THE ENGINE INDICATOR
Autographic and associated designs from James Watt until the present day
AIDS, ACCESSORIES AND OVERVIEW
JOHN WALTER
Indicator Diagrams for Marine Engineers

By W.C. McGibbon M.I.E.S.

Third Edition
THE ENGINE INDICATOR
autographic and associated designs from James Watt to the present day

5. AIDS, ACCESSORIES AND OVERVIEW

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PRODUCED IN GREAT BRITAIN
This multi-volume project began life as a simple guide to the indicator. I had become involved in 1993 with the British Engineerium in Hove, Sussex, England, where a small group of steam-engine indicators had been placed in a show-case with minimal explanation. My father had worked for Dobbie McInnes, the principal British manufacturer of indicators in the twentieth century, and so I had a vague idea of what they had been designed to do.

A search of the museum storerooms revealed more instruments, often in good condition, and so we decided to make a better display. I set out to provide a short overview and captions for the individual items, but this only succeeded in proving how little I knew. I then ransacked the museum library for additional information. There were many fascinating nineteenth-century ‘steam engineering’ textbooks, but these concentrated more on the utility of the indicator than on its history. Some gaps were filled with material drawn from the pages of Engineering (the museum library had a more-or-less complete set from 1868 to the 1960s), which included some superb engravings, but progress was slow. It was apparent that very few colleagues in the museum industry knew much about the history of the indicator, though one or two informative articles had been published in Germany and the U.S.A.

Gradually, I began to piece a story together. This was greatly helped by the enthusiasm of individual collectors, by other museums with indicators of their own, by obtaining patent specifications, and by drawing together manufacturers’ and distributors’ literature. What had once been a fog of information slowly cleared into a cogent narrative. There were many gaps where information had proved difficult (if not impossible) to obtain; and many hunches were shown to be mistaken. Yet progress was made. This was helped greatly by the interest shown by the Engineerium, in particular by its founder Jonathan Minns (1938–2013), and then by Ian McGregor and the Canadian Museum of Making when the Engineerium closed in 2005.

I would also like to pay tribute to the many people who have helped to bring the project to this point. In particular, I am grateful to Dr Bruce Babcock of Amanda, Ohio, U.S.A., for chasing information, taking superb
photographs, and keeping me on the right track; I owe Larry Parker thanks for details of his wonderful collection of indicators; I thank Ben Russell of the Science Museum, Internal Fire, and the Powerhouse Museum in Sydney, Australia. I’m also grateful for the support of individuals far too numerous to mention individually (I hope this corporate ‘thank you’ will suffice!).

The project soon grew too large to be published conventionally, and it was decided to break it into sections. These are being released in electronic form, at least for the moment, because we are well aware that information is still needed. There are far fewer gaps than there were five years ago, but this is not to say that none remain…

The individual booklets in the series are currently intended to be:

1. In the beginning: Watt and McNaught.
2. Amplification: internal-spring patterns.
5. Aids, accessories and overview.

JOHN WALTER, PORTSLADE, 2017
Virtually all indicators were supplied in a well-fitted box, usually wooden, accompanied by a range of accessories. Comparatively few of the instruments that survive are now accompanied by all these parts, and it is now widely assumed that any slot, space or hole in the box indicates that fittings are missing. Turnscresws, oil bottles, the tiny cylindrical pencil lead/scriber point containers, and sometimes even springs are easily lost, but some indicator outfits were only supplied with the basic minimum of components. The manufacturers obviously encouraged purchasers to buy more, boosting the total price, but some clients had specific needs and required only a single spring (or, at best, a duplicated spring of one particular strength). This applied particularly to owners of single-cylinder steam engines, or to users of compound or multiple-expansion engines who purchased an indicator to be used with each cylinder instead of one with three springs. The former method was often preferred by water-pumping stations and similar installations where there could be two or more identical engines. It was clearly easier to use three separate indicators than take time to change springs, though the investment required, initially at least, was considerably greater.

Some makers, such as Crosby and Trill, mounted their springs in pairs on brackets or studs. The presence of an empty bracket or a stud is a sure sign that the springs have been lost. However, this is not necessarily true of spring holders in the form of holes drilled into wood blocks which have been pinned and glued inside the box walls—a method favoured by the British makers, such as Elliott and Dobbie McInnes, and also often in Europe. Though the design of the boxes was not always standardised (Dobbie McInnes, in particular, made many differing forms), the spring block almost always had a minimum of four holes or pegs. The boxes of indicators made prior to the First World War show greater variety of design than those made after 1918, when attempts were made to standardise components.

Some indicators were accompanied by unusually large quantities of springs—one Crosby has been seen with no fewer than fourteen—but comparatively few purchasers specified more than four, excepting consulting
engineers and insurance-company inspectors. The four-hole block met most demands, therefore, and purchasers who asked for more than four springs either got specially-adapted boxes or simply another four-hole block attached elsewhere on the box walls.

In 1895, Hine & Robertson of New York City were offering the Robertson-Thompson indicator ‘...Packed in a fine polished walnut or mahogany case, with two springs and two straight cocks, or two springs and one three way cock, oil, screw-driver, cards and book’. A catalogue of Bachelder indicators

Plate 2. This Ashcroft-made Tabor indicator, no. 1138, dates from the late 1880s. Though the contents of the box are standard—two steam cocks, a selection of springs on pegs—the fittings in the lid-tray and the way in which the scale-rulers are carried is most unusual. The essentially hand-made nature of these instruments, however, encouraged variations in fixtures and fittings to be made if a prospective purchaser was prepared to pay for them. Canadian Museum of Making collection.
and accessories published in 1905 by John Bushnell & Co. of New York noted that each nickel-plated instrument was supplied in a polished hardwood box with two flat springs (which, being adjustable, was all that the purchaser needed), 'two straight-way Cocks, or one thee-way, one tri-angular boxwood scale, 100 diagram blanks, pencils, screw driver, wrench, extra cord, bottle of oil, etc, and a treatise on Indicator and Engine Practice'.

Advertising literature published in 1917 shows that each Crosby instrument came in a lockable velvet-lined walnut case with a compartmented lid. In addition to the indicator, the case contained one spring and a small scale-ruler, one straight steam cock, fifty diagram cards, a hank of indicator cord, a spring bracket, a cord adjuster, one small oil bottle, a turn-screw, a hollow wrench, and an instruction book.

The 1919 Dobbie McInnes catalogue noted the basic outfit as a 'polished teak-wood case of special design with folding platform and compartment for

Plate 3. This engraving of a Maihak indicator in its box shows the accessories that were supplied prior to the First World War. They include the steam cock (Indikatorhahn, 'h'), the springs (Indikatorfeder, 'd'), the diagram paper in its slot (Indikatorpapier, 'p'), scale rules (Maßtabe, 'm'), a spare drum spring (Ersatz Trommelfeder, 'r'), a spare spring-locking cap (Ersatz Federschlußschraube, 'r2'), the hooked lever (Hakenschlusssel, 'n'), a cord hook (Schnurhaken, 's'), the trace points in a small sheet-steel cylinder (Büchschen Schreibstifte, 'b'), a needle (Anzugdorn, 'a'); a cylinder cleaner (Zylinderwischer, 'w'), a screwdriver (Schraubenzieher, 'v') and an oil bottle (Ölkännchen, 'o'). From A. Staus, Der Indikator, 1911.
**Plates 4 and 5.** The extensive range of accessories accompanying 1902-type Dreyer, Rosenkranz & Droop indicator no. 7184, dating from the first decade of the twentieth century. *Canadian Museum of Making collection.*
diagram cards, etc., lock and key, and complete with Cylinder Cock, Spare Paper Drum Spring, Hexagon Spanner, Turn screw, Set Square, Detent Cord Adjuster, Case of Spare Pencils, Plate Cord Adjuster, Radial Dividing Board, and Cylinder Cleaner Rod (no springs or scales)…’ Dobbie McInnes had originally included a solitary spring and a matching scale with each indicator, but was keen to maximise income in the depressed post-war era: the standard Design No. 1 ‘1st Quality’ (nickel plated) external-spring indicator cost £20 in 1919, with each spring and scale costing 18/- and 2/- respectively.

In 1923, the U.S.-made Star ‘Class B Outside Spring Indicator with detent’ was supplied in a ‘light, neat strong quartered oak case with lock and key and two snap catches’ containing two springs, two spring scales (rulers), a pad of Patented Metallic Faced Indicator Cards, a spool of Special Silk Indicator Cord, a screwdriver, a hollow hexagon wrench, a box of metallic points, a bottle of Special Indicator Oil, and two straight two-way or one three-way cock. Interestingly, the accompanying engraving shows one spring on the indicator and the other alone in a multi-hole block.

**DISTRIBUTION**

One of the biggest disappointments for the indicator enthusiast is the customary lack of ownership markings. This is something of a surprise, particularly as the largest steamship lines—Cunard or White Star, for example—marked even the smallest items of cutlery, and military or naval usage was invariably signalled by inspectors’ or property markings. Yet marked indicators are the exception to the rule.

At their most impressive, ownership marks may take the form of metal plates fixed to the lid of the box; lesser examples will be confined to a stamped, branded or scratched identifier such as T.W.A.115 OR FALMER H.P., the former signifying indicator no. 115 belonging to the Thames Water Authority and the latter identifying an instrument confined to the high-pressure cylinders of two large triple-expansion engines installed in a pumping station belonging to the Brighton Waterworks Undertaking.

Among the indicators that have been reported with marks have been an external-spring Star owned by the Jones & Laughlin Company steelworks of Pittsburg, Pennsylvania; a selection of American-Thompsons used by the Fulton Engineering & Ship Building Company of San Francisco, California, and the Terre Haute Traction & Light Company of Terre Haute, Indiana; two triple sets of internal-spring Crosby indicators belonging to the Maryland Steel Company; a Robertson-Thompson used by the Diamond Crystal Salt Company of Saint Claire, Maryland; and a Dobbie McInnes Pattern ‘A’
internal-spring instrument used aboard the British steamship *Corncrake* of the General Steam Navigation Company. Another American-Thompson indicator is marked PROP. CITY OF DETROIT, and an internal-spring Trill by the McCluskey Cotton Oil & Peanut Mill of Americus, Georgia.

Presentation inscriptions are very rare, but often exceptionally interesting. For example, the gift of two 'New Model' (external spring) Crosby indicators marked PRESENTED TO MASS. INST. OF TECH. BY CROSBY STEAM & VALVE helps date the introduction of this particular design: the inspection of indicators ‘31-S’ and ‘32-S’ was made on 14th February 1904.

THE BOXES
The box accompanying large-size Design No. 1A indicator no. D1A 7812L, supplied by Dobbie McInnes Ltd to the British Engine, Boiler & Electrical Insurance Co. Ltd of Manchester c. 1908, typifies boxes of the era in most important respects. The dark-stained teak body is constructed of four side pieces or ‘walls’ tongued and grooved together. Excepting the folding wall, each side-piece is additionally held to its neighbour with two flat-head wood screws. The walls are attached to a solid base-board by ten short wood screws, with a small hemispherical brass stud at each corner. The left-hand wall, viewed with the lock forward, folds downward; there are two six-screw brass hinges. The indicator body was held on a circular brass boss, attached to the folding box-wall with three screws, by screwing the union nut on to the matching thread.[1]

A small brass plate, attached to the top edge of the folding wall with two screws, has a central circular hole cut to receive a small tapering brass peg on the bottom edge of the left hand box-lid wall. The fold-down flap of this particular box is restrained by a sheet-brass bar, attached by a screw to a small brass ‘L’-bracket (anchored in the edge of the flap with two small wood screws), which is slotted to receive a small dome-head screw fixed in the rear wall of the box. Other Dobbie McInnes boxes of the same period relied on six-link brass restraining chains to link a dome-head screw set in the folding wall to another set in the back wall of the box body.

Looking downward, with the lock at the base, the box contains a seven-peg ‘L’-block for the springs, placed at bottom right. To the left lies a wood block, hollowed vertically, which probably once held a tap or a reamer. Moving

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[1] Bosses made from 1915, during the First World War when brass was reserved for important tasks, were made of a lead/zinc alloy. Components of this type (presumably from wartime stocks) were still being used by Dobbie McInnes & Clyde Ltd during the early 1920s. The alloy became very brittle as it aged, and many bosses subsequently fractured or disintegrated.
Plates 6, 7 and 8. These three boxes contained Design No. 1 indicators supplied by Dobbie McInnes to the British Engine, Boiler & Electrical Insurance Co. Ltd prior to the First World War.

The uppermost illustration shows the box of large-drum indicator no. D1A 5615L (delivered c. 1906); the middle picture shows the box of D1A 7528 (c. 1908, with the standard size drum); and the third shows the box of D1A 7812L (c. 1908), another of the large-drum instruments, intended for use with steam engines, that gave diagrams identical in size to those of the Richards indicators that had previously been used.

Though the boxes were made only a few years apart (and though they each contain broadly similar accessories), the fittings clearly vary: note, for example, the position of the spring pegs and the slots for the scale rules.

Canadian Museum of Making collection.
leftward, across an intervening space, a vertical block is drilled to accept the spare drum spring and a shallow block with two rectangular compartments accept the rules. These blocks are all glued in place.

Three wooden pegs or bosses, attached to the floor towards the top left of the box (looking down, with the lock at the base), are believed to have accepted washers. To the right lies a small brass strip, orientated laterally, with each end formed as a semi-circle. Attached to the floor with two small screws, this seems to have accommodated a solid wooden rod and a separate cleaner.[2] The steam cock lay beneath the elevated spring-peg block. One end of the cock entered a circular cut in a wooden plate attached to the right-hand end wall; the other lay in a cut-out in a wooden block, orientated laterally, with a sheet-brass latch pivoting on a wood screw. A slim wooden block, placed longitudinally, supports the body of the indicator; and a small brass catch, pivoting on a brass base of similar size (held to the floor with two short screws), retains a flat steel spanner with an appropriately slotted body.

The exterior of the box body contains the lock mechanism, in brass, with a suitable keyhole cut through the front surface of the wooden wall.[3] There are also two swivelling retaining hooks, each attached to the front of the box body with a flat-head wood screw; these mate with small dome-head screws protruding from the front box-lid wall. The boiler inspectors’ indicator boxes all seem to have been fitted with leather handles, stitched at each end over a swivel held in a transverse slot under a round-ended retainer, attached to the front of the box with two flat-head screws. However, the boxes of most pre-1914 Dobbie McInnes indicators had a turned wooden barrel-shape handle pinned at each end to a brass riser plate. A cylindrical peg on each riser plate enters a housing formed as part of the oval brass base, which is attached to the right box body wall by two flat-head wood screws.

Rising on two brass six-screw hinges, the box lid is made similarly to the box body, from four tongued, grooved and screwed side-pieces and a separate lid held by twelve flat-head wood screws. The front lid wall is inletted for a brass two-hook striker plate for the lock, held in place by three flat-head wood screws. Two small dome-head screws protrude to provide bearings.

2. None of the indicators from this particular source had all the original accessories. Consequently, it is possible that a screwdriver may have been substituted for either the rod or the cleaner. Indicators used with internal-combustion engines were usually accompanied by a steel tube instead of the wooden rod.

3. The lock of the box accompanying D1A 7812L displays an illegible trademark and an oval cartouche containing H. A. S. over 16112/07 and PATENTED. British records reveal that this particular patent was sought on 13th July 1907 by ‘Henry Alexander Squire, of Avondale, Bloxwich, in the County of Stafford’ and accepted on 7th May 1908 to protect ‘improvements in one lever and tumbler locks for use in cabinet locks, mortice locks, padlocks and latches...’ Henry Squire & Sons Ltd still make locks in Wolverhampton.
for the swivelling retainers on the box body. There is also a small rectangular
maker’s plate, etched into aluminium-alloy sheet, which reads typically
DOBBIE MCINNES LIMITED over the address HEAD OFFICE/57, BOTHWELL ST./
GLASGOW separated by a decorative vertical line from AND AT/SO. SHIELDS/
LIVERPOOL/& LONDON. The style of the lettering is distinctively Art Nouveau.

The interior of the lid has a boxwood flap, attached by two small four-
screw hinges. The flap is held closed by a small knob and tongue, which
engages a cut in the inner surface of the front wall of the lid, beneath the striker
plate for the lock, when rotated to the closed position. An internal partition,
glued into a slot in a wooden fillet at the outer end and fixed into the lid wall
with a small tongue at the hinge end, divides the interior of the lid into two
compartments—narrow to the left, broad to the right. These compartments
could hold instruction books, radial divider cards and indicator-card blanks. Instruction labels pasted on the outside of the lid flap often prove to be
replacements; in some cases, however, new labels were attached to the inner
surface instead.

Dobbie McInnes boxes may also be found with compartments for the
cylindrical two-part sheet-steel pencil and tracer boxes, or slots for squares
and the jointed dividers. Those made after 1919, and again from the mid
1930s onwards, were somewhat simplified. The springs were inserted in holes
drilled in blocks (a return to the original pre-Design No. 1 era), and the inner
flap to the box lid was eventually abandoned.

SPRINGS
With a few exceptions, and from the earliest days, engine indicators have
relied on coil springs interposed between the piston and a suitable abutment
to register changes in pressure. The concept was effectively ‘right first time’;
Watt and McNaught used springs of this type, and even though the long and
somewhat loosely constrained springs tended to twist and buckle in use, the
meagre pressures of the day were not enough to cause undue worry. But as
pressures rose and running speeds increased, the ability of indicators to cope
was tested. Springs became shorter and stiffer, greatly improving performance
at the expense of progressive reductions in the size of the diagrams.

Very little research into the progression of spring-design has been done,
but it is evident that the Richards indicator and the McNaughts of the same
period shared springs that were virtually identical in design, if not in size:
a single coil soldered at each end in flanged brass collars. This allowed the
performance of each spring to be adjusted before the collars were secured.
Final adjustment was usually undertaken by filing the wire in the coil.
DOBBIE-McINNES Normal Size

MARK V DIESEL INDICATOR

MARKING ON SPRINGS.—Springs are calibrated and marked (to the table below) for the largest area piston with the outfit. The large figures engraved on the heads represent the pressure scale, and the smaller figures the maximum pressure for which the springs are suitable. To double or quadruple the scale of a spring, employ a spare piston and cylinder of ½ or ¼ the largest area supplied.

<table>
<thead>
<tr>
<th>SPRING lb./sq. in. per inch</th>
<th>MAX. PRESSURE lb./sq. in.</th>
<th>SPRING mm. per kg./sq. cm.</th>
<th>MAX. PRESSURE kg./sq. c.m.</th>
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<td>Vac. plus 9</td>
<td>30</td>
<td>Vac. plus 0.6</td>
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<tr>
<td>16</td>
<td>17</td>
<td>22.5</td>
<td>1.2</td>
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<td>20</td>
<td>25</td>
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<td>30</td>
<td>45</td>
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<td>32</td>
<td>Atmos. 64</td>
<td>11.25</td>
<td>Atmos. 4.5</td>
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<td>72</td>
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<td>2000</td>
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There is nothing to show that the design of this type of indicator spring is to be credited to Charles Richards, as is customary; but neither does any evidence point to John McNaught as the originator. It may simply have evolved to a point where it was regarded as standard, even though a few designers tried to make something which was different. The massive springs that accompanied the Hopkinson indicators had single brass collars, but, despite the promoter’s claims, were ineffectual. A.G. Brown, in *The Indicator and its Practical Working* (published c. 1889), said of the Hopkinson that the ‘excessive weight of the moving parts…will, by their inertia, invariably distort the diagram. The long slender spring used creates by distortion considerable friction in the instrument, which still further increases the error’.

The Thompson indicators and the earliest Tabor instruments also made use of the single-coil spring. On 27th September 1881, however, Allen Sill ‘of Boston, Massachusetts, Assignor to the Ashcroft Manufacturing Company’, received U.S. Patent no. 247700 to protect a ‘Spiral Spring for Indicators’. The
novelty lay in the use of two strands of wire, wound in opposite directions to anchor in conventional collars. The specification drew attention to the advantages of using ‘two or more separate coils and rigidly connecting the same at their respective ends, said coils being arranged in respect to each other so that a tendency of either to bulge when compressed will be counteracted by the others, and a direct and simultaneous movement of each coil [will be] transmitted.’ The Sill-type spring was used very successfully in the Ashcroft-made Tabor indicators, and adapted by many other indicator manufacturers once the patent had run its course.

Another approach was taken by Gillman Brown of West Newbury, Massachusetts, assignor to the Crosby Steam Gage & Valve Company of Boston. U.S. Patent 256281, issued on 11th April 1882, protected a counter-wound spring made of a single strand of wire. A small ball at the base of the spring centred in a slot in the shank of the piston. The threaded tip of the piston rod screwed into the tail of the piston-shank to constrain the spring. This design was used very successfully by Crosby, and then by the Crosby copyists—Maihak, Lehmann & Michels, Bacharach and others.

A catalogue published by the Crosby Steam Gage & Valve Company, shortly before the First World War began, recorded the range of indicator springs as 4, 8, 12, 16, 20, 24, 30, 40, 50, 60, 80, 100, 120, 150, 180, 200, 250 and 300lb ‘to the inch’, which referred to the amount of pressure required to move the indicator pointer by the specified amount. The metric sizes were 2, 2·5, 3, 4, 5, 6, 7, 8, 10, 12, 15, 16, 18, 20, 30, 45 and 60; these figures, however, referred to the height in millimetres the pointer moved for each additional 1 kg/sq.cm of pressure. The classification of the metric springs was the opposite of the imperial patterns, as the ‘2mm’ version was thirty times stronger than the ‘60mm’ type.

Indicators accompanied by a wide range of springs were often used by consulting engineers or by representatives of insurance societies; those with only a single spring will usually prove to have been used with a specific engine. Triple-expansion engines were often accompanied by three indicators, one for each cylinder—high pressure, intermediate, and low pressure.

**MISCELLANEOUS ACCESSORIES**
The idea of operating indicators with electromagnets had occurred to many experimenters seeking to use several instruments simultaneously, or in locations—such as the running plate or buffer-beam of a railway locomotive!—where remote operation was desirable. Among the first attempts to use electrical operation were made by the Briton Frederick
Plate 11. This Schaeffer & Budenberg indicator was made in the U.S.A. during the First World War, based on (but not identical to) the German-made equivalent. It is fitted with a Sargent-type electromagnetic actuator.

By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
Sargent (British Patent 3383 of 1894, US Patent 450731 of 21st April 1891) and by Frederick Lane of Brookline, Massachusetts, who assigned U.S. Patent 530433 of 4th December 1894 to Crosby. The Sargent system was efficient enough to eclipse its contemporaries, and, though rare, is the one most regularly encountered on surviving indicators. The patent drawing shows it attached to a Tabor-like indicator, without the guide plate, but the distinctively-shaped electromagnetic controller will be found on virtually every important type of indicator used in North America.

Indicator boxes contained a variety of small accessories. Among the most common are the steam cocks, usually double-ended or 'two way'. Made of brass, nickel-plated brass or (more rarely) steel, with handles of wood or vulcanite, they allowed the indicator to be connected with suitable cocks on the cylinder—sometimes with the assistance of adaptors in the era before screw threads and pipe sizes had been properly standardised. The boxes of individual indicators, particular the earliest Elliott-made Richards examples, contained a threaded tap to adapt cylinder cocks to accept the union nut. Most British and European indicator boxes contained only a single steam cock, but many American sets (particularly the Tabors) were supplied with a pair of two-way cocks to facilitate taking diagrams from each end of the
cylinder. A special three-way cock was sometimes substituted, enabling a single indicator to be connected to either end of a cylinder at will, as long as the three-way cock had been connected with both of the cylinder cocks.

Spare pistons could be supplied to enable individual instruments to be used with steam engines and internal-combustion engines alike, or with engines of similar type but greatly differing performance. Maihak and similar indicators often required special cylinder seats to accept small-diameter pistons, and these may also be found in the box.

Spanners and screwdrivers were usually provided, though were usually the first of the accessories to be lost or taken for other purposes. Some of the Maihak, Bacharach and Nakano boxes included pliers, and (particularly in German sets) there are often special wrenches for springs, drum collars or cylinder inserts. Short tubes or rods slipped over or into the arms of the union nut, improving leverage,

Squares and jointed parallel dividers were commonly supplied in British and European boxes to ease the task of analysing diagrams, but only rarely

Plate 15. The idiosyncratic but efficient and fast-running Willans engine, designed and developed in Britain, was popular with power-generating agencies prior to the First World War. Taken in 1904, this photograph shows a group of three cylinder single-acting triple-expansion engines at work in Nelson, Lancashire. *John Walter collection.*
with American indicators (unless they had been supplied for sale in Britain). Glass-body oil bottles are common to virtually all sets, usually closed with a cork. The German boxes made prior to 1914, particularly by Schaeffer & Budenberg and Dreyer, Rosenkranz & Droop, often protected these bottles within elegant cylindrical wooden containers with hemispherical lids. Hanks of cord, diagram paper, and tracer-points contained in small two-part sheet-steel cylinders customarily completed each set.

REDUCING GEAR
The comparatively small size of the recording drum on even the largest Richards indicator faced the analytical engineer with a major problem. The stroke of even the smallest engine was considerably greater than the 4.5–5 inches that represented the limits of diagram length, and the stroke of a beam engine or a large horizontal mill engine could exceed ten feet. The engine-testing handbooks illustrate many ways of reducing the motion of the crosshead to suit the indicator, with the assistance of rods, bars, pulleys, pantographs or

Plate 16. A typical wooden pantograph, typical of many used to reduce the movement of a cross-head to the length of an indicator diagram. By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
lazy tongs. Some of the solutions gave diagrams that were approximations, particularly where the reducing mechanism failed to convert the movement of the crosshead proportionately to the motion of the indicator, but the errors were often small enough to be ignored among the other approximations—not least of which was the questionable performance of any spring-and-pointer indicator.

There were a few champions of systems that involved rods and gearing, avoiding the stretching of cord or even braided wire, but these methods failed to prosper. Excepting the pantographs and the lazy tongs, which could be purchased commercially, most of the rod and bar systems were the extemporisations of individual engineers. This approach was actively championed by many of the textbooks, as it permitted the quirks of individual engines to be accommodated. In addition, many of the solutions were simple and acceptably accurate.

Another approach, which found increasing favour with consulting engineers during the twentieth century, was the reducing wheel. Most popular in Germany and the U.S.A. prior to 1914 (but not in Britain), this usually consisted of a large-diameter wheel, connected by cord or wire to the crosshead, which shared a common axis with a much smaller wheel that accepted the indicator-drum cord. Though the reducing gear usually incorporated an additional spring, the wheels were often made of aluminium to keep their weight (and inertia) as low as possible, and could be adapted to a variety of different strokes simply by substituting pulleys.

It was not unusual for reducers to be accompanied by several wheels to lead the cord to the reducer drum from the cross-head, or comparable reciprocating component of the engine; and as many as eight carefully-graduated exchangeable pulleys translated the long stroke of the reducer drum (by way of a cord) into the short stroke required by the paper drum of the indicator. The free-standing Rea reducer shown in Plate 9–16 displays a large aluminium cross-head wheel, wrapped with cord, which would have been used with long-stroke engines. A smaller aluminium wheel, destined for use with short-stroke engines, can be seen in the bottom right-hand corner of the box. Above this lies a set of wooden pulleys, stacked in order of a size on a post, with another wooden pulley (top left) installed next to the large spur gear on the leftward extension of the operating spring guide-rod.

Though its genesis could be seen in some of the ‘one-off’ French indicators of the 1860s, the earliest reducing gear seems to have been developed in the late 1870s: the work of Ladislav Staněk, then domiciled in Prague, capital of the Austro-Hungarian province of Bohemia. This design, originally intended
to be used separately from the indicator, was patented in 1878 and exploited initially by Dreyer, Rosenkranz & Droop. Adapted to connect with the indicator, making a more compact and probably more rigid unit, the Staněk reducer became very popular: minor adaptations were still being offered by Maihak and Lehmann & Michels in 1939.

The idea of reducing the stroke of an engine to manageable proportions with the assistance of a Staněk-type wheel—or something comparable—was not lost on designers in the U.S.A. The earliest successful design was the work of William Houghtaling, whose U.S. Patents 494482 of 28th March 1893 (for

Plate 17. Houghtaling reducing gear, patented in 1894, attached to an external-spring Tabor indicator. Photograph by courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.

the basic concept) and 517006 of 20th March 1884 (for an improved clutch) were duly assigned to the Ashcroft Manufacturing Company. Application for the 1893 patent had been made as early as December 1891.

Offered as an accessory with the Tabor indicator, the perfected Houghtaling reducer consisted of a vertical pulley accepting drive from a suitable part of the engine and a transverse shaft with a rapid-pitch helical thread. The shaft meshed with a toothed ring on the base of the paper drum.

When a diagram was to be taken, the mechanism was thrown into gear with the assistance of a clutch, and the drum reciprocated until the clutch was released. Variations in the stroke of the engine piston were to be handled initially by a series of pulleys fitted to the transverse shaft or, finally, by a single replaceable pulley. The Houghtaling reducer was more compact (and probably stronger) than many of the designs that followed. More conventional
was the work of Edward Rea (U.S. Patent 521815, ‘Steam-Engine Indicator’, accepted on 26th June 1894) and Levi Snow & Frank Pierpont (U.S. Patent no. 515175, ‘Reducing Mechanism for Steam Engine Indicators’, accepted on 20th February 1894).

Though the Snow & Pierpont patent was granted first, the application to protect the Rea design was earlier: 17th June 1893 compared with 14th August 1893. Both reducers were produced commercially. The Rea version accompanied the Straight Line indicator (q.v.), and the Snow & Pierpont equivalent, licensed to the Thompson & Bushnell Company of New York, promoter of the Bachelder indicator, became the ‘Ideal’. Ideal reducing wheels

Plate 19. This Rea-type free-standing reducer was made by Hine & Robertson of New York, probably in 1895. Accessories of this type will often be found with ‘Straight Line’ indicators, but could be adapted for use with rival patterns. By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
were supplied to fit a variety of indicators, and will be found, for example, included in the boxes containing American Thompsons.

Protected by U.S. Patent no. 589358, ‘Reducing Mechanism for Steam-Engine Indicators’, granted to Alpheus Lippincott on 31st August 1897 and assigned to James L. Robertson of New York City, the ‘Victor’ reducing wheel was made largely of aluminium and, so its promoters claimed, would ‘work perfectly on any indicator made, at all speeds up to 500 revolutions per minute and from six inches to eight feet stroke by change of one bushing’. The large reducing wheel, fitted directly beneath the drum, drove an intermediate wheel under the support bracket. The spindle of the intermediate wheel projected upward to receive the exchangeable bush (usually wooden) that transmitted the motion to the recording drum. Victor wheels are marked PAT’D AUG. 31. 97.

Also made by Robertson, the ‘Improved Victor’ had a auxiliary single-pulley fairlead held beneath the base of the main wheel (which had lightening holes instead of spokes) by a butterfly nut and a more robust aluminium wheel to transmit motion to the drum; the way in which the cord was secured—to a additional knurled cap—was also refined. The platform of wheel no. 4465, numbered on the edge, is marked PAT. APPLIED FOR, across the top face, and IMPROVED “VICTOR” over J.L. ROBERTSON & SONS. N.Y. on the other edge.

Victor and Improved Victor reducing wheels were customarily boxed with the indicators, though a few separately-cased examples will be found. The ‘Climax’ wheel was similar to the Victor, but attached to a separate standard; if a Victor was not to be used, the Climax could be placed between an indicator and the take-off point on the engine to achieve the same result.

Among other commercially exploited designs, William Trill of Corry, Pennsylvania, marketed the ‘Faultless’ reducing wheel included as part of U.S. Patent 724525 of 7th April 1903, sought in February 1902 to protect a ‘Record Indicating Device’.

Trill reducing gear, accompanied by nine aluminium bushes, could handle virtually any piston stroke from six inches to five feet. The patent drawings show a bronze liner inside the body to receive the piston, a double back link, a pillar-like front link standard, and a blow-by vent on a collar around the body beneath platform level (series-made indicators had a vent tube protruding beneath the junction of platform and body). The most important claims to

 Plates 20 and 21, preceding page. Robertson-Thompson indicator no. 7099, dating from c. 1907, is fitted with the Lippincott-designed ‘Improved Victor’ reducer no. 4465. Note the exchangeable wooden pulleys and metal bushes. Museum of Making collection.
novelty lay in the reducing gear, with a special double-pulley bracket attached to a rod pendent from the support platform. The pulleys were connected with a coil spring, allowing the upper one, pivoted independently, to provide a detent by clamping the cord.

The Crosby Steam Gage & Valve Company preferred a wheel developed by Frank Wolfe of Boston, Massachusetts. In his February 1900 specification submitted in application for what became U.S. Patent no. 689528, accepted on 24th December 1901, Wolfe claimed that he sought to improve ‘reducing-wheels or reducing mechanism for steam-engine indicators, and more particularly…the support for such reducing mechanism. Its object is to provide for attaching such support directly to the cylinder of the steam-engine or to an indicator-cock interposed between it and the cylinder, thereby relieving the steam-engine indicator from severe strains and avoiding consequent errors… Reducing-motions similar in purpose are well-known; but heretofore in all cases they have consisted of independent means erected between the cross-head of the steam-engine and the indicator attached to the

cylinder... or they have been designed as to be attached to the indicator itself below the drum... In the first case it is inconvenient, cumbersome, and often inoperative or very difficult to operate. In the other case its attachment to the indicator tends to distort or injure the indicator by the strain which is thus brought upon it by the movement of the cross-head...’

Wolfe-type reducing gear was very distinctive, with a serpentine bracket between the indicator cylinder and the union nut; it also had a tubular spring case extending horizontally above the main cord-pulley, carried directly beneath the indicator drum. A Table in the Crosby handbook gives details of

Plate 23. The Wolfe-patent reducer was made in quantity by the Crosby Steam Gage & Valve Company. Note the spring case protruding laterally. This is the older type, with bevel gears; later examples had spur wheels. By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
“...Attach the reducing wheel bracket directly to the cylinder cock of the steam engine by means of the union 4 below the standard 1. Connect the indicator to the threaded nipple 5 at the top of the standard 1, with the paper drum of the indicator standing toward the horizontal spring case 14 of the reducing wheel. Adjust the position of the reducing wheel, by turning the standard 1, until the cord pulley 26 of the reducing wheel is directly in line with the crosshead of the engine.

'To locate the Cord Guide. Loosen the clamping screw and move the cord guide bracket 24 around until it is in the proper position to allow the cord to pass directly through the hole in the cord guide post 28 without rubbing, to the crosshead of the engine. Be sure that the cord guide bracket 24 is close to the shoulder on the blued steel bushing on which it turns; then secure it in place by turning the clamping screw.

'To Adjust the Stroke Pulley. Remove the outer knurled nut 27 on the end of the spring case. Then the spring case 14, containing the spring, can be easily pulled off the spindle with the fingers, by means of the knurled head 16. The hub of the large disc, marked with the large figure 1, serves as the smallest stroke pulley...and also forms the bearing or support for the larger stroke pulleys when they are used. The disc can be removed by pulling it outward with the fingers, disengaging it from the two pins that hold in proper position on the spindle. There are five stroke pulleys provided... Select the proper stroke pulley and place it in position on the hub of the disc. Replace the disc on the spindle in its proper position, engaging the two pins; then replace the spring case 14, turning it until it will slip on over the square on the spindle, to the shoulder, and replace the knurled nut 27.

'To Change the Gears for Different Strokes. For the longer lengths of stroke the smaller
pinion gear marked S is used, and for the shorter strokes the pinion gear marked L should be used. These pinions fit upon their shaft, to engage the large gears that remain permanently in position at 30 on their common shaft. The small pinion marked S engages with the larger gear, and the larger pinion marked L engages with the smaller gear, to provide the proper length of indicator cord travel in combination with the five stroke pulleys provided.

If it becomes necessary to change a pinion, to provide for any special engine stroke desired, remove the screw 31 that secures the small blued steel pinion and pull the pinion gear from its shaft with the fingers. Then slip the other pinion onto the shaft in its place and replace the screw 31. The larger pinion gear marked L is commonly used for strokes from 10 to 36 inches, and the smaller pinion gear marked S may be used for the longer strokes.

'To Adjust the Tension of Spring. Unscrew the knurled nut 27 at the end of the spring spindle, allowing the spring case to be drawn forward slightly from the square on its spindle until it can be turned by means of the knurled cap 16. When the rubber stop on the cord is against the cord guide post 28, the knurled cap of the spring case may be turned to the left not more than one-half turn. When the tension is properly adjusted, push the spring case 14 back to its firm position on the spindle and replace the knurled nut 27.

One-quarter turn of the knurled cap 16 will generally give sufficient tension to hold the cord taut on the return stroke. Turning the spring tension more than one-half turn will only put excessive strain upon the cord. The most accurate results in the use of the reducing wheel will not be accomplished when there is too great tension on the spring. The measured pull on the reducing wheel, when the rubber stop is against the cord guide post 28, should be about ¾ lb. And ordinarily should not exceed 1 lb., when the indicator drum cord is not attached.

'To Attach the Indicator Cord. With the proper stroke pulley in place, carry the cord from the indicator drum through the guide pulleys and down over the reducing wheel stroke pulley. Pass the end of the cord through the notch in the flange of the large disc of the reducing wheel pulley and secure it around the clip on the outside of the flange, drawing the indicator drum away from its stop, enough to give some tension to the indicator cord, before making it fast. When the detent mechanism is against its stop, it should hold the indicator drum away from the drum stop. Take care that the guide pulleys of the indicator are turned in proper position so that the indicator cord runs freely on its guide pulley without side friction.

'To Operate the Detent. When the finger lever 25 of the detent mechanism is pushed to its downward position to release the clutch engagement, the indicator drum will operate freely; but when the lever 25 is turned to its upward position so that the clutch jaws engage the detent disc, the indicator drum will complete the stroke, but will then be released from engagement with the reducing wheel mechanism until the lever handle 25 is again turned downward.

This is a patented improvement of much practical importance...”
the pulleys that were to be used to adapt the Wolfe reducing-wheel to engines of different stroke-length, and an idea of the size of the resulting diagrams. For example, an engine with a ten-inch stroke required a combination of stroke pulley ‘5’ and pinion gear ‘L’ to give a diagram that was three inches long, whereas an engine with a 72-inch stroke gave a diagram 3.8 inches long by combining stroke pulley ‘i’ and pinion gear ‘S’.

Though designed for use with Crosby indicators, Wolfe reducing gear could be used with instruments of other makes simply by substituting special nipples (part 5 on the diagram) which screwed into the frame or ‘standard’.

The frequency with which survivors are found suggests that reducing wheels enjoyed their greatest success in North America prior to 1914, and there is little doubt that production of the most important designs numbered in thousands.

Plate 25. American Steam Gauge external-spring indicator no. 6178, with Ideal reducing wheel no. 3210A. By courtesy of Bruce Babcock, Amanda, Ohio, U.S.A.
In Europe, however, the situation is less clear. This is partly because few of the Staněk-type reducers popularised in Germany were sold as individual units (most were included in ‘boxed sets’ with a suitable indicator), and partly because it is unclear if the Staněk instruments, when sold separately, were numbered in a series of their own or simply within the range allotted by Dreyer, Rosenkranz & Droop—for example—to their indicators.

Evidence suggests that the British were less enthusiastic about reducing systems than their German cousins, preferring a variety of ‘bar and cord’ improvisations suggested by the leading engine-management and indicator-practise textbooks. Though Crosby, Staněk and similar imports were sold in small numbers, the only reducing gear to reach production status in Britain was patented on 8th June 1901 (no. 12365/1900, ‘Improvements in Steam Engine and like Indicators’) by John Reginald Jones, ‘Gentleman’, and Francis Richard Wade, ‘Engineer’.[4]

The patent drawings show an elongated platform containing a large helical spring, known to Jones & Wade as the ‘banjo-plate’, with an indicator drum at one end and two pulleys ‘mounted on a common shaft’ at the other. The lower, large-diameter pulley accepted a cord attached to a suitable reciprocating point on the engine; the upper, the smaller, was connected by cord to the indicator drum. Changing the upper pulley allowed for the differences that would be found in the length of piston strokes. A pivoting bracket between the lower pulley and the banjo plate carried a cord-guide pulley (fairlead) at its tip. The cord guide contained rollers which were designed to serve as a detent by ‘nipping the cord when it travels in one direction but…permitting the cord to travel more or less freely in the other direction’.

Dobbie McInnes Ltd of Glasgow made what has become known simply as ‘Wade Gear’ in quantity, though a comparison of photographs with the patent drawings reveals that changes had been made to use the banjo-plate in conjunction with a conventional Design No. 1 indicator. Though the patent drawings were unresolved—no way of attaching the indicator to a steam cock was shown—there is little doubt that the Dobbie McInnes version was inferior. The banjo-plate was attached only by a nut to the threaded drum-retaining spigot beneath the platform, and, even though the separate

4. Tracing the inventors proved difficult, partly because the 1901 census of England and Wales revealed both of them to have been boarders. John Reginald Jones was born in Banbury, Cheshire, c. 1873; in 1901, he was listed as ‘Mechanical Engineers Manager’ and as an ‘Employer’ at 133 Disraeli Road, Wandsworth. Francis Richard Wade, born in 1874 in Beeston, Nottinghamshire, was listed in 1901 as a ‘Mechanical Engineer’ in Coundon Road, Coventry. It seems most likely that Wade was responsible for the invention, but that Jones may have financed it. Unfortunately, no details of the licensing agreement with Dobbie McInnes have survived.
fairlead bracket was eventually abandoned in favour or a block pivoting on
the tip of the banjo-plate, the impression is nonetheless one of fragility. Wade
Gear has none of the solidity of the Staněk pattern, even though the pulleys
share a common axis. The manufacturer, of course, preferred to emphasise
perceived strengths: ‘Transmitting its motion to the indicator by means of
a cord this Reducing Apparatus is much preferable than others of a similar
nature having worm gear contact, as the latter are not only necessarily heavier

Plate 26. Dobbie McInnes D1B indicator no. 18433 (c. 1919) was boxed with Wade Gear no.
474, shown here. Though the box bears its manufacturer’s marks, constructional details
are unusual: for example, the indicator is held in place by a peg in the box-bottom and a
cut-out plate in the lid to receive the indicator-drum knob. John Walter collection.
Plate 27. A composite view showing both sides of Dobbie McInnes D1B indicator no. 18433 (1919?) fitted with Wade reducer no. 474. Note the comparative fragility of the fixing system, relying on entirely on an under-platform retaining nut. *John Walter collection.*
and set up friction, but are subject to breakdown due to wear and tear...or to the presence of grit in the gearing.'

Yet Wade Gear still sold in quantity, probably mostly to academics and researchers. Survivors are rarely seen, but an examination of several examples shows that changes were made during a ‘production life’ of about forty years. Consequently, the reducers are more likely to have been made in batches throughout the period than as a single run of parts at the very beginning.

The 1919 Dobbie McInnes catalogue was still advertising the original form of Wade Gear, with a separate fair-lead bracket pivoting on the pulley-wheel axis. This followed the patent drawing in most respects. The text confirms that the ‘frame carrying the cord guiding pulley is hinged so that the cord pulley can be set at any angle. This cord pulley is provided with a clutch or brake...which, when in action, prevents the return of the cord to the wheel, thereby stopping the motion of the whole gear and retaining the paper drum in a fixed position to allow fresh diagram cards to be fixed’.

Wade Gear, ‘nickel plated throughout’, was being offered in 1919 for £9, including ‘one wheel to suit a given stroke’, or for £10 in a ‘polished wooden case, with 3 sets of wheels to suit strokes from 6 feet downwards’. A footnote

Plate 28. A view of the undersurface of Wade Gear no. 474, made by Dobbie McInnes Ltd of Glasgow c. 1919. This represents the improved pattern, with the fairlead pivoting on the frame. Note also the large helical spring inside the pulley. John Walter collection.
added that, if Wade Gear was ordered with an indicator, the box of the latter could be adapted to include the reducer and its accessories for fifteen shillings extra. Most surviving examples of Wade Gear are boxed with indicators.

Unfortunately, the only example of the first-type Wade Gear that could be traced, no. 221, is contained in its own box; though it accompanies small Design No. 1 indicator D1B 12829, there is no evidence to confirm that it also dates from c. 1913. The next oldest, no. 474 accompanying indicator D1B 18433 (c. 1919), represents the ‘Improved Model’ or ‘New Model’ with the fairlead bracket swivelling on the tip of the banjo-plate: much stronger than the original separate-bracket design inspired by the 1901 patent. It is suspected that the changes were made during the First World War, but evidence is lacking. The other survivors are all more recent—no. 635, accompanying D1A 25378 (Dobie McInnes & Clyde, c. 1933), and no. 694 with D1A 30900 (Dobie McInnes, c. 1942).

Plate 29. This typically European or Staněk-type reducing wheel was boxed with an indicator made by Lehmann & Michels in the 1920s for sale in France. The pulleys were almost always made of aluminium alloy. Canadian Museum of Making collection.
The engine indicator was the first device that could give experimenters, manufacturers and the operators of steam (and later, internal-combustion) engine operators an idea of the internal working of their engines. Previously, valves had been set, valve-gear had been adjusted and eccentrics altered largely by ‘feel’: the knowledge, acquired by experience, that allowed men—or so they thought—to adjust their engines by sight and sound.

Improvements in efficiency were not the goal of the earliest colliers who operated wheezy, slow-moving atmospheric engines. Pit-head dross was plentiful and, with nothing to compare, the consumption of prodigious quantities of fuel went unremarked.

Gradually, however, experimenters such as John Smeaton began to probe more deeply into the working of the engines. When the first Watt beam engines appeared in the 1770s, operating at high pressure compared with the atmospheric engines and also fitted with effective condensers, the improvements in economy became clear to all. It is to Watt and his employee John Southern that credit for the indicator is customarily given, and there is no doubt that even this primitive moving-tablet recorder gave a real insight to what happened within the cylinder.

Increases in boiler pressure and then running speed forced the development of better indicators, including the McNaught of the late 1820s and then the Richards of the 1860s, which was the first instrument to successfully amplify the movement of the piston. The ability to obtain comparatively large-scale diagrams from steam engines was a huge step forward. Though experiments undertaken in Germany in the 1870s suggested that the indicator was often much less accurate than its champions claimed, unless properly made and constantly checked, most instruments gave good service—assuming that the strength of the spring was matched to the operating pressures of an individual engine. An indicator used by a consulting engineer can often be identified by the proliferation of springs in the box, whereas an instrument acquired specifically to regulate a particular single-cylinder engine may be accompanied by nothing but a solitary replacement spring of the same rating as the spring within the indicator itself.

The introduction of high-speed engines (whether steam, gas or oil) placed additional demands on indicators, leading to investigations of operational limits. Indicators all have critical frequencies where their own oscillations interfere too greatly with the diagram trace; the weight of the moving parts were excessive in the earliest designs, but even some of the later ultra-light
versions were unable to cope satisfactorily with high pressures or excessive speeds. This partly explained the decline in popularity of Richards indicators after 1900 in favour of lightweight designs such as the Crosby, although they were amongst the simplest and sturdiest of all.

The advent of springs that were mounted externally was another great advance, as it isolated the spring from the effects of steam-heat and also allowed springs to be changed with much greater ease than any of the internal-spring designs had allowed. Attempts were also made to develop optical indicators, but these were customarily confined to colleges, universities and research facilities; even at the end of twentieth century, conventional external-spring indicators were still being made for use with (in particular) large marine diesel engines.

Among the most obvious advantages of the indicator was the saving of fuel—and, therefore, money—that could be made by correcting faults in the supply of steam or the setting of valves. The textbooks of the day gave copious examples of the difference between bad practice and good, reserving particular scorn for the practice of setting engines ‘by ear’. Though this undoubtedly offended the sensibilities of many individual
minders, the gradually increasing use of the indicator in the late nineteenth century undoubtedly made a difference to the consumption of coal. This was particularly valuable in districts where coal was in short supply, or at sea where the gradual reduction in the use of sail (and the large distances between coaling stations) emphasised the value of economical use of fuel.

George Barrus drew attention to potential benefits: “The engines of a company having 200 miles of [rail-]road in operation use in the neighborhood of 400 tons of coal per day, which, at $5.00 per ton, represents the annual expenditure of $750,000. If the application of the indicator resulted in preventing a waste of only 5 per cent of fuel, it would save the company $37,500 per year’.

Shipping companies were among the most enthusiastic champions of the indicator, particularly once use of triple-expansion engines and high-pressure boilers had become widely established. The need to balance the output of each cylinder was important, and it was vital to ensure that multiplicatted engines—large ships could have four—performed similarly.

By 1900, ships could travel huge distances on surprisingly small amounts of fuel, with a tremendous effect on global trade. A typical tramp steamer of the pre-1914 period consumed 1.2–1.5lb of coal for each indicated horsepower-mile; a ship with engines of 1500ihp, which was typical of the period, would usually consume coal at the a rate of 200–250lb per nautical mile.

ANALYSING THE DIAGRAM
With few exceptions, all mechanically operated volume/pressure indicators produce diagrams of similar form. Indeed, any attempt to break this rule—maximum-pressure recorders excepted—has been doomed to failure; engineers are traditionally conservative, and often reluctant to depart from established practice.

The use of indicators has been described in great detail (see Bibliography), but, in its most basic form, an indicator diagram would consist of a rectangle created from the rise in pressure shown on the vertical axis and the passing of time shown horizontally. The latter is expressed by the reciprocation of the recording drum, giving a diagram in the form of a ‘closed loop’.

A steam engine works by allowing steam to enter a cylinder behind a piston, then pushing the piston along to the opposite (far) end of the cylinder. The piston is connected to a crank, and the crank is often connected to a heavy flywheel. If the engine is single acting, the steam would be exhausted at the end of the piston stroke and the momentum of the flywheel, once the engine was running, would return the piston passively to its original position. Steam
would be introduced, and the cycle would recommence. Most engines are double-acting, however. When the steam is exhausted from one side of the piston at the end of the outward stroke, another charge of steam is introduced on the other side of the piston to actively push the piston back again. This results in continual motion as steam is admitted and exhausted on both sides of the piston alternately.

Most engines ‘cut off’ the supply of steam at about 25–50 per cent of the piston stroke. This is due to a desire to economise, using the ability of steam to expand within the cylinder (‘expansive working’). It is standard practice, therefore, to shut the inlet valve long before the piston has travelled the length of the cylinder, allowing steam to provide impetus by continuing to expand even though pressure drops as volume increases. Opening the exhaust valve shortly before the end of the piston stroke allows pressure to fall quickly during the last few inches of piston-travel.

As the piston travels back to its start position, propelled by a fresh admission of steam on the crank side, it does so against a certain amount

Plate 31. Sea-borne trade depended greatly on the efficiency of the steamship and, in particular, its engines. Indicators were customarily carried aboard to monitor performance (and, therefore, fuel consumption), though very few properly attributable examples survive. This painting shows a Peninsular & Oriental steamer of the 1880s coaling by moonlight in the Arabian Gulf. John Walter collection.
THE "STANDARD" AVERAGING PLANIMETER."

This instrument is of the "Amsler" type, and is capable of giving the most accurate results, either for M. E. P. work, or areas in square inches and tenths. The tracer bar is adjustable to the card length, so that this "arithmetic" is dispensed with in computing indicator cards. Letters from many prominent users bear testimony of their accuracy and convenience. Price in velvet lined morocco case with special mahogany board $15.00

THE "LIPPINCOTT" PLANIMETER, PRICE $15.

This instrument has been designed to obviate the defects which exist in other instruments of the class.

The wheel is made knife-edged, and is free to move on its shaft, so there can be no slipping upon the surface, so that it gives perfectly accurate results, whether the wheel travels upon the roughest table or bench, or the finest paper. Its accuracy therefore is not dependent upon the texture of the surface upon which it is used.

The scale is hermetically sealed in a glass tube, which forms a frictionless shaft upon which the wheel moves. This scale can never become soiled, or affected by atmospheric influences.

Three of these interchangeable scale tubes are furnished with each instrument, each containing two scales to correspond with the ordinary indicator springs, and the M. E. P. may be read direct, without computation for the following springs: 8, 10, 12, 16, 20, 24, 30, 32, 40, 50, 60, 80, 100 and 120.

No injury to the edge of the wheel, or bending of the tracer point can possibly affect its reading.

Broken tubes replaced for six cents in stamps, to cover mailing expenses.

Areas in square inches and tenths may be also read direct from scale. Catalogue, giving further particulars, sent upon request.
of back pressure. Closing the exhaust valve shortly before the end of the stroke traps and then compresses the residual steam in the cylinder, which is vital to the smooth running of the engine as it allows lost motion (‘slack’) in the crank and associated pins to be taken-up gradually. The inlet valve then admits steam, pressure climbs rapidly to its maximum value, and the cycle begins again.

The diagram is no longer the horizontal rectangle it would have been if full-pressure steam was admitted for the entire stroke; instead, it takes the form of a vertical rectangle (where steam is admitted at full pressure) joined to a truncated right-angle triangle representing the part of the cycle where the expansive properties of the steam that is already in the cylinder are being used to promote economy. Rounded corners show the point at which the admission of full-pressure steam has been cut off, where admission or exhaust occurs, and where the cushioning effects of residual steam prevents unnecessary stress on the engine components.

The position of the base of the diagram in relation to the atmospheric line will show the levels of back pressure, and whether the engine is fitted with a condenser (when the baseline will lie below the atmospheric line and will indicate a vacuum).

Diagrams may be taken from one end of the cylinder only, though, with the aid of multi-way cocks, will often be taken from both ends in sequence and present a mirror-image appearance. The greater the symmetry of the mirroring, the more consistently an engine is performing. There can be good reasons why the power developed on each stroke is not identical, but this balancing is nevertheless an ideal if often theoretical goal.

To guard against an indicator card being untypical, several traces would be run on a single card; in most cases, assuming the engine was working reliably without any change in load, the lines would reinforce each other. The ‘limiting’ indicators achieved a similar goal by building up a single trace of narrow horizontal slices taken from as many as fifty sequential strokes.

Plate 32. Taken from a leaflet published in the late 1890s by J.L. Robertson & Sons of New York, successors to Hine & Robertson, this shows the Lippincott planimeter, with a recording wheel to slide along a glass tube during the tracing movement. The reading could be taken against the paper scale inserted in the tube. Though similar in principle to the later Willis and Trill planimeters, the Lippincott pattern was too fragile to withstand careless use; the glass tubes broke easily, and excessive friction sometimes prevented ‘free slippage’ of the recording wheel along the surface of the tube. By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
An indicator diagram could draw attention to a wide range of problems with an individual engine. On many occasions, the diagram revealed that the setting that was claimed to be perfect ‘by ear’ or ‘by eye’ was anything but ideal, and changes could often be made to improve economy or reduce the strain on the components. Diagrams could reveal a wide variety of faults simultaneously; those that were due to bad valve-timing or leaky pipes were easily addressed, but poor design and bad construction were, of course, much more difficult to correct.

**ANALYTICAL TOOLS**
The traces provided a surprising amount of information, among the most useful being the ‘atmospheric line’ drawn simply by allowing the drum to revolve without allowing steam to reach the indicator piston. Each spring was marked with a ‘scale’ that, in imperial-measure terms, signified the weight required to move the tracer of the indicator by one inch. A ’24’ spring, therefore, required a weight of 24lb to move the pointer by an inch; and each
inch of diagram-height, therefore, equalled a steam pressure of 24lb. Trial and error showed that hot springs performed differently to those that were tested cold, but most manufacturers were aware of the problem and calibrated accordingly. Though there were undoubtedly errors from spring to spring, and also from indicator to indicator, the system was efficient enough to provide acceptable results.

Once the horizontal lines of pressure had been deduced, the ‘mean pressure’ of the cylinder could also be obtained in any of several ways. The simplest was to divide the diagram into narrow vertical sections, total the heights of the sections, and then divide the result by the number of sections. This gave a good approximation, and was helped by the manufacturers who provided grids to facilitate an accurate division into sections. One or two companies even made folding multi-bar dividers.

Another way, potentially more accurate and often quicker, was to use a polar planimeter. Invented in the 1850s by a Swiss mathematician, Jacob Plate 34. The Improved Coffin Planimeter, incorporating details from Levi Snow’s U.S. patent of 1903, was made in quantity by John S. Bushnell Company of New York prior to 1910. By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
The No. 3 planimeter differs somewhat in design from the two previously described. It is capable of measuring larger areas, and by means of the adjustable arm A, giving the results in various denominations of value, such as square decimeters, square feet, and square inches; also of giving the average height of an indicator diagram in fortieths of an inch, which makes it a very useful instrument in connection with indicator work.

Recording mechanism

Fig. 7 [omitted] shows in detail the recording mechanism of a No. 3 planimeter, from which the method of reading from either instrument may be easily understood. G is the counting disc, D the roller wheel, and E the vernier. From the counting disc we read 1 (ten), for the last figure that has passed the index line on the post J; from the roller wheel we read 4 (units), for the last figure that has passed zero on the vernier; we also read 7 (tenths), for that number of graduations beyond 4 that have also passed zero on the vernier (shown by the dotted line n), then from the vernier we read 3 (hundredths), because the third graduation on the vernier coincides with a graduation on the roller wheel. The complete reading will then be 14.73 square inches. When starting from zero the movement of the counting disc need not be noted when measuring single indicator diagrams, as they are of less than ten square inches area.

Directions for Measuring an Indicator Diagram with a No. 1 or No. 2 Planimeter

Care should be taken to have a flat, even, unglazed surface for the roller wheel to travel upon. A sheet of dull finished cardboard serves the purpose very well.
Set the weight in position on the pivot end of the bar P, and after placing the instrument and the diagram in about the position shown in the cut [not shown], press down the needle point so that it will hold its place; set the tracer point at any given point in the outline of the diagram, as at F, and adjust the roller wheel to zero. Now follow the outline of the diagram carefully with the tracer point, moving it in the direction indicated by the arrow, or that of the hands of a watch, until it returns to the point of beginning. The result may then be read as follows: Suppose we find that the largest figure on the roller wheel D, that has passed by zero on the vernier E, to be 2 (units), and the number of graduations that have also passed zero on the vernier to be 4 (tenths), and the number of the graduation on the vernier which exactly coincides with the graduation on the wheel to be 8 (hundredths), then we have 2.48 square inches as the area of the diagram. Divide this by the length of the diagram, which we will call 3 inches, and we have .8266 inches as the average height of the diagram. Multiply this by the scale of the spring used in taking the diagram, which in this case is 40, and we have 33.06 pounds as the mean effective pressure per square inch on the piston of the engine.

Directions in Using the No. 3 Planimeter

No. 3 planimeter is somewhat differently manipulated, although the same general principle pertains. The figures on the wheels may represent different quantities and values according to the particular adjustment of the sliding arm A. If it is desired merely to find the area in square inches of an indicator diagram, set the sliding arm so that the 10 [square] inch mark will exactly coincide with the vertical mark on the inner end of the sleeve H at K, Fig. 7 [not shown]. The sliding arm is released or made fast by means of the set-screw S.

With the wheels at zero and the planimeter and diagram in the proper position trace the outline carefully, and read the result from the roller wheel and vernier, the same as directed for the No.1 and No. 2 instruments.

Example: Suppose, in a diagram so measured, we read from the figures on the roller wheel 3 (tens), from the graduations on the roller wheel 0 (tenths), and from the vernier 8 (hundredths), then we have 35.2 fortieths of an inch, which, divided by 40, gives 0.88 of an inch, the average height. This multiplied by the scale of the spring used, which in this case is 60 pounds, gives 52.8 pounds as the M. E. P.

To find the average height of an indicator diagram at one measurement, set the sliding arm so that the steel points on its upper side shall be just the length of the diagram—measured on a line parallel with the atmospheric line—apart, as shown in Fig. 9 [not shown]. With this adjustment the figures on the counting disc represent hundreds, those on the roller wheel tens, the intermediate graduations units, and the vernier gives the decimal. Place the instrument in position with the wheels at zero, and trace the outline of the diagram. The result of the reading will be its average height in fortieths of an inch.

Example: Measuring the same diagram as before, suppose we read from the figures on the roller wheel 3 (tens), from the graduations 5 (units), and from the vernier 2 (tenths); then we have 35.2 fortieths of an inch, which, divided by 40, gives 0.88 of an inch, the average height. This multiplied by the scale of the spring used and we have 52.8 pounds.
Amsler,[5] these instruments automatically calculated the area of an enclosed figure with the aid of graduated wheels and verniers. Their popularity as mathematical instruments ensured that huge quantities were made. Many

5. Jakob Amsler was born in Stadeln bei Brugg on 16th November 1823. While studying in the universities of Jena and Königsberg, he changed course from theology to mathematics and physics. Receiving a doctorate in 1848, he returned to Switzerland, patented the polar planimeter in 1853, and married Elsie Laffon in 1854. Amsler then took the surname 'Amsler-Laffon' (this is not widely recognised). When Amsler-Laffon died in January 1912, more than 50,000 planimeters had been made in Schaffhausen alone.
engine-indicator manufacturers, such as Crosby and Dobbie McInnes, offered ‘own brand’ planimeters; however, these were customarily purchased from specialist manufacturers in Europe or (subsequently) the U.S.A.

The simplest form of instrument associated with steam engines is an ‘area planimeter’, often resembling a large sugar-tongs. The pole arm is straight, except for a curve at the base necessary to provide clearance for the integrating wheel, which is attached to the ‘carriage’—usually in the form of a shaft with needle-bearing ends—in turn attached to brackets on the trace arm. Both arms end in points: the pole arm has a needle, designed to stick into the paper or base board, and the trace arm has a blunted pointer. A small weight can generally be attached to the pole arm to keep the needle point in place. The simplest forms of these instruments, set for a single pre-determined value (e.g., 10 square inches) have integrating wheels divided into units and tenths, relying on a vernier scale on the carriage or trace arm to give an accurate reading. A more sophisticated version, sharing the basic construction, had an additional counter driven by a worm gear on the integrating wheel shaft.

Area planimeters are operated simply by selecting a fixed point outside the diagram, where the needle on the tip of the pole arm is anchored, and

Plate 36. The finalised form of the Lippincott planimeter is shown here, made by Hine & Robertson c. 1895. By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
The area of the diagram can then be read off the scales and converted to mean height, mean effective pressure, or indicated horsepower.

The more sophisticated polar planimeters rely on the same method of interpretation, but have additional features. The integrating wheel, worm, counter-wheel and vernier may be carried on a carriage that can be slid along the trace bar, allowing the instrument to be set to different base units. These are usually marked somewhere on the bar, either in the form of lines scribed at pre-determined points or as a ruled scale (metric or imperial measure) that allows arbitrary settings to be made. Planimeters of this type were accompanied by special setting-tables that also offered a variety of constants allowing large areas to be measured from inside the diagram.

Plate 37. This ‘Improved Willis Planimeter’, no. 2188, made in the U.S.A. by Robertson of New York, dates from c. 1904. Note the rotating boxwood scale and the blued-steel wheel that slides along the bar to allow a reading to be taken. John Walter collection.
In addition to conventional Amsler-type polar planimeters—made by Amsler, Coradi, and many others—there have been several idiosyncratic designs. In the U.S.A., for example, Hine & Robertson of New York and their successors, James L. Robertson & Sons, offered Lippincott and Willis planimeters; and the Trill Indicator Company, was still offering improved Willis-type planimeters in 1916. These differ greatly from the Amsler type in construction, though they are used similarly and the underlying theory of operation is identical.

Among the first methods of assessing the area of an indicator diagram was provided by John Coffin of Syracuse, New York State, patentee (U.S. 258993, accepted on 6th June 1882) of an ‘Averageometer or Instrument for Measuring the Average Breadth of Irregular Planes’. The Coffin Averager was originally made by the Ashcroft Manufacturing Company of Bridgeport, Connecticut, alongside the Tabor indicators. The Averager was essentially a linear planimeter combined with a board-like base, with a metal channel set into the left edge and a clamp sliding in another channel placed horizontally across the centre. To use an Averager, the diagram was attached to the board with its vertical edges against the fixed clamp on the left and the adjustable clamp to the right. The point of the trace arm was then taken around the diagram in the usual way, allowing the integrating wheel to record movement.

Plate 38. The Trill planimeter of the era immediately prior to the First World War was a variation of the Lippincott and Willis patterns, relying on a sliding wheel to record movement. *By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.*
Most Averagers had wheels with a circumference of 2.5in and a six-inch trace arm, giving a total of 15 sq.in for one turn of the integrating wheel.

The reading on the wheel and its vernier gave the area of the diagram. Raising the trace-point vertically along the edge of the adjustable clamp until the readings returned to zero gave the mean effective pressure by measuring the height of the new trace-point position above the atmospheric line with the appropriate spring-scale.

The self-contained nature of the Averager, allowing diagrams to be analysed without the use of a separate sheet of paper, persuaded several inventors to improve on Coffin’s design. They included Levi Snow of New Haven, Connecticut (U.S. Patent 718166 of 13th January 1903), and Ernest F. Chase of Bridgeport, Connecticut (U.S. Patent 783568 of 28th February 1905); and Frederick Blanchard, Ernest Cocker and Philip Darling (U.S. Patent 961836 of 21st June 1910). Snow’s planimeter was licensed to the John S. Bushnell Company of New York, to made in quantity alongside the Bachelder indicators; the Blanchard, Crocker & Darling patent was assigned to the Ashcroft Manufacturing Company of Bridgeport, Connecticut, but the planimeter was probably only made in very small numbers.

Other designs included one by Eugene Higgins of Lansing, Michigan, whose polar planimeter was the subject of U.S. Patent 301594, accepted on 5th July 1884. Another was the work of Ernest Kimmel and Edward Claussen of Providence, Rhode Island, recipients of U.S. Patent 336812 (accepted on 23rd February 1886) to protect an ‘Instrument for Measuring the Mean Height of Steam-Engine-Indicator Diagrams’; a third was the work of Almon Calkins, whose ‘Polar Planimeter’ was the subject of U.S. Patent 458698 of 1st September 1891. The Kimmel & Claussen planimeter may have been the first to include pointers which could be set to the width of the diagram; however, this feature was subsequently copied by many others.

More successful commercially was the planimeter patented by Alpheus C. Lippincott of New York City (U.S. no. 569107 of 6th October 1896). This had a polar arm and a tracing arm, often adjustable, but the integrating wheel and vernier scales of the Amsler pattern were replaced by a sharp-edged wheel that was free to slide on an arm that consisted of a glass tube containing a paper scale corresponding to the rating of the indicator spring. Planimeters of this type, made by Hine & Robertson of New York, were customarily provided with several tubes, each often containing a three-sided card.

The Willis planimeter was protected by patents granted to Edward J. Willis of Richmond, Virginia, on 13th November 1894 (U.S. no. 529008), 9th July 1895 (542511, reissued on 22nd September 1896 as no. 11568) and 23rd
April 1901 (no. 672581). Made by the James L. Robertson & Sons Company in New York City, the Willis design was similar to the Lippincott type—so similar, indeed, that Willis planimeters usually acknowledged the Lippincott patent as well as their own protection.

The fragile glass tube was replaced with a sliding rod, running beneath a small roller at each end of the carriage, and the position of an indexing wheel on the rod could be read off a scale on the rear of the planimeter carriage. The scale was customarily a triangular ruler (enamelled metal in a few cases) carrying six different scales. The ruler could be rotated or removed and inverted to give access to the scale matching the rate of the spring that was being used in the indicator.

Originally made by the Engineering Power Company, the Trill planimeter was a modification of the Willis pattern, with readings provided not by the edge of the wheel but by pointers sliding against two triangular scale-bars.

Plate 39. This area-type planimeter was made in Germany for Keuffel & Esser of New York, probably towards the end of the nineteenth century. By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
Attached to a carriage that had been extended to support the adjustable trace arm at its mid point, the bars provided scales for 10, 12, 16, 20, 25, 30, 32, 40, 50, 60, 70 and 80 divisions per inch, enabling the Trill planimeter to be used with any indicator equipped with springs of these particular ratings. The extendable polar arm customarily pivoted to fold into the planimeter case to save space.

The manufacture of planimeters has been restricted to a handful of specialist instrument-makers, such as Amsler and Coradi in Switzerland; Dennert & Pape (‘Dupa’, later ‘Aristo’), Mayr, Höhmann & Co. (‘Maho’), Ott, and Reiss in Germany; the Los Angeles Scientific Instrument Company (‘Lasico’), Bowen & Company and Keuffel & Esser in the U.S.A.; W.F. Stanley in Britain (‘Allbrit’); Koizumi and other precision-engineering businesses in Japan; one manufacturer in Poland; and at least two factories in the Soviet Union. Patents of improvement were granted in many countries; in Britain,

**Plate 40.** Made by Dennert & Pape (‘Dupa’), this German Amsler-type polar planimeter also bears the marks of R. McAughtry & Son of Glasgow, distributors of Maihak indicators. No. 31622 is accompanied by a 1938-vintage insert. *Museum of Making* collection.
for example, William F. Stanley and Alfred Amsler were granted Patent no. 13567/94, published in July 1895, to protect a means of altering a planimeter to compensate for asymmetric shrinkage in the paper of the diagram.

Individual planimeters may occasionally be found with the markings of distributors. These can include a few of the indicator makers, such as Elliott Brothers of London (an Amsler area planimeter has been seen marked regulated by over Elliott Bros. on the trace arm), but usually prove to be drawing- or mathematical-equipment suppliers such as Stanley & Co. Ltd of London (later the makers of ‘Allbrit’ instruments), A.G. Thornton Ltd of Manchester, or Cooke, Troughton & Simms Ltd. Others may display the name of an engineering supplier such as John Cail of Newcastle-upon-Tyne, on an Amsler planimeter accompanying an Elliott-Richards indicator; John Halden & Company ‘of London & Manchester’, on an Amsler-type instrument; W.H. Harling Ltd of London, on another Amsler planimeter; McAughtry & Son

Plate 41. This Reiss Model 3005 polar planimeter, no. 10518, was made in 1968 by V.E.B. Mess- u. Zeichengeräten of Bad Liebenwerda (in what was then the German Democratic Republic). Instruments of this type were often sold for use with the Maihak-type indicators being made by Metallwerker of Meerane/Sachsen. John Walter collection.
and Smail Sons & Co. Ltd of Glasgow, usually found on Ott-made planimeters accompanying Maihak indicators; or, in the U.S.A., the B.K. Elliott Company of Pittsburgh, Pennsylvania, and the Eugene Dietzgen Company of Chicago.

One of the simplest ways of calculating the area of a diagram involves a Prytz or hatchet planimeter—proposed by a Danish mathematician in 1875, and often home-made. It consists simply of a rod, bent at one end to a trace-point and at the other into a flattened blade or ‘hatchet’ orientated on the longitudinal axis of the rod. The rod is placed with the tracer on a convenient point of the diagram, and the position of the hatchet marked by pressing it onto the paper.

The tracer is then taken around the diagram line until it returns to the starting point. The position of the hatchet is once again marked. The distance of the arc connecting the two positions of the hatchet multiplied by the length of the planimeter gives an approximation of the area enclosed by the diagram. Accuracy is affected by the length of the rod, and by the ability of the user to avoid pushing or pressing the hatchet out of its true path. Errors can easily reach ten per cent, and it is hard to see the hatchet planimeter either as a suitable replacement for the traditional ‘sectoring’ method or for the much more sophisticated polar planimeter. Used properly, however, it undoubtedly does give a very rapid guide to the magnitude of an enclosed area.

Plate 42. This Prytz or ‘hatchet’ planimeter was made by Bruce Babcock of Amanda, Ohio, from bar stock. It works as well as those that were sold commercially!
SPEED COUNTERS

The planimeter was one of the most important analytical tools to be associated with the engine indicator, but its role in the process was limited to assessments of a single card-trace. In addition, each trace was no more than a snapshot of engine performance—a single stroke at a single moment in time—and gave only a hint of the useful work that could be done. To assess performance realistically, therefore, the engineer needed to know how fast the engine was running and how efficiently the power generated in a cylinder was being passed to a pump, line-shafting, a saw or any of the many other practical applications. A perceptible loss of efficiency could always be found between the engine cylinder and the point at which machinery could be driven.

The earliest steam engines ran very slowly, allowing speeds to be assessed by counting strokes against the clock. This method remained practicable into the second half of the nineteenth century, as speeds rarely exceeded 100 rpm, but the advent in the early 1860s of the high-speed Porter-Allen engine (which also inspired the creation of the Richards indicator) made visual assessment impossible.

An answer was provided by mechanically-driven ‘speed counters’ driven from any suitable rotating surface if the exact centre could be accessed. Counters, also known as ‘tallies’ were an age-old invention; gear-trains dated back to the Greeks—possibly even to the Babylonians—and astronomical clocks of surprising efficiency had been a feature of mediaeval technology.[5]

Boulton & Watt had fitted many of their steam engines with mechanical tallies to register each piston stroke, from which royalty payments were calculated, but there is no evidence that a true speed counter had been developed prior to the grant of U.S. Patent 80612 (‘Improvement in Counting-Registers’) on 4th August 1868 to Jacob Detrick of San Francisco.

This ‘improvement in Pocket Counters’ consisted of a small disc-like housing containing a 100-tooth cog, graduations on which showed on a raised annulus against a pointer or index on the outer casing of the instrument. The operator simply placed the revolving worm-shaft, placed tangentially to the cog, on the rotating surface and pressed down on the projecting handle to engage the two. The counter then moved one tooth for each revolution.

5. The discovery of the so-called ‘Antikythera mechanism’, in a shipwreck dating c. 85 BCE, confirms that the use of gear-trains to process complicated calculations were known to the ancient Greeks. Recent studies have shown the mechanism to be an orrery, allowing reconstructions to be made. Though questions have still to be answered (including back-tracking constructional knowledge to the Babylonians), there is little doubt that the Antikythera Mechanism represented such a significant advance that the early history of technology must be extensively revised.
When a hundred revolutions had been made, a second disc-register moved one notch; consequently, the Detrick instrument had a theoretical recording capability of ten thousand revolutions.

The design was simple, sturdy and efficient, with a ‘sharp-pointed head or, in lieu of it, a flat rubber or gutta percha head’. Detrick assigned the patent to himself and William R. Eckert of San Francisco, and it is assumed that sales were made commercially.[6] Soon, however, others began to monopolise supply. Their designs fell broadly into two groups: simple patterns, which were nothing if not sturdy, and a group of ever-increasingly complex instruments which usually failed to stand the test of time. It is hard not to conclude that inventors, promoters and manufacturers were often too keen to evade patent legislation, and also that complexity was too readily assumed to be synonymous with efficiency.

The ‘Improvement in Rotary Measures’ patented in the U.S.A. on 12th September 1876 by Daniel Davis Jr. and Edward Wright of Worcester, Massachusetts, no. 182177, was another of the ultra-simple devices. It consisted of little more than a case, usually a decorative brass casting, often nickel-plated to give the illusion of superior quality, in which a worm-shaft meshed with a graduated cog. The index was an arrow-headed pointer held by a screw passing through the cog spindle into the back of the case.

The patent shows several types of tip for the worm-shaft, including detachable sleeves, but surviving Davis & Wright speed counters invariably have the shaft drawn to a point. Many are also marked with the 12th September 1876 patent-date and Woodman’s patent. Davis & Wright assigned their patent to William Hudson of Worcester at the time of the grant, but the counters were subsequently made by a variety of metalworking businesses—presumably without benefit of licence—and so, at least at the time of writing, the participation of ‘Woodman’ remains unclear.

Davis & Wright continued to exert an influence on design into the twentieth century, and many patents were merely additions to or adaptations of the basic pattern. They included the counters credited to Willis Churchill of Newark, New Jersey, ‘Improvements in Speed-Indicators for Shafting’.

6. There is a slight possibility that Detrick counters were made by the Connecticut Cutlery Company of Naugatuck, Connecticut, which was claiming to be a maker of ‘Speed Indicators’ as early as 1871.

Plate 44. This nickel-plated Wright & Davis-type counter, in its original cardboard box, bears nothing other than ‘S & B’ on the recording disc. This could indicate manufacturer by (or more probably for) Schaeffer & Budenberg of New York. John Walter collection.
AIDS, ACCESSORIES AND OVERVIEW

The Starrett designs—the most popular, and most widely copied of the simple mechanical counters—remained in production well into the second half of the twentieth century. There are however, only a handful of individual patterns known by the early 1900s as the Numbers 104, 106 and 107 (also known as ‘Models’). Protected by U.S. Patent 557446 (‘Speed-Measure’), granted on 31st March 1896 to Laroy S. Starrett of Athol, Massachusetts, No. 107 was the oldest of the three. It could be distinguished by a double-register mechanism, with an outer ring of graduations registering each single turn and an inner annulus, operated by what the written specifications call a ‘spring finger’, to show hundreds of turns. No. 106 was similar, but had an improved single-

Plate 45. Typical pre-1914 mechanical speed counters. From top left: an ultra-simple instrument, unmarked but comparable with others marked ‘Paragon’. Then come three Starrett examples: a No. 107, showing the spring-finger used to transmit data to the inner registering disc; a No. 106, with a single scale; and the all-metal No. 104. The Starretts are all clearly marked with their patent dates. John Walter collection.

The Starrett designs—the most popular, and most widely copied of the simple mechanical counters—remained in production well into the second half of the twentieth century. There are however, only a handful of individual patterns known by the early 1900s as the Numbers 104, 106 and 107 (also known as ‘Models’). Protected by U.S. Patent 557446 (‘Speed-Measure’), granted on 31st March 1896 to Laroy S. Starrett of Athol, Massachusetts, No. 107 was the oldest of the three. It could be distinguished by a double-register mechanism, with an outer ring of graduations registering each single turn and an inner annulus, operated by what the written specifications call a ‘spring finger’, to show hundreds of turns. No. 106 was similar, but had an improved single-

7. Eugene Smith assigned a half-share in his patent to Clifton C. Scudder of St Louis.
disc register incorporating a ‘curved annular spring’ to prevent excessive sideplay in the counting mechanism—a claim made in U.S. Patent 786073, granted on 28th March 1905 to Stafford P. Walsh of San Francisco, assignor to the L.S. Starrett Co. of Athol, Massachusetts. No. 106 and No. 107 are now usually found with rosewood handles.

The No. 104, a simple single-disc pattern with a diced handle forged integrally with the counter body, was protected by Starrett’s U.S. Patent 58042 (‘Speed-Indicator’) of 13th April 1897.[8]

Starrett speed indicators were usually accompanied by a pair of worm-shaft heads mounted on detachable sleeves, protected by U.S. Patent 601800 granted to Laroy Starrett on 5th May 1898. The No. 107, the most expensive (costing $3 in 1908), could be supplied in a fabric-covered wooden case; No. 104 and No. 106 (each $1 in 1908) came in cardboard boxes, though leather pouches could be supplied to order. The Starretts also inspired counters marketed by the Goodell-Pratt Company of Greenfield, Massachusetts, on the basis of a patent (‘Revolution-Counter’, U.S. no. 1172793) granted on 22nd February 1916 to Oscar Hapgood of Orange, Massachusetts.

Among more complicated designs were the twin-disc counter invented by Adrien Sainte of Paris (‘Improvement in Rotary Speed-Indicators’, U.S Patent no. 211274 of 7th January 1879), which was made in quantity in Europe—by Sainte himself—and in the U.S.A. by the Connecticut Cutlery Company of Naugatuck, Connecticut, in the 1880s. The U.S.-made Sainte counter seems

to have been superseded by 1890 by “L.B. Taylor’s Patent Speed Indicator”, but no relevant protection for this counter (which was basically an enclosed-case version of Sainte’s) has been found.\[9\]

The ‘tongs’ of Robert J. Pratt of Greenbush Heights, New York (‘Speed Indicator’, U.S. Patent 299677 of 3rd June 1884), and the clumsy tube patented by Amon Calkins of Bridgeport, Connecticut (‘Speed-Measure’, U.S. no. 435012, 26th August 1890), were among the less successful counters. But the same could not be said of the pistol-like mechanical counters developed successively by Louis B. Holmes of Cohoes, New York State (U.S. Patent 418411 of 31st December 1889), Wilbur F. Dial of Bridgeport, Connecticut (U.S. 508686 of 14th November 1893), and William T. Lintner of Gloversville, New York State (U.S. Patents 520792 of 5th June 1894 and 527557 of 16th October 1894). Holmes assigned rights in his patent to William Lintner; Dial, to Lintner and William Sporborg of Gloversville.\[10\]

Advertised as the ‘Paragon’, the fully-developed ‘pistol-grip indicator’ was made in quantity by Lintner in Gloversville. The production version, with a ball-race bearing for the worm-shaft and engagement controlled by pressing the ‘trigger’ (pivoting the upper cradle downward), is a virtual facsimile of the drawings accompanying a patent granted on 29th May 1900 (U.S. 650465) to Harvey Hubbell of Bridgeport, Connecticut.

There is no evidence to show that rights in this patent were assigned to anyone other than the patentee, but surviving counters of this type invariably bear Lintner marks on the frame and are accompanied by Lintner literature. Decoration on their moulded grips includes acknowledgements only of the Holmes, Dial and Lintner patents.

Consequently, it could be concluded either that series production only began sometime between the submission of the Hubbell patent application on 24th October 1899 and the eventual 1900 grant, or that Lintner had already improved construction to a point where Hubbell based his work on something that was already in production. Unfortunately, the Paragon

8. Protection had been sought on the same day as U.S. Patent 557446, 20th May 1895, even though the final grants were made more than a year apart.
9. U.S. legislation makes acknowledgement of a patent grant mandatory, though the information is only given in date form on artefacts. No marks of this type are found on Taylor speed indicators, however; even if the Sainte patent was being used as the basis of the claim, this should still have been acknowledged on the instruments. It has been suggested that ‘Taylor’ was actually the English engineer Leslie Bown Taylor (better known for firearms), and thus that the ‘Patent’ had not been obtained in the U.S.A. The suggestion is worthy of consideration, even though it seems improbable.
10. When the The History of Fulton County was published (in 1878?), Lintner was employed to manage the showrooms of Wheeler & Wilson, sewing-machine manufacturers, and the Cayadutta shirt manufactory. It is assumed that he began trading independently only in the mid 1890s.
indicators are rarely seen, and opportunity has yet to be taken to examine any of them in detail.

The combination speed counter/time-recorder patented in the U.S.A. on 28th February 1888 by George S. Heath of Hartford, Connecticut (‘Speed-Indicator’, no. 378836), was surprisingly successful for such a complicated design: made for about a decade by The Eddy Electrical Mfg Co. of Windsor, Connecticut, “Heath’s Patent Self Timing Speed Indicator” was still being distributed commercially when the First World War began.

Dial-like construction, with an elongated drive-shaft, is most distinctive; the greatest advantage of the Heath mechanical counter, however, was the incorporation of a timer to allow assessments to be made without a separate clock or stop-watch.

Another class of speed indicator was provided with worm-shafts driving digital counters. Several of these have been reported, but their history and chronology is unclear, though a Scotsman, John Ciceri Smith of Edinburgh,

Plate 48. The Heath self-timing indicator (top) was still being offered for sale when this distributor's catalogue was printed in 1908.

*John Walter collection.*
THE ENGINE INDICATOR

patented a small digital micrometer in Britain on 22nd October 1890\textsuperscript{11} and comparable counting indicators are known to date from the same era.

The digital 'Speed Indicator' patented in the U.S.A. on 5th November 1907 (no. 870203) by Charles W. Sponsel of Hartford, Connecticut, was made in quantity by the Veeder Mfg Co. of Hartford and its successor, Veeder-Root, Inc. This indicator, superficially resembling a rifle cartridge, was still being made in the 1970s—acknowledging only the 1907 patent in its markings!\textsuperscript{12}

It will be noted that the story has dealt only with counters originating in the U.S.A., where (until proved otherwise) it is assumed that the first designs appeared. It could be expected that a similar developmental history occurred in Europe, but this does not seem to be so. Some crudely made copies of the Davis & Wright instrument were undoubtedly made in continental Europe,

\textbf{Plates 49 and 50.} This interesting mechanical counter, possibly British and dating from the first quarter of the twentieth century, is unmarked except for 'R' and 'L' (the direction of shaft rotation). Digital readings are displayed in four small ports in the base-plate. The instrument is tiny: less than 11cm long. \textit{John Walter collection.}

\textsuperscript{11} British Patent 16856/90. Smith was also granted U.S. Patent 495379 of 11th April 1893.
\textsuperscript{12} Ironically, an 'improvement' patented in the U.S.A. on 31st January 1911 (no. 983096) by Amasa Trowbridge of Hartford, assignor to the Veeder Manufacturing Co., failed to prosper.
and perhaps also in Birmingham; a few have been found bearing the marks of Schaeffer & Budenberg, but their provenance is unknown—they certainly lack the constructional qualities associated with this particular manufacturer, and it is likely that they were bought-in.

It seems that the simplicity and efficiency of the comparatively inexpensive U.S.-made counters (particularly the Starretts) did not commend commercial exploitation to European manufacturers. Moore & Wright made a Starrett-type counter in Sheffield, probably only after the First World War had ended, but the British placed greater store on “Young’s Patent Speed Indicator” (subsequently known as “Elliott’s Portable Speed Indicator” and then simply as the ‘Elliott Speed Indicator’), patented in 1881 and offered commercially by Elliott Brothers of The Strand, London, from the summer of 1882 onward.

This drum-type counter was a much more sophisticated product than the Starretts and their rivals, and promised to generate greater profitability.

Plate 51. Still acknowledging the U.S. Patent granted in 1907 to Charles Sponsel, this Veeder-Root mechanical speed indicator is accompanied by an inventory tag showing that it was supplied to the West German government in 1975. The inclusion of a NATO Standard Number (‘NSN’) in documentation shows that the counter originated in the U.S.A (‘00’ national code) and was probably intended for the Bundeswehr. John Walter collection.
A brief review published in *The Engineer* on 18th August 1882 noted that ‘The want of an instrument which will instantaneously and correctly indicate the speed of dynamo-electric and other machines adapted to run at high speeds has been often experienced by by engineers and others employing such machines.'
The Young indicator worked by ‘means of a small high-speed centrifugal governor arranged within in the casing…and acting upon an index or pointer… Two or more spindles are provided…upon which to place the carrier for thrusting against the end of the shaft. These spindles are provided with multiplying or reducing gear, so that both high and low speeds can be indicated, the dial having two or more graduated circles for this purpose.’ The most obvious feature of the Young system was that it was not an accumulative counter in the manner of the simple Davis & Wright or Starrett instruments; instead, it showed the actual running speed directly on the dial.

Most pre-1900 Young-type indicators worked in two comparatively slow speed ranges (usually 100–500 and 400–2000 rpm), but later examples, including no. 19537 shown in Plate 52, are often set for 500–2500 and 2000–10000 rpm. Indicator no. 12605, marked by ‘ELLIOTT BROTHERS’ over ‘(LONDON) LIMITED’, has three ranges: 100–500, 400–2000 and 800–4000 rpm. Consequently, the dial has three sets of graduations instead of the customary two. The style of the manufacturer’s marking dates production to later than 1916, when Elliott Brothers became a limited-liability company. The first Young speed indicators were made in the 1880s, but production seems to have been comparatively slow until at least the end of the nineteenth century. Thereafter, however, their importance grew greatly and surviving indicators will be found with serial numbers greatly in excess of 30000.

Plate 53. An engraving of a typical early twentieth-century hand tachometer, unmarked but almost certainly the work of Schaeffer & Budenberg of Magdeburg, Germany. Note the three positions for the spindle: 500, 1000 and 2000 rpm. Like the Young-patent indicator shown in the previous illustration, the tachometer shows the actual running speed of the machine under test. From Engine Testing, originally published in 1902 by the International Correspondence Schools Ltd, London.
However, not all of them display Elliott’s name; no. 19537 illustrated in Plate 52 is marked ‘BUCK & HICKMAN LTD’, while no. 12820 is marked ‘DOBBIE McINNES LTD’ over ‘GLASGOW & LONDON’. The style of the latter mark suggests that it pre-dates 1921, when Dobbie McInnes metamorphosed into Dobbie McInnes & Clyde Ltd, as it seems unlikely that the indicator post-dates the 1937 reversion to the original company name.

It is easy to assume that Buck & Hickman, Dobbie McInnes and others simply bought the speed indicators from Elliott Brothers when required, but it is just possible that other contractors were recruited during the either or both of the world wars to accelerate production—though the apparent use of only a single range of serial numbers seems to make this unlikely.

Schaeffer & Budenberg offered sophisticated hand-held ‘tachometers’, speed indicators with a sliding-gear mechanism offering two speed ranges. These can be found with markings which include British (Broadheath or Manchester) or U.S. (New York) addresses, but were invariably made in the company’s Magdeburg manufactory prior to the First World War. They were expensive: the standard hand-held Schaeffer & Budenberg tachometer cost $55 in the U.S.A. in 1908, at a time when the Starrett No. 104 speed indicator cost merely a dollar.
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¶ C.F. Budenberg MSc: ‘Steam Engine Indicators’—a lecture given before the Owens College Engineering Society on 4th February 1890. Reported in The *Practical Engineer*, 14th February 1890, pp. 98–100; 21st February 1890,
Plates 54 and 55. The backs of two typical British cards of the 1890s, used to promote the merits of the Hall-Brown indicator for maritime use and the Tabor indicator for more general purposes. Ephemera of this type was often produced for individual clients—insurance companies, for example. John Walter collection.

pp. 114–16; 28th February 1890, pp. 139–140; 7th March 1890, p. 151; 14th March 1890, pp. 171–2; and 28th March 1890, pp. 198–9.


§ Loughnan Pendred: ‘High-Speed Engine Indicators’, a paper read before the Institution of Mechanical Engineers, London, on 19th January 1923. It was summarised in Engineering, 26th January 1923, pp. 119–26. The article
also contains detailed descriptions and drawings of the Burstall optical and Collins micro-indicators.


Plate 56. This 1894-vintage advertisement from Cassier’s Magazine draws attention to the introduction of compact steam engines, developed partly to satisfy demands for self-contained power-plants and partly to compete with first hot-air and then internal-combustion engines. John Walter collection.


**Plate 57.** Promotional cards of this type, backed by a radial divider to ease the task of interpreting diagrams, were regularly included with Dobbie McInnes and Dobbie McInnes & Clyde indicators. *John Walter collection.*
—The Engine Indicator. Diesel : Steam. (‘With Specimen Diagrams showing Engine Faults’). Dobbie McInnes Ltd and Dobbie McInnes & Clyde Ltd, Glasgow; various editions, nor dated.

—The Indicator Book (‘A Description of the Latest Types of Engine Indicators and Accessories, with Information on Taking and Reading of Indicator Cards’). Trill Indicator Company, Corry, Pennsylvania; © 1916.


Plate 58. Printed on translucent paper, this was prepared partly as a promotional tool (Globe briefly distributed Tabor indicators in Britain) and partly to provide a method of comparing actual performance with thermodynamic theory. John Walter collection.

Plate 59. The highly decorative title page of the 1899 edition of the Dreyer, Rosenkranz & Droop catalogue. Material of this type is often the most important guide to identifying and dating individual instruments. John Walter collection.


¶ N. Hawkins ME: Hawkins' Indicator Catechism. A Practical Treatise ('for the use of Erecting and Operating Engineers, Superintendents, Students of Steam Engineering, etc'). Theo Audel & Co., New York City; 1898, 1901, 1903 and 1904 editions. The covers are generally marked 'Practical Treatise on the Steam Engine Indicator', with "Hawkins' Indicator" on the spine.


¶ Andrew Jamieson MInstCE: A Text Book on Steam and Steam Engines ('Specially Arranged for the use of Science and Art, City and Guilds of London Institute, and other Engineering Students'). Charles Griffin & Co., London; twelfth edition, 1897.

—[Ewart S. Andrews BSc (Eng.), reviser]: A Text Book of Heat and Heat Engines ('Specially Arranged for the Use of Engineers Qualifying for the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Electrical Engineers...'). Charles Griffin & Co. Ltd, London; vol. 1, eighteenth edition, 1919.


John McNaught: *Description and Use of Macnaught’s Improved Indicator and Dynamometer for Steam Engines*. J.H. Cowan, Glasgow; the original edition of 1828, and a later version of 1834. The monograph was subsequently reprinted and enlarged several times to become a book.


Edward F. Miller [Ed.]: *Practical Instructions relating to the Construction and Use of the Steam Engine Indicator*. Crosby Steam Gage & Valve Company, Boston, Massachusetts, U.S.A.; many editions—1905, 1910, 1911 and 1917 versions have been among those that have been consulted.


Plate 60. The introduction of the autographic indicator allowed the performance of steam engines to be assessed under many conditions. The wooden hoarding on the running plate of this London, Brighton & South Coast Railway locomotive, photographed in the early years of the twentieth century, protected engineers endeavouring to take diagrams at high speed! John Walter collection.


¶ Charles T. Porter: *Description of Richards’ Improved Steam Engine Indicator. With Directions for its Use*. Elliott Brothers, London; undated (probably c. 1864).
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§ Thomas Pray, Jr.: Twenty Years with the Indicator ('Being a Practical Text-Book for the Engineer or the Student, with no Complex Formulae”). American Steam Gauge & Valve Mfg. Co., Boston, Massachusetts, USA; ‘newly arranged and complete in one volume’, 1917 (originally published separately: Volume I © 1882, Volume II © 1885, and combined in 1888.)


§ D. Scott and A. Jamieson LL.D: The Engineer and Machinist’s Assistant ('Being a Series of Plans, Sections and Elevations of Steam Engines, Spinning Machines, Mills for Grinding, &c…'). Blackie & Son, Glasgow, Edinburgh and London, no date (c. 1850?).

§ John Sothern: Verbal Notes and Sketches for Marine Engineers ('Specially arranged to suit the Board of Trade Regulations, and intended as a General Reference Book for Marine Engineers'). James Munro & Co. Ltd, Glasgow; sixth edition, ‘revised and enlarged’, 1908. The eighteenth and nineteenth editions (J.K. Bowden, Ed., “Verbal” Notes and Sketches for Marine Engineer Officers, 'A Manual of Marine Steam Engineering Practice), each by Munro and each in two volumes, are undated.

§ Anton Staus, Dipl.-Ing.: Der Indikator unde seine Hilfseinrichtungen. Julius Springer Verlag, Berlin; 1911.

§ Heinrich]. Steuding: Messung mechanischer Schwingungen. VDI Verlag, Berlin; 1928

Plate 61. These drawings accompanied a British patent granted in 1877 to Henry Lea, protecting one of the earliest integrating indicators. Specifications of this type are among the most useful reference tools. Courtesy of the UK Intellectual Property Office, London.
C.H. Thirkell, Extra Chief, and Edward Ingham AMIMechE: Engines and Boiler Accessories (‘Edited by the Staff of the Bennett College for the use of Students’). The Bennett College, Sheffield; c. 1913.


HOW MANY INDICATORS...?

A prediction of total quantity based on serial numbers.

AMERICAN STEAM GAUGE COMPANY
36 Chardon Street and Jamaica Plain, Boston, Massachusetts, U.S.A. Incorporated in 1854 as the ‘Steam Gauge Company’, this metalworking business was claiming by the 1890s to be the sole manufacturer of the ‘American Thompson Improved Indicator’. An advertisement in Cassier’s Magazine for August 1894 claimed that over five thousand indicators had been made, and that they had been ‘adopted by the United States Navy for use on all the new Cruisers and Gunboats to be built’. The advert notes the company’s products—in addition to the indicators—as pressure gauges and vacuum gauges, water gauges, gauge cocks, whistles, revolution counters, marine clocks, pyrometers, hydrometers, salinometers and ‘all instruments incidental to the use of steam’.

1. RICHARDS TYPE
   Observed numbers: –440–
   Possible number range: 1–750

2. INTERNAL- AND EXTERNAL-SPRING THOMPSON TYPES
   Observed numbers: –99–8886–
   Possible number range: 1–9500
   Notes: these indicators are believed to have been contained in one series, observed numbers being 99–8723 (internal spring) and 5864–8986 (external spring). The same range may extend to include the U.S. Schaeffer & Budenberg-type external-spring indicators (q.v.) which replaced the American Steam Gauge Thompson c. 1915.
   Estimated total production: 9,500

ASHCROFT MANUFACTURING COMPANY
111 Liberty Street, New York City (sales office), and Bridgeport, Connecticut, U.S.A. Founded in 1851 as the ‘Ashcroft Steam Gauge Works’, this metal-smithing business was the sole maker of Tabor indicators ‘Approved and Adopted by the U.S. Government on all the New Cruisers’, according to the August 1894 Cassier’s Magazine (but see also ‘American Steam Gauge Company’!). Ashcroft also made steam- and vacuum gauges ‘with patent seamless drawn tube’, steam traps, marine clocks, test gauges, and all instruments ‘for measuring steam, air, gas or water’.
1. TABOR INDICATORS, INSIDE-SPRING TYPE:
   
   Observed numbers: -227–6281–
   
   Possible number range: 1–6625.
   
   Notes: production may have ceased early in favour of the external-spring instrument, though it is more likely that the two co-existed for a few years. However, it is assumed that only a single number series was used.
   
   Estimated total production: 6,625.

2. TABOR INDICATORS, EXTERNAL-SPRING TYPE:
   
   Observed numbers: -6035–10025–
   
   Possible number range: 6025–11000.
   
   Notes: see (1), above. If the designs co-existed, there would have been more inside-spring and fewer external-spring examples.
   
   Estimated total production: 4,975.

BACHARACH INSTRUMENT COMPANY
Pittsburgh, Pennsylvania, U.S.A.

1. MAIHAK-TYPE SPRING TYPE:
   
   Observed numbers: -50791–56246–
   
   Possible number range: 50001–60000?
   
   Notes: numbered in a single series, with the possible exception of the bar-spring type (one reportedly numbered 99675 [59675?]). A standard instrument has been reported with a number in the very low 40000s.
   
   Estimated total production: 10,000+

2. PREMAX PEAK-PRESSURE INDICATOR:
   
   Observed numbers: -999–2650–
   
   Estimated total production: 3,500+

3. COOKCO BALL-CHECK INDICATOR:
   
   Made to a Bacharach patented design.
   
   Observed numbers: -A0662C–
   
   Estimated total production: 1,000+

BUFFALO INDICATOR COMPANY
Buffalo, New York State, U.S.A.

JOHN BUSHNELL & COMPANY
New York City, U.S.A.

BACHELDER INDICATOR
   
   Observed numbers: -690–3090–
   
   Possible number range: from ‘i’?
Notes: two different types of instrument, the original and an improved Thompson-linkage type
Estimated total production: 3500+

J. CASARTELLI & SON
(later ‘& Son’, then ‘& Son Ltd’, and then apparently ‘& Son’ again). Trading in the 1890s from Market Street, Manchester, England, this instrument-making business made a variety of indicators. A directory produced during the First World War records that ‘J. Casartelli & Son, of Hayes Yard Works, Garratt Street, Manchester’ were ‘opticians and instrument makers’ specialising in ‘Mining dials, engine indicators, &c’. The company employed 28 people in 1917.

1. MIXED INTERNAL AND SEMI-EXTERNAL SPRING TYPES:

   Observed numbers: −45−3412−
   Possible number range: 1−5000+ (see notes).

   Notes: the Casartelli indicators seem to form a continuous series (with the exception of the rare unnumbered ... pattern). Casartelli-Richards instrument no. 5010 has been reported; this is clearly not an Elliott-made piece from the 1870s, but whether it could date as late as 1920 (as predicted by the number) seems questionable. In addition, as with so many of the instrument makers, it is not entirely clear if telescopes and other items were numbered in the same sequence as the indicators. Consequently, the total given here could be considerably overstated.

   Estimated total production: 3500.

CORRY INSTRUMENT COMPANY
Corry, Pennsylvania, U.S.A. Purchaser of the business of William Trill (q.v.) in 1945. It is not known if production of indicators continued (Corry became known for oxygen regulators for the aircraft industry), but it is at least likely that some were assembled from existing parts. Repairs to Trill and other indicators were certainly undertaken for some years. The Corry Manufacturing Company, which is still trading, was an outgrowth of the instrument-making business.

CROSBY STEAM GAGE & VALVE COMPANY
38 Central Street, Boston, Massachusetts, U.S.A. A manual for the patented reducing wheel, dated December 1918, gives the addresses of the Crosby offices as 44 Dey Street, New York; 186 North Market Street, Chicago; and 147 Queen Victoria Street, London E.C. In addition to indicators, Crosby made
a wide range of accessories, including three way steam cocks, large-diameter and continuous-recording indicator drums, and two types of reducing wheel (the original of c. 1900 and a New Model introduced in 1918).

1. **INTERNAL-SPRING TYPE:**
   - **Observed numbers:** –158–15837–
   - **Possible number range:** 1–16000.
   - **Notes:** numbered in a single series.
   - **Estimated total production:** 16,000.

2. **EXTERNAL-SPRING TYPE, FIRST PATTERN:**
   - **Observed numbers:** –0391–01323–
   - **Possible number range:** 1–01500.
   - **Notes:** numbered in a separate series. The oldest known are numbered ‘31-S’ and ‘32-S’, but the significance of this is currently unknown as no major differences in design have been reported.
   - **Estimated total production:** 1,500.

3. **EXTERNAL-SPRING, SECOND PATTERN:**
   - **Observed numbers:** –142D–7249D–
   - **Possible number range:** 1D–7500D.
   - **Notes:** numbered in a separate series.
   - **Estimated total production:** 7,500.

**DOBBIE MCINNES, DOBBIE MCINNES & CLYDE**

The company had its origins in the business of Alexander Dobbie (1815–87), a watch- and clockmaker who began trading from 20 Clyde Place, Glasgow, in 1841. By 1851, Dobbie was listing himself as a maker of nautical instruments and a seller of maritime charts in addition to his horological interests. The census of 1851 recorded that Dobbie, described as a ‘Master Chronometer Maker’, employed six men and two apprentices.

A move to 24 Clyde Place occurred in 1857, the adjoining No. 25 being added in 1873. This was apparently a consequence of the disastrous explosion in Tradeston Flour Mills, which had flattened the workshop in the summer of 1872, a number of Dobbie’s workmen being among the injuries. A branch office at 31 Centre Street was also maintained from 1886 onward.

Alexander Dobbie was joined in the 1880s by his youngest son, John Clark Dobbie (c. 1855–1910). In 1886, the company became ‘Alexander Dobbie & Son’, but the elder Dobbie died on 18th February 1887 and John Clark Dobbie—by then being described as a ‘nautical instrument maker’ — succeeded to the business by buying out his father’s share after an agreement with the executors.
A period of enlargement followed, with retail premises being opened in Commerce Street and a new workshop created at 120 Broomielaw. A move to 44 & 45 Clyde Place occurred in 1892, formerly the premises of the moribund M. Walker & Son. The Broomielaw workshop was then closed, but Dobbie continued to prosper.

The most important acquisition, in 1893, was the business and goodwill of Thomas Struthers McInnes (q.v.), following the death of the proprietor in 1892 and the sequestration of his business. Operations were reconstituted as ‘T.S. McInnes & Co. Ltd’, work continuing in the original workshops independently of Alexander Dobbie & Son.

An associated business opened in London in 1894, trading as ‘Dobbie, Son & Hutton’, and the trading style of the parent company became ‘Alexander Dobbie & Son Ltd’ in 1896. More subsidiaries followed: shops at 28 Cathcart Street, Greenock and in South Shields were opened in 1897, and ‘Dobbie, Hutton & Gebbie’ was formed in Cardiff in 1899. Finally, in 1903, an amalgamation of the two separate interests produced Dobbie, McInnes Ltd. A new head office was opened at 45 Bothwell Street (moved to 57 Bothwell Street in 1908), and a branch was opened in Liverpool in 1907.

The Dobbie workshop continued to make watches, clocks and nautical instruments, as well as being ‘chemical, mathematical, optical and philosophical instrument makers’ (according to Angus McLean, Local Industries of Glasgow and the West of Scotland, 1901); the McInnes portion continued to make steam-engine indicators and associated engineering equipment. John Clark Dobbie received twenty patents in 1887–1910, ranging from improved indicators to a ship’s log and mariners’ compasses. The indicators were habitually known as ‘McInnes Dobbie’ prior to the end of the First World War, and as ‘Dobbie McInnes’ thereafter.

John Clark Dobbie died in 1910, to be superseded by his son Alexander B. Dobbie, though his eldest brother, Professor Sir James Dobbie (1852–1924), became chairman—apparently only after the end of the First World War. A directory produced during the First World War notes the company’s pre 1914 output as “Engine (steam and Diesel, &c.) indicators. Pressure and vacuum gauges, steam and mechanical specialities for engine testing and equipment. Ships’ compasses, sounding machines, and nautical instruments generally”. The company was employing 164 people in Bothwell Street and a workshop in Broomloan Road, Govan.

Dobbie McInnes & Clyde Ltd succeeded Dobbie McInnes Ltd in 1921. The enclosed spring Patterns ‘A’ and ‘B’ were largely abandoned, though individual sales were still being made as lat as 1940. However, production
of the exposed-spring McInnes Dobbie No. 1A (1898 patent) indicators continued with few important changes—though work on the No. 2, No. 3 and the improved 1904 patent or ‘caged spring’ types ceased. The markings on the instruments changed to ‘Dobbie McInnes’ to reflect the change in company structure. On 1st January 1937, ‘Dobbie McInnes & Clyde Ltd’ reverted to the original name. Dobbie McInnes continued work after the end of the Second World War, under the guidance a Nobel Prize winner, the chemist Sir Norman Haworth (1889–1950, son-in-law of Sir James Dobbie); eventually, however, Dobbie, McInnes was swallowed in 1984 by the Cunningham Shearer Group and its operations merged with Young & Cunningham.

1. **Mixed Internal- and External-Spring Types:**

   **Observed numbers:** –735–33398–, 45000–48587–
   **Possible number range:** 1–5000.

   **Notes:** in a single series, numbered from 1, probably skipping numbers from about 35000 to 45000. With the break for Dobbie McInnes & Clyde between 19121 and 21080; and a reversion to Dobbie McInnes between 25378 and 26668.

   **Estimated total output:** 40,000.

2. **Hopkinson Flashlight Indicator:**

   **Observed numbers:** –58–183–
   **Possible number range:** 1–250.

   **Notes:** in a separate series.

   **Estimated total production:** 250.

3. **Farnboro Spark-Trace Indicator:**

   **Observed numbers:** GM 764
   **Possible number range:** not known.

   **Notes:** probably numbered in a separate series, but may, perhaps, have run on from the Hopkinsons.

   **Estimated total production:** 750.

4. **Sulzer-Type Peak-Pressure Instruments:**

   **Observed numbers:** 1184–4776
   **Possible number range:** from ‘1’.

   **Notes:** ‘observed numbers’ for ‘ECPC’ indicators. It is assumed that ‘ECPB’ instruments lay at the beginning of the series, but evidence is still lacking

   **Estimated total production:** 5,500.

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**Dreyer, Rosenkranz & Droop**

Hannover, Germany (‘Dreyer, Rosenkranz & Droop AG’ from 1922)

**Observed numbers:** –728–13589–
Possible number range: probably from ‘1’.
Notes: to add.
Estimated total production: 20,000+.

ELLIOTT BROTHERS (LTD)
449 Strand and 101–102 St Martin’s Lane, London, England. This long-established mathematical and optical instrument maker was responsible for a broad range of indicators—including Richards, Darke, Wayne and Simplex patterns. However, the British market seems to have been surrendered to Dobbie McIntnes Ltd (q.v.) and few Elliott-made examples can be reliably dated later than 1910.

1. RICHARDS-TYPE INDICATORS:
   Observed numbers: –137–18113–
   Possible number range: 1–23000
   Notes: indicator no. 22007 has been reported, but not yet verified.
   Estimated total production: 23,000?

2. HIGH-SPEED ELLIOTT-DARKE INDICATORS (SMALL AND LARGE):
   Observed numbers: (small) –30–2579–, (large) –8368–11637–
   Possible number range: 1–12500
   Notes: numbered in a separate sequence. The assessment assumes that the two sizes of Elliott-Darke indicator were numbered in the same sequence, without wholesale skipping of number-blocks.
   Estimated total production: 12,500

3. SIMPLEX INDICATORS:
   Observed numbers: –453(‘A’)–918(‘B’)–
   Possible number range: 1–1000
   Notes: in a separate series. It is assumed that ‘A’ (large) and ‘B’-suffix (small) instruments were numbered together, though evidence is lacking.
   Estimated total production: 1,000

ENGINEERING APPLIANCE COMPANY

ENGINEERING & POWER COMPANY
range from 4503 to 4993, but it is not clear from the meagre available data if the series began at ‘1’.

ENGINEERS INSTRUMENT COMPANY
New York City, U.S.A.
1) Calkins Internal-Spring Type
   *Observed numbers:* –23–152–
   *Possible number range:* 1–250?
   *Notes:* to add.
   *Estimated total production:* 250.

PAUL GARNIER
Paris, France. A renowned clock- and watchmaker, Garmier and his son (also named Paul) made a variety of indicators. These were often on a ‘one off’ basis for trials with the Conservatoire des arts et métiers or the Academie Française. Garnier indicators included copies of the McNaught, including some ‘lining’ examples; the Martin piston-type indicator, with a Thompson amplifying system; a disc-pattern Martin; and the Deprez lining design. A solitary exposed-spring indicator, essentially similar to the German Stauss and Lehmann/Maihak patterns has also been found. Its age and rarity are difficult to determine satisfactorily.

HALL BROWN (BUTTERY & CO. LTD)
Helen Street Engine Works, Govan, Glasgow, Scotland. This marine engineering business began trading in Helen Street in 1893, but failed in 1901 after making distinctive Thompson type indicators from c. 1895 onward. It was succeeded by A. Rodger & Co., active on the same site until 1912.
1. Thompson-Type Internal-Spring Instruments:
   *Observed numbers:* –296–1295–
   *Possible number range:* 1–1500.
   *Notes:* only five of these ‘Type A’ indicators have been recorded to date.
   *Estimated total production:* 1,500.

HANNAN, AND HANNAN & BUCHANAN
Robertson Street, Glasgow, Scotland (1905). This mechanical engineering business was formed in 1861 as ‘John Hannan (Engineers)’, trading from 31 Robertson Street until becoming ‘Hannan & Buchanan’ in 1869. The premises moved to 75 Robertson Street at much the same time, where work continued until 1966. These instrument-making businesses made and/or sold standard
McNaught-type indicators; modified a few Richards indicators purchased from Elliott Bros. (and, therefore numbered in the Elliott ranges); and then made Richards indicators in large numbers until 1914 or later. A small-scale ‘high speed’ Richards derivative was also developed. McKinnell & Buchanan external-spring indicators and Thompson-type instruments were made in the 1895-1906 period, the latter with three-digit numbers (‘103’, ‘104’), but it is assumed that production was negligible. No H&B Thompson is known to survive.

*Estimated total production*: 10,000+, assuming that indicators were numbered in a series of their own, and not with any other instruments marketed by Hannan & Buchanan.

**HINE & ROBERTSON**

New York City, U.S.A.

1) **ARC AND STRAIGHT-LINE INDICATORS**

*Observed numbers*: (Arc) –211–229–; (Straight Line) –512–3106–

*Possible number range*: from ‘1’?

*Estimated total production*: uncertain.

2) **THOMPSON TYPE**

*Observed numbers*: –200–8038–

*Possible number range*: 1–9000.

*Notes*: numbered in a single series.

*Estimated total production*: 9,000.

**J. HOPKINSON**

Huddersfield, England

*Observed numbers*: see notes.

*Possible number range*: probably from ‘1’. See notes.

*Notes*: Hopkinson made a concentric-axis indicator (no numbered survivors have yet been reported) and then a non-amplifying version with an offset drum (five numbered 211–708 with a sixth said to be no. 1029). He was claiming to have sold 1200 indicators by 1875, but confirmation is lacking and it is just possible that other instruments were included in the number series.

*Estimated total production*: 1,250.

**VICTOR LEFEBVRE**

Paris (?), France. Made Thompson-type indicators in 1880–95, including a patented improvement with the piston spring isolated in a separate ventilated chamber.
LEHMANN & MICHELS/LEMAG
Hamburg, Germany
Observed numbers: –1576 – 5205–
Possible number range: from ‘1’
Notes: the numbering system changed after the Second World War, either
starting again (at 50000?) or employing a two-digit ‘date prefix’ to the
numbers. Too few indicators have been examined to be certain.
Estimated total production: 20,000+

LEUTERT
Germany
Observed numbers: –50Z1 94389–
Possible number range: runs on from the Maihaks (q.v.).
Notes: to add.
Estimated total production: 25,000?

LIPPINCOTT
New York City, U.S.A.
Observed numbers: –1010 – 9056–
Possible number range: 1 – 10000.
Notes: all apparently numbered in the same series (external-spring indicators
currently confined to 8045–8075).
Estimated total production: 10,000.

W.G. LITTLE & COMPANY
Bexley, Kent, England. Made Little’s Patent Integrating Indicator from about
1897 until shortly before the First World War.

T.S. MCINNES
or M’Innes; Glasgow, Scotland (1889–1903). Thomas Struthers McInnes,
a maker of nautical instruments, began trading from 56 Waterloo Street,
Glasgow, in 1889—perhaps succeeding a short lived partnership of McInnes
& Cairns. The trading style became ‘T.S. McInnes & Company’ in 1890, a
move to 86 York Street and 341 Argyle Street occurring in 1892. McInnes
died in 1893, when the assets of his business were acquired by John Dobbie.
The name then changed again to ‘T.S. McInnes & Co. Ltd’ in 1894, based at
41 Clyde Place (listed as 41 & 42 Clyde Place from 1896 onward). In 1903,
the McInnes company amalgamated with A. Dobbie & Son to form ‘Dobbie
McInnes’ (q.v.).
1. **MCINNES INTERNAL-SPRING TYPE:**
   
   *Observed numbers:* –337–3642–
   *Possible number range:* 1–3750.
   
   Notes: McInnes’ name has also been found on a Richards-type indicator, no. 244, presumably numbered in the same basic sequence. As McInnes was an instrument maker, it is possible that other items were numbered in the same series as the indicators, and thus that the assessed total is actually over-stated. However, a substantial number of McInnes indicators were marketed after the business passed to Dobbie in 1893.
   
   *Estimated total production:* 3,500.

**MCNAUGHT**

Made by a wide variety of contractors in the middle of the nineteenth century, but probably never available in large numbers.

*Estimated total production:* 500–800.

**H. MAIHAK & CO.**

Hamburg, Germany (‘H. Maihak AG’ from 1910)

*Observed numbers:* (old) –2027–42760–; (new) 50Z–53399, 30–54323

*Possible number range:* from ‘1’...or from ‘1001’? ‘New’ or post-1950 production may have been numbered from 50001.

Notes: it is assumed that all the indicators made prior to 1939 were numbered in a single series. However, the system subsequently changed and it is possible that the instruments were numbered with what is either a two-digit ‘year’ prefix or a new cumulative sequence. This currently makes overall production levels almost impossible to determine with any degree of confidence.

*Estimated total production:* 50,000+

**METALLWERKER, HUGO VOSS (DDR)**

Meerane in Sachsen, German Democratic Republic. Formed soon after the end of the Second World War, this state-owned engineering business made a variety of external-spring indicators. Catalogues normally acknowledge a debt to Crosby, as the Metallwerker instruments used an essentially similar recording mechanism. A feature of this particular range was the spectacular variety of piston options; a similarly wide variety of springs; and accessories such as remote-release devices and continuous-roll drums.

A 1963-vintage catalogue produced on behalf of the principal distributor, Deutsche Export- u. Importgesellschaft Feinmechanik Optik GmbH (of ‘Berlin C2, Schicklerstrasse 7’), noted that Metallwerker made ‘Torsograph,
Vibrograph, Tachograph, Extensograph, Registrierappärate, Tastograph, Spezialappärate. The indicators were minor modifications of the Lehmann & Michels patterns.

Observed numbers: none.
Possible number range: not known.
Notes: no indicators of this type have yet been reported in detail. It is possible that up to five digits were used, but confirmation is lacking.
Estimated total production: 25,000?

NAGANO SEISAKUSHO
Japan
Observed numbers: 89522
Possible number range: not known
Notes: to add.
Estimated total production: 20,000+

NOVELTY IRON WORKS
New York City. The first manufacturer of indicators active in the USA. Made McNaught-type designs, one of which survives in the Smithsonian Museum collection.

JAMES L. ROBERTSON & SONS
204 Fulton Street, New York City, with ‘Branch Offices in Boston, Philadelphia, St. Louis’. This well-established metalworking business made a variety of indicators, patenting attachments such as the ‘Pneumatic device’, allowing two indicators to be operated simultaneously, and the ‘Take-Up Device for use in connection with Detent on Indicator’ in May 1895 and June 1901 respectively.

1) ROBERTSON–THOMPSON INTERNAL–SPRING INDICATORS
Observed numbers: −261–8308–
Possible number range: from ‘1’.
Total production: 9,000?

SCHAEFFER & BUDENBERG
This well-known engineering company, with branches in Britain and the U.S.A. in addition to Germany, was originally formed to exploit a riband-spring pressure gauge patented in 1849 by Bernhard Schaeffer. The original partners were Schaeffer himself, Christian Friedrich Budenberg (1815–83), and Franz Primaveri, a master mechanic. Trading in Magdeburg as ‘Schaeffer & Co., Mechanische Werkstatt’ continued until Primaveri left the business in
1852 and the style ‘Schaeffer & Budenberg’ was adopted. A move to Buckau, then a village several kilometres from the centre of Magdeburg, occurred in 1859. The company initially concentrated on Schaeffer-type pressure gauges, changing to the Bourdon pressure-tube design as soon as patents protecting the French design lapsed in the mid 1860s.

The success of these products (particularly in Britain from 1853 onward) allowed Schaeffer & Budenberg to grow rapidly. An agency was established in Manchester in 1857 by Arnold Budenberg, brother of Christian Friedrich, initially to meet the demands of the Lancashire cotton industry but later to supply the needs of not only the British Empire but also the U.S.A. The success of the Bourdon-type pressure gauges then persuaded the Schaeffer & Budenberg management to begin assembly not only in Manchester but also in New York from c. 1873 onward. Most of the components were supplied from Buckau. However, a factory was opened in Whitworth Street in Manchester in 1896 and there is no doubt that many components were made there; the same seems to be true of the New York establishment, which was enlarged at this time.

By 1914, the company was operating factories in Buckau (which had become an administrative district of Magdeburg in 1887), Manchester, New York, Paris, Lille and Milan. There were depots and sales offices in Vienna, Liege, Prague, St Petersburg, Stockholm, Hamburg, Zurich, Glasgow and London. By 1916, four thousand people (Beschäftigte) were being employed in sixteen different locations (Standorten).

When the First World War began, shortly after Schaeffer & Budenberg had moved from Whitworth Street in Manchester to a purpose-built factory in Broadheath (near Altrincham, Cheshire), the British operations were sequestered by the British Crown. Work continued under the directorship of British-born Frederick Budenberg—who had succeeded his father Arnold in 1888—to ensure that supplies of the gauges and machinery that were vital to the war effort were still being distributed throughout the British Empire.

In March 1918, Frederick Budenberg, who was by then a British citizen, was allowed to buy the British branch of Schaeffer & Budenberg back from the British Crown and re-registered it as the ‘Budenberg Gauge Co. Ltd’. Almost as soon as the war ended, however, boiler fittings, valves, hooters and whistles, indicators, measuring instruments and pumps were once again imported from Magdeburg-Buckau to be sold alongside pressure gauges made in Britain.

Frederick Budenberg died in 1941, to be succeeded by his son Christian Frederick. The business was once again placed under government control,
making a variety of pressure gauges and hydraulic operating systems until 1945. The German shareholding was then finally liquidated. Pressure gauges, dial thermometers and valves were made so successfully that a new factory was opened in Amlwch (Wales) in 1963 and a manufacturing subsidiary was formed in Australia, but the Budenberg family sold the business to Burnfields Ltd in 1991. Finally, in 2002, the Budenberg Gauge Co. Ltd moved from Altrincham to Irlam, on the outskirts of Manchester.

After the end of the Second World War, Schaeffer & Budenberg GmbH ceased to trade. However, operations recommenced in what was to become the German Democratic Republic—initially as Magdeburger Armaturenwerke (‘MAW’) and then as VEB MAW ‘Karl Marx’. 

**Observed numbers:** –221–21275–

**Possible number range:** from ‘1’

**Notes:** no details of post-war production (nor details of the serial numbers of indicators) have yet been found.

**Estimated total production:** at least 25,000

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**SCHAEFFER & BUDENBERG (U.S.A.)**

66 John Street, New York City, and 22 West Lake Street, Chicago, Illinois (salesrooms); Brooklyn, New York (factory). The North American arm of the well-known German manufactory, this made the ‘Improved Thompson Indicator’, ‘adapted for all speeds, unsurpassed for Simplicity, Reliability, and Excellence of Workmanship. Sold at moderate prices’. S&B also made tachometers, pressure gauges ‘for all purposes’, engine counters and registers, marine clocks and thermometers, the ‘Peerless’ and ‘Manhattan’ injectors, together with reducing and regulating vales (according to Cassier’s Magazine of August 1894). A later Schaeffer & Budenberg ‘American’ catalogue, which includes the external-spring design, also noted the ‘American Ideal Reducing Wheel’ among the company’s products.

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**STAR BRASS MFG CO.**

31 Lancaster Street, Boston, Massachusetts, USA (saleroom and factory); 28 New Bridge Street, London EC, England (saleroom, listed in 1905). Listed in the August 1894 edition of Cassier’s Magazine as a maker of steam-, water- and vacuum gauges, ‘with non-corrosive movements’, this business also made revolution counters, marine- and locomotive clocks, sight-feed lubricators and oil cups, ‘pop’ safety valves, and ‘boiler appliances in general’. The Star name has also been linked with indicators, a relevant patent being granted in Britain in the 1890s.
1) **INTERNAL-SPRING INDICATORS:**

*Observed numbers:* –113–212–

*Possible number range:* 1–300

*Notes:* to add

*Estimated total production:* 300?

2) **EXTERNAL-SPRING INDICATORS:**

*Observed numbers:* –654–735–

*Possible number range:* 300–1000?

*Notes:* to add.

*Estimated total production:* 700?

**ISAAC STOREY & SONS**

Empress Foundry, Cornbrook, Manchester. This foundry and engineering business made at least two hundred Kenyon’s Patent Pistonless Indicator (*c.* 1880–5). By 1917 the business, losing its independence, had become part of United Brass Founders & Engineers.

**TAYLOR (OKILL)**

Bolton, England

*Observed numbers:* imperial, –6035–9822–; metric, –2027–

*Possible number range:* from ‘1’?

*Notes:* the Okills seem to have been numbered in at least three groups—the original ‘P’ series (–P515–); the New Model (–91–); and the perfected type, which are probably in separate imperial and metric series (judged by the style of the counters).

*Estimated total production:* 13,500+

**THOMPSON & BUSHNELL COMPANY**

Trading in August 1894 from 110 Liberty Street, New York City, after a recent move, this partnership made the Bachelder Adjustable Spring Indicator, ‘for any speed or pressure’, and the ‘Ideal’ reducing wheel. The advertisement lists other products as “Grimm’s Patent Injector Blower, and Thompson’s Patent Soot Sucker for cleaning Boiler Tubes. Shaking, Interlocking and Sectional Grate Bars, Steam Specialities and Supplies…”

1) **BACHELDER INDICATOR**

*Observed numbers:* –353–636–

*Possible number range:* from ‘1’.

*Notes:* to add.

*Total production:* not known.
TRILL INDICATOR COMPANY
Corry, Pennsylvania, U.S.A. Founded by William L. Trill in 1901, this made a selection of internal- and external-spring indicators. Business is said to have declined after Trill’s death in 1943, though employees continued to trade until the end of the Second World War. The moribund Trill business was then purchased by the Corry Instrument Company (q.v.). Production is difficult to assess, as Trill never numbered its internal- and external-spring indicators individually. Allowing for an increase in output for the 1942–5 era, total production may have been in the region of 16,000.

WHYTE, THOMSON & CO. LTD
Glasgow, Scotland. Renowned as a maker of nautical instruments, this business traced its history back to a move from Greenock to Glasgow by nautical-instrument maker David Heron (1827) and the formation in 1836 of ‘David Heron & Company’. After a chequered trading history, including two bankruptcies, Heron relinquished in 1864 control of what was originally a ‘Ship Chandlery and Nautical Ware House’ (but had become a compass adjuster and nautical-instrument maker) to his son-in-law, James Whyte. Whyte seems to have taken James Thomson as an apprentice, and Whyte & Company, formed in the 1870s, became ‘Whyte, Thomson & Company’ in 1889. Premises were maintained at 144 Broomielaw, with a workshop (‘Neptune Works’) in Harmony Row, Govan.

Subsequent moves of the offices included 96 Hope Street (1912), 159 Queen Street (1923), 47 Cadogan Street (1927) and 57 Bothwell Street in 1934. The workshop remained in Harmony Row until 1915, when it was relocated in North Woodside Street until moving to 191–3 Broomloan Road in 1948.

The founding owners of Whyte, Thomson & Co. were James Thomson and James Whyte, Junior. A branch was maintained in South Shields from 1902 until 1916, and trading continued until 1934. James Thomson and James Wilson then helped to create Christie & Wilson, and William D. Whyte re-formed the original operations as ‘Whyte, Thomson & Co. Ltd’, which continued to trade until 1953.

Whyte, Thomson & Co. gained a silver medal at the 1886 Edinburgh exhibition, showing, according to the Official Catalogue, a variety of “Nautical instruments…for ships’ use. Binnacle Stands and Compasses for yachts etc. Lifeboat Binnacles and Spirit Compasses… Clinometer, Salinometer, Sextants, Chronometer Clocks, Telescopes, Thermometers, etc…” A claim that ‘pressure gauges, vacuum gauges, engine counters and indicators, lamps and cabin fittings’ were being made, on the basis of an entry in Glasgow and...
Its Environ (1891), suggests that indicators were made in comparatively small numbers prior to the First World War. Whyte, Thomson & Company employed more than seventy people in 1891. Manufacturing facilities were maintained even though there is evidence that demand was so high that instruments were regularly acquired from other Glasgow makers to fulfil orders. Two of the addresses given on Whyte, Thomson ephemera—57 Bothwell Street, 191–3 Broomloan Road—are those of Dobbie McInnes, and it is clear that Whyte, Thomson & Company had an agreement with their landlords until trading finished (perhaps on the death of William Whyte) in 1953.

*Observed numbers:* –351–

*Possible number range:* not known.

*Notes:* only a single Whyte, Thomson indicator has been found. It is suspected (but not confirmed) that other instruments were included in the numbering series.

*Estimated total production:* not more than 100.