rotating bending	shot peened (8-10 C)*

* 8-10 C is a higher intensity than 16-20 A.

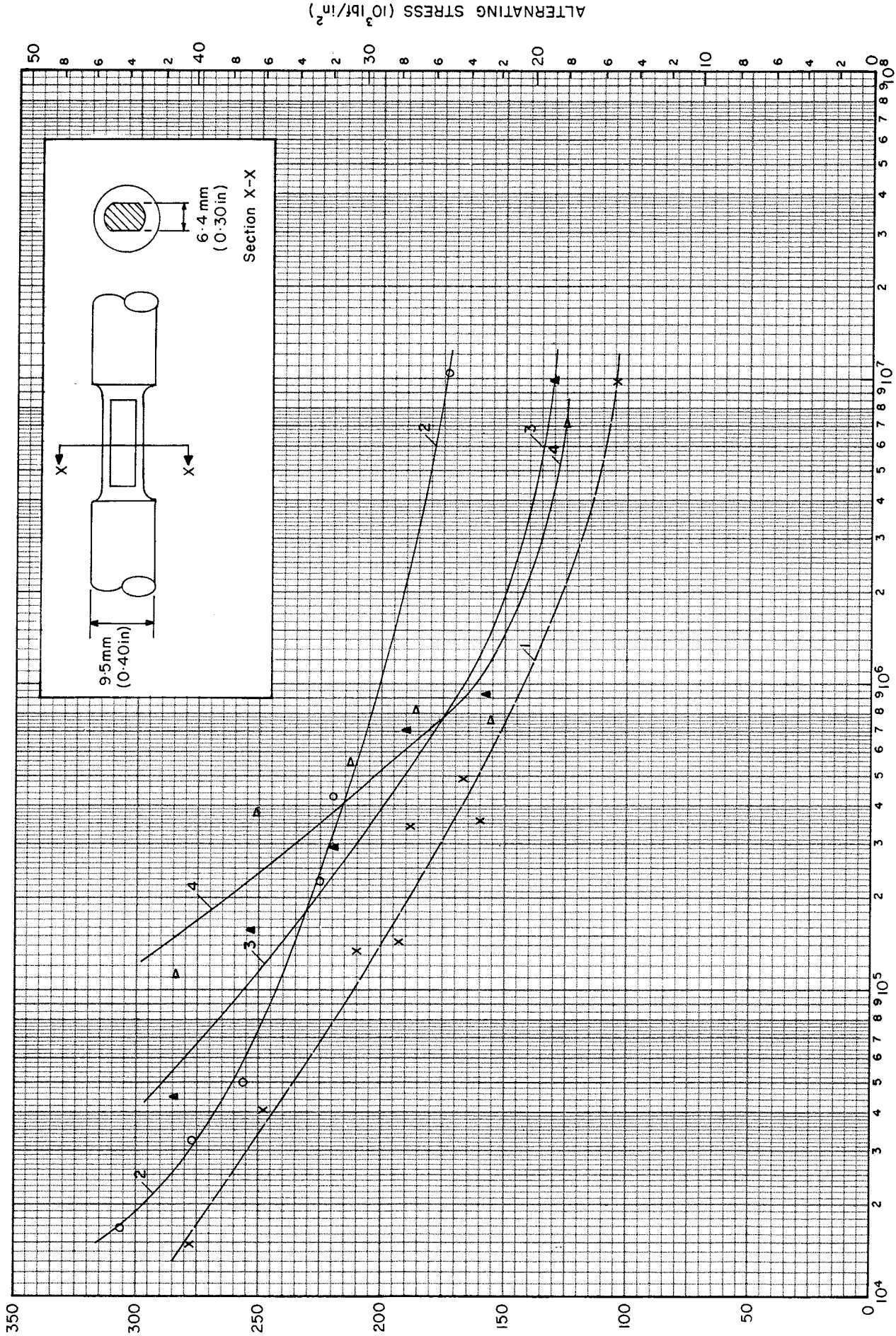
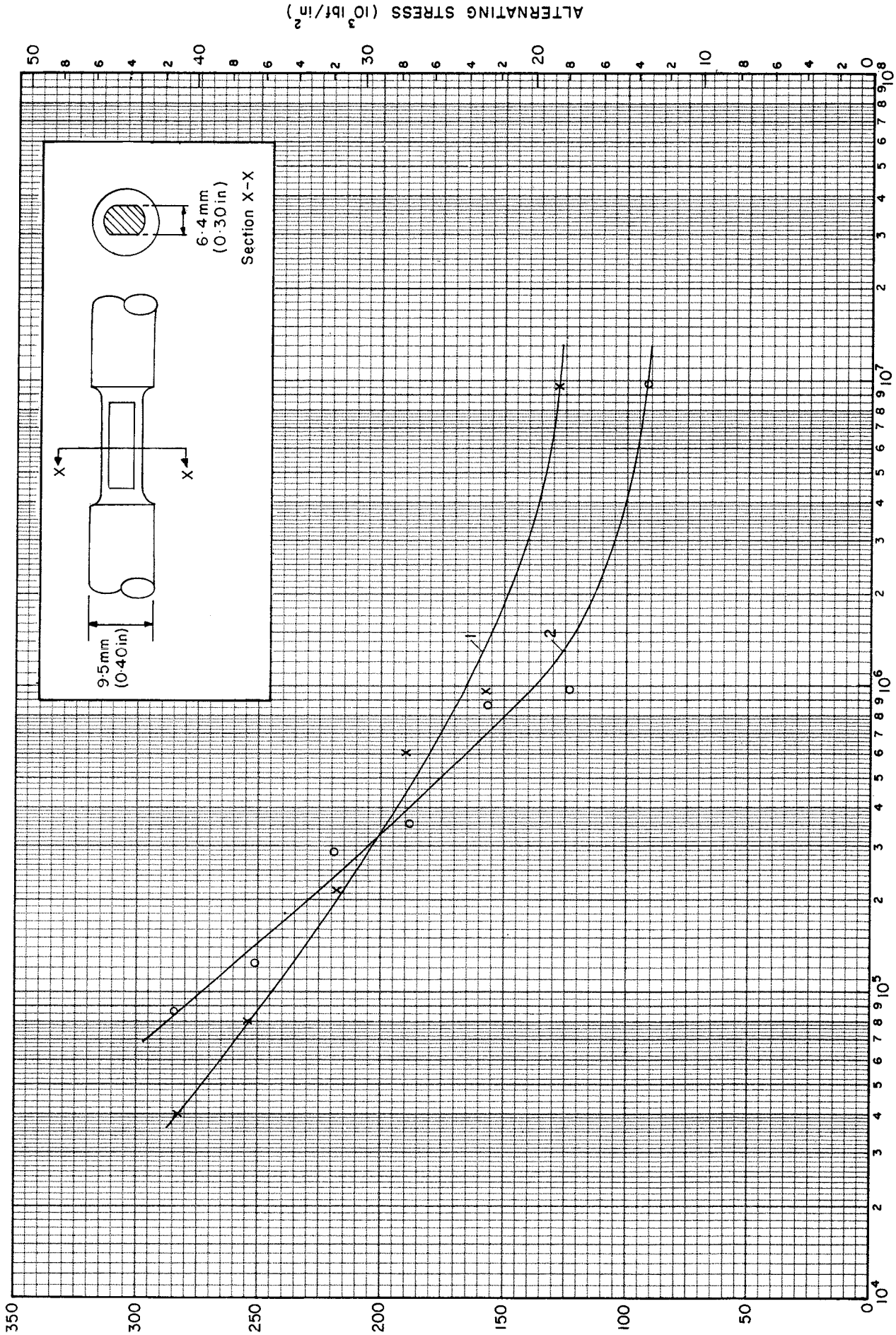


FIGURE 6. ENDURANCE (CYCLES)

FIGURE 6.

TABLE 7 Guide to Figure 7

The effects of different shot peening intensities on the fatigue strength of an aluminium alloy tested in rotating bending with fretting.				
Alloy : 2014A				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	12	fretting fatigue, rotating bending	shot peened (16-20 A)
2	○	12	fretting fatigue, rotating bending	shot peened (8-10 C)



ENDURANCE (CYCLES)

FIGURE 7.

TABLE 8 Guide to Figure 8

The effects of different combinations of heat treatment and shot peening on the fatigue strength of an aluminium alloy tested in rotating bending.				
Alloy : 7075				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	9	rotating bending	unpeened
2	○	9	rotating bending	shot peened (0.012-0.016 A) after single stage ageing
3	▲	9	rotating bending	shot peened (0.012-0.016 A) after two stage ageing
4	▷	9	rotating bending	shot peened (0.012-0.016 A) after solution heat treatment but before ageing
5	●	9	rotating bending	shot peened (0.012-0.016 A) after solution heat treatment and ageing but before final ageing

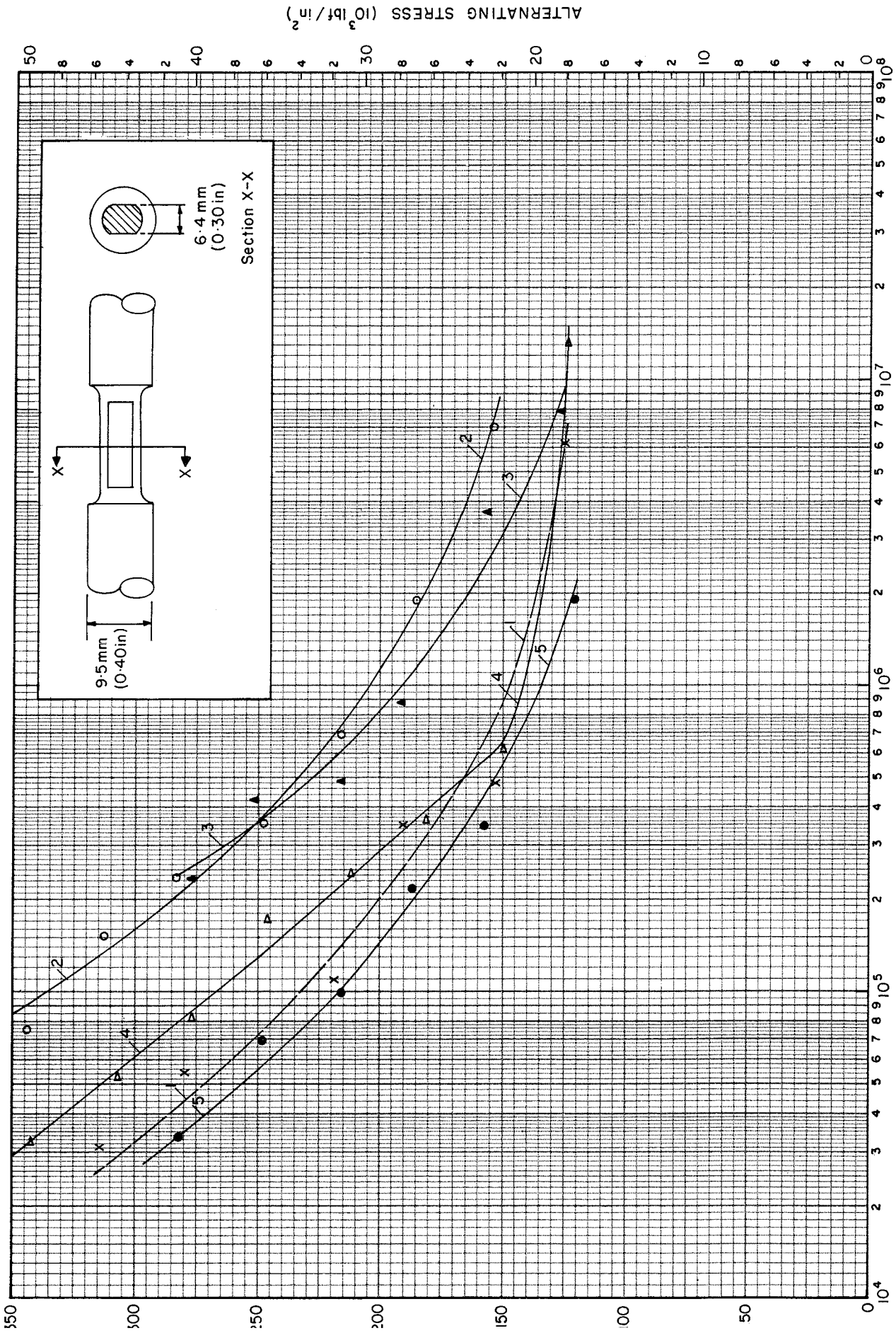


FIGURE 8.

TABLE 9 Guide to Figure 9

The effects of different combinations of heat treatment and shot peening on the fatigue strength of an aluminium alloy tested in rotating bending with fretting.				
Alloy : 7075				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	9	fretting fatigue, rotating bending	unpeened
2	○	9	fretting fatigue, rotating bending	shot peened (0.012-0.016 A) after single stage ageing
3	▲	9	fretting fatigue, rotating bending	shot peened (0.012-0.016 A) after two stage ageing
4	▷	9	fretting fatigue, rotating bending	shot peened (0.012-0.016 A) after solution heat treatment but before ageing
5	●	9	fretting fatigue, rotating bending	shot peened (0.012-0.016 A) after solution heat treatment and ageing but before final ageing

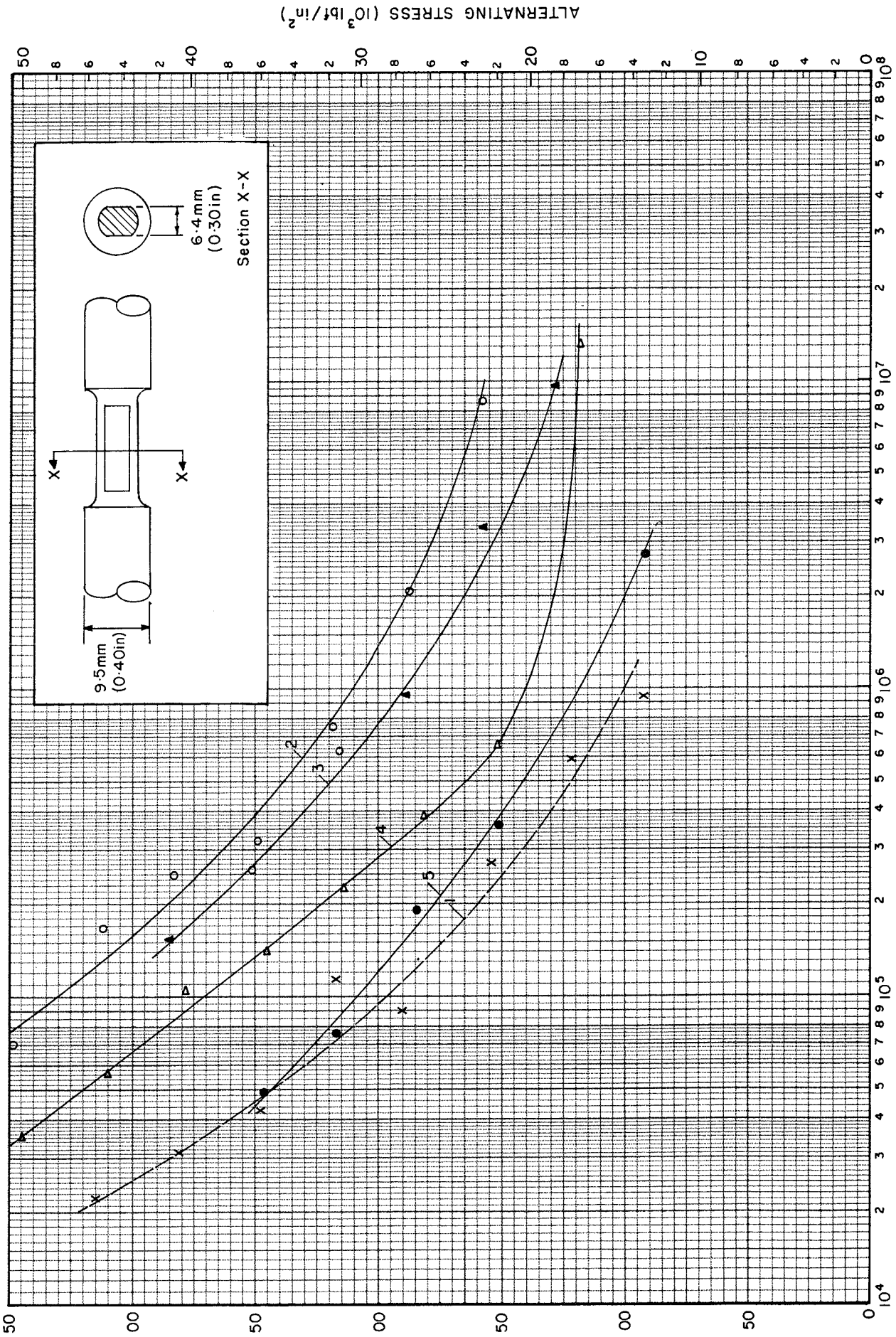


FIGURE 9.

TABLE 10 Guide to Figure 10

The effects of shot peening on the fatigue strength of aluminium alloy transverse load carrying fillet welds.				
Alloy : Al-5Zn-1Mg				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	1	transverse load carrying fillet weld (MIG method), stress ratio = 0	unpeened
2	○	1	transverse load carrying fillet weld (MIG method), stress ratio = 0	shot peened (0.3 mm (0.01 in) on A2 strip)

Note: Most failures of the unpeened specimens occurred at the toe of the weld. Most failures of the peened specimens occurred at the root of the weld.

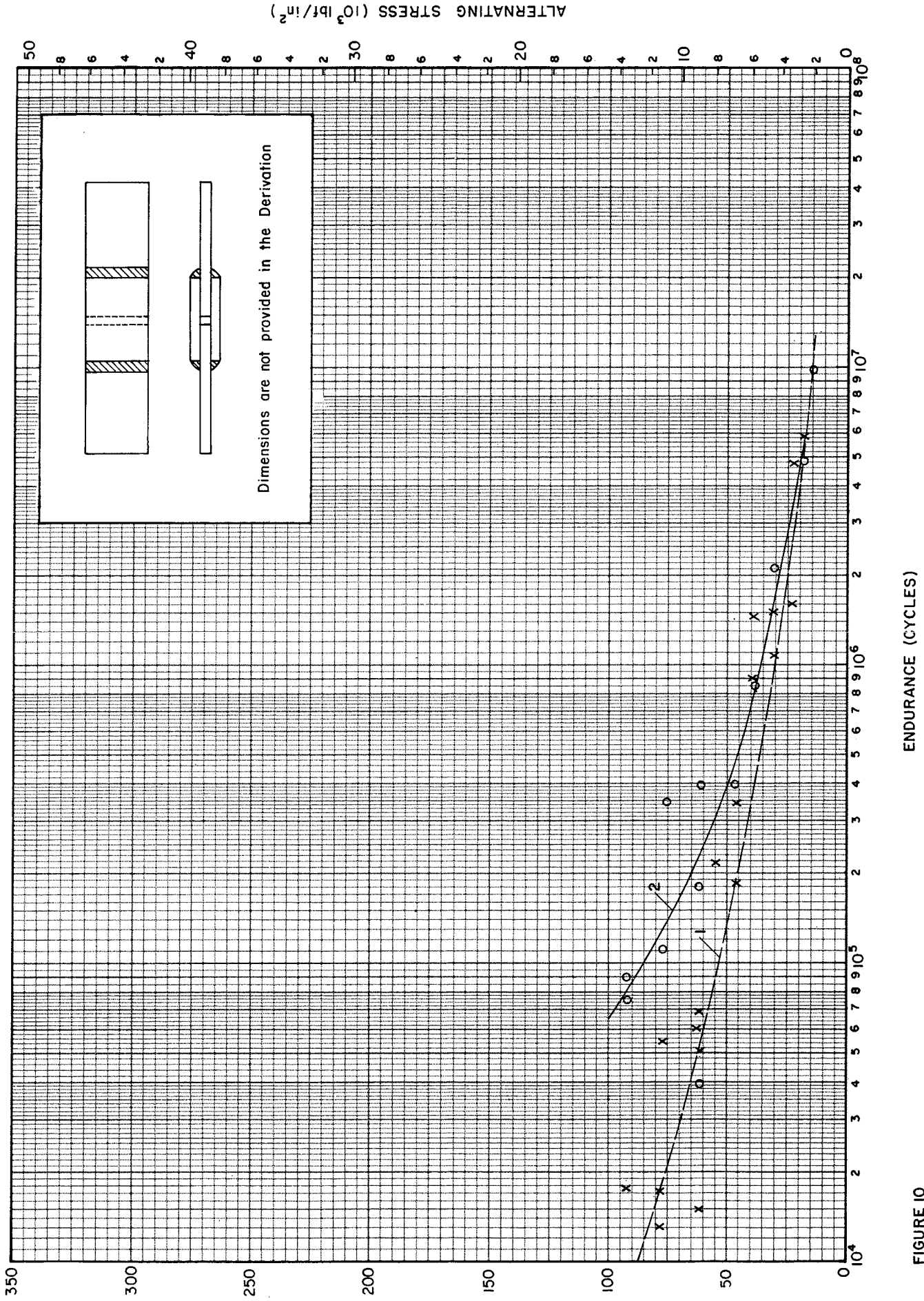


TABLE 11 Guide to Figure 11

The effects of shot peening on the fatigue strength of aluminium alloy transverse butt welds.				
Alloy: Al-5Zn-1Mg				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	1	transverse butt weld (MIG method), stress ratio = 0	unpeened
2	○	1	transverse butt weld (MIG method), stress ratio = 0	shot peened (0.3 mm (0.01 in) on A2 strip)

Note: Most failures occurred at the toe of the weld.

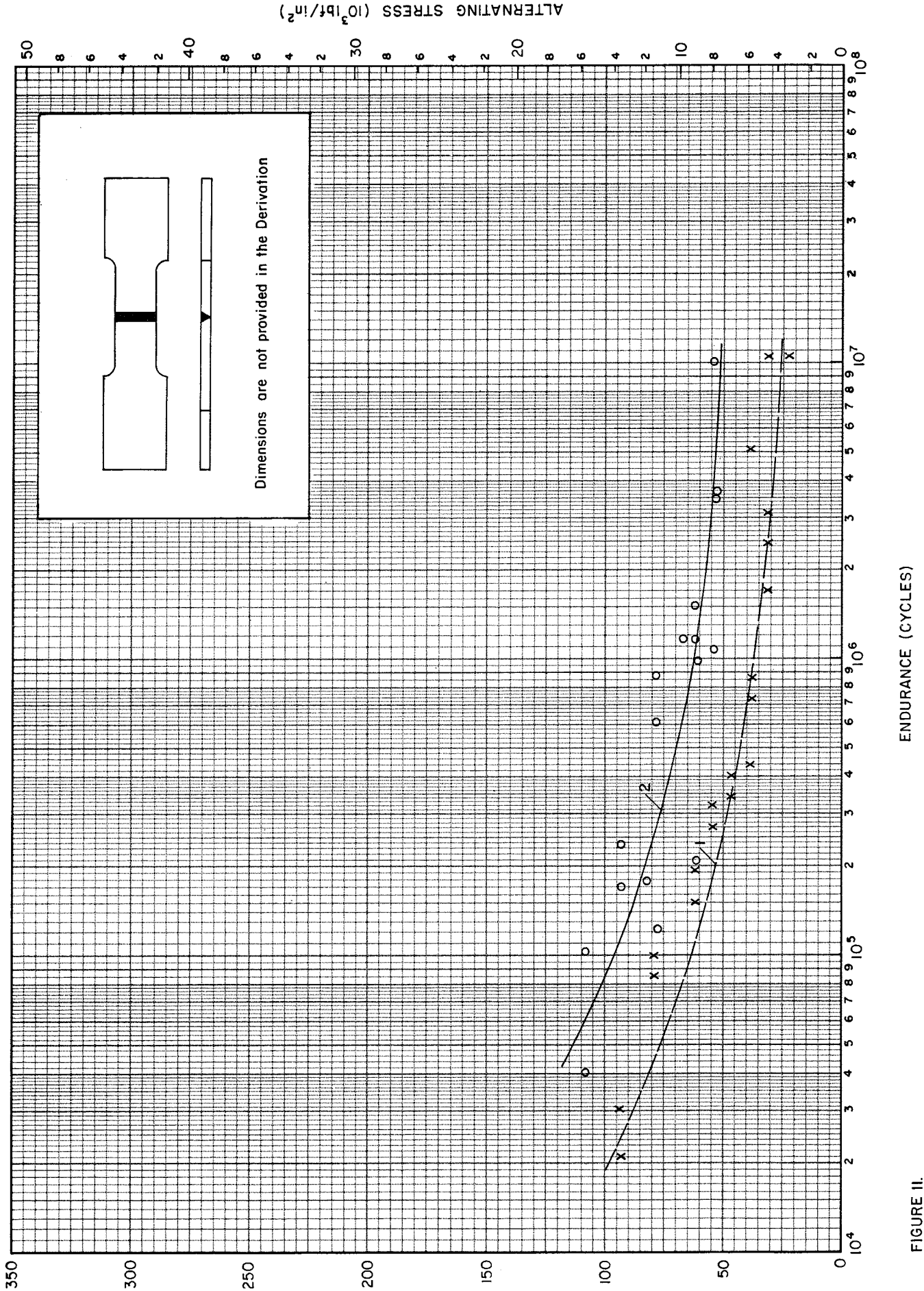


FIGURE II.

TABLE 12 Guide to Figure 12

The effects of different shot peening intensities with different types of shot on the fatigue strength of welded aluminium alloy tested in salt water.				
Alloy: Al-5Zn - 2Mg				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	×	7	welded (MIG method) tensile test sample tested in 2% NaCl solution	unpeened
2	○	7	welded (MIG method) tensile test sample tested in 2% NaCl solution	peened (0.14 mm (0.0055 in) A2) ceramic shot
3	▲	7	welded (MIG method) tensile test sample tested in 2% NaCl solution	peened (0.24 mm (0.0094 in) A2) ceramic shot
4	▷	7	welded (MIG method) tensile test sample tested in 2% NaCl solution	peened (0.16 mm (0.0063 in) A2) glass shot

Note: The specimen type is not illustrated in the derivation nor are details on the failure origins provided.

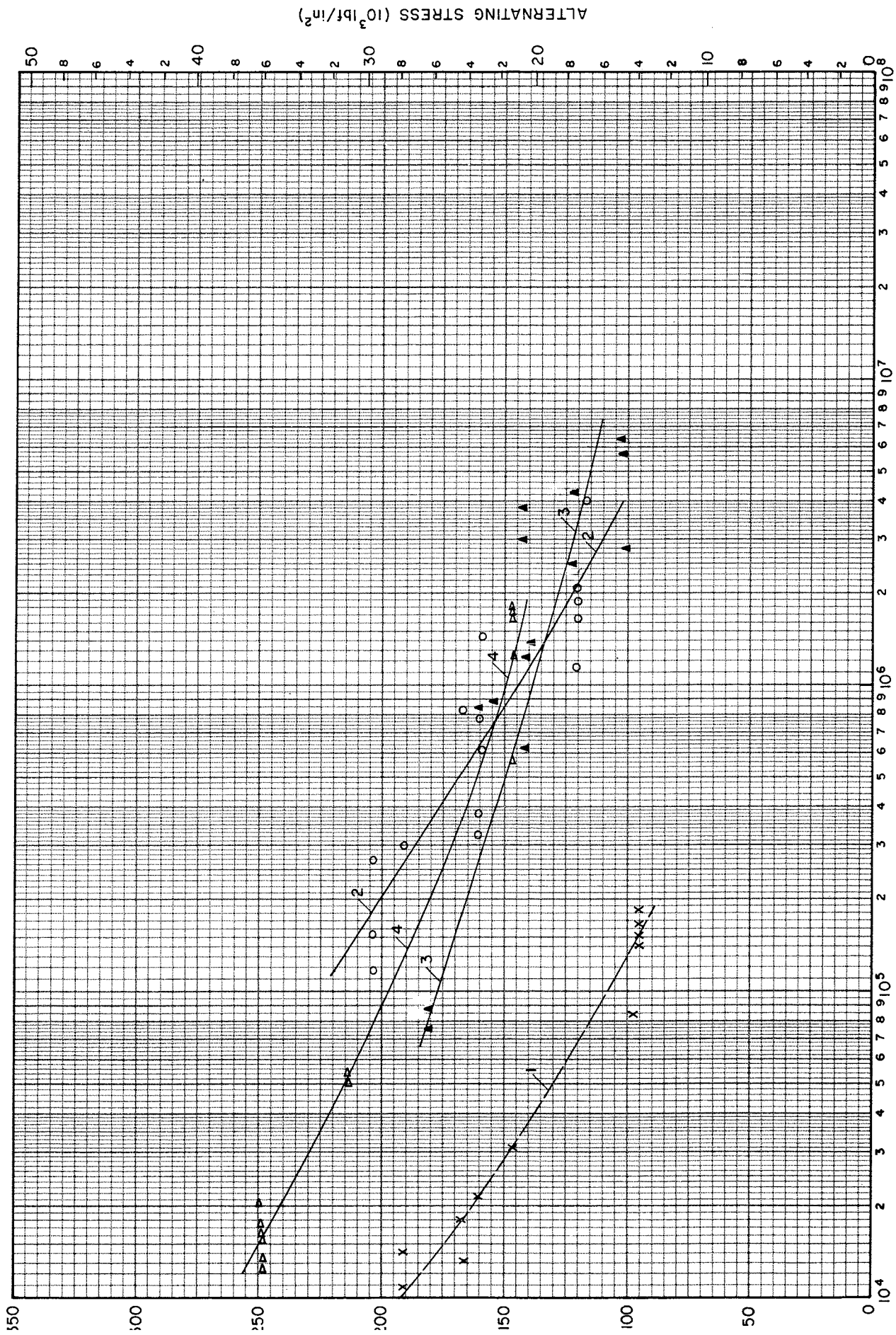


FIGURE 12. ENDURANCE (CYCLES)

TABLE 13 Guide to Figure 13

The effect of shot peening of the fatigue strength of a medium carbon steel.				
Alloy : 080M40 medium carbon steel (En 8)				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	15	rotating bending,	unpeened
2	○	15	rotating bending,	shot peened (0.45 mm (0.018 in) on A strip)

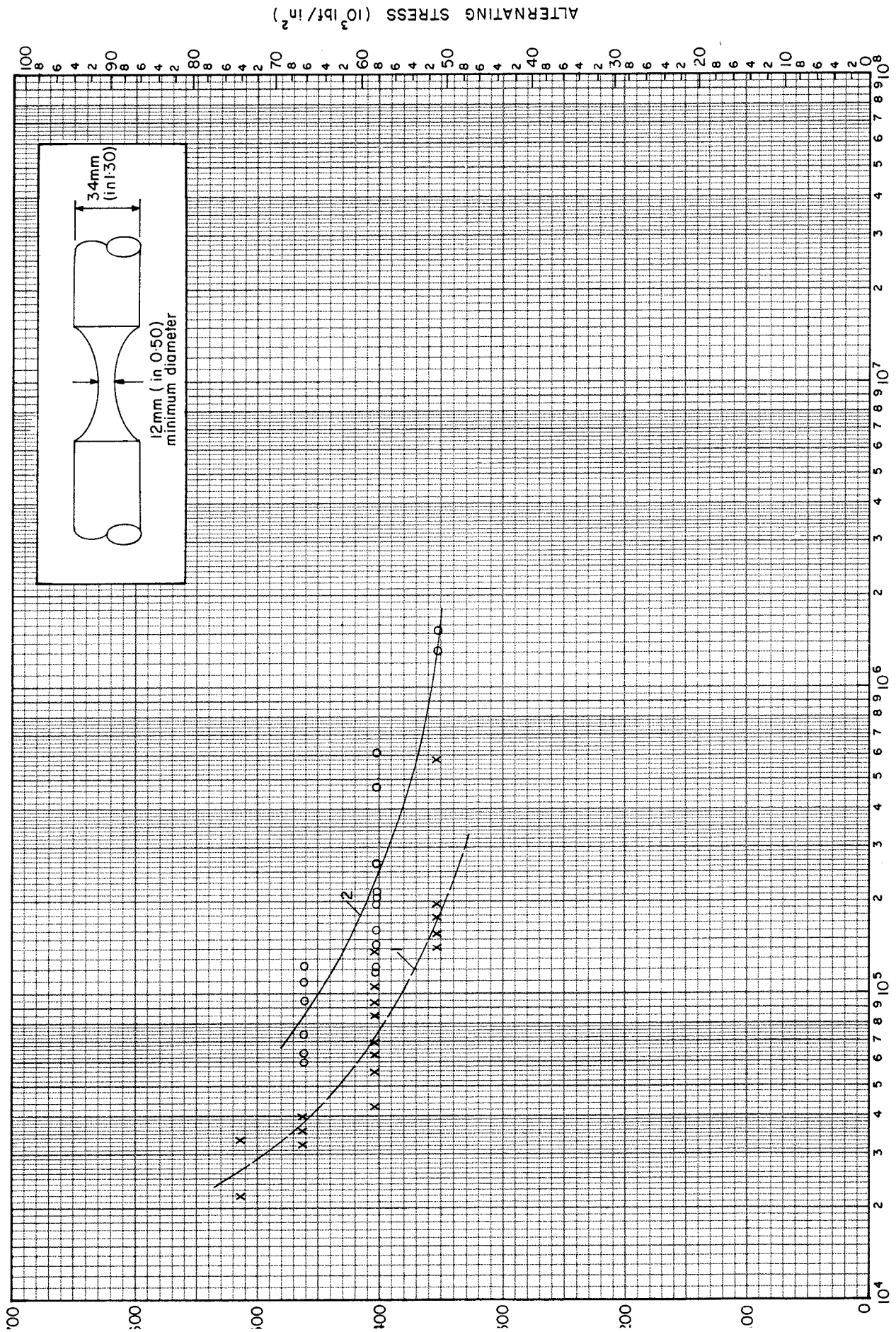


FIGURE 13.

TABLE 14 Guide to Figure 14

The effects of shot peening on the fatigue strength of maraging steel transverse butt welds.				
Alloy : 18% Ni maraging steel				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	X	1	transverse butt weld (MIG method), stress ratio = 0	unpeened
2	○	1	transverse butt weld (MIG method), stress ratio = 0	shot peened (0.3 mm (0.01 in) on A2 strip)

Note: Most failures occurred at the toe of the weld.

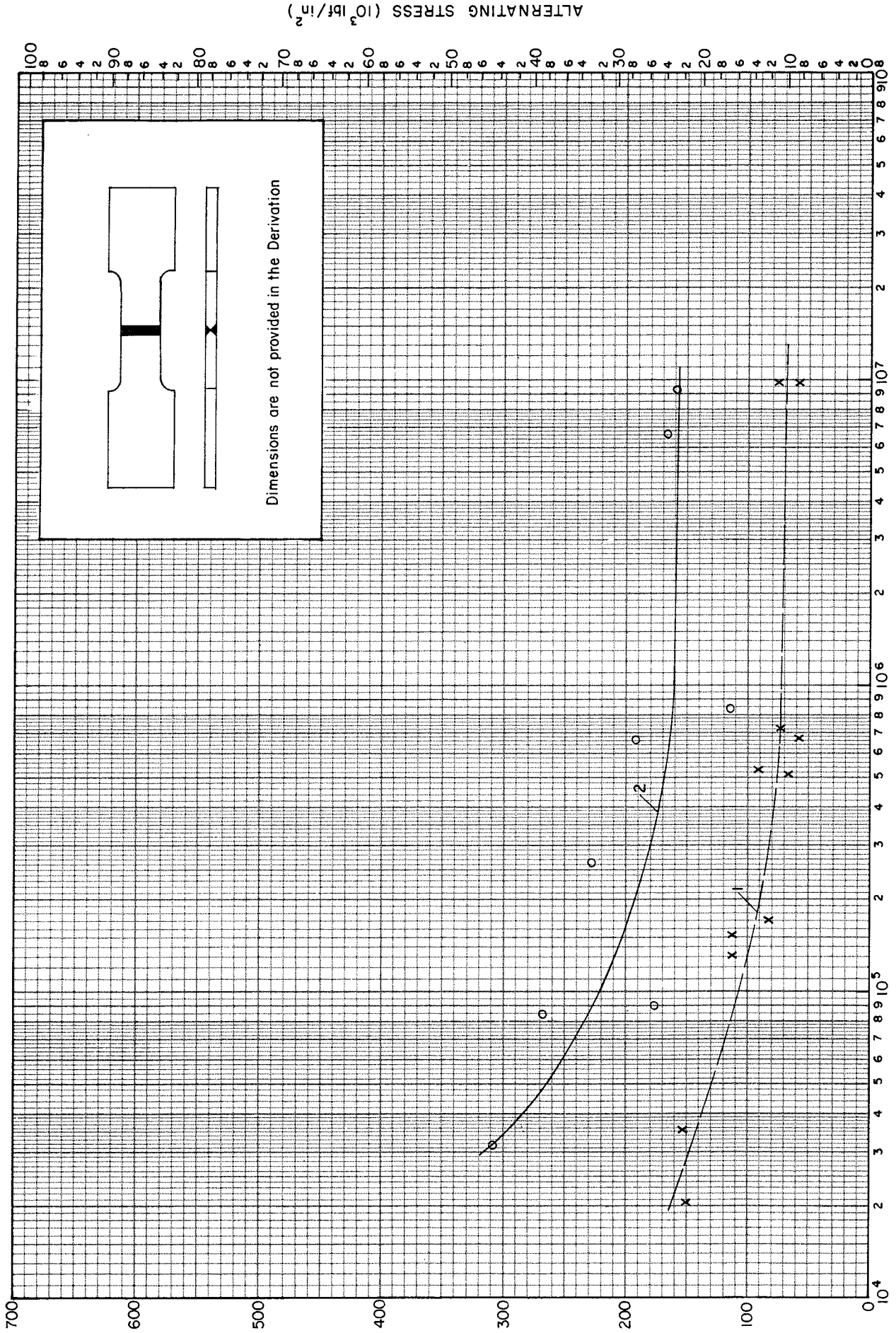


FIGURE 14 ENDURANCE (CYCLES)

TABLE 15 Guide to Figure 15

The effects of shot peening on the fatigue strength of maraging steel transverse load carrying fillet welds.				
Alloy : 18% Ni maraging steel				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	1	transverse load carrying fillet weld (MIG method), stress ratio = 0	unpeened
2	○	1	transverse load carrying fillet weld (MIG method), stress ratio = 0	shot peened (0.3 mm (0.01 in) on A2 strip)

Note: In the unpeened specimens failure occurred at the toe of the weld while in the peened specimens the failure was along the cover plates from the root of the weld.

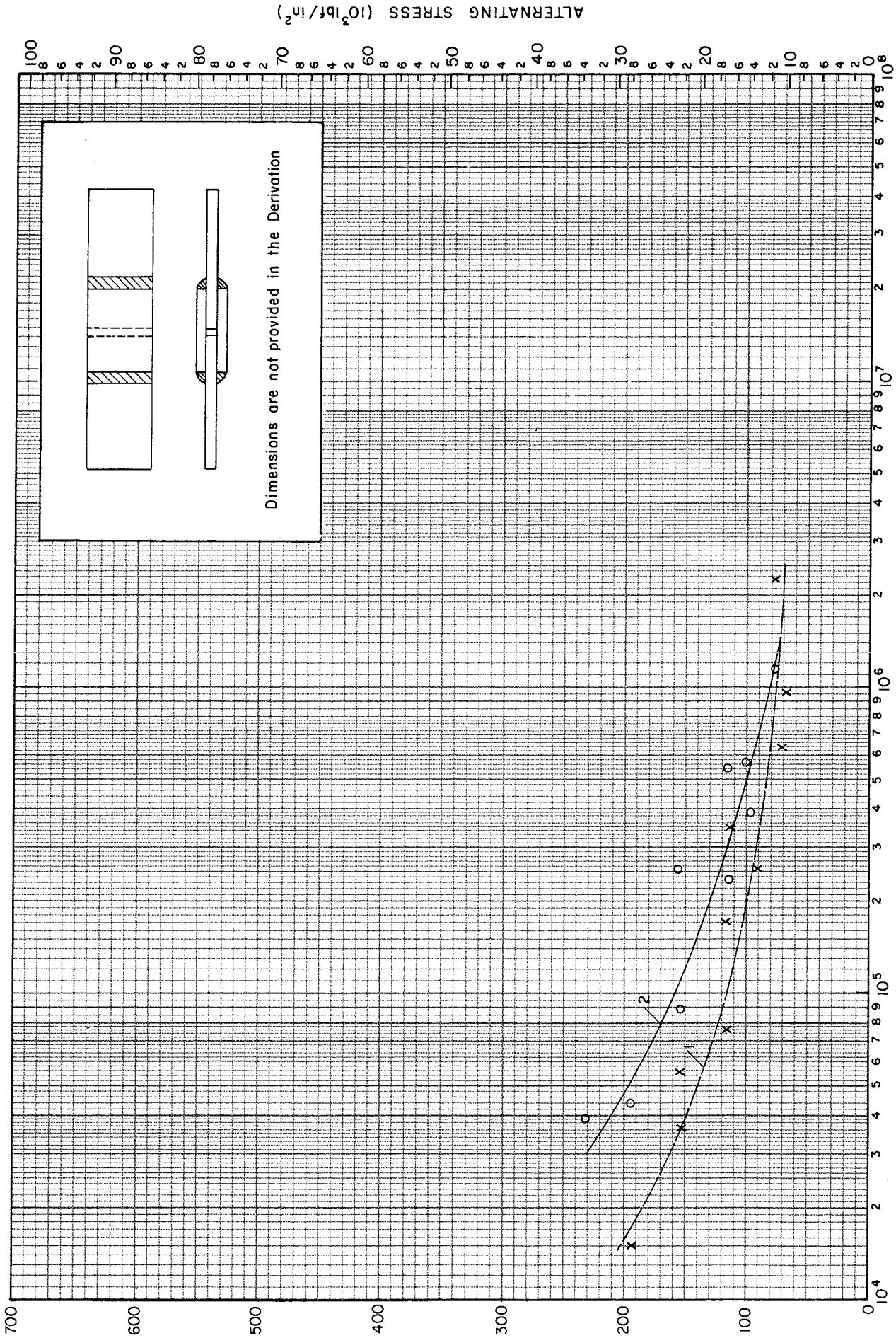


FIGURE 15.

TABLE 16 Guide to Figure 16

The effects of shot peening and shot peening followed by stretching on the fatigue strength of a steel.				
Alloy : En 58A austenitic stainless steel				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1	x	2	fretting fatigue, rotating bending	unpeened
2	○	2	fretting fatigue, rotating bending	shot peened (0.008-0.012 A)
3	▲	2	fretting fatigue, rotating bending	shot peened (0.008-0.012 A) and then stretched to 1.0% strain

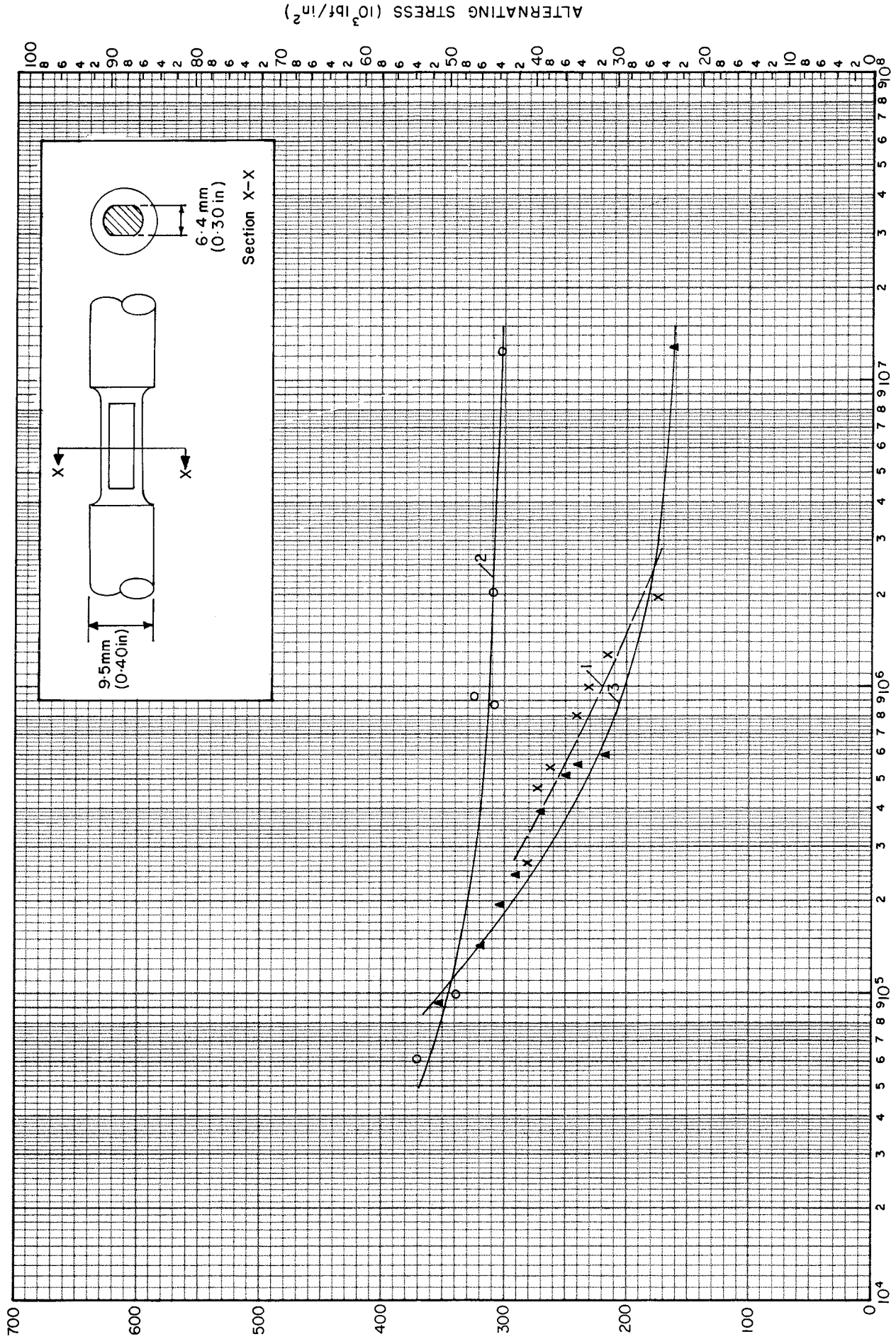


FIGURE 16. ENDURANCE (CYCLES)

TABLE 17 Guide to Figure 17

The effects of shot peening on the fatigue strength of a titanium alloy at different temperatures with fretting.				
Alloy : Ti-6Al-4V				
<i>Curve number</i>	<i>Symbol</i>	<i>Derivation number</i>	<i>Test type</i>	<i>Notes</i>
1*	none	14	fretting fatigue, axial loading, stress ratio = 0.1	unpeened, room temperature
2	○	14	fretting fatigue, axial loading, stress ratio = 0.1	shot peened (0.24 mm (0.0094 in) on A2 strip), room temperature
3*	none	14	fretting fatigue, axial loading, stress ratio = 0.1	unpeened, 350°C (662°F)
4	▷	14	fretting fatigue, axial loading, stress ratio = 0.1	shot peened (0.24 mm (0.0094 in) on A2 strip), 350°C (662°F)

* Individual data points are not provided in the Derivation.

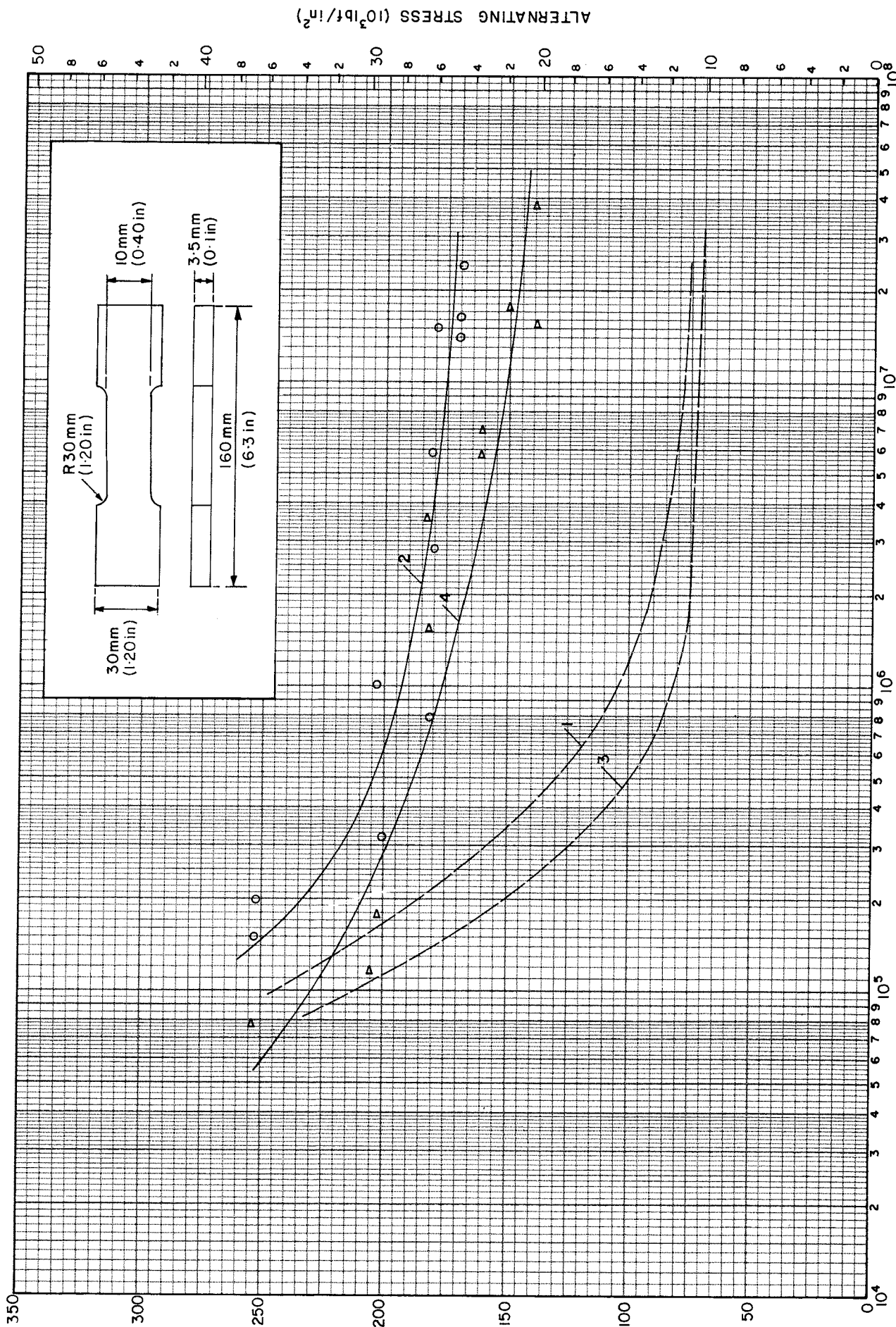


FIGURE 17.

92015

Guide to the effect of shot peening on fatigue strength ESDU 92015

ISBN 0 85679 823 1, ISSN 0958-0379

Available as part of the ESDU Sub-series on Fatigue. For information on all ESDU validated engineering data contact ESDU International, 27 Corsham Street, London N1 6UA, or P.O. Box 1633, Manassas, VA 22110, USA.

Shot peening can produce significant increases in the fatigue strength of many components. This Item presents data from a large number of fatigue endurance tests carried out on steels, titanium alloy and aluminium alloys. These data show the increases in fatigue strength it is possible to achieve with shot peening. Data were obtained from fatigue and fretting fatigue tests. Data are provided for various specimen types including welded specimens. Most of the tests were carried out in air at room temperature but a few tests were carried out in salt water or at elevated temperatures. The data are presented in 17 figures, mostly as S-N curves. The figures are accompanied by tables which provide the test details.

© ESDU International plc, 1992

All rights are reserved. No part of any Data Item may be reprinted, reproduced, or transmitted in any form or by any means, optical, electronic or mechanical including photocopying, recording or by any information storage and retrieval system without permission from ESDU International plc in writing. Save for such permission all copyright and other intellectual property rights belong to ESDU International plc.

