BRITISH STANDARD

BS 1761:1951

Specification for

Single bucket excavators of the crawler-mounted friction-driven type

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:—

Admiralty*
Air Ministry
Associated Offices Technical Committee*
Association of Consulting Engineers (Incorporated)*
British Chemical Plant Manufacturers' Association
British Compressed Air Society
British Electrical and Allied Manufacturers' Association*
British Engineers Association
British Internal Combustion Engine Manufacturers' Association
British Iron and Steel Federation*
British Railways, The Railway Executive*
Crown Agents for the Colonies*
Department of Scientific and Industrial Research
Engineering Equipment Users' Association
Institute of Marine Engineers
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Institution of Civil Engineers*
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Institution of Mechanical Engineers*
Institution of Mechanical Engineers (Automobile Division)
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Locomotive Manufacturers' Association
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Ministry of Supply*
Ministry of Transport*
Ministry of Works
Office of the High Commissioner for India
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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:—

Association of Crane Makers
Ballast, Sand and Allied Trades Association
British Constructional Steelwork Association
Cable Makers Association
Dock and Harbour Authorities Association
Engineering and Allied Employers National Federation
Excavator Manufacturers' Association
Federation of Civil Engineering Contractors
Institution of Engineering Inspection
Institution of Structural Engineers
Ministry of Agriculture and Fisheries
National Federation of Building Trades Employers

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 5 September 1951

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Amendments issued since publication

Amd. No.	Date	Comments

Contents

[1)] BS 1775, "*Steel tubes for mechanical, structural and general engineering purposes.*"

Foreword

This standard makes reference to the following British Standards:—

BS 7, *Rubber-insulated cables and flexible cords.*

BS 46, *Keys and keyways and coned shaft ends.*

BS 168, *Industrial electric motors and generators.*

BS 302, *Round strand steel wire ropes for cranes.*

BS 436, *Machine cut gears. A. Helical and straight spur.*

BS 545, *Machine cut gears. B. Bevel (with helical, curved and straight teeth).*

BS 591, *Wrought iron and mild steel hooks of the "C" or Liverpool type.*

BS 621, *Wire ropes of special construction for engineering purposes, inclusive of cranes, lifts and excavators.*

BS 649, *Internal combustion engines for stationary and industrial purposes and auxiliary purposes on shipboard, excluding carburettor-type engines.*

BS 693, *Oxy-acetylene welding in mild steel.*

BS 721, *Machine cut gears. C. Worm gearing.*

BS 765, *Internal combustion engines, carburettor-type, excluding aero-engines.*

BS 825, *Mild steel shackles for lifting purposes.*

BS 938, *Metal arc welding as applied to tubular steel structural members.*

BS 980, *Steel tubes for automobile purposes.*

BS 1083, *Precision hexagon bolts, screws, nuts (B.S.W. and B.S.F. threads) and plain washers.*

BS 1116, *Flexible trailing cables for quarries and metalliferous mines.*

BS 1775, *Steel tubes for mechanical, structural and general engineering purposes.*

BS 1856, *General requirements for the metal arc welding of mild steel.*

NOTE Attention is also drawn to the list of British Standards given in Appendix E.

The object of this specification is to secure the general observance of such fundamental principles as appear desirable to ensure reliability and safety without restricting the excavator manufacturer in his selection of the most appropriate design for the purpose in view. The specification gives the minimum requirements for single bucket excavators of the sizes enumerated.

It should be noted that the factor of safety for excavators is arrived at on a basis different from that used in the crane standards. In this case the factor is related to the maximum engine output and not to the maximum working load, and the use of the machine as a crane is limited by stability conditions.

The appendix dealing with the design of struts has been prepared to follow the general method of application of the Perry-Robertson formula adopted in other British Standards.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 44 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 Scope

This British Standard applies to single bucket excavators of all sizes up to $2^1/_2$ cu. yd. bucket capacity, in which the various motions are controlled through friction clutches from a single power unit.

The shovel capacity ratings, in cubic yards, of the excavators covered by this standard are as follows:—

$^1/_4$, $^3/_8$, $^1/_2$, $^5/_8$, $^3/_4$, 1, $1^1/_4$, $1^1/_2$, $1^3/_4$, 2 and $2^1/_2$ cu. yd.

The types of equipment dealt with are as shown in Figure 1–Figure 7.

2 Definitions

2.1
face shovel

an excavator with the type of "front end" equipment shown in Figure 11, p. 19

2.2
dragline

an excavator with the type of "front end" equipment shown in Figure 12, p. 21

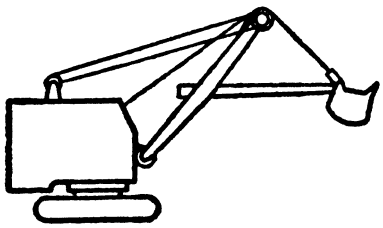


Figure 1 — Face shovel

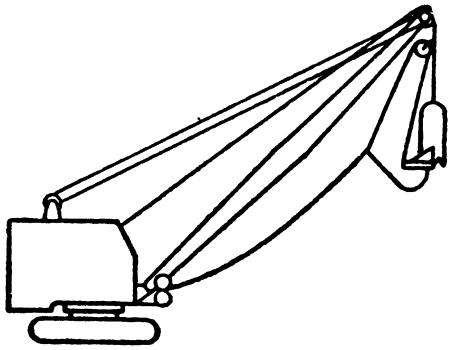


Figure 2 — Dragline

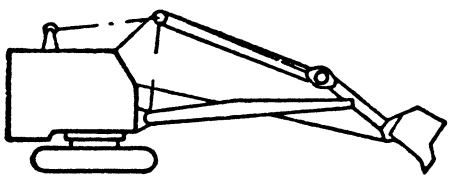


Figure 3 — Drag shovel

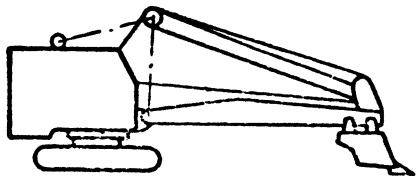


Figure 4 — Skimmer

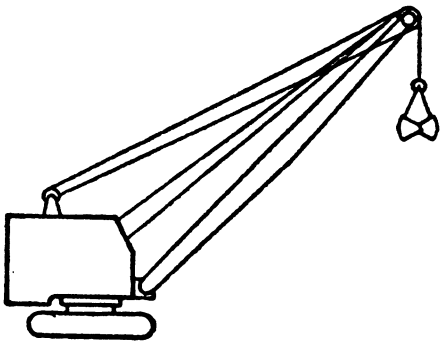


Figure 5 — Grabbing crane

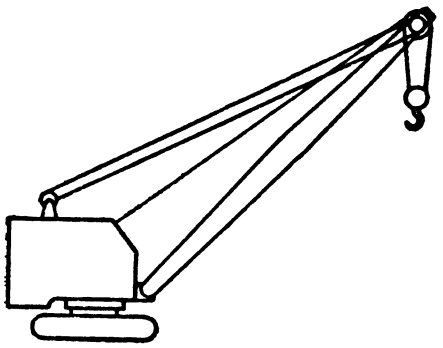


Figure 6 — Crane

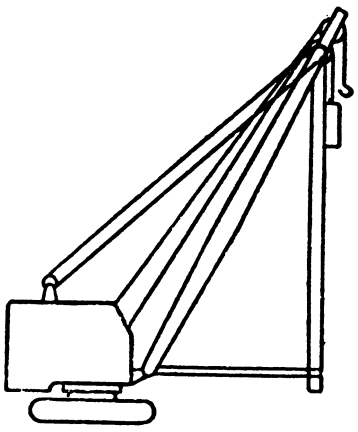


Figure 7 — Pile driver

2.3
drag shovel

an excavator with the type of "front end" equipment shown in Figure 13, p. 23, usually employed for trench cutting

2.4
skimmer

an excavator with the type of "front end" equipment shown in Figure 14, p. 25

2.5
grabbing crane

a machine with the type of "front end" equipment shown in Figure 15, p. 27, and operated by one or two ropes

2.6
lifting crane

a machine of the type shown in Figure 16, p. 29, operated by a single or multi-part rope

2.7
pile driver

an excavator with the type of "front end" equipment shown in Figure 17, p. 31

2.8
crawlers

the self-laying tracks and associated mechanisms assembled in frames as units

2.9
governed engine speed

the speed at which an engine operates to give full load for a particular governor setting

2.10
single rope pull

the pull at the mean rope centres on the drum, calculated from the horse power available, as defined in Clause **6** a)

2.11
rope speed

the speed in feet per minute of a single rope as defined above

2.12
working radius

the horizontal distance measured from the axis of rotation of the machine to a vertical line through the centre of gravity of the suspended load, when the machine is standing on a level surface

2.13
"front end" equipment

all fittings and attachments from, and including, the jib or boom footpin(s), together with any extra fittings that may be required on the revolving frame to operate such equipment

2.14
jib or boom

the main member of the "front end" equipment extending from the pins or sockets provided on the rotating frame

2.15
jib or boom length

the axial distance between the centres of the footpin(s) and the hoist or head pulleys

2.16
jib or boom angle (α)

the angle between the horizontal line and the straight line drawn between the centres of the boom socket or boom footpin and the centres of the hoist or head pulley pin

2.17
bucket

the digging and carrying part of the excavator

2.18
shovel crowding and retracting

the act of moving the bucket and the bucket arm outwards and inwards

2.19
shovel bail

the member sometimes used to attach the bail block or hoisting rope to the bucket (see Figure 11, p. 19)

2.20
bail block

the sheave and its housing by which the hoisting rope is connected to the bucket either directly or through a bail

2.21
rated capacity of bucket

the "struck" capacity, without taking into account any material adhering to the projecting parts of the teeth

for dragline buckets, see Appendix G

3 Information to be supplied with inquiry or order

All information regarding the conditions under which the machine is to be used, together with the particulars given in Appendix A, so far as they apply, should be supplied with the inquiry or order.

4 Information to be supplied by the manufacturer

The manufacturer shall supply with the tender the information enumerated in Appendix B.

5 Compliance with statutory requirements

The purchaser shall, at the time of the inquiry or order, disclose to the manufacturer any statutory requirements to which the machine will be subject when in use and which are intended to ensure its safe working, and the machine shall be so constructed as to comply with these requirements.

A list of statutory provisions affecting excavators and cranes to be operated in Great Britain is given in Appendix C.

6 Power unit

a) *Engine H.P.* The engine horse power shall be the brake horse power that can be carried for one hour at the rated governed speed provided that this output does not exceed 110 per cent of the 12-hour rated working load as defined in BS 649, "*Reciprocating internal combustion engines for marine auxiliary and land service (excluding carburettor type),*" or BS 765, "*Internal combustion engines, carburettor type, excluding aeroengines.*" If the engine is required to work under tropical conditions this shall be stated by the purchaser at the time of the inquiry or order.

It is recommended that starters should be fitted to power units of 30 h.p. and over.

b) *Electric motor.* When an electric motor is fitted it shall have a maximum torque (assuming equal prime mover speeds) of about 5 per cent above the engine maximum torque, provision being made for the peak load voltage drop normally met in practice on excavator installations. Any motor fitted shall comply with BS 168, "*Industrial electric motors and generators.*"

7 Service conditions

a) *Excavator*. The machine, when equipped as an excavator, shall be deemed to be working under service conditions when it is:

i) Performing a working cycle, namely:

A. digging with maximum effort without stalling the power unit.

B. hoisting and slewing simultaneously to the dump position.

C. returning to the digging position.

ii) Travelling limited distances, including frequent steering (see Clauses **26** and **27**).

b) *Crane*. The machine, when equipped as a crane, shall be deemed to be working under service conditions when it is handling any load up to the safe working load, under the following conditions:—

i) Performing a working cycle, namely:

A. hoisting or lowering the load or the jib.

B. hoisting and slewing simultaneously to the unloading position.

C. returning to the lifting position.

ii) Travelling limited distances with the load, and on reasonably level ground, including frequent steering (see Clauses **26** and **27**).

8 Materials

The materials used in the construction of the machine shall comply with the requirements specified in the appropriate British Standards enumerated in Appendix E, or shall possess qualities equivalent to those possessed by materials complying with such British Standards.

9 Factor of safety

The machine shall be so designed and constructed that when it is working under service conditions (see Clause **7**) the stress in any part shall not exceed the lowest ultimate tensile stress of the material divided by the specified factor.

The factor of safety for all parts of the machine shall be not less than 4 for steel and not less than 6 for cast iron, except when a maximum allowable working stress is hereinafter specified.

10 “Front end” equipment

The machine shall be so constructed as to permit the mounting and efficient working of face shovel, dragline, grab, crane, or pile-driving equipment and, where practicable, skimmer or drag shovel equipment.

11 Standard jib length

For machines having a rated capacity as indicated below, the standard length of dragline or crane jib shall be as follows:—

Rated shovel bucket capacity	Standard length of dragline or crane jib
cu. yd.	ft.
1/4	25
3/8	28
1/2	40
5/8	40
3/4	40
1	45
1 1/4	45
1 1/2	45
1 3/4	50
2	55
2 1/2	60

NOTE Other lengths, within title limits of stability (Clauses **14** and **15**) may be supplied if required by the purchaser. It is recommended, however, that whatever length of jib it is intended to employ, the duties should be such that the angle of the jib may approach but not exceed 75° to the horizontal when the machine is stationary.

12 Crawler bearing length

The length of the crawler bearing on the ground shall be computed as follows:—

Centre distance of sprocket and end idler roller plus the pitch dimension of one track link.

13 Face shovel working range

The normal working ranges and dimensions of face shovels (Figure 11, p. 19) shall be those appropriate to a jib angle, α, of 45°.

14 Forward stability

a) *Tipping load.* The tipping load is the load which brings the machine, when it is standing on hard level ground with the jib in any position, to the point of tipping. For this purpose the tread belts shall not be tight, so that at the moment of tipping the tread rollers lift from the upper side of the tread belt in contact with the ground.

b) *Stability*

i) *General.* The stability of a machine shall comply with the requirements of sub-clauses ii) to vi) appropriate to the type of front end equipment fitted and for this purpose the machine shall be in working order (with the cooling system full and the main fuel tank half-full) and standing on hard level ground.

ii) *When equipped as a crane or dragline.* The stability shall be defined in terms of the safe working load and shall be determined according to the following formulae. The value obtained with Formula No. 1 shall not exceed 66⅔ per cent and the value obtained with Formula No. 2 shall be not less than 50 per cent.

For grabbing crane duties the safe working load shall be taken as 85 per cent of the value found by Formula No. 1 or 75 per cent of the value found by Formula No. 2. In this case, the safe working load is the combined weight of the grab and contents.

For dragline duties the safe working load is the combined weight of the bucket and spoil.

Formula No. 1.

$$\frac{100}{1+\frac{0.01\times R\times F}{B}} = \text{safe working load expressed as percentage of tipping load.}$$

where R = Radius at which load is lifted, in feet.

F = Coefficient as per values given in the following table.

B = Smaller side of rectangle forming base; this rectangle being formed by the centre-to-centre distance of the driving sprockets and the tensioning rollers as the other.

Formula No. 2.

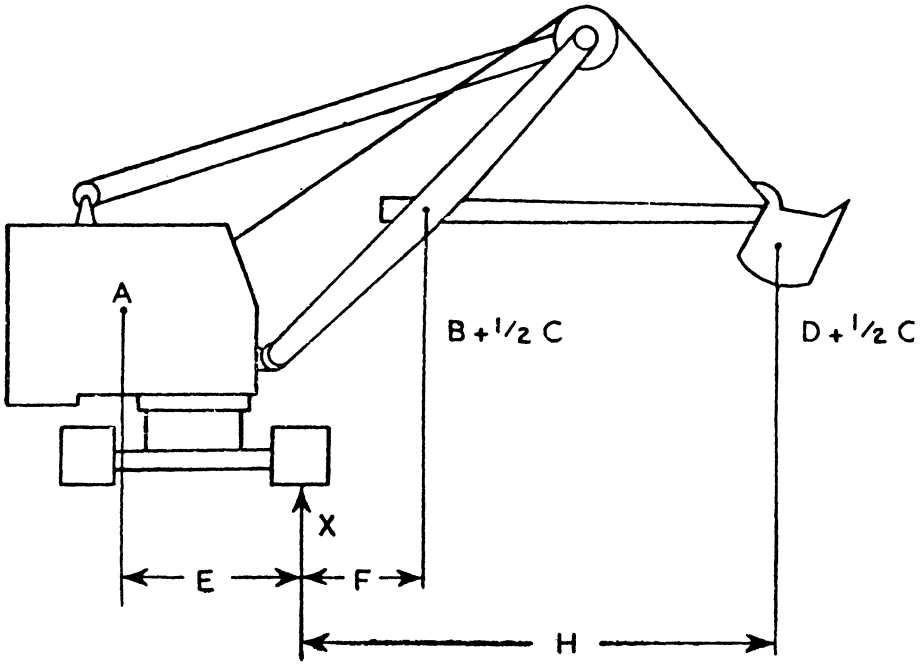
$$\frac{R\times F}{B} = \text{percentage of safe working load to be added to bring machine to the point of tipping.}$$

where R, F and B are as defined for Formula No. 1.

Dimension "B"	Coefficient "F"
ft.	
10 or more	11.1
9	11.2
8	11.5
7	11.9
5.5	12.8
4.75	13.4
3.5 or less	14.7

NOTE When Formula No. 1 is used, the safe working load will be a percentage of the tipping load. When Formula No. 2 is used, the result will show the percentage of the safe working load which is to be added to the safe working load to give the tipping load.

iii) *When equipped as a face shovel.* The stability shall be determined according to the following formula and the stability value so obtained shall not exceed 56 per cent.

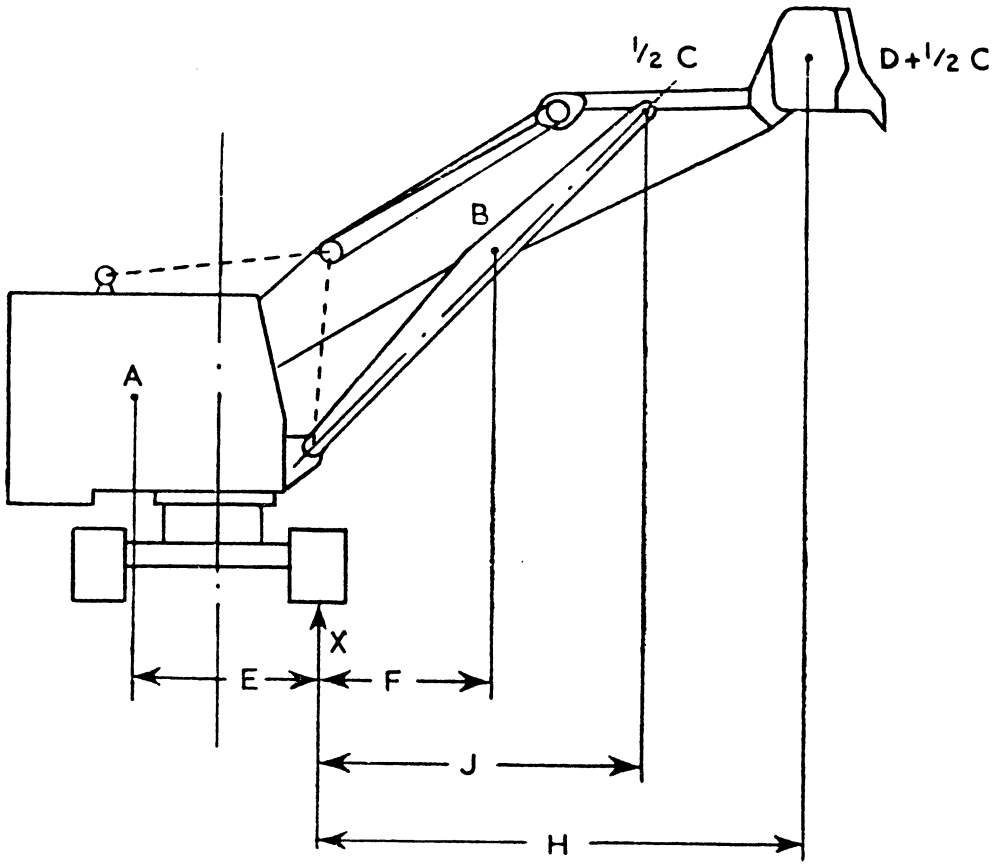


A = total weight less B, C and D.
B = weight of boom, boom machinery, saddle block and the weight of the ropes.
C = weight of bucket arm.
D = weight of bucket, bail block and spoil.
X = fulcrum point.
Backward moment = (A × E) – [(B + ½ C) × F].
Forward moment = (D + ½ C) × H.

$$\text{Stability per cent} = \frac{(D + \tfrac{1}{2}C)\,H}{(A \times E) - [(8 + \tfrac{1}{2}\,C) \times F]} \times 100.$$

Figure 8

iv) *When equipped as a drag shovel.* The stability shall be determined according to the following formula and the stability value so obtained shall not exceed 56 per cent.



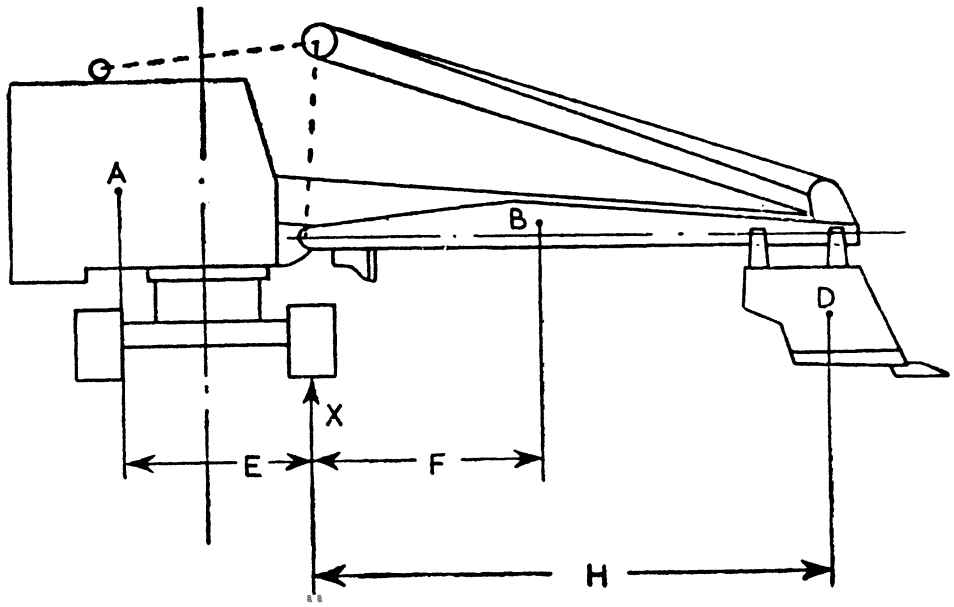
A = total weight (bare machine).
B = weight of boom, boom machinery and half weight of the ropes.
C = weight of bucket arm.
D = weight of bucket, bail block and spoil.
Backward moment (machine less load) = (A × E) – (B × F).
Forward moment (due to load, spoil, bucket and handle) = [(D + ½ C) × H + (½ C × J).

$$\text{Stability per cent} = \frac{[(D + \tfrac{1}{2}C) \times H]}{[(A \times E) - (B \times F) + (\tfrac{1}{2}C \times J)} \times 100$$

NOTE The condition of maximum stability is normally obtained with the boom and bucket arm approximately horizontal.

Figure 9

v) *When equipped as a skimmer*. The stability shall be determined according to the following formula and the stability value so obtained shall not exceed 56 per cent.



A = total weight (bare machine).
B = weight of boom, boom machinery and half weight of the ropes.
D = weight of bucket and spoil.
X = fulcrum point across crawler.
Backward moment (machine less load) = (A × E) – (B × F).
Forward moment (due to load, spoil and bucket) = D × H.

$$\text{Stability per cent} = \frac{D \times H}{(A \times E) - (B \times F)} \times 100$$

Figure 10

vi) *When equipped as a pile driver*. When lifting the pile and the hammer, and taking account of the full weight of the leaders, the stability shall be equivalent to that specified for the normal crane stability rating.

15 Backward stability

To ensure adequate backward stability of the machine when used as a crane, dragline, or for grabbing duties, the centre of gravity of the machine, shall be not farther from the axis of rotation than 70 per cent of the minimum radial distance from the axis of rotation to the backward tipping fulcrum. For this purpose the machine shall be resting on hard level ground, in working order (i.e. with the cooling system full and the main fuel tank half-full) without load, and with the jib at its minimum working radius.

16 Lifting capacity and load indicator

In determining the load that can be lifted at any given radius or in determining the radius at which a given load can be lifted, slings, equalizer beams, and all similarly used auxiliary load-handling devices, shall be considered as part of the load.

The excavator, when fitted with a crane jib, shall bear a legible and permanent inscription stating the length of jib, the safe working loads, the maximum grab or dragline loads, and the appropriate radii.

A clear record of the working radii and of the safe working load at those radii shall be given by means of an indicator which shall be visible to the driver, and also from ground level.

When required by the purchaser an automatic safe load indicator of an approved type shall be fitted.

17 Slewing

The acceleration of the superstructure, measured at the extremity of the jib or boom at its maximum radius, shall not exceed 4 ft/sec/sec. and the retardation of the superstructure, measured at the same point, shall not exceed 8 ft/sec/sec.

18 Structure

The structure shall be so designed as to withstand all the stresses arising under service conditions, including the following:—

a) The bending and shear stresses caused by slewing the boom in either direction with an acceleration of 4 ft/sec/sec. and a retardation of 8 ft/sec/sec. measured at the boom point.

b) A horizontal force, acting in either direction along the axis of the boom point pin, equal to a quarter of the maximum rated load, as an allowance for the inertia of the load during slewing.

The jib or boom feet and the members by which they are connected to the revolving bedplate shall be of steel.

Diaphragm braces shall be provided to stiffen the jib and to ensure safe transport.

19 Struts, including jibs

The slenderness ratio l/k for any strut shall be obtained by dividing the *effective* length[2)] of the strut, in inches, by the minimum radius of the gyration, in inches, of any cross-section within the middle third of the length.

The slenderness ratio l/k of struts entirely of lattice construction shall not exceed 80.

Where a strut consists of two channels or plated sections connected by latticing, the ratio l/k shall not exceed 100 in the lattice direction. For jibs of box or solid construction the ratio l/k shall not exceed 100.

For bracings the ratio l/k shall not exceed 180.

The latticing and plating of a strut member shall be so proportioned as to resist the maximum transverse shear at any cross-section. This shear shall be assumed to be divided equally between the planes of bracing concerned, but the value allowed for transverse shear in the direction of each axis of the strut as a whole shall in no case be less than $2^1/_2$ per cent of the maximum axial load under service conditions, plus the shear at such planes of bracing due to simultaneous transverse loads on the member.

Struts shall be so designed as to comply with the provisions of Appendix F.

20 Working stress in finished precision bolts and set screws used in the excavator structure and machinery

The calculated shearing and bearing stresses of bolts shall not exceed those set out in Appendix D for bolts complying with BS 1083, "*Precision hexagon bolts, screws, nuts (B.S.W. and B.S.F. threads) and plain washers*." Black bolts shall not be used in the main structure of the excavator.

21 Working stresses in rivets used in the structure

The calculated shearing and bearing stresses of rivets shall not exceed those given in Appendix D.

22 Rotating rollers

The superstructure shall rotate upon a ring of live rollers, or rollers with fixed axles, or rollers with moving axles.

The load on the rollers shall not exceed the value obtained from the following formula:—

$$L = 6B \times c \times d$$

where B = lesser Brinell hardness number of the surfaces in contact.
c = width of roller (inches).
d = mean diameter of roller (inches).
L = load (pounds).

[2)] This is also known as the "equivalent length."

23 Mats

When mats are required by the purchaser, the drawings shall be provided by the manufacturer. If the mats are made of timber they shall be not less than 6 in. in thickness.

Adequate provision shall be made for lifting and laying the mats.

24 Splices

The strength of splices in a steel structural member shall be not less than the strength of the member. Where bolts are used they shall be turned and fitted into drilled or reamered holes.

25 Welding

It shall be permissible to use fusion welding as a method of construction provided the welding of steel tubes is in accordance with BS 938, "*Metal arc welding as applied to tubular steel structural members*" and the welding of other members is in accordance with either BS 693, "*Oxy-acetylene welding in mild steel,*" or BS 1856, "*General requirements for the metal arc welding of mild steel.*" The maximum permissible stresses shall not exceed the following:—

Nature of stress and weld	Maximum permissible stress
	tons/sq. in.
Tensile and compressive stress in butt welds	5.6
Shear stress in butt welds	3.5
Stress in end fillet welds in lap joints	4.9
Stress in all other fillet welds	3.5

26 Travelling on a gradient

The machine, when fully equipped and unloaded, shall be capable of travelling backwards or forwards on a gradient of 1 in 4 on reasonably smooth, firm and dry ground.

27 Steering

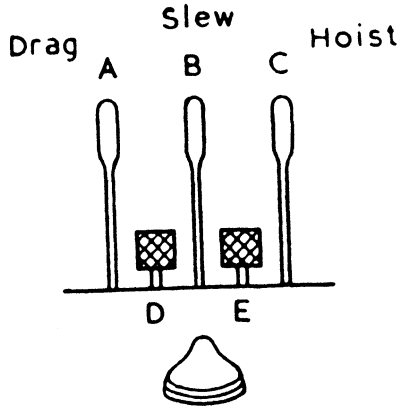
The machine shall be capable of being steered either to the left or to the right when travelling under service conditions in either direction and on reasonably level ground.

28 Controls

Controlling hand levers and pedals shall be placed in positions that will allow the driver ample room for operation and control and a good view of his work. Complete control of the travelling and steering functions shall be from the operator's position in the cab. The total travel of the handles of main control levers shall be not greater than 18 in. for a lever working in one direction and not greater than 9 in. on either side of the neutral position for two-way levers.

Table 1 — Controls

NOTE This arrangement of controls applies both for left-hand and right-hand drives.



Lever	Positive crowd shovel		Dragline		Skimmer		Drag shovel		Crane		Grabbing crane	
	Direction	Motion	Direction	Motion	Direction	Motion	Direction	Motion	Direction	Motion	Direction	Motion
A	Push	Crowd	Pull	Drag	Push	Skim	Pull	Drag	—	—	Push	Hoist and close
	Pull	Retract										
B	Push	Slew left	Push	Slew left	Push	Slew left	Push	Slew left	Push	Slew left	Push	Slew left
	Pull	Slew right	Pull	Slew right	Pull	Slew right	Pull	Slew right	Pull	Slew right	Pull	Slew right
C	Pull	Hoist	Pull	Hoist	Pull	Raise boom	Pull	Raise boom	Pull	Hoist	—	—
D	Depress	Crowd brake	Depress	Drag brake	Depress	Bucket brake	Depress	Bucket brake	—	—	Depress	Hoist and close
E	Depress	Hoist brake	Depress	Hoist brake	Depress	Boom brake	Depress	Boom brake	Depress	Hoist brake	Depress	Hold and lower

The travel of pedals shall not exceed 9 in.

The relative positions and movements of the main control levers shall be in accordance with Table 1 on page 13.

Where practicable, each control shall be provided with a suitable locking device to prevent accidental movement of the control, unless it is so placed or constructed that accidental movement is impossible.

Each lever or pedal shall bear a suitable identification letter, and a chart similar to that shown in Table 1 shall be displayed in the operating cab.

29 Guarding

Effective guards shall be provided for gear wheels, chain drives and revolving shafts, couplings, collars and set screws, or similar moving parts, unless those parts are made safe by design or by position, or are effectively guarded by parts of the excavator structure.

NOTE In Appendix C reference is made to statutory obligations under Section 17 of the Factories Act, 1937, and under Regulation 86 of the Building (Safety, Health and Welfare) Regulations, 1948, relative to the construction and sale of new machinery. This Appendix also enumerates the sections of the Factories Act, 1937, and statutory provisions made thereunder, which affect the construction and use of excavators covered by this British Standard.

a) *Design. Fixed guards.* The guards may be of sheet metal, perforated or expanded metal, wire mesh, wood, pressed fibre or other material as may be deemed most suitable, and should completely encase the parts concerned. The guards shall be suitably designed to allow for routine inspection and maintenance work.

The guards shall be substantially constructed of material suitable to withstand the atmospheric conditions in the situation in which the guards are to be used, and shall be sufficiently rigid to resist distortion.

The guards shall be securely attached to fixed supports.

b) *Thickness.* The thickness of metal guards shall be not less than 18 S.W.G. (0.048 in.), and the thickness of wooden guards shall be not less than $^3/_4$ in.

NOTE An increased thickness, or the use of corrosion resisting material, is desirable in damp and corrosive atmospheres.

c) *Size of opening and clearance.* The minimum clearance between the guards and the moving parts and the size of opening in guards of perforated metal, woven wire, metal lattice or similar material, shall be in accordance with the following requirements:—

Size of opening	Minimum clearance
in.	in.
Not exceeding $^3/_8$	$^7/_8$
Over $^3/_8$ up to and including $^1/_2$	2
Over $^1/_2$ up to and including $1^1/_4$	4
Over $1^1/_4$ up to and including $1^1/_2$	5

NOTE Size of opening means the greatest dimensions of the opening, except in the case of slotted material, when the length of the slot may be disregarded if the width of the slot does not exceed $^1/_2$ in.

30 Travelling and slewing

A travelling lock or self-sustaining brake and a slewing lock shall be fitted.

31 Rotating and fixed shafts and axles

Shafts and axles shall have ample rigidity and adequate bearing surfaces for their purpose. They shall where necessary be finished smoothly, and when shouldered shall be provided with generous fillets.

32 Keys, keyways and splines

Keys and keyways shall be in accordance with BS 46-1, "*Keys and keyways and coned shaft ends,*" and the bottom corners of keyways may be rounded. Splines shall be accurately machined.

33 Gearing and pawls

Machine cut gears shall, as far as is practicable, be in accordance with the following British Standards:—

BS 436, *Machine cut gears. A. Helical and straight spur. Class C, Commercial cut gears.*

BS 545, *Bevel gears (machine cut).*

BS 721, *Machine cut gears. Worm gearing. Class C, Commercial cut gears.*

a) Gearing and pawls shall be of steel, with the following exceptions:—

i) Pinions may be of compressed fabric, or of bronze.

ii) Worm wheels may be made with cast iron or steel centres and bronze rims.

iii) Worms, when meshing with steel wheels, may be of bronze.

b) Keys in gear trains shall be so locked that they cannot work loose.

c) Where worm gearing is used as a first motion drive it shall, under test, have the same load and time rating as the driving motor, and the maximum temperature rise of the oil bath when measured by thermometer shall not exceed 100 °F. (56 °C.) above the atmospheric temperature.

34 Driving clutches and brakes

Driving clutches and brakes on both main drums shall be so designed that they exert a torque not less than the maximum torque which can be applied from the prime mover when developing its full load (see Clause **6**). The stresses in any part of the brake and clutch construction while such torque is being exerted shall not exceed those laid down in Clause **9**. Brake weights, where used, shall be firmly bolted to their levers.

The wearing surfaces of all brake and clutch drums shall be machined and shall be cylindrical, smooth, concentric and free from defects. Brake and friction clutch linings shall be protected from the ingress of water and oil. They shall be effectively secured, and due allowance shall be made for reasonable wear. There shall be adequate clearance between all parts of brake levers and other parts of the machine to ensure full application of each brake, when properly adjusted and with brake linings and actuating parts not unduly worn.

Brakes and friction clutches shall be provided with a simple and easily accessible device to compensate for the wear of the linings.

The operating effort for clutches or brakes shall not exceed 30 lb. for hand operation and 60 lb. for foot operation.

An independent lock of the progressive ratchet type shall be provided for the controls of each drum brake.

A positive lock shall be fitted to the boom hoist; it shall be automatically operated by the pulling in or pulling out of the clutch actuating the boom hoist, unless the boom hoist is of the worm drive type, in which case a friction brake shall be fitted.

The reversing clutches for the travelling and slewing motions shall be capable of transmitting the full power of the prime mover (see Clause **6**).

35 Wire ropes

Unless otherwise specified by the purchaser, ropes shall be in accordance with BS 302, "*Round strand steel wire ropes for cranes,*" or BS 621, "*Wire ropes of special construction for engineering purposes, inclusive of cranes, lifts and excavators,*" but rope of 6 × 61 construction shall not be used.

The guaranteed breaking load of the boom hoist ropes for cranes and grabbing cranes shall be not less than six times the maximum working load (Factor of safety = 6). For grabbing cranes the load on the rope shall be assumed to be the weight of the grab and its contents.

For excavators used as draglines, the factor of safety shall be not less than six for the hoist and boom hoist ropes, assuming the full bucket to be suspended at the boom point. The factor of safety for the drag rope shall be taken as not less than 3, calculated on the maximum horse power being applied to this motion.

For excavators used as shovels, skimmers and drag shovels, all ropes shall have a factor of safety of not less than 4, calculated on the maximum horse power being applied to the particular motion.

36 Rope drums

The sizes of drums shall, wherever practicable, be in accordance with the following values:—

Type of rope	Minimum drum or pulley diameters at the bottom of the rope groove. C = circumference of rope D = diameter of rope	
4 × 37	8.5C	27D
6 × 19 6 × 19 Scale, with independent wire rope core. 17 × 7 6 × 25 flattened strand	7.5C	23.5D
6 × 24	7.0C	22.0D
6 × 37 34 × 7	6.0C	19.0D

Drums with diameters less than 80 per cent of the diameters tabulated above shall not, under any circumstances, be employed; but the sizes given above may, with advantage, be increased.

Drums shall be flanged at both ends. When the rope is fully wound on the drum the flanges shall project a distance of not less than approximately two rope diameters. Rope anchorages shall be readily accessible.

If drum lagging is required, or provided, so that the rope speed on the barrels can be altered, a list of these linings and the appropriate speeds shall be fixed on the inside of the driving cab for the information of the operator.

37 Rope pulleys

When practicable, the diameters of pulleys at the bottom of a groove shall be not less than those specified for drums in the preceding clause.

Pulleys carrying ropes that are periodically unloaded shall be provided with guards to retain the ropes in the grooves, and guide pulleys or rollers shall be fitted on the boom and other parts of the structure, where required, for the purpose of preventing chafing of the ropes.

38 Pulley and drum grooves

The bottom of the groove of the pulley supporting the rope shall be a true arc of a circle for a distance equal to one-third of the circumference of the rope, and the radius of the groove shall be larger than the radius of the rope by not less than the following amounts:—

Circumference of rope	Increase of groove radius
in.	in.
2 and under	$^1/_{32}$
$2^1/_8 - 2^3/_4$	$^3/_{64}$
$3 \quad - 3^1/_2$	$^1/_{16}$
$3^3/_4$ and over	$^3/_{32}$

The pulley shall be grooved to a depth equal to one and a half times the diameter of the rope and the groove shall be smoothly finished.

The angle of the flare of the sides of the pulley grooves shall be 52°.

Drum grooves, where provided, shall be smooth finished, and the edges shall be well rounded.

39 Angle of lead

For grooved drums and pulleys the angle of lead shall not exceed 5° (1 in 12).

For plain drums the angle of lead shall be reduced.

The use of overlapping ropes for ordinary service is not recommended.

40 Lifting hooks

Hooks shall be in accordance with BS 482, "*Wrought iron and mild steel hooks,*" and shall rotate upon ball or roller bearings. Alternatively, hooks shall be in accordance with BS 591, "*Wrought iron and mild steel hooks of the "C" or Liverpool type.*" They may be fitted with safety attachments when required.

41 Shackles

Shackles, when fitted to excavators used as cranes, shall be in accordance with BS 825, "*Mild steel shackles for lifting purposes.*"

42 Lubrication

Provision shall be made for the lubrication of bearings, including ball and roller bearings. All lubricating nipples shall be readily accessible.

Ball and roller bearings shall be packed with grease during initial assembly.

NOTE A range of lubricating nipples is quoted in BS 1486-1, "*Lubricating nipples and adaptors.*"

43 Electrical cables for power circuits

Cables shall comply with statutory requirements and with BS 7, "*Rubber-insulated cables and flexible cords.*" Cables smaller than 7/029 shall not be used for the mains to the motors.

The current in any cable under service conditions shall not exceed the current rating specified in the I.E.E. Regulations[3)] for the type of cable and the conditions of installation adopted.

All cables shall be adequately protected against mechanical damage.

When cables and wires are drawn into a metal conduit, the conduit shall be of heavy gauge welded or solid-drawn metal tube or flexible metallic tubing, and shall be screw-jointed or solder-jointed. The conduit shall preferably be sealed to prevent ingress of air and moisture; alternatively, it shall be drained.

The protection provided for cables against mechanical injury shall comply with statutory regulations where applicable.

Trailing cables shall comply with the requirements of BS 1116, "*Flexible trailing cables for quarries and metalliferous mines.*"

44 Instruction book

A book giving adequate instructions for the operation of the machine and the changing of the equipment shall be provided, and it is recommended that a chart or charts summarizing the information essential to the safe driving and operation of the machine should be attached to the inside wall of the cab.

A list of spare parts shall be provided with each machine.

45 Driver's cab

The cab or house shall be completely enclosed and shall give adequate protection to the engine, machinery and operator. Provision shall be made for access to the machinery and for an uninterrupted view of digging and lifting operations.

The operator shall have a view to both sides of the cab.

[3)] These are the Regulations for the Electrical Equipment of Buildings issued by the Institution of Electrical Engineers.

46 Testing

Before being put into service the machine shall be tested under service conditions (see Clause **7**).

For the purpose of this clause the machine shall be deemed to be fulfilling the requirements of Clause **7** a) i) when it is performing the digging cycle with a load in the bucket; for this purpose, the rated capacity of the bucket shall be assessed at 25 per cent in excess of 1.35 tons per cu. yd.

For cranes, grabbing cranes and dragline excavators the safe working load shall be in accordance with the provision of Clause **14** b), but the test load shall be 25 per cent in excess of the ordinary crane rating.

If required by the purchaser, a machine fitted with one of the following types of front-end equipment may be subjected to a digging test:—

Dragline

Face shovel

Drag shovel

Skimmer

Grabbing crane

This requirement shall be specified at the time of the enquiry or order.

The manufacturer shall be at liberty to employ his own driver to drive the machine under test.

47 Painting

Where two surfaces will be in permanent contact, each shall receive, after being thoroughly scraped and cleaned and immediately before being assembled, one coat of red lead, the surfaces being brought together while still wet.

This requirement does not apply to welded connections.

Two coats of paint shall be applied to all structural parts of the machines before they leave the manufacturer's works. Painting shall be carried out after thoroughly scraping and cleaning and when the surface of the metal is dry.

48 Identification

For the purposes of identification, machines as supplied shall bear the manufacturer's name and serial number. In addition, each separate item of "front-end" equipment shall bear the manufacturer's serial number.

It is recommended that the identification plate should be visible from the outside of the machine at ground level.

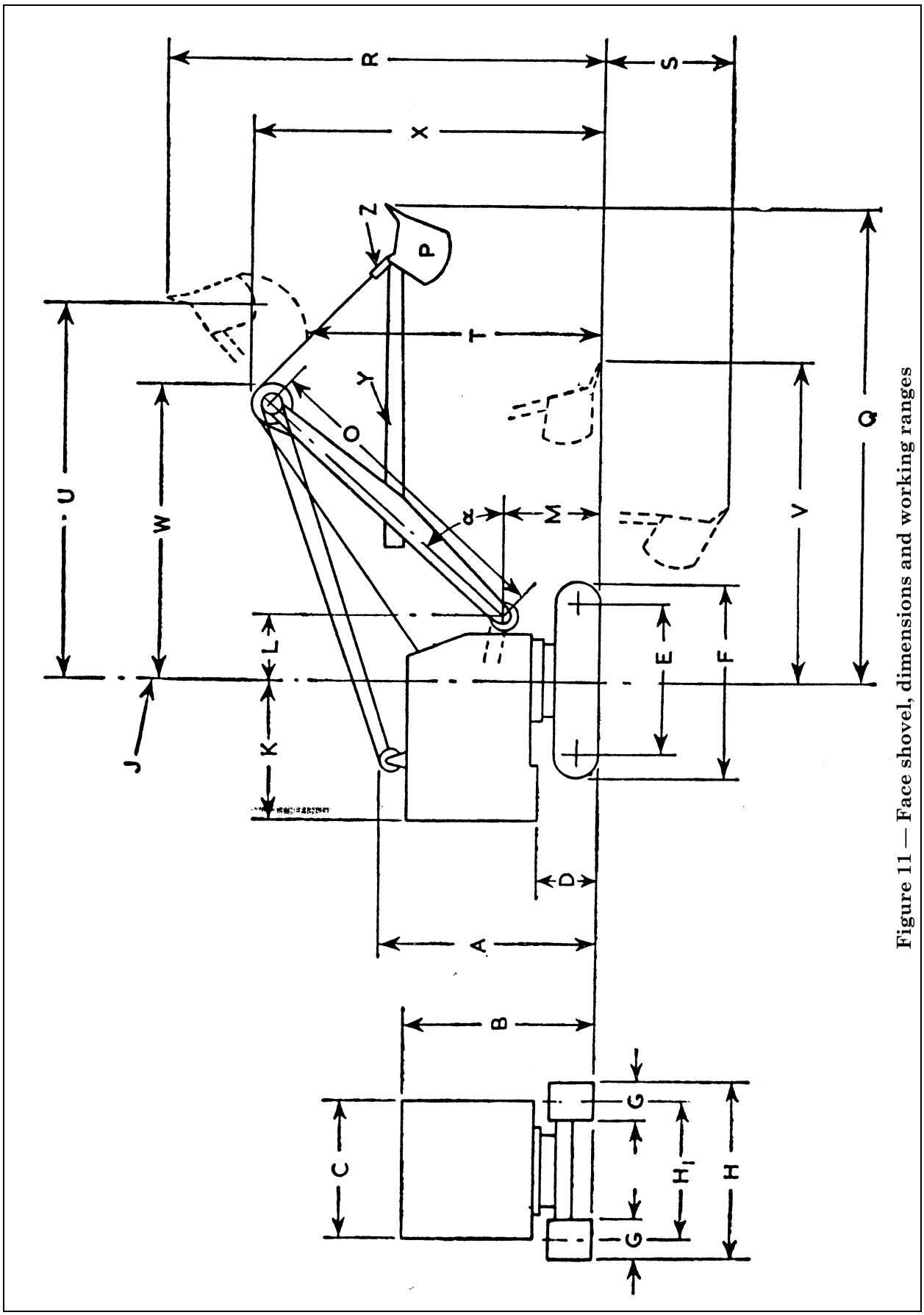


Figure 11 — Face shovel, dimensions and working ranges

A = Clearance height above floor — jib or boom lowered.
B = Height to top of cab, above floor.
C = Width of cab.
D = Clearance under rotating superstructure to floor.
E = Centre to centre of sprocket and idle roller.
F = Overall length of crawler.
G = Track width.
H = Overall width of crawlers
H1 = Centres of crawler rollers.
J = Axis of rotation.
K = Tail radius.
L = Radius of jib- or boom-foot pin.
M = Height of jib- or boom-foot pin above floor.
O = Length of jib or boom.
P = Shovel bucket.
Q = Maximum cutting radius.
R = Maximum cutting height above floor.
S = Maximum cutting depth below floor.
T = Maximum dumping height above floor.
U = Dumping radius at maximum height above floor.
V = Clean up radius at floor level.
W = Minimum jib point pulley radius.
X = Clearance height of boom point pulley above floor.
Y = Shovel bucket arm.
Z = Bail.
α = Jib or boom angle.

Key to Figure 11 — Face shovel

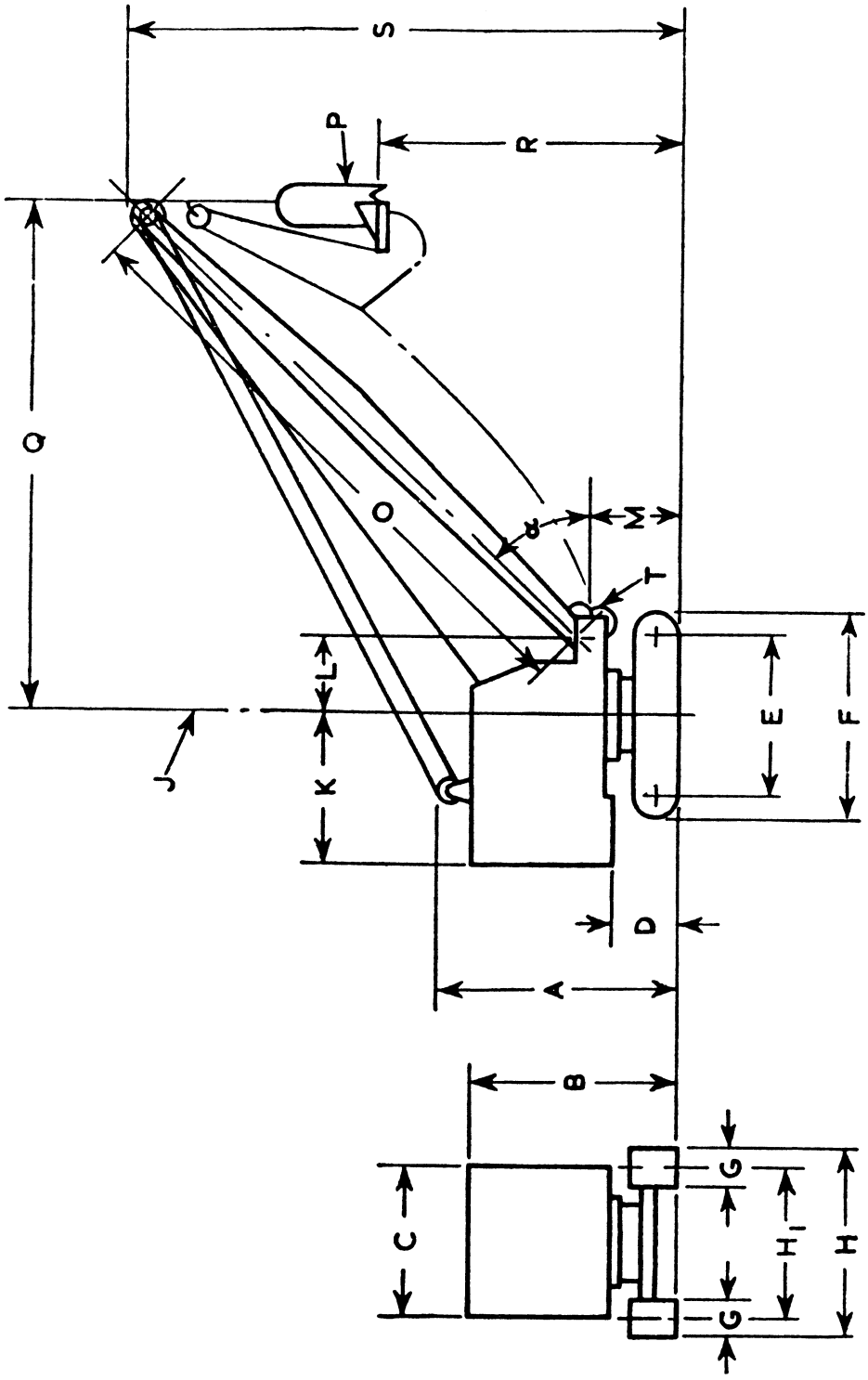


Figure 12 — Dragline, dimensions and working ranges

A = Clearance height above floor — jib or boom lowered.
B = Height to top of cab, above floor.
C = Width of cab.
D = Clearance under rotating superstructure to floor.
E = Centre to centre of sprocket and idle roller.
F = Overall length of crawler.
G = Track width.
H = Overall width of crawlers.
H_1 = Centres of crawler rollers.
J = Axis of rotation.
K = Tail radius.
L = Radius of jib- or boom-foot pin.
M = Height of jib- or boom-foot pin above floor.
O = Length of jib or boom.
P = Dragline bucket.
Q = Jib point pulley radius.
R = Maximum dumping height above floor.
S = Clearance height of boom point pulley above floor.
T = Fairlead.
α = Jib or boom angle.

Key to Figure 12 — Dragline

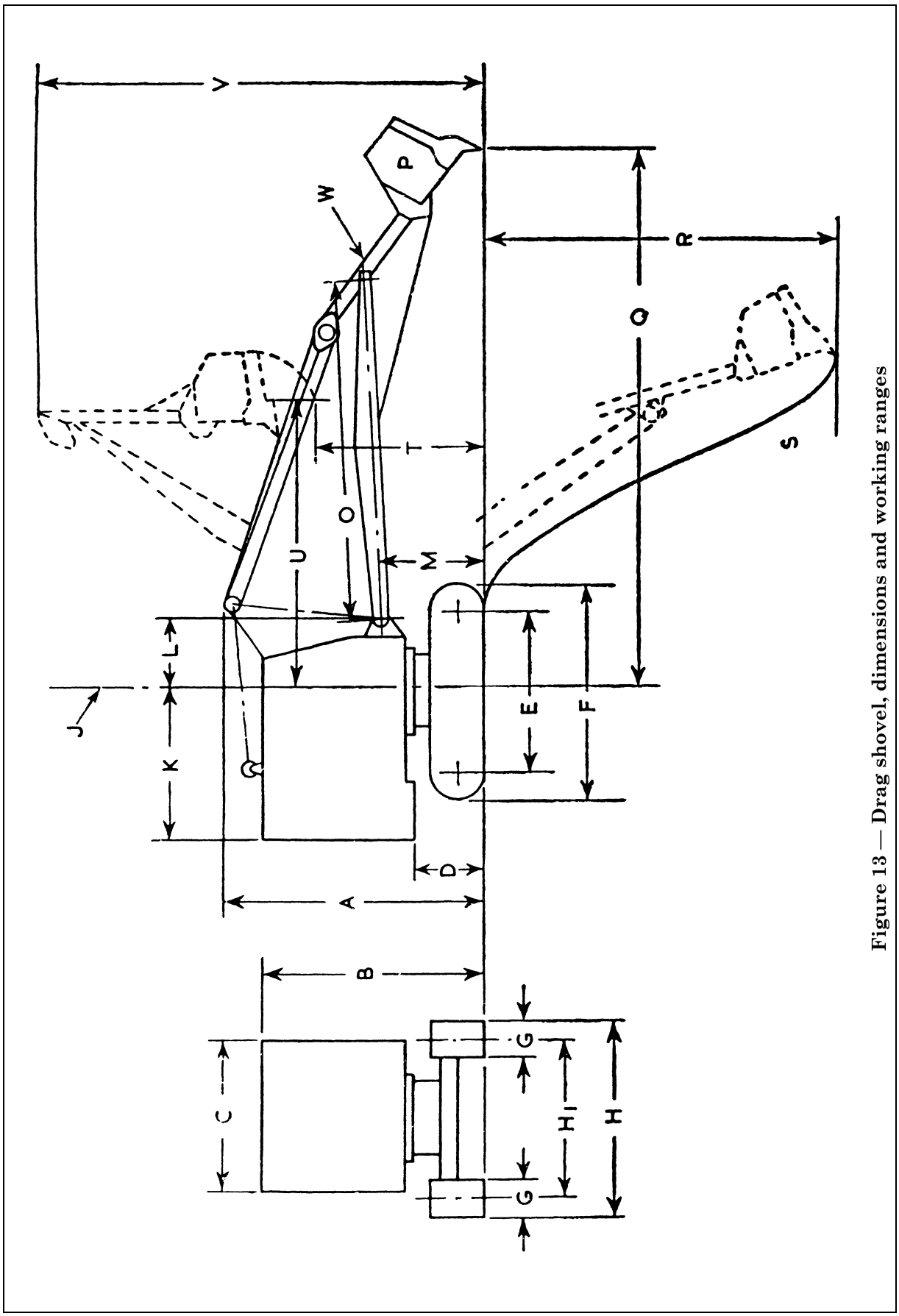


Figure 13 — Drag shovel, dimensions and working ranges

A = Clearance height above floor — jib or boom lowered.
B = Height to top of cab, above floor.
C = Width of cab.
D = Clearance under rotating superstructure to floor.
E = Centre to centre of sprocket and idle roller.
F = Overall length of crawler.
G = Track width.
H = Overall width of crawlers.
H_1 = Centres of crawler rollers.
J = Axis of rotation.
K = Tail radius.
L = Radius of jib- or boom-foot pin.
M = Height of jib- or boom-foot pin above floor.
O = Length of jib or boom.
P = Drag shovel bucket.
Q = Maximum cutting radius.
R = Maximum cutting depth.
S = Width of cut with standard knives.
T = Maximum dumping height (through door) above floor.
U = Minimum dumping radius (through door) at maximum height above floor.
V = Clearance height of boom point above floor with boom at minimum radius.
W = Drag shovel bucket arm.

Key to Figure 13 — Drag shovel

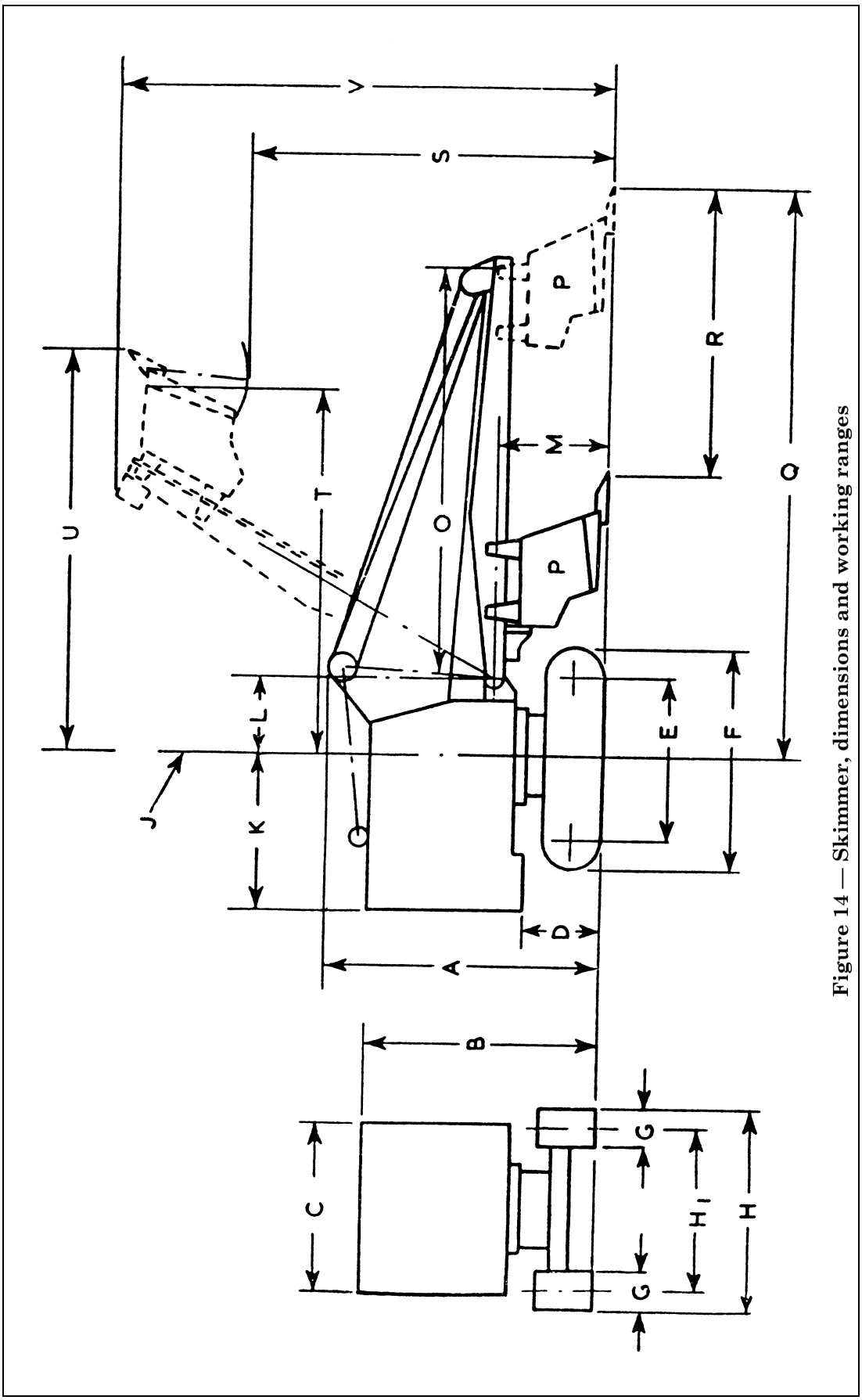


Figure 14 — Skimmer, dimensions and working ranges

A = Clearance height above floor — jib or boom lowered.
B = Height to top of cab, above floor.
C = Width of cab.
D = Clearance under rotating superstructure to floor.
E = Centre to centre of sprocket and idle roller.
F = Overall length of crawler.
G = Track width.
H = Overall width of crawlers.
H_1 = Centres of crawler rollers.
J = Axis of rotation.
K = Tail radius.
L = Radius of jib- or boom-foot pin.
M = Height of jib- or boom-foot pin above floor.
O = Length of jib or boom.
P = Skimmer bucket.
Q = Maximum cutting radius.
R = Travel of bucket.
S = Maximum dumping height above floor.
T = Minimum dumping radius at maximum height above floor.
U = Clearance radius at maximum height above floor.
V = Clearance height of boom point pulley at maximum height above floor.

Key to Figure 14 — Skimmer

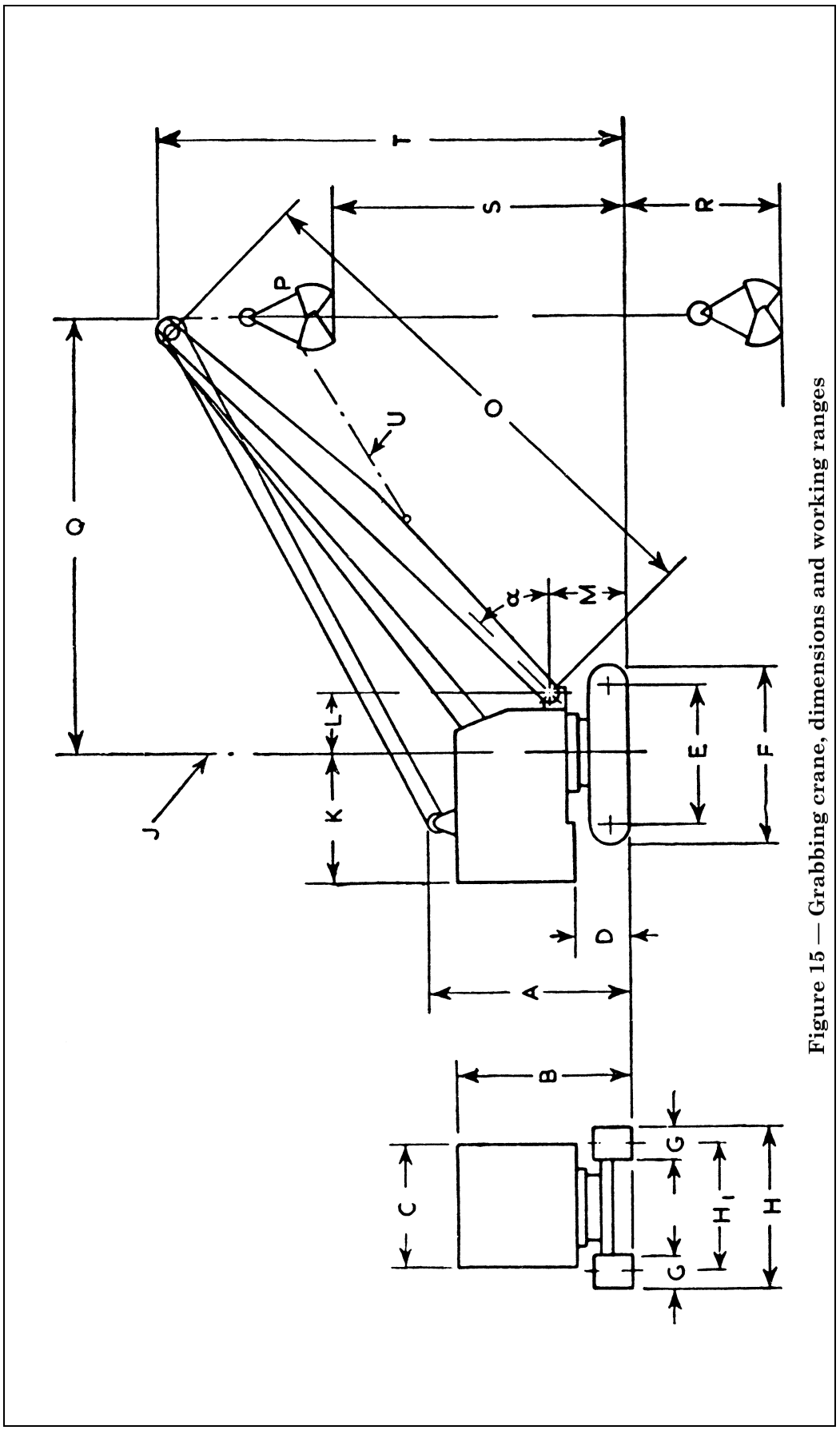


Figure 15 — Grabbing crane, dimensions and working ranges

A = Clearance height above floor — jib or boom lowered.
B = Height to top of cab, above floor.
C = Width of cab.
D = Clearance under rotating superstructure to floor.
E = Centre to centre of sprocket and idle roller.
F = Overall length of crawler.
G = Track width.
H = Overall width of crawlers.
H_1 = Centres of crawler rollers.
J = Axis of rotation.
K = Tail radius.
L = Radius of jib- or boom-foot pin.
M = Height of jib- or boom-foot pin above floor.
O = Length of jib or boom.
P = Grab bucket.
Q = Jib point pulley radius.
R = Maximum digging depth below floor.
S = Maximum dumping height above floor.
T = Clearance height of jib point pulley above floor.
U = Tagline (bridle gear) rope.
α = Jib or boom angle.

Key to Figure 15 — Grabbing crane

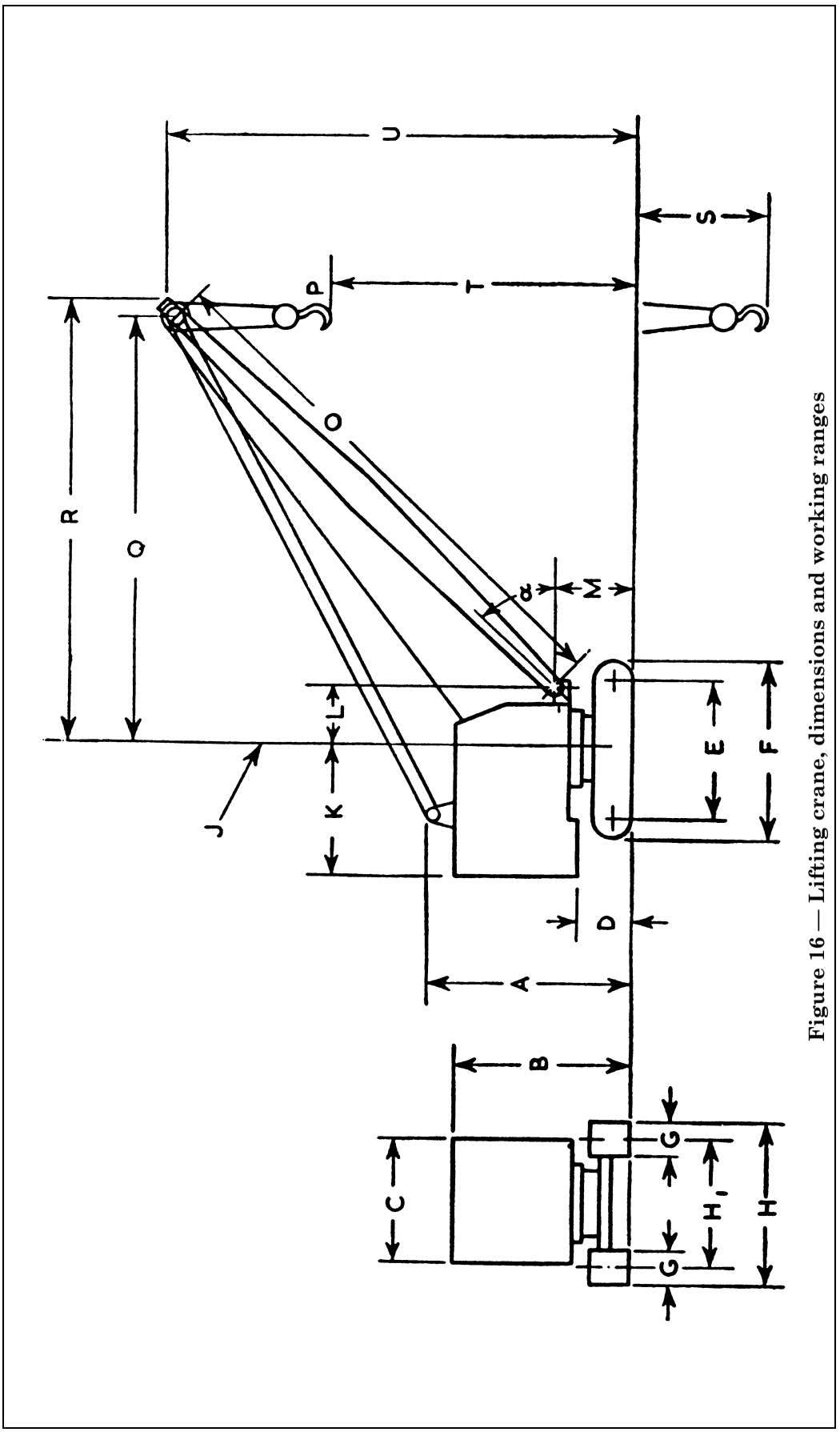


Figure 16 — Lifting crane, dimensions and working ranges

A = Clearance height above floor — jib or boom lowered.
B = Height to top of cab, above floor.
C = Width of cab.
D = Clearance under rotating superstructure to floor.
E = Centre to centre of sprocket and idle roller.
F = Overall length of crawler.
G = Track width.
H = Overall width of crawlers.
H_1 = Centres of crawler rollers.
J = Axis of rotation.
K = Tail radius.
L = Radius of jib- or boom-foot pin.
M = Height of jib- or boom-foot pin above floor.
O = Length of jib or boom.
P = Crane hook.
Q = Working radius of load.
R = Jib point pulley radius.
S = Maximum depth of crane hook below floor.
T = Maximum height of hook above floor.
U = Clearance height of boom point pulley above floor.
α = Jib or boom angle.

Key to Figure 16 — Lifting crane

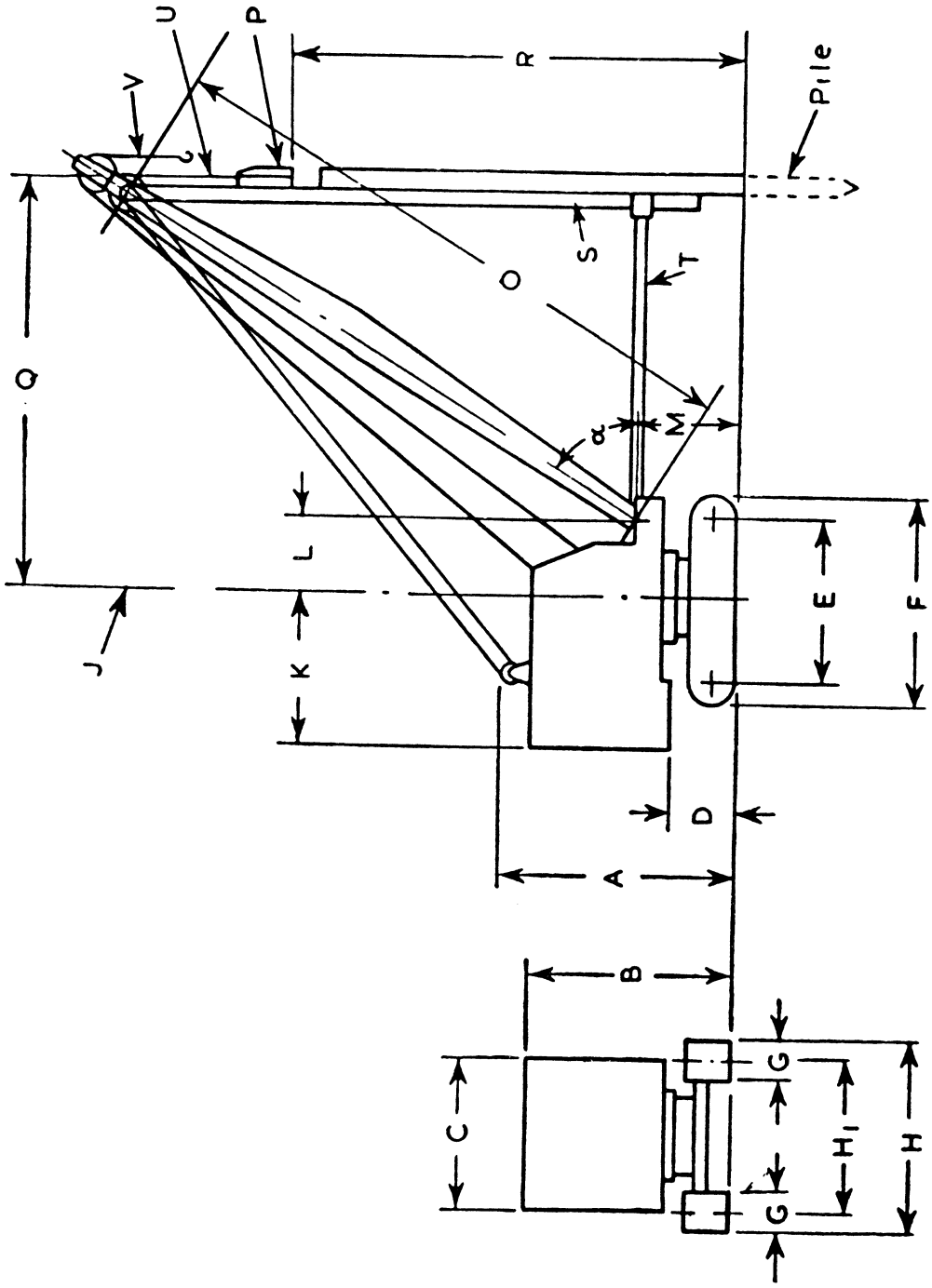


Figure 17 — Pile driver, dimensions and working ranges

A = Clearance height above floor — jib or boom lowered.
B = Height to top of cab, above floor.
C = Width of cab.
D = Clearance under rotating superstructure to floor.
E = Centre to centre of sprocket and idle roller.
F = Overall length of crawler.
G = Track width.
H = Overall width of crawlers.
H_1 = Centres of crawler rollers.
J = Axis of rotation.
K = Tail radius.
L = Radius of jib- or boom-foot pin.
M = Height of jib- or boom-foot pin above floor.
O = Length of jib or boom.
P = Pile driving hammer.
Q = Pile radius.
R = Maximum height of hammer above floor.
S = Piling frame leaders.
T = Piling frame brace.
U = Pile hammer rope.
V = Pile handling rope.

Key to Figure 17 — Pile-driver

Appendix A Information recommended to be supplied with inquiry or order

1. Type of front-end equipment required.
2. Capacity of bucket in cubic yards.
3. Digging depth.
4. Dumping radius.
5. Dumping height.
6. Weight of material to be handled in excavated condition.
7. Type of excavation likely to be encountered, such as:
   Easy digging, i.e. sand, loose earth and similar material.
   Mixed digging.
   Hard digging, i.e. blasted rock, etc.
8. Width of trench to be cut (for drag shovel equipment).
9. Working load and appropriate radii (for crane equipment).
10. State if a digging test is required.

Appendix B Information to be supplied by manufacturer

1. Clearance height with jib or boom lowered.
2. Height to top of cab.
3. Width of cab.
4. Rear end clearance radius of rotating superstructure.
5. Arc of swing, degrees.
6. Width of crawler treads.
7. Overall width of crawlers.
8. Overall length of crawlers.
9. Centre distance of sprocket and end idler roller.
10. Approximate working height.
11. Bearing area (see Clause **12**).
12. Average ground pressure under safe working conditions, lb/sq. in.
13. Developed brake horse power of engine at governed speed, with a statement as to whether horse power ratings are with or without accessories.
14. Governed speed in revolutions per minute.
15. Working weight complete, less “front-end” equipment.
16. Weight of “front-end” equipments being supplied including all sheaves.
17. Weight of bucket, where applicable.
18. Weight of rotating superstructure complete with cab, “A” frame, power unit, shafting, gearing and drums, and all normal accessories carried on the revolving platform.
19. Weight of carriage less crawler units, but including axles, transmission gears and shafts.
20. Weight of crawler side frames complete with tracks, idler, sprocket and rollers.

For each face shovel, drag shovel or skimmer submitted the manufacturer shall furnish, in addition, for the purposes of comparison, the data indicated in the items below:

21. Shovel bucket capacity in cubic yards.
22. Length of boom.
23. Length of bucket arm.
24. Maximum dumping height for 45° angle of boom.
25. Dumping radius at maximum height for 45° angle of boom.
26. Maximum dumping radius for 45° angle of boom.
27. Maximum cutting height for 45° angle of boom.

28. Maximum clean-up radius at crawler tread level for 45° angle of boom.
29. Maximum digging depth below ground level.
30. Bucket single rope speed.
31. Bucket single rope pull.

For each crane, dragline, or grabbing crane submitted, the manufacturer shall furnish in addition, for purposes of comparison, the data indicated below. These data are applicable only when the machine is standing on hard level ground.

32. Crane safe working load in tons of 2 240 lb. at 16 ft. radius.
33. Length of jib.
34. The minimum operating radius.
35. Safe working load for each increment of the radius given in Item 34.
36. Maximum operating radius.
37. Estimated ratio of lifting capacity to tipping load, as a percentage.
38. Hoisting rope speed (single rope).
39. Hoisting rope pull (single rope).

For each dragline excavator submitted the manufacturer shall furnish, in addition, the following:

40. Drag rope speed (single rope).
41. Drag rope pull (single rope).

Appendix C Acts, regulations and orders affecting excavators in the United Kingdom

Factories Act, 1937, Sections 12–17, 23–24, 26 and 31.

Factories Act, 1948, Section 6.

The Chains, Ropes and Lifting Tackle (Register) Order, 1938, dated 16th June, 1938, S.R. & O., 1938, No. 599.

The Cranes and other Lifting Machines (Register of Examinations) Order, 1938, dated 16th June, 1938, S.R. & O. 1938, No. 600.

Certificate of Exemption No. 1 Annealing Factory Form 661, dated 4th August, 1938.

Docks Regulations, 1925, S.R. & O. 1925, No. 231. Regulations 18, 19, 20 and 46.

Docks Regulations, 1934, S.R. & O. 1934, No. 279. Regulations 3, 18–22, 25–29, 33–34, 49, 51 and the Schedule of manner of test and examination before taking lifting machinery and gear into use.

Docks Regulations, 1934, Certificate of Exemption No. 1 Annealing Factory Form 1950, dated 1st June, 1934.

Shipbuilding Regulations, 1931, S.R. & O. 1931, No. 133. Regulations 34–37, 39–41 and 53.

Building (Safety, Health and Welfare) Regulations, 1948, S.I., 1948, No. 1145.
Regulations 2–3, 5, 29, 34–41, 43–60, 63–65, 85–86, 91 and the First and Third Schedules to these Regulations.

Electricity Regulations, 1908, S.R. & O. 1908, No. 1312.

Electricity (Factories Act) Special Regulations, 1944, S.R. & O. 1944, No. 739.

Mines and Quarries Act, 1954, Sections 81, 82, 83, 84, 85 and 87.

Coal and other Mines (Electricity) Regulations, 1956, S.I., 1956, No. 1766.

Miscellaneous Mines (Electricity) Regulations, 1956, S.I., 1956, No. 1779.

Quarries (Electricity) Regulations, 1956, S.I., 1956, No. 1781.

NOTE Certain of the above requirements apply only if an excavator is used as a crane.

Appendix D Maximum permissible stresses in fastenings

Maximum allowable stresses for finished precision steel bolts, nuts, and set screws used in the excavator structure

Ultimate tensile stress	Tensile working stress	Maximum working shear stress	Maximum bearing stress	
			Uni-directional	Multi-directional
tons/sq. in.	tons/sq. in.	tons/sq. in.	tons/sq. in.	tons/sq. in.
28	4	6	12	7
35	5	7	14	$8^1/_2$
40	$5^3/_4$	8	15	9
45	$6^1/_2$	9	17	10
50	7	10	18	11
55	8	11	20	12
60	$8^1/_2$	12	20	12
65/75	9	13	20	12

Maximum permissible stresses for rivets used in the excavator structure

Ultimate tensile stress	Maximum working shear stress	Maximum bearing stress	
		Uni-directional	Multi-directional
tons/sq. in.	tons/sq. in.	tons/sq. in.	tons/sq. in.
28	4	8	5
35	$4^1/_2$	9	$6^1/_2$

Appendix E List of British Standards applicable to materials to be used in the manufacture of excavators

Cast iron.

BS 1452 "*Grey iron castings.*"
Grade 10
Grade 17

Malleable iron castings.

BS 310 "*Blackheart malleable iron castings.*"

Mild steel bars and forgings.

BS 32 "*Steel bars for the production of machined parts for general engineering purposes.*"
Grade 1 (min. ultimate tensile stress 35 tons/sq. in.)
Grade 2 (min. ultimate tensile stress 28 tons/sq. in.)

Case hardening steel.

BS 970 "*Wrought steels.*"
EN 32 A, EN 32 B } Carbon case-hardening steel.

Structural steels.

BS 15 "*Structural steel.*"

BS 548 "*High-tensile structural steel for bridges, etc., and general building construction.*"

BS 968 "*High tensile (fusion welding quality) structural steel for bridges, etc., and general building construction.*"

BS 1775 "*Steel tubes for mechanical, structural and general engineering purposes.*"

Medium carbon steel bars and forgings.

BS 970 "*Wrought steels.*"
EN6, 6A 35/45 ton bright carbon steel.

High tensile steel bars and forgings.

BS 970 "*Wrought steels.*"
EN16 Manganese-molybdenum steel
EN24 $1^1/_2$ per cent nickel-chromium-molyb-denum steel.

Phosphor-bronze and gunmetal.

BS 1400 "*Copper alloy ingots and castings.*"

Carbon steel castings.

BS 3100, BS 592 "*Carbon steel castings for general engineering purposes.*"
Grade A. 28 tons/sq. in. ultimate tensile stress.
Grade B. 32 tons/sq. in. ultimate tensile stress.
Grade C. 35 tons/sq. in. ultimate tensile stress.

Alloy steel castings.

BS 3100, BS 1456 "*$1^1/_2$ per cent manganese steel castings.*"

BS 3100, BS 1457 "*Austenitic manganese steel castings.*"

Appendix F Design of struts

Section a.

Maximum permissible axial stresses F_a in pin jointed struts of uniform cross-section, in tons per square inch.

l/k	BS 15 and Grade 15 tubes to BS 1775[a]	BS 548	BS 968	Grade 20 tubes to BS 1775[a]	*l/k*	BS 15 and Grade 15 tubes to BS 1775[a]	BS 548	BS 968	Grade 20 tubes to BS 1775[a]
0	6.92	9.17	8.68	8.68	140	1.98	2.18	2.14	2.11
10	6.55	8.78	8.25	8.23	150	1.77	1.92	1.89	1.88
20	6.17	8.37	7.83	7.77	160	1.58	1.71	1.69	1.67
30	5.80	7.90	7.36	7.31	170	1.43	1.52	1.51	1.5
40	5.43	7.43	6.91	6.83	180	1.29	1.37	1.35	1.35
50	5.06	6.92	6.42	6.32	190	1.17	1.24	1.23	1.22
60	4.68	6.36	5.91	5.81	200	1.07	1.12	1.12	1.11
70	4.31	5.76	5.38	5.27	210	0.98	1.02	1.01	1.01
80	3.94	5.12	4.84	4.74	220	0.90	0.94	0.93	0.93
90	3.55	4.43	4.26	4.15	230	0.83	0.86	0.85	0.85
100	3.17	3.81	3.69	3.61	240	0.76	0.79	0.79	0.79
110	2.82	3.28	3.20	3.15	250	0.71	0.74	0.73	0.73
120	2.50	2.84	2.77	2.74	300	0.50	0.51	0.51	0.51
130	2.22	2.47	2.43	2.40	350	0.38	0.38	0.38	0.38

[a] BS 1775, "*Steel tubes for mechanical, structural and general engineering purposes.*"

Section b.

Combined stresses: bending and axial compression. Members subject to both axial compression and bending stresses shall be so proportioned that the quantity:

$$\frac{f_a}{F_a} \text{ plus } \frac{f_{bc}}{F_{bc}} \text{ does not exceed unity.}$$

or

$$F_2 \text{ does not exceed } f_a + F_{bc}\left(1 - \frac{f_a}{F_a}\right)$$

where:

f_a = axial compressive stress.

F_a = maximum permissible compressive stress in axially loaded struts (see Section *a* and Chart 1).

f_{bc} = the sum of compressive stresses due to bending about both rectangular axes.

F_{bc} = the permissible compressive stress for members subject to bending (see Chart 2 for formulae and values).

F_2 = Maximum compressive stress at extreme fibre due to combined bending and direct compression.

Section c.

Variation in stress allowance over length of strut. The combined axial compression and bending stress at any section distance X from one end, shall not exceed F_x where:

$$F_x = f_a + K\left(1 - \frac{f_a}{F_a}\right)$$

with a maximum allowable value for F_x

of 6.92 tons/sq. in. for steel to BS 15 and Grade 15 tubes.

of 9.17 tons/sq. in. for steel to BS 548.

of 8.68 tons/sq. in. for steel to BS 968 and Grade 20 tubes.

where:

f_a = the stress resulting from direct compression only.

F_a = the working stress per square inch specified in section *a* and Chart 1.

K = a factor from Chart 3 for steel to BS 15 and Grade 15 tubes to BS 1775.[a]

= a factor from Chart 4 for steel to BS 548.

= a factor from Chart 5 for steel to BS 968 and Grade 20 tubes to BS 1775.[a]

[a] BS 1775, "*Steel tubes for mechanical, structural and general engineering purposes.*"

Section d.

Spacing of lacing bars. The maximum spacing of lacing bars, whether connected by riveting or welding, shall be such that the effective slenderness ratio l/k_1 of the components of the strut between successive connections shall be less than the most unfavourable slenderness ratio of the member as a whole; where l is the effective length between the centres of the pairs of lattice bars to each component and k_1 is the minimum radius of gyration of the section.

NOTE Where lacing bars are not lapped to form the connection to the components of the strut they shall be so connected that there is no appreciable interruption in the triangulation of the system.

Section e.

Effective length.[4] The effective length shall be computed as follows:—

End condition	Effective length
Both ends rounded or pin-jointed. (This also applies to struts having single rivet or bolt connections.)	The actual length.
One end fixed and the other rounded but held in position against sideways movement. (This also applies to the bay lengths of the main members of a braced jib.)	0.85 of the actual length.
Where both ends are fixed. (This also applies to bracing members having welded or multiple rivet or bolt connections.)	0.7 of the actual length.
Where one end is fixed and the other rounded and free to move sideways. (This also applies to the plan view of a jib.)	1.5 to 2 times the actual length, depending on the degree of restraint to sideways movement.

Section f.

Formulae from which the maximum permissible axial stresses are derived. For values of l/k in excess of 80 the average stress on the gross sectional area of a strut or other compression member in steel shall not exceed the value of F_a obtained by the formulae:

$$K_2 F_a = \frac{f_v + (\eta + 1) f_e}{2} - \sqrt{\left[\frac{f_v + (\eta + 1) f_e}{2}\right]^2 - f_v f_e}$$

where:

F_a = the permissible average stress in tons per square inch.

K_2 = load factor or coefficient of 2.6 for the purpose of this standard.

f_v = minimum yield stress in tons per square inch.

f_e = Eulerian value = $\dfrac{\pi^2 E}{\left(\frac{l}{k}\right)^2} = \dfrac{13000\pi^2}{\left(\frac{l}{k}\right)^2}$

η = $0.003\ l/k$

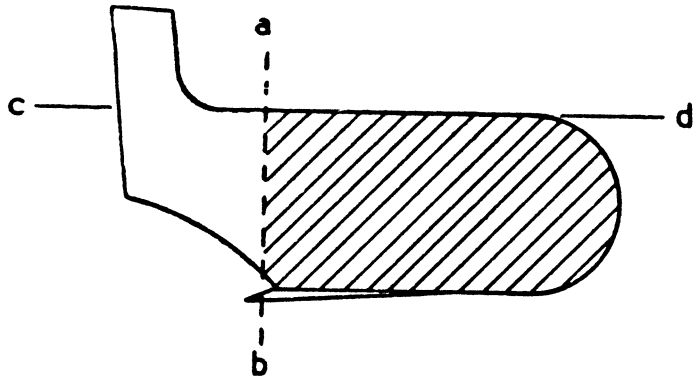
k = slenderness ratio = $\dfrac{\text{effective length}}{\text{radius of gyration}}$

For values of l/k less than 80 the value of F_a shall not exceed that obtained from the continuation of the curve between F_a for $l/k = 80$ and

$F_a = \dfrac{\text{minimum ultimate tensile stress}}{4}$ for $l/k = 0$ (see chart 1)

[4] This is also known as the "equivalent length."

Appendix G Capacity rating of buckets



a. Dragline.

Dragline buckets shall be rated according to the formula, C = V × K,

in which C = rated capacity of bucket.

V = actual inside volume of dragline bucket, behind a vertical line *a–b* at right angles to the bottom of the bucket, and passing through the forward cutting edge of the lip, disregarding teeth or tooth bases; and below a plane *c–d* passing through the upper edges of the bucket. No deductions shall be made for the volumes occupied by teeth, tooth bases, or overlapping joints.

K = variable factor established for various sizes of buckets, as set out on page 39.

A tolerance of ± 2 per cent shall be allowed on the figures obtained from the formulae.

b. Face shovel, drag shovel and skimmer.

The rating of these buckets shall be the actual plate level capacities, disregarding the carrying capacity of the teeth.

Values of variable factor "K"

Bucket size	**K**
yards $^1/_4$	0.87
$^3/_8$	0.88
$^1/_2$	0.89
$^3/_4$	0.90
1	0.91
$1^1/_4$	0.925
$1^1/_2$ to $2^1/_2$ incl.	0.935

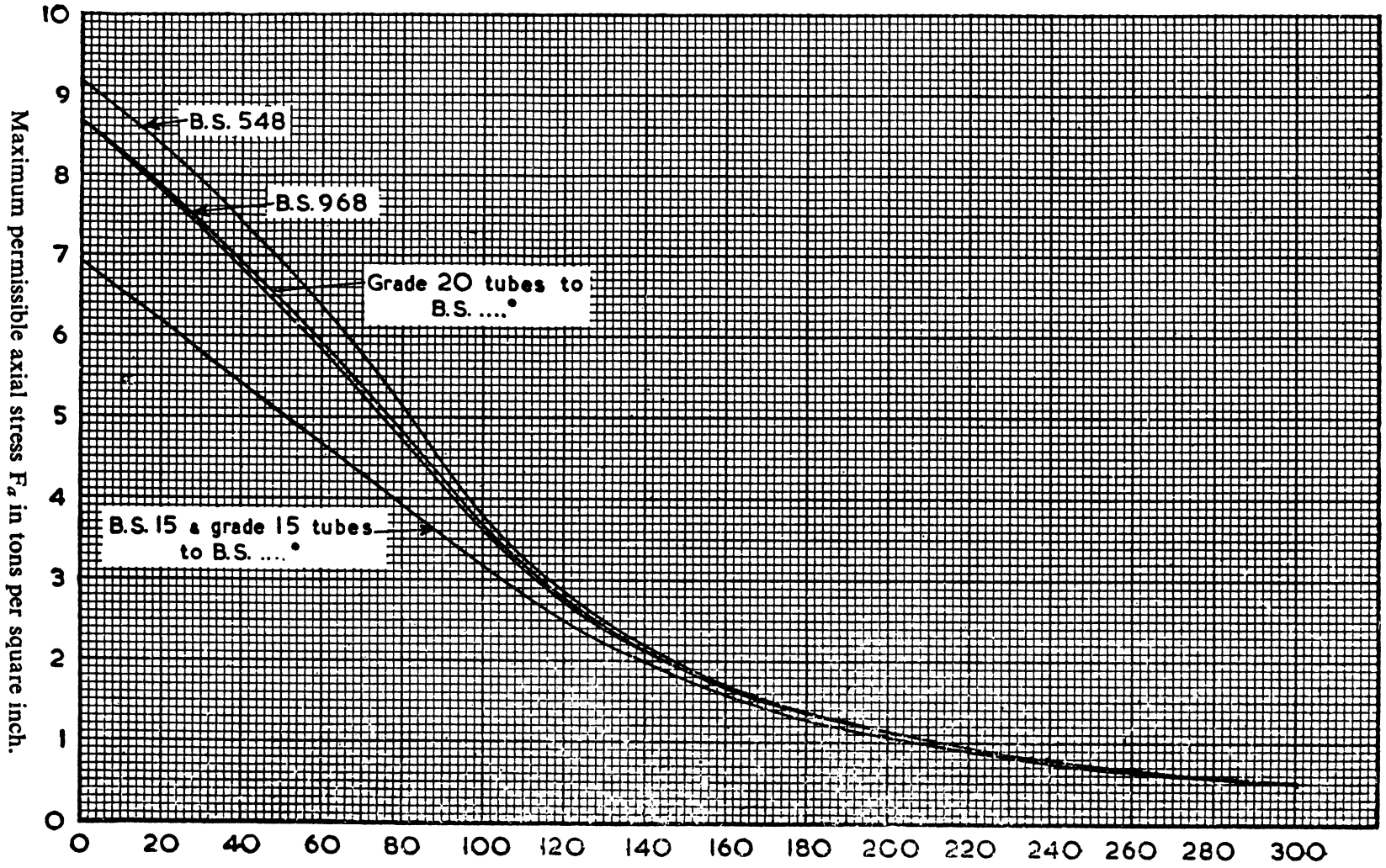


Chart 1 — Values of maximum permissible stress, F*a*

* BS 1775, *"Steel tubes for mechanical, structural and general engineering purposes."*

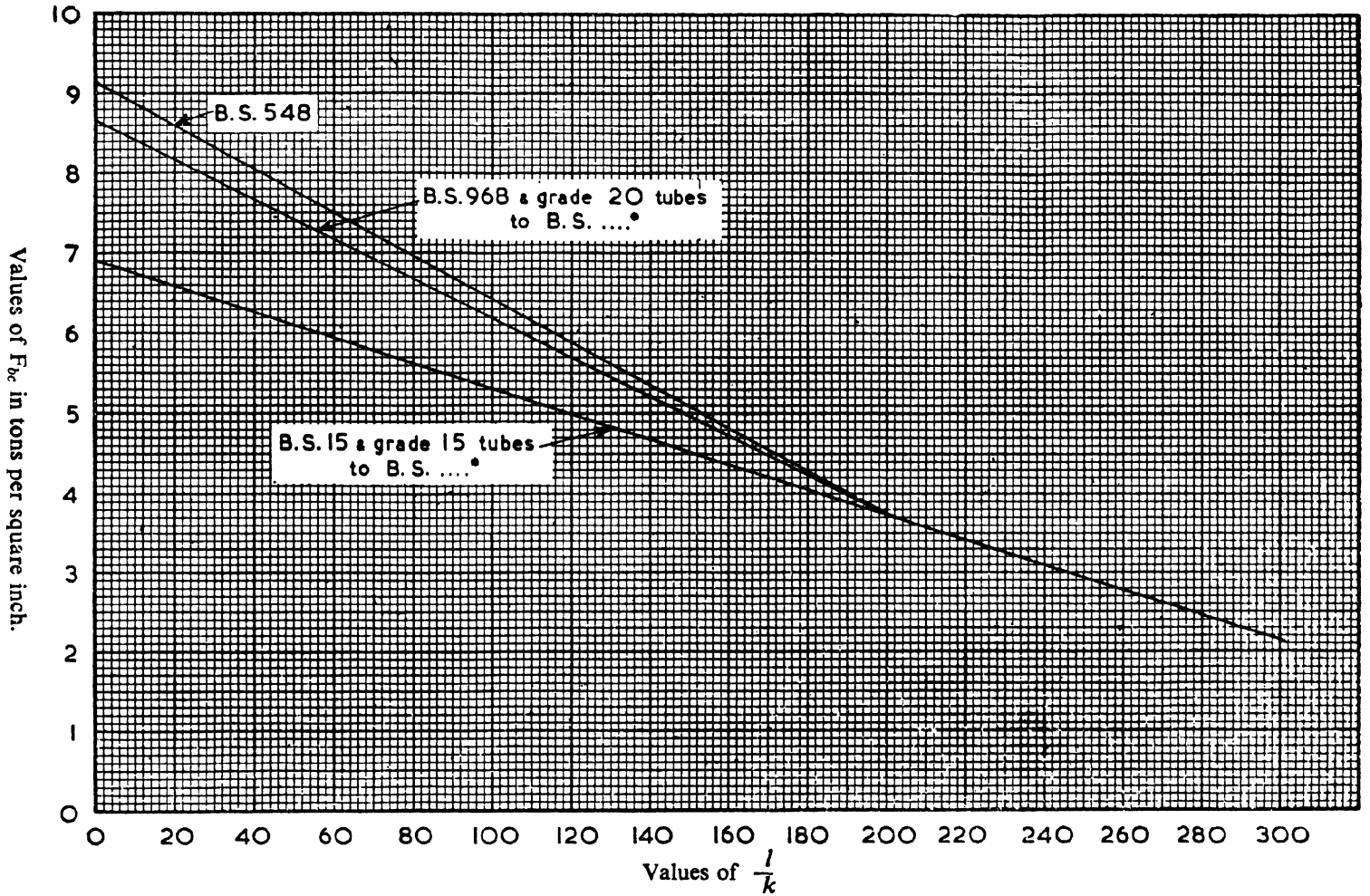


Chart 2 — Values of F_{bc}

B.S. 15 *and Grade* 15 *tubes to B.S.* 1775 *

$F_{bc}=6{\cdot}92\left(1-0{\cdot}0023\frac{l}{k}\right)$ for all values of $\frac{l}{k}$

B.S. 548

$F_{bc}=9{\cdot}17\left(1-0{\cdot}00296\frac{l}{k}\right)$ for values of $\frac{l}{k}$ up to 200

$=6{\cdot}92\left(1-0{\cdot}0023\frac{l}{k}\right)$ for values of $\frac{l}{k}$ over 200

B.S. 968 *and Grade* 20 *tubes to B.S.* 1775 *

$F_{bc}=8{\cdot}68\left(1-0{\cdot}00284\frac{l}{k}\right)$ for values of $\frac{l}{k}$ up to 200

$F_{bc}=6{\cdot}92\left(1-0{\cdot}0028\frac{l}{k}\right)$ for values of $\frac{l}{k}$ up to 200

* **B.S. 1775,** ' Steel tubes for mechanical, structural and general engineering purposes.'

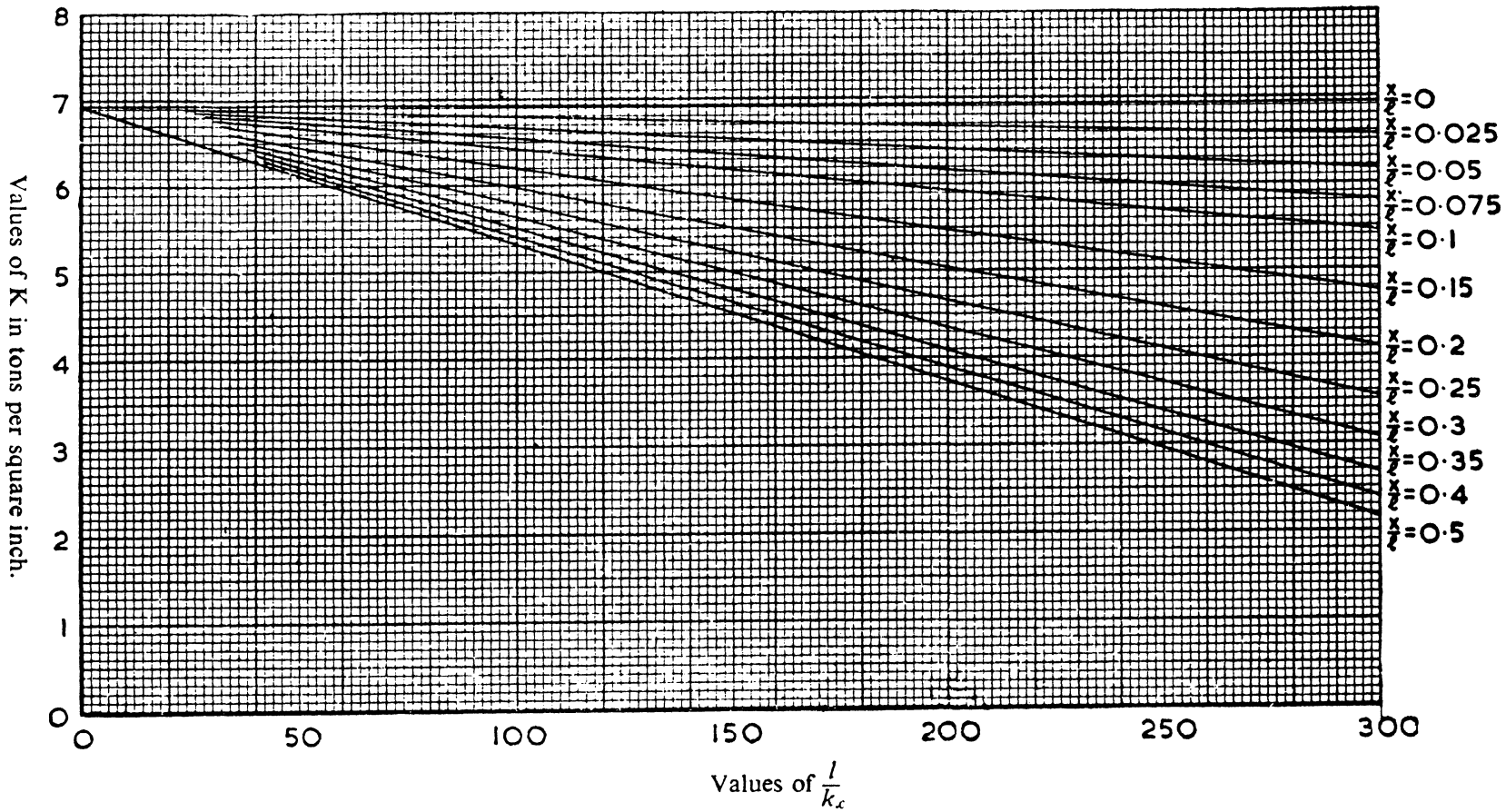


Chart 3 — Values of K for steel complying with BS 15, "Structural steel" and Grade 15 steel tubes complying with BS 1775, "*Steel tubes for mechanical, structural and general engineering purposes*"

$$K = 6{\cdot}92\left(1 - 0{\cdot}0023\,\frac{l}{k_x}.\sin\frac{180x}{l}\right) \text{ for all values of } \left(\frac{l}{k_x}.\sin\frac{180x}{l}\right)$$

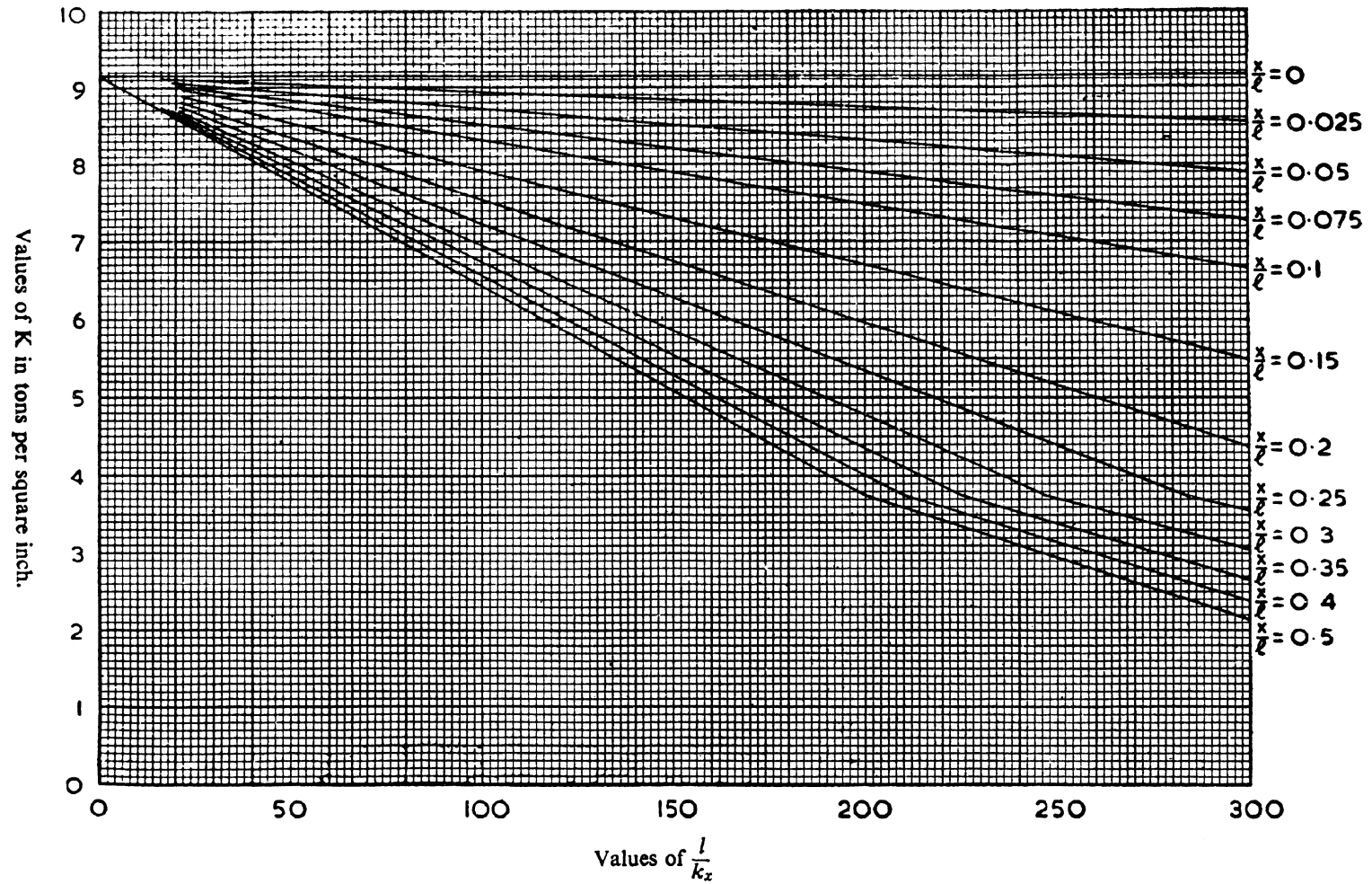


Chart 4 — Values of K for steel complying with BS 548, "*High-tensile structural steel for bridges etc., and general engineering purposes*"

$K = 9{\cdot}17\left(1 - 0{\cdot}00296\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ for values of $\left(\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ up to 200. $K = 6{\cdot}92\left(1 - 0{\cdot}0023\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ for values of $\left(\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ over 200.

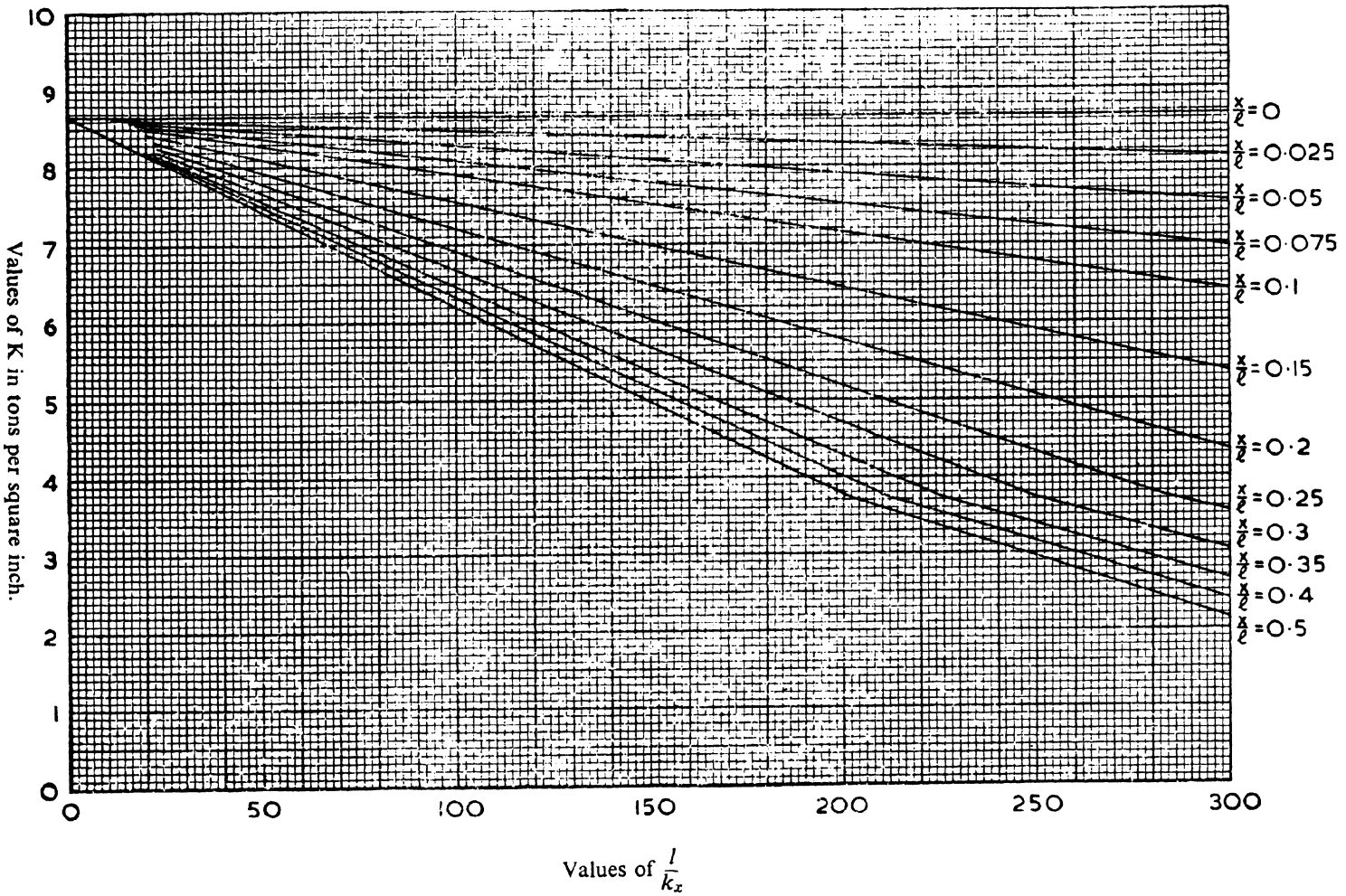


Chart 5 — Values of K for steel complying with BS 968, "*High tensile (fusion welding quality) structural steel for bridges, etc., and general building construction*," and Grade 20 steel tubes complying with BS 1775, "*Steel tubes for mechanical and general engineering purposes.*"

$K = 8{\cdot}68\left(1 - 0{\cdot}00284\,\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ for values of $\left(\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ up to 200. $K = 6{\cdot}92\left(1 - 0{\cdot}0023\,\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ for values of $\left(\frac{l}{k_x}.\ \sin\frac{180x}{l}\right)$ over 200.

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