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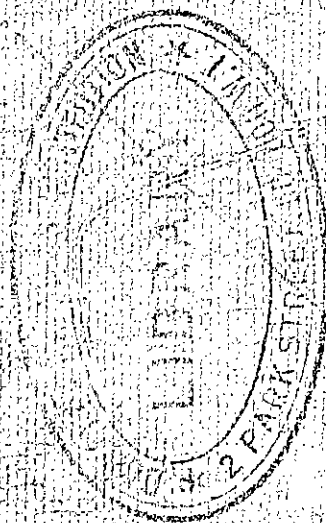
BRITISH STANDARD 2573 : Part 1 : 1966

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SPECIFICATION FOR

PERMISSIBLE STRESSES IN CRANES

Part 1. Structures



BRITISH STANDARDS INSTITUTION

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PERMISSIBLE
STRESSES IN CRANES

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B.S. 2573 : Part 1 : 1966

Price 20/- net

BRITISH STANDARDS INSTITUTION

INCORPORATED BY ROYAL CHARTER

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THIS BRITISH STANDARD, having been approved by the Mechanical Engineering Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 19th May, 1966.

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The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 4000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, price 15s. The B.S. Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

- B.S. 4. Structural steel sections.
Part 1. Hot-rolled sections.
Part 2. Hot-rolled hollow sections.

B.S. 15. Mild steel for general structural purposes.

B.S. 153. Steel girder bridges.
Part 3B. Stresses.

Part 4. Design and construction.

B.S. 327. Power-driven derrick cranes.

B.S. 357. Power-driven travelling jib cranes (rail-mounted low carriage type).

B.S. 466. Electric overhead travelling cranes for general use in factories, workshops and warehouses.

B.S. 639. Covered electrodes for the manual metal-arc welding of mild steel and medium-tensile steel.

B.S. 968. High yield stress (welding quality) structural steel.

B.S. 1757. Power-driven mobile cranes.

B.S. 2452. High pedestal or portal jib cranes.

B.S. 2762. Notch ductile steel for general structural purposes.

B.S. 2799. Power-driven rail-mounted tower cranes.

B.S. 3579. Heavy duty electric overhead travelling and special cranes for use in steel works.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following B.S.I. references relate to the work on this standard:
Committee references MEE/41, MEE/41/7.

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CO-OPERATING ORGANIZATIONS

The Mechanical Engineering Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

- * Associated Offices' Technical Committee
- * Association of Consulting Engineers
- Association of Mining Electrical and Mechanical Engineers Board of Trade
- British Chemical Plant Manufacturers' Association
- British Compressed Air Society
- * British Electrical and Allied Manufacturers' Association
- British Gear Manufacturers' Association
- British Internal Combustion Engine Manufacturers' Association
- * British Iron and Steel Federation
- British Mechanical Engineering Federation
- British Railways Board
- * Crown Agents for Oversea Governments and Administrations
- Electricity Council, The Generating Board and the Area Boards in England and Wales
- Engineering Equipment Users' Association
- Gas Council
- Institute of Marine Engineers
- Institution of Civil Engineers
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- Institution of Heating and Ventilating Engineers
- * Institution of Mechanical Engineers (Automobile Division)
- Institution of Mechanical Engineers
- * Institution of Production Engineers
- Locomotive and Allied Manufacturers' Association of Great Britain
- London Transport Board
- Machine Tool Trades Association
- * Ministry of Defence, Army Department
- Ministry of Defence, Navy Department
- * Ministry of Labour (H.M. Factory Inspectorate)
- * Ministry of Power
- Ministry of Public Building and Works
- Ministry of Technology—National Engineering Laboratory
- * Ministry of Transport
- National Coal Board
- National Physical Laboratory (Ministry of Technology)
- Radio Industry Council
- Royal Institute of British Architects

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this standard:

- Aluminium Federation
- Association of Cranemakers
- British Constructional Steelwork Association
- British Transport Docks Board
- Contractors Plant Association
- Dock and Harbour Authorities Association
- Electrical Trades Union
- Excavator Makers' Association
- Federation of Civil Engineering Contractors
- Federation of Wire Rope Manufacturers of Great Britain
- High Commission of India
- Institute of Welding
- Institution of Engineering Inspection
- Institution of Structural Engineers
- Lifting Equipment Manufacturers' Association
- Ministry of Technology—Building Research Station
- National Federation of Building Trades Employers

BRITISH STANDARD SPECIFICATION FOR

PERMISSIBLE STRESSES IN CRANES

Part 1. Structures

FOREWORD

This second revision has been prepared as a result of the experience gained in the use of the second edition published in 1960. It is intended to form the basis for the design of all types of cranes and appropriate references to this British Standard have been introduced in the relevant British Standards for cranes.

The basic stresses given herein are related to the yield points of the steels listed, and it is not intended at this stage to introduce basic stresses for materials other than steel. Consideration is, however, being given to preparing a further revision of the standard in terms of limit state design.

During the revision the treatment of impact factors has been further simplified and, with regard to fluctuation of stresses in members, it is recognized that the loading conditions causing fatigue are different from those causing other forms of failure. The fluctuation factors have accordingly been omitted from the calculations required to cover normal service conditions and a separate verification of members which are subject to fluctuations of stress is required in addition to the normal calculations for service conditions. In consequence, permissible working stresses for fatigue are now related to specified numbers of stress cycles and various classes of constructional details, thereby implementing, where appropriate, the principles adopted in the latest edition of B.S. 153 : Parts 3B and 4.

The opportunity has also been taken to modernize the standard in certain other respects including a simplification of the clauses dealing with basic stresses in bending. Appendix C dealing with effective lengths of crane jibs has been expanded and a new Appendix D giving notes on crane classification has been introduced.

NOTE. Where metric equivalents are stated, the figures in British units are to be regarded as the standard. The metric conversions are approximate. More accurate conversions should be based on the tables in B.S. 350, 'Conversion factors and tables'.

SPECIFICATION

SCOPE

1. This specification provides the basis for computing stresses in crane structures in order to secure economy in design and reliability in operation. For this purpose it includes a classification of cranes depending on their duty

and the number of hours in service per year, as set out in Table 1. The correct classification of a crane is important and should be the joint responsibility of the purchaser and manufacturer (see Appendix D).

DEFINITIONS AND SYMBOLS

2. a. For the purposes of this British Standard the following definitions apply:

(i) *Dead load*. All the loads of constant magnitude and position which act permanently on the structure or member.

(ii) *Live load*. Any load except wind load which gives rise to variation of stress in a member. Such variation may be due to change of position or magnitude, or both, of an externally applied load, or to the movement of the crane structure itself.

(iii) *Inertia forces*. The forces produced by change of velocity.

(iv) *Wind load*. The forces produced by the velocity of the wind, which is assumed to act horizontally.

NOTE. It may be necessary in exceptional circumstances to take account of snow load and temperature variation and to make allowances for corrosion due to atmospheric conditions.

(v) *Basic stresses* are those set out in Clauses 11, 12, 13 and 16, and Tables 2, 4, 5, 6, 7, 8, 10, 11, 12, 13 and 14.

(vi) *Permissible working stress* is numerically equal to the basic stress multiplied by the relevant duty factor.

(vii) *Service conditions* are those under which a crane is operating up to its designed capacity.

b. The following symbols are used in this standard:

NOTE. Symbols used only in Appendix C are not included in this list.

A = A symbol for $\frac{170\,000}{(l/r_y)^2} \sqrt{\left[1 + \frac{1}{20} \left(\frac{lT}{r_y D}\right)^2\right]}$.

A_e = Total enclosed area of section.

A_s = Area, obtained by projecting a silhouette of the unloaded structure onto a plane normal to the direction of the wind.

a = The greater clear dimension of the web in a panel.

B = A symbol for $\frac{170\,000}{(l/r_y)^2}$.

b = The lesser clear dimension of the web in a panel.

C_o = Euler critical stress.

C_s = Critical stress in the compression element of a solid web beam in bending.

c = Shape coefficient for wind load.

D	= Depth.
d	= Depth of panel in a solid web plate (see Clause 13a).
d_1	= The clear distance between flange angles, or where there are no flange angles, between flanges (ignoring fillets); but where tongue plates having a thickness not less than twice the thickness of the web plate are used, d_1 is the depth of the girder between the flanges, less the sum of the depths of the tongue plates or eight times the sum of the thicknesses of the tongue plates, whichever is the less.
d_2	= Twice the clear distance from the compression flange angles or plate or tongue plate to the neutral axis.
d_3	= The clear depth of web between root fillets.
E	= Young's modulus.
f_{ac}	= The calculated axial compressive stress.
f_{at}	= The calculated axial tensile stress.
f_b	= The calculated bearing stress.
f_{bc}	= The calculated compressive bending stress.
f_{bt}	= The calculated tensile bending stress.
f_c	= The equivalent stress due to a combination of shear and other stresses.
f_{max}	= Maximum stress.
f_{min}	= Minimum stress.
f_q	= The calculated shear stress.
G	= Modulus of rigidity.
h	= Height above ground level.
h_c	= Distance between flange centroids.
h_s	= Projection of a stiffener component from a web.
I	= Moment of inertia.
I_t	= Moment of inertia of the compression flange only about y-y axis of girder.
I_x	= Moment of inertia about the axis normal to the plane of bending.
I_y	= Moment of inertia about the axis lying in the plane of bending (the y-y axis).
K	= Torsion constant.
K_s	= Load factor.
K_1	= A coefficient making allowance for reduction of thickness or breadth of flanges.
K_2	= A coefficient to allow for inequality of tension and compression flanges.
L	= Actual length.

- L_b = The length of a beam over which an applied concentrated load is assumed to disperse.
- l = Effective length.
- M = The applied bending moment.
- N = The number of stress cycles.
- P = The lateral force to be taken by a stiffener.
- P = The permissible fatigue stress
- P_{ac} = The permissible compressive stress in axially loaded members.
- $P_{ac,bas}$ = The basic permissible compressive stress in axially loaded members.
- P_{at} = The permissible axial tensile stress.
- P_{bc} = The permissible compressive stress in bending.
- $P_{bc,bas}$ = The basic permissible compressive stress in bending.
- P_{bt} = The permissible tensile stress in bending.
- $P_{q,bas}$ = Basic average shear stress.
- R = Reaction on bearing.
- r = Radius of gyration.
- r_y = Radius of gyration about the y-y axis.
- S = Length of each element of the periphery.
- S_t = The maximum permitted clear distance between stiffeners.
- S_1 = Actual distance between stiffeners.
- T = Effective thickness.
- T_{max} = Maximum thickness.
- t = Web thickness.
- t' = The thickness of the thinnest plate, or the aggregate thickness of two or more plates provided that those plates are adequately connected together.
- V = Wind velocity.
- W = Total load.
- W_L = Wind load.
- W_p = Wind pressure.
- W_{ph} = Wind pressure at height h ft above ground level.
- W_1 = Load in tongs.
- W_2 = Weight of mast and tongs.
- w = Warping constant.
- X_1 = The ratio of the total area of both flanges at the point of minimum bending moment to the corresponding area at the point of maximum bending moment.

- X_2 = The ratio of the moment of inertia of the compression flange alone about its axis parallel to the y-y axis of the girder as a whole to that of the whole section about the y-y axis of the girder, both at the point of maximum bending moment.
- Y_s = Yield stress.
- y_c = Distance from the neutral axis of the girder to the extreme fibre in compression.
- y_t = Distance from neutral axis of the girder to the extreme fibre in tension.
- Z_x = Gross section modulus about x-x axis.
- η = 0.003 l/r .
- μ = $\frac{I_x - I_y}{I_x}$.
- π = Circumference divided by diameter of a circle.

DESIGN CONSIDERATIONS

3. The structure as a whole and each part of it shall be designed to withstand the effect of any possible combination of loads under each of the conditions specified below.

a. Crane in use under service conditions.

(i) Loads to be taken into account:

Dead loads.

Live loads (including the hook load which is augmented by the impact factor, see Clause 5).

Service wind load (see Clause 8) acting horizontally in any direction.

Inertia forces (due to linear or angular acceleration and deceleration (braking)).

(ii) In addition, each member in which fluctuating stresses occur shall be checked for fatigue in accordance with Clause 7 taking the following loads into account:

A. For Class 1 and 2 cranes:

Dead loads.

Live loads (including the hook load).

Inertia forces (due to linear or angular acceleration and deceleration (braking)).

B. For Class 3 and 4 cranes:

Dead loads.

Live loads (including the hook load which is augmented by the impact factor, see Clause 5).

Inertia forces (due to linear or angular acceleration and deceleration (braking)).

- b. Crane out of use. Loads to be taken into account:

Dead loads.

Out of service wind load (see Clause 8) acting horizontally in any direction.

- c. Crane being erected or dismantled. Loads to be taken into account:

Dead loads.

Erection forces and effects.

Wind load as appropriate (see Clause 8).

PERMISSIBLE WORKING STRESSES

4. The calculated stress in each part of the structure, due to the loading conditions specified in Clause 3 shall not exceed any of the following:

- a. Under conditions specified in Clause 3a(i). The basic stress (see Clause 2a(v)) multiplied by the duty factor (see Clause 6).

- b. Under conditions specified in Clause 3a(ii). The permissible stress for fatigue (see Clause 7).

- c. Under conditions specified in Clauses 3b and 3c. The basic stress (see Clause 2a(v)) multiplied by a factor of 1.13.

IMPACT FACTOR

5. The impact factor applies to the motion of the hook load in a vertical direction and covers inertia forces, including shock. In calculating live loads in members of the structure, the hook load shall be multiplied by the impact factor, values of which are given in Table 1 for the various classes of crane.

DUTY FACTOR

6. The duty factors given in Table 1 which are related to the crane classifications shall be applied to all basic stresses set out in Clauses 11, 12, 13 and 16 and Tables 2, 4, 5, 6, 7, 8, 10, 11, 12, 13 and 14.

FLUCTUATIONS OF STRESS (FATIGUE) IN MEMBERS

7. a. General. Members which are subjected to fluctuations of stress are liable to suffer from fatigue failure, and this may be caused by loads which are very much lower than those which would be necessary to cause failure under a single application. The initiation of fatigue cracks is due, primarily, to stress concentrations introduced by the constructional details. Discontinuities such as bolt or rivet holes, welds and other local or general changes in geometrical form set up such stress concentrations from which fatigue cracks may be initiated, and these cracks may subsequently propagate through the connected or fabricated member.

All details shall be designed to avoid, as far as possible, stress concentrations likely to result in excessive reduction of the fatigue strength of members or connections. Care shall be taken to avoid sudden changes of shape of a member or part of a member, especially in regions of tensile stress or local secondary bending.

- b. Loads and stresses to be considered. Allowance for fatigue shall be made for the combination of stresses due to dead loads, live loads and inertia forces as defined in Clause 3a(ii).

Stresses due to wind forces may be ignored in considering fatigue.

Elements of a structure may be subjected to a very large variety of stress cycles varying both in range (f_{min}/f_{max}) and in magnitude of maximum stress (f_{max}), where f_{min} is the minimum stress in the element during a particular stress cycle and f_{max} is the maximum stress in the element during the same stress cycle. To determine the range of f_{min}/f_{max} , the extreme conditions due to combinations of the loads described above which can occur in a single cycle of operation in actual service shall be used.

- c. Number of stress cycles. For calculation purposes, the number of stress cycles, N , for all members of the structure shall be as set out in Table 1.

NOTE. A more detailed treatment of stress spectrum is given in B.S. 153, 'Steel girder bridges', Part 3B, 'Stresses', which may be used subject to agreement between the purchaser and the manufacturer.

- d. Permissible working stresses. Table 3 sets out the permissible working stresses for fatigue for various values of f_{min}/f_{max} , for different numbers of stress cycles and classes of constructional details. This table covers mild and high tensile steels fabricated or connected by welding, riveting or bolting under seven classes of constructional details as described in Subclause e.

The value of the working stress, f_{max} , shall not exceed the maximum permissible tensile or compressive fatigue stress, p , as determined from Table 3. Where coexistent bending and shear stresses are present, the working stress referred to is the principal stress at the point under consideration.

- e. Classes of constructional details. In Table 3 (Class A to Class G) the values of permissible stresses are given separately for the classes of details stated below for steels to B.S. 15*, B.S. 2762† and B.S. 968‡. S S S 436 C

NOTE. Except where specifically stated to the contrary, the permissible fatigue stresses for any particular detail are the same for both mild and high tensile steel. However, where fatigue is not a criterion for design, the use of high tensile steels may be advantageous.

CLASS A.

- (i) Plain steel in the as rolled condition with no gas cut edges.
(ii) Members fabricated with continuous full penetration longitudinal or transverse butt welds with the reinforcement dressed flush with the plate surface

* B.S. 15, 'Mild steel for general structural purposes'.

† B.S. 2762, 'Notch ductile steel for general structural purposes'.

‡ B.S. 968, 'High yield stress (welding quality) structural steel'.

and the weld proved free from defects by non-destructive examination, provided also that the members do not have exposed gas cut edges.

Welds shall be dressed flush by machining or grinding, or both, which shall be finished in the direction parallel to the direction of the applied force.

CLASS B.

(i) Members fabricated with continuous longitudinal butt welds with full or partial penetration made with either a submerged or open arc automatic process but with no intermediate start-stop positions within the weld length.

(ii) Members fabricated with continuous longitudinal fillet welds made with either a submerged or open arc automatic process but with no intermediate start-stop positions within the weld length.

NOTE. If a 'stop' should accidentally occur in a weld which is supposed to be free of start-stop positions, the weld crater shall be chipped or machined back in the form of a taper over a length of at least eight times the weld size, and the weld shall then be re-started at the top of the tapered slope. On completion the surface of the weld at the start-stop position shall be ground smooth. The object of this procedure is to eliminate the possibility of lack of fusion or trapped slag at the weld root and a change of shape of longitudinal surface profile of the weld.

CLASS C

(i) Members fabricated with continuous longitudinal butt welds, including fabricated beams with full web penetration of the web to flange welds, with start-stop positions within the length of the weld.

(ii) Members of high tensile steel to B.S. 968 fabricated or connected with rivets or bolts.

CLASS D

(i) Members fabricated with full penetration transverse butt welds made in the shop by manual welding with electrodes other than deep penetration electrodes, provided that all runs are made in the downhill position and that there is no undercutting. This does not include welds made on a backing strip if the backing strip is left in position.

(ii) Members fabricated with full penetration transverse butt welds, other than above, and having the weld reinforcement dressed flush and with no undercutting.

(iii) Members with continuous longitudinal fillet welds with start-stop positions within the length of the weld.

(iv) Members of mild steel to B.S. 15 or B.S. 2762 fabricated or connected with rivets or bolts.

CLASS E

(i) Members fabricated with transverse butt welds, other than above, or with transverse butt welds made on a backing strip.

(ii) Members fabricated with full penetration cruciform butt welds (see Fig. 1).

CLASS F

(i) Members with T type full penetration butt welds (see Fig. 2).

(ii) Members with intermittent longitudinal or transverse non-load-carrying fillet or butt welds, except for those details covered in Class G below (see Fig. 2).

(iii) Members connected by transverse load-carrying fillet welds.

CLASS G

(i) Members connected by longitudinal load-carrying fillet welds (see Fig. 3a).

(ii) Members connected by load-carrying cruciform welds (see Fig. 3b).

(iii) Members with intermittent longitudinal non-load-carrying fillet or butt welded attachments on or adjacent to their edges (see Fig. 3c).

NOTE. In Classes F and G a weld is considered as load carrying with respect to the member under consideration if it transmits a major part of the load in that member.

f. Connections, riveted or bolted.

(i) *Connections made with rivets and bolts.* No allowance for fatigue shall normally be made in calculating the required number of rivets or bolts in a riveted or bolted connection except that all rivets or bolts subjected to reversal of stress shall be proportioned for the arithmetical sum of the load in the member corresponding to $f_{\max}$ plus 50 per cent of the load of opposite sign corresponding to $f_{\min}$.

(ii) *Connections made with friction grip bolts.* No allowance for fatigue shall normally be made in calculating the required number of bolts.

g. Load-carrying fillet welds (see Fig. 3).

These welds shall be designed such that the stress on the total effective throat area of fillet welds does not exceed the relevant figure given in Table 2 for Class G details.

Load carrying fillet welded joints shall be designed so that secondary bending stresses are not introduced (i.e. single lap joints may not be used).

For minimum sizes of fillet welds, see B.S. 1856, 'General requirements for the metal-arc welding of mild steel', or B.S. 2642, 'General requirements for the metal-arc welding of medium tensile weldable structural steel to B.S. 968'.

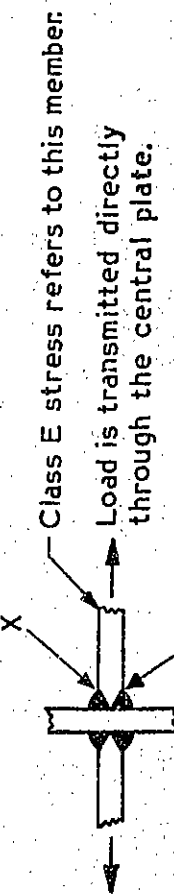


Fig. 1. Class E full penetration cruciform butt weld

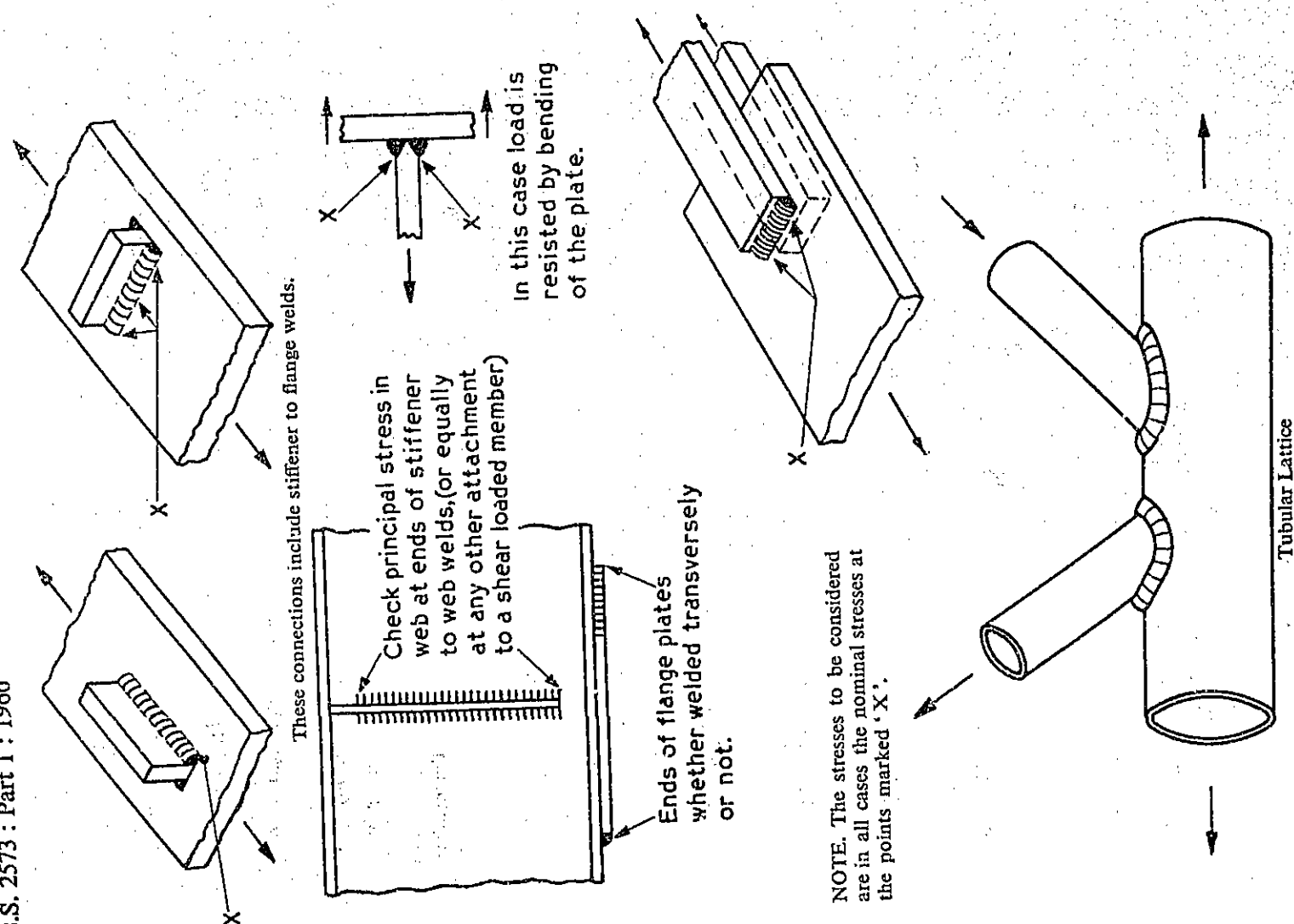


Fig. 2. Typical Class F weld details

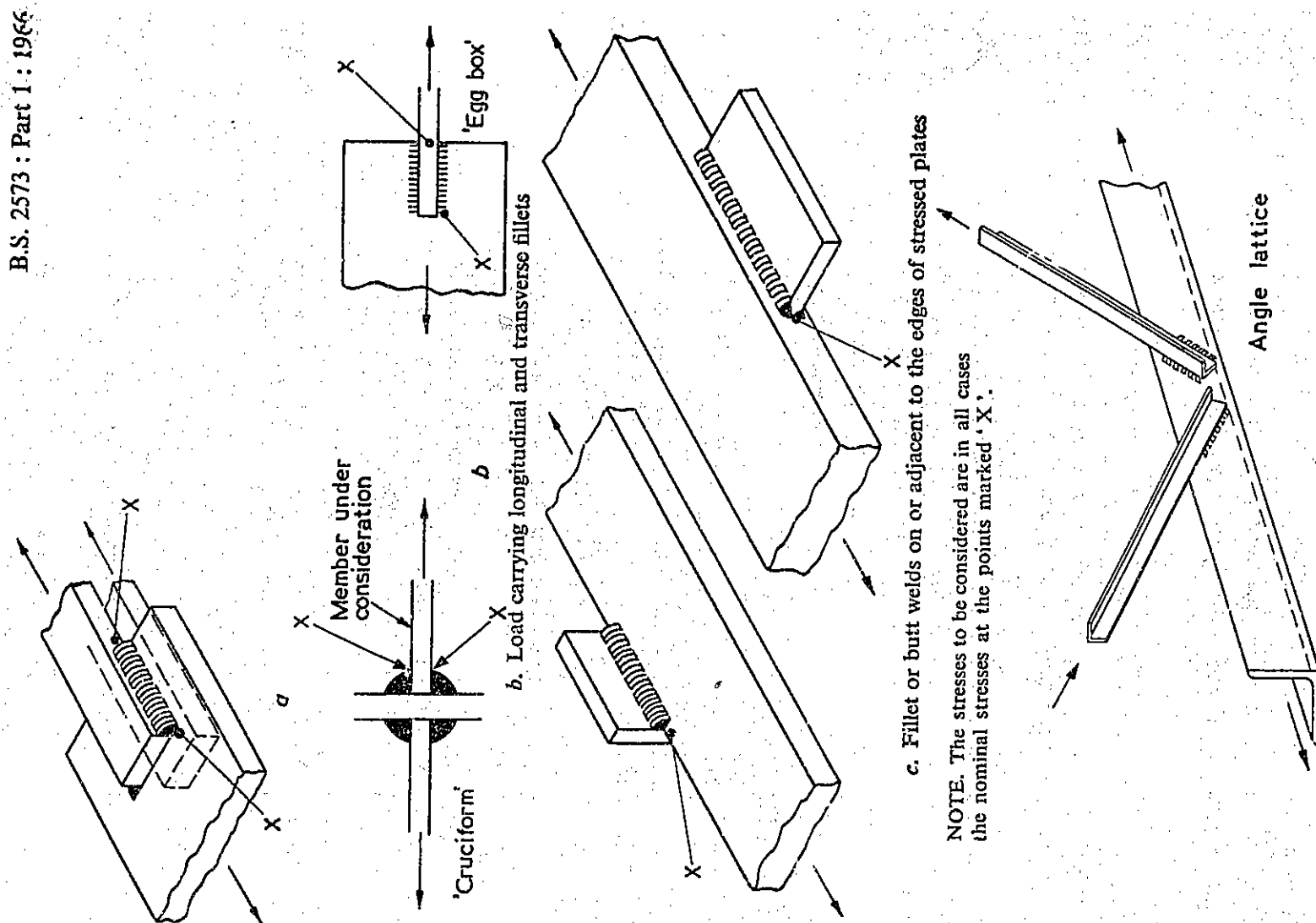


Fig. 3. Typical Class G weld details

WIND LOAD

8. The wind load on the structure shall be calculated according to the following formula:

$$W_L = c A_s W_p$$

where

W_L = wind load in lbf.

A_s = area in square feet, obtained by projecting a silhouette of the unloaded structure onto a plane normal to the direction of the wind.

c = shape coefficient:

for cabins, machinery houses and other plane surfaces = 1.0,
for latticed structures built of angles, joists, tees = 1.5,
for latticed structures built of tubes = 1.1.

W_p = wind pressure in lbf/ft².

= 0.0035 V^2 lbf/ft² where V = wind velocity in mile/h.

For cranes working in the United Kingdom, values of W_p shall be not less than those given below:

Height	Wind pressure W_p lbf/ft ²	
	In service (Clause 3a)	Out of service (Clause 3b)
Parts of crane under 100 ft from ground level	5	28
Parts of crane over 100 ft and under 200 ft from ground level	5	32
Parts of crane over 200 ft and under 300 ft from ground level	5	34

The out of service wind pressure on parts of a crane which are more than 300 ft above ground level shall be calculated from the formula:

$$W_{ph} = 34 \left(\frac{h}{300} \right)^{0.17}$$

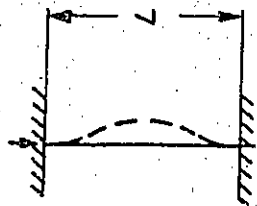
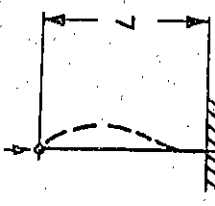
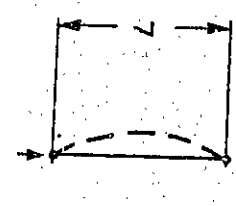
where

W_{ph} = the wind pressure in lbf/ft² at a height h ft above ground level.

An increased pressure may have to be allowed for situations outside the United Kingdom.

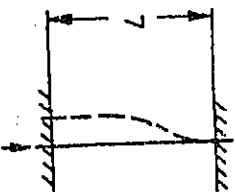
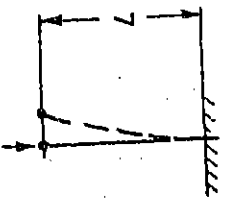
EFFECTIVE LENGTHS

9. a. Struts. For the purpose of calculating l/r for struts the following effective length (l) shall be taken:

Diagrammatic representation	Restraint conditions	Effective length, l
	Effectively held in position and restrained in direction at both ends	0.7L
	Effectively held in position at both ends and restrained in direction at one end	0.85L
	Effectively held in position at both ends but not restrained in direction	1.0L

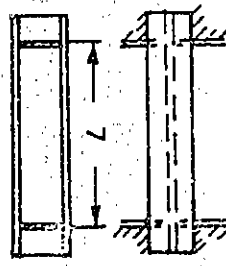
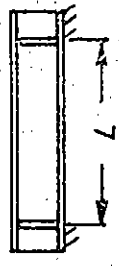
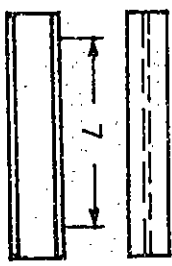
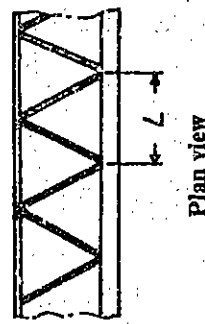
continued

9. a. Struts—continued.

Diagrammatic representation	Restraint conditions	Effective length, l
	Effectively held in position and restrained in direction at one end and at the other partially restrained in direction but not held in position	1.5L
	Effectively held in position and restrained in direction at one end but not held in position or restrained in direction at the other end	2.0L

For the effective length of a jib in plan see Appendix C.

b. Plate girders and rolled beams. The effective length (l) of the compression flange for buckling normal to the plane of the girder to be used in Clause 12 shall be as given below, except that, when the load is applied to the compression flange and both the load and the flange are free to move laterally, the values given shall be increased by 20 per cent.

Diagrammatic representation	Restraint conditions for flanges of plate girders	Effective length, l
(i) No lateral bracings between compression flanges. No cross frames.		
	With ends completely restrained against lateral bending and twisting of section	0.7L
	With ends partially restrained against lateral bending and twisting of section	0.85L
	With ends unrestrained against lateral bending and twisting of section	1.0L
(ii) Effective lateral bracing direct to compression flange.		
		1.0L