THE ENGINE INDICATOR

Autographic and associated designs from James Watt until the present day

AMPLIFICATION: INTERNAL-SPRING PATTERNS

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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 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; and I thank Ben Russell of the Science Museum, Internal Fire, and the Powerhouse Museum in Sydney, Australia. I’m grateful for the support of individual respondents far too numerous to mention separately (I hope this corporate ‘thank you’ will suffice!).

The project has grown too large to be published conventionally, and has been broken 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:*

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

JOHN WALTER, PORTSLADE, 2017
The earliest indicators were well suited to the slow-running stationary engines of their day, but the introduction of fast-running high pressure machines — railway locomotives in particular — caused serious problems. Daniel Gooch, then the Locomotive Superintendent of the Great Western Railway, produced a horizontal-cylinder apparatus incorporating two half-elliptical springs and a slide valve instead of a turn cock.

Developed during the Gauge War of the 1840s, this indicator is described in Chapter Eight. Unfortunately, though it was an advance of great significance, the Gooch indicator provided diagrams of such an unusual form that it remained unique to the Great Western Railway.

The next great advance occurred in the U.S.A., owing to the interest shown in engine design by Charles Talbot Porter (1824–1910). Porter had trained as a lawyer, following in his father’s footsteps, but had no real enthusiasm for his profession. An unhappy experience with a client, who offered rights to a new ‘wonder engine’ in return for a discharge of a bill, failed to discourage Porter. ‘Once bitten, twice shy’ goes the adage; yet Porter then became embroiled with another client who had invented a stone-dressing machine. Inefficient though the original design soon proved to be, Charles Porter worked long and hard to improve it, in the process discovering in himself unappreciated practical skills.

The stone-dressing machine was a great, if short-lived success. It paved the way for the Porter Governor, which improved the performance of many a steam engine from the 1850s onwards, and the existence of the Porter Governor led to an association with a mechanic named John Allen, whom Porter had met, by chance, on a visit to a client with a troublesome engine. Allen had designed what he felt was a better way of controlling a steam engine than the classical adjustable slide valve, which was not effectual enough when engine speeds rose beyond a particular point.

Porter not only persuaded Allen that his design was worthwhile—even though it had not then been committed to paper, Allen had chalked a diagram on the engine-room floor! — but also suggested a high-speed engine
that could result from a marriage of the Allen ‘liberating gear’ and Porter’s fly-ball governor. The first high-speed Porter–Allen engine was built in 1861, ran successfully, and inspired the creation of a larger machine shown at the International Exhibition in London in 1862.

There is aroused great controversy, as it was felt by many that its high speed posed a real threat to life and limb. The running speed was so great, indeed, that only the indicator supplied with the machine could produce useful pressure/time diagrams. Porter reminisced:

“…The subject of an indicator directly presented itself, Mr. Allen invited Mr. Richards and myself to his engine-room, and took diagrams for us with a McNaught indicator. This was the first indicator that either of us had ever seen. Indicators were then but little known ill this country. The Novelty Iron Works made a very few McNaught indicators, almost the only users of which were the Navy Department and a few men like Ericsson, Mr. Stevens, Mr. Sickles, and Mr. Corliss. I told Mr. Richards that we must have a high-speed indicator, and he was just the man to get it up for us. He went to work at it, but soon became quite discouraged. He could not see his way. I told him I was not able to make any suggestion, but the indicator we must have, and he had to produce it.

“After some months he handed me a drawing of an indicator which has never been changed, except in a few details. This important invention, which has made high-speed engineering possible, came from the hands of Mr. Richards quite perfect. Its main features, as is well known, are a short piston motion against a short, stiff spring; light multiplying levers, with a Watt parallel motion, giving to the pencil very nearly a straight line of movement; and a free rotative motion of the pencil connections around the axis of the piston, which itself is capable of only the slight rotation caused by the compression or elongation of the spring.

“Elegant improvements have since been made, adapting the indicator to still higher engine speeds: but they have consisted only in advancing further on the lines struck out by Mr. Richards. In fact, this was all that could be done—giving to the piston a little less motion, lightening still further the pencil movement, and making the vertical line drawn by the pencil more nearly a straight line.

“I took Mr. Richards’ drawing to the Novelty Iron Works and had an indicator ready for use when the engine was completed. The engine was made by the firm of McLaren & Anderson on Horatio street, New York, for their own use. It was set up by the side of their throttle-valve engine, and was substituted for it to drive their machinery and that of a kindling wood
yard adjoining for which they furnished the power. It ran perfectly from the
start, and saved fully one-half of the fuel. In throttle-valve engines in those
days the ports and pipes were generally so small that only a part of the boiler
pressure was realized in the cylinder, and that part it was hard to get out, and
nobody knew what either this pressure or the back pressure was. I have a
diagram taken from that engine, which is here reproduced.

“The indicator was quickly in demand. One day when I was in the shop
of McLaren & Anderson, engaged in taking diagrams from the engine, I had
a call from the foreman of the Novelty Iron Works. He had come to see if
the indicator was working satisfactorily, and, if so, to ask the loan of it for a
few days. The Novelty Iron Works had just completed the engines for three
gunboats. These engines were to make 75 revolutions per minute, and the
contract required them to be run for 72 consecutive hours at the dock. They
were ready to commence this run, and were anxious to indicate the engines
with the new indicator.

“I was glad to have it used, and he took it away. I got it back…with the
warmest praise; but none of us had the faintest idea of the importance of the
invention…”

Charles Brinkerhoff Richards (1833–1919) was a successful Brooklyn-
born consulting engineer with whom Porter had previously had contact. A
talented and versatile designer who was to be known for his work with the Colt
firearms-making company, Richards ultimately became not only Professor of
Mechanical Engineering, Sheffield Scientific School, Yale University, but also
one of the world’s leading authorities on heating and ventilation systems.

Richards had been in the throes of moving his office from New England
to New York when Porter made the first approach, but was willing to help.
To his great credit, Richards had been largely right first time; indicators were
still being made to his basic design in 1900, changed only in detail from the
prototype. The Richards Indicator amazed onlookers in the Crystal Palace by
recording perfect diagrams at an unprecedented 150 rpm. No other indicator
of the day would have coped in such circumstances, owing to the inertia of
heavy moving parts and the effects of vibration on feeble springs.

The Record of the International Exhibition, 1862 described the principal
improvements as the substitution of “very light moving parts, attached to a
short, and therefore stiff spring, instead of the comparatively heavy moving
parts, attached to a long, weak, and therefore tremulous spring. The motion
is multiplied by a lever of the third order, and a parallel motion is employed to
guide the recoil spring in a straight line… It is very little more complex than
the [common] M’Naught instrument”.

PAGE 9
The new indicator attracted so much attention that it was used to test all but two of the British-made engines that were present, and was borrowed by the noted engineer-journalist Zerah Colbourn (American, incidentally) to test one of the others in camera.

Charles Porter stayed in England after the 1862 International Exhibition finished, keen to promote not just the Porter–Allen engine but also the Richards indicator. His experiences with the engine were unhappy, as the initial contractor (Oswald, Grierson & Company of Manchester) failed in 1866 and a subsequent liaison with the autocratic Joseph Whitworth was equally unproductive. The indicator fared better, and Porter describes how development had proceeded: “...I learned that the McNaught and the Hopkinson indicators were in common use in England, that one or both of these were to be found in the engine rooms of most mills and manufacturing establishments, and that if the Richards indicator were properly put on the market, there would probably be some demand for it, although at existing engine speeds, those in use appeared to be satisfactory. A special field for its employment would doubtless be found, however, in indicating locomotives. I felt sufficiently encouraged to set about the task of standardizing the indicator, and during the winter of 1862–3 made a contract with the firm of Elliott Brothers, the well-known manufacturers of philosophical apparatus, and engineering and drawing instruments, to manufacture them according to my plans.

“This was my first attempt to organize the manufacture of an instrument of any kind, and I set about it under a deep sense of responsibility for the production of an indicator that should command the confidence of engineers in its invariable truth. I found that the opportunity I had enjoyed for studying the subject, in the daily use of the indicator which I had brought to the exhibition, was an invaluable preparation for this work.

“I decided...to increase the multiplication of the piston motion, by means of the lever, from three times to four times, thus reducing by one-quarter the movement of the piston required to give the same vertical movement to the pencil, and, second, to increase the cylinder area from one-quarter to one-half of a square inch. The latter was necessary in order to afford sufficient room for springs of proper size, and for reliable strength in their connections.

“The first problem that presented itself was how to produce cylinders of the exact diameter required, .7979 of an inch, and to make an error in this dimension impossible. This problem I solved in the following manner. At my request Elliott Brothers obtained from the Whitworth Company a hardened steel mandrel about 20 inches in length, ground parallel to this exact size and
Plates 2 and 3 show Elliott-Richards indicator no. 317, one of the oldest to be found (dating c. 1864). Note the hexagonal nut retaining the fairlead, and knurling on the cylinder caps. The case label (below) is probably original, with decorative corners to the box-rule.
certified by them. Brass tubes of slightly larger size and carefully cleaned were
drawn down on this mandrel. These when pressed off presented a perfect
surface and needed only to be sawed up in lengths of about 2 inches for each
cylinder. Through the whole history of manufacture that removed all trouble
or concern on this account.

“The pistons were made as light as possible, and were turned to a gage that
permitted them to leak a little. The windage was not sufficient to affect their
accuracy; a thickness of silk paper on one side would hold the pistons tight;
but they had a frictionless action, and the cover of the spring case having two
holes opening to the atmosphere, there could be no pressure above the piston
except that of the atmosphere.

“The second problem was to ensure the accuracy of the springs. This
was more serious than the first one. The brass heads of the springs were
provided with three wings instead of two, which mine had. The spring, after
being coiled and tempered, was brazed into the grooves in the first two wings,
and the third wing was hammered firmly to it. This prevented the stress on
the spring from reaching the brazed joints, and these heads never worked
loose. One head was made fast at once; the other was left free to be screwed
backward or forward until the proper length of the spring was found.

“To ensure freedom from friction, I determined to adjust and test the
springs in the open air, quite apart from the instrument. For this purpose I
had a stout cast-iron plate made, with a bracket cast on it, in which the slides
were held in a vertical groove, and bolted this plate on to the bench, where it
was carefully levelled. The surface of the plate had been planed, a small hole
drilled through it at the proper point, and a corresponding hole was bored
through the bench. A seating for the scales also was planed in the bracket,
normal to the surface of the block. The spring to be tested, in its heads as
above described, was set on the block, and a rod which was a sliding fit in
the hole was put up through the bench, block and spring. This rod had a
head at the lower end, and was threaded at the upper end. Under the bench
a sealed weight, equal to one-half the extreme pressure on the square inch to
be indicated by the spring, was placed on the rod.

“Between the spring and the scale, I employed a lever, representing that
used in the indicator, but differing from it in two respects. It was of twice
its length, for greater convenience of observation, and it was a lever of the
first order, so that the weight acting downward should represent the steam
pressure in the indicator acting upward.

“The weight was carried by a steel nut screwed on the end of the rod and
resting on the upper head of the spring to be tested. This nut carried above
it a hardened stirrup, with a sharp inner edge which intersected the axis of the rod, produced. A delicate steel lever was pivoted to turn about a point at one-fifth of the distance from the axis of the rod to the farther side of the scale seat. The upper edge of this lever was a straight line intersecting the axis of its trunnions. The short arm of the lever passed through the stirrup, in which it slid as the spring was compressed, while the long arm swung upward in front of the scale. The latter was graduated on its farther side, and the reading was taken at the point of intersection of the upper edge of the lever with this edge of the scale.

“The free head on the spring was turned until the reading showed it to be a trifle too strong. It was then secured, and afterwards brought to the exact strength required by running it rapidly in a lathe and rubbing its surface over its entire length with fine emery cloth. This reduced the strength of each coil equally.

“This was a delicate operation, requiring great care to reduce the strength enough and not too much. A great many springs had to be made, several being generally required, often a full set of ten, with each indicator. This testing apparatus was convenient and reliable, and the workmen became very expert in its use.

“The spring when in use was always exposed to steam of atmospheric pressure. At this temperature of 212° we found by careful experiment that all the springs were weakened equally, namely one pound in forty pounds. So the springs were made to show 39 pounds instead of 40 pounds, and in this ratio for all strengths.

“This system of manufacturing and testing was examined in operation by every engineer who ordered an indicator, the shop on St. Martin's Lane [in central London] being very convenient. They generally required that the indicator should be tested by the mercurial column. The Elliotts being large makers of barometers had plenty of pure mercury, so this requirement was readily complied with, and the springs were invariably found to be absolutely correct. We never used the mercurial column in manufacturing, but were glad to apply it for the satisfaction of customers.

“I employed the following test for friction. The indicator when finished was set on a firm bracket in the shop. The spring was pressed down as far as it could be, and then allowed to return to its position of rest very slowly, the motion at the end becoming almost insensible. Then a fine line was drawn with a sharp pointed brass wire on metallic paper placed on the drum. The spring was then pulled up as far as possible and allowed to return to its position of rest in the same careful manner. The point must then absolutely re-
trace this line. No indicator was allowed to go out without satisfying this test. The workmanship was so excellent that they always did so...

“Mr. Henry R. Worthington once told me, long after, that on the test of an installation of his pump in Philadelphia, after he had indicated it at both steam and water ends, the examining Board asked him to permit them to make a test with their own indicator, which they did the next day. They brought another indicator, of Elliott’s make, like his own, but the number showed it to have been made some years later. ‘Would you believe it,’ said he, ‘the diagrams were every one of them absolutely identical with my own!’ I replied that the system of manufacture was such that this could not have been otherwise. I wish to acknowledge my obligation to Elliott Brothers for their cordial co-operation, their excellent system of manufacture and the intelligent skill of their workmen, by one of whom the swivelling connection of the levers with the piston rod was devised. The indicator was improved in other...respects, but I here confine myself to the above, which most directly affected its accuracy. This soon became established in the public confidence.

“During my stay in England, about five years longer, the sale of indicators averaged three hundred a year, with but little variation. The Elliotts then told me that they considered the market to have been about supplied and looked for a considerable falling off in the demand, and had already reduced their orders for material. Eight years after my return I ordered from them two indicators for use in indicating engines exhibited at our Centennial Exhibition at Philadelphia. The indicators had from the first been numbered in the order of their manufacture. These came numbered over 10,000.

“The indicators were put on the market in the spring of 1863, and I sought opportunity to apply them on locomotives. In this I had the efficient co-operation of Zerah Colburn, then editor of The Engineer. Their first application was on a locomotive of the London & Southwestern Railway [sic], and our trips, two in number, were from London to Southampton and return. The revelations made by the indicator were far from agreeable to Mr. Beattie, the chief engineer of the line. Mr. Beattie had filled his boilers with tubes 7/8 of an inch in diameter...’

Richards declined to patent the indicator, leaving the task to Porter in return for a $100 fee and a ten per cent royalty on each instrument. Porter subsequently obtained patents in many countries, including ‘Steam Engine Indicators’, British Patent 1450/62 granted to C.T. Porter, and ‘Improved Steam-Engine Indicator’, U.S. Patent 37980 granted on 24th March 1863 to ‘C.B. Richards, of Hartford, Connecticut, assignor to C.T. Porter, of New York, N.Y.’ Elliott-Richards indicators had improved amplifiers, with the
Plate 4, below. Taken from the patent granted in the U.S.A. in 1863, these drawings show the original prototype of the Richards indicator, made by the Novelty Iron Works. It differed in many respects from the perfected version marketed by Elliott Brothers of London from 1863 onward, the most obvious features being the design of the fairlead, and the plate-like standard to give support to the short-throw amplifying mechanism. By courtesy of the U.S. Patent Office, Washington DC.
A Richards-type indicator

Taken from Jamieson’s *A Text-Book on Steam and Steam Engines* (1897), this illustration of Richards indicator shows a brass piston tube C forged integrally with the base for the recording drum D, to which paper or card could be attached with the assistance of two brass fingers. The tube contained a tight-fitting piston P and a spiral spring SS, and was connected to the engine cylinder by a steam cock SC. Serpentine arms or ‘standards’ A, carried on a collar which could rotate on the piston tube, supported the parallel-motion system PM. Rotating the collar allowed the pencil or scriber P mounted on PM to be brought into contact with paper on the recording drum D. The piston rod PR was carried up through a cap screwed into the piston tube, to be pivoted to the inner parallel-motion arm by a small link. The outer parallel-motion arm was connected with the inner arm by a short vertical link, which carried the pencil T at its mid-point. The drum was revolved by a cord S attached to the moving parts of the engine, acting over the customary small pulley GP, and was returned by a volute or coil spring in the drum-base.

parallel-motion components made in the form of two thin bars instead of a single flimsy rod. A better method of connecting the piston rod to the parallel motion with a swivel is usually attributed to an employee of Elliott, Edward Darke, and the provision of exchangeable springs was also a helpful novelty: in 1874, the range of springs extended from 15 lb/sq.in to 175 lb/sq.in. To allow such flexibility in a single instrument, Elliott instruments had a piston-area of ½ sq.in, double that of the Richards prototype.
The Richards Indicator required careful manufacture and accurate assembly to work efficiently and was also surprisingly expensive. However, as the popularity of high-speed engines increased dramatically in the 1860s and 1870s, so the need for sophistication grew. Many Richards-type indicators were made over a forty-year period, most of them being advertised as ‘improved’. The principal alterations concerned the drum spring, which was often changed from a coil in the drum-base to a coil around a vertical post. Novelty was sometimes introduced into the cord pulley or the indicating-pointer linkage, though the basis of the instrument almost always remained unchanged.

Classifying these instruments is complicated by the involvement of a variety of manufacturers in the U.S.A., Britain and Europe. Little is known of the production history of the Elliott-Richards indicator, excepting that, according to Charles Porter’s reminiscences, production for the first five years averaged three hundred annually and had reached ten thousand (at least according to serial numbers!) by the time Porter acquired indicators to test machinery that was to be sent to the Centennial Exhibition of 1876. But even these meagre details allow dating to be attempted, accepting a margin of error of ‘plus or minus one year’.

There is little doubt that only Elliott Brothers of 449 Strand, London, made Richards-type indicators in Britain until the ten-year licensing agreement reached with Porter in 1863 had run its course. Consequently, virtually all of the indicators numbered below 10000 were of this type even though the construction of the wooden cases may vary. Elliott-Richards indicator no. 914, probably dating from 1866, was entirely nickel-plated, but instruments of this type are rare; it is not yet clear if Elliott considered them to be ‘First Class’, in the way that Dobbie McInnes did, or if they were made only to an occasional individual order.

The instruments all conformed to the same pattern, even though minor changes were made to the basic design—for example, the platform was strengthened, and first a knurled wheel-nut and then a wing-nut replaced the hexagonal nut originally used to hold the drum and fairlead bracket in place.

The provenance of a few survivors can be deduced: a small metal label with the name of Henry Sharp, Jones & Co. of Bourne Valley Pottery, Poole, is fixed to the lid of the box of no. 4845, and no. 5125 was used at one time by the Great Western Railway. Markings were originally confined simply to ELLIOTT BROS over LONDON. on the small standard protruding from the rotating collar, with PATENT over ‘No ××××’ on the long standard. The lowest number reported is currently 317, but it is not known if production began at ‘1’
or, alternatively, ‘100’. Elliott Brothers made ‘Improved Richards’ indicators into the early years of the twentieth century. Though production was slowed by the introduction of better designs (Elliott also made Simplex and Wayne indicators described elsewhere), at least 23,000 Richards-type instruments had been made.

Plate 6. Richards indicator no. 1760, made by Elliott Brothers of London c. 1868. It is believed to have been purchased, second-hand, by an English agricultural engineering business—J.B. & T. Edlington of Gainsborough, Lincolnshire—either when new premises were opened in 1873 or when a workshop was added in 1874–5. John Walter collection.
The addition of the ‘Darke Detent’ had been the only major change. Designed by Edward Darke and protected by British Patent 3702/75 of 25th October 1875, this allowed the drum to be stopped without disconnecting the driving cord, so that, for example, the diagram could be changed. A small bar slid horizontally, inside a distinctive retaining disc attached to the front of the body by two short screws, to intercept a ratchet-ring on the base of the drum.

Elliott-Richards no. 9875, a continuous recording indicator, is currently the oldest known to have been fitted with the detent mechanism. Owned by the locomotive engineers R. & W. Hawthorn, it most probably dates from the year in which the Richardson patent was granted: 1878. Consequently, unless the indicator has been altered, the serial number seems to undermine Porter’s remark that the indicators he acquired prior to the Centennial Exhibition had five-digit numbers.

Plate 7. Richards indicator no. 9875 was made by Elliott Brothers in the 1870s, perhaps as late as 1878 as the drum contains Richardson’s patent continuous-recording mechanism. Marks on the cylinder barrel show that the instrument was used in the ‘Loco. Dept.’ of R. & W. Hawthorn, well-known locomotive manufacturers. Canadian Museum of Making collection.
Many surviving Elliott-Richards indicators were clearly handled by other agencies, notably Hannan & Buchanan of Glasgow, and Joseph Casartelli of Market Street, Manchester. Prior to the mid 1870s, these instruments were simply bought from Elliott Brothers and are appropriately marked on the serpentine standards supporting the pointer linkage. However, at least one of the Hannan & Buchanan examples (no. 6760) has Richard’s Patent where the ‘Elliott Bros.’ mark would normally lie—even though constructional details affirm that it is an Elliott product. Indicator no. 16097, with the strengthened body, a wing-nut drum/fairlead retainer and a Darke Detent, lacks acknowledgement of Richards’ Patent; and the ELLIOTT BROS LONDON mark, in two lines, lies on the front edge of the platform.

Once the agreement between Porter and Elliott Brothers had come to an end (1873?), and protection offered by the British patent ceased (in 1876), instrument makers who had once been forced to buy Elliott-made indicators were free to copy the basic design. Joseph Casartelli of Manchester seems to have been the most active, replacing the original Richards design with an improved form. The changes were comparatively minor—to the piston, in the addition of rotation limiting pins and steam-escape ports—but the construction was noticeably different in virtually every detail.

The platform was greatly strengthened (the original Elliott type had proved to be prone to bend) and the contours of the cylinder and the rotating collar were refined. It is assumed that numbering began from ‘1’, as indicator no. 45 takes this form. The most important marking, an acknowledgement of

Plate 8. The label of a packet of cards—British, c. 1910. Author’s collection.
the British patent granted to Casartelli and Potter in 1875, is placed vertically on the rear of the collar.

Casartelli ‘Improved Richards’ indicators usually have numbers running into the 2000s, later examples displaying a large round-cornered rectangular port cut through the rear of the body to allow air to circulate and steam to escape. One instrument is said to be numbered ‘5010’, which begs a question. If, as has been assumed, Casartelli numbered all the indicators in a single

Plate 9. Richards indicator no. 16097 was made by Elliott Brothers of London in the early 1880s. This particular example (with the linkage displaced) has a Darke-patent detent on a collar that slides laterally, allowing the operator to interrupt the reciprocating motion of the drum to allow a card to be changed. Canadian Museum of Making collection.
series (Richards- and Crosby-based alike), a number in the 5000s suggests that work was still continuing when the First World War began.\[3\]

The Richards-type indicators made in Glasgow by Hannan & Buchanan present a mystery. It was once assumed not only that they had been purchased from Elliott Brothers, complete or as components, but also that the numbers involved were small. A search of Post Office directories then revealed that

3. The serial numbers of the perfected Atkinson-patent gas- and steam-engine indicator of 1908–11 are currently only 3120–3412, which would suggest that this Richards indicator dates from 1914 or even later.
Hannan & Buchanan regularly claimed to have been ‘sole manufacturers [my italics] of the Richards indicators in Scotland’, and that entries drawing attention to the design were continuing in 1911/12. This cast new light on serial numbers, which had also been assumed to lie within the ranges ascribed to Elliott-made instruments yet now seem more likely to have been unique to Hannan & Buchanan. But it would mean that production, previously thought to have amounted to only a few hundred, could have exceeded ten thousand if no other types of gauge or measure were included in the same series.

John Hannan, son of James Hannan and Janet Low(e), was born c. 1831 in Kilmarnock and married Elizabeth McMillan on 14th July 1857, when he was...
Plate 13 shows Casartelli-Richards indicator, no. 2171, presumed to date from the 1890s. Note that though essentially similar to no. 45 (plate 12), it has a large port in the back of the body to promote cooling and a Darke detent.
living at 89 Carrick street, Glasgow, and listed as a ‘Mathematical Instrument Maker’. Hannan would have had to serve the customary apprenticeship, probably bound to one of Glasgow’s manufacturers before starting to trade on his own account⁴. The first Glasgow Post Office Directory to include an entry was that of 1861/2, placing Hannan at 31 Robertson Street. This was a large lodging house, with a small workshop on or in the vicinity of the property where the manufacture of steam engine indicators could be undertaken. These would have been of McNaught type, though Hannan described an improved version to the shipbuilders’ institution in 1866.

The entry in the 1862/3 directory is the same, except that 31 Robertson Street is listed as ‘workshop and house’ and Hannan is described as ‘engineer’; 1863/4 and 1864/5 are also the same, except that his ‘house’ is listed elsewhere. From 1865/6 to 1868/9, Hannan was an ‘instrument maker’, with a workshop at 75 Robertson Street (‘house: 3 Eglinton Street’ in 1866/7). In the 1869/70 directory, however, the name of John Hannan had been supplanted by Hannan & Buchanan of 75 Robertson Street and 45 Robertson Lane, ‘makers of engine indicators and steam gauges’.⁵

Nothing has yet been found in Scottish archives to explain the change of trading style, nor why the services of Hannan were apparently no longer deemed necessary. The census of 1881 shows John Hannan as an ‘Engine Fitter’, living at 3 Melville Street, Glasgow, with his wife Elizabeth, daughters Jessie and Kate, and 18-year old son James (‘Rivet Maker’). A ‘John Hannan’ died in Glasgow on 21st July 1889 of stomach cancer: undeniably the one-time mathematical instrument maker, he is described in the death notice merely as a ‘Brass finisher (Journeyman)’.

What had happened to Hannan? An explanation may be found in an entry in the register of deaths for 26th May 1868, which records the fate of his 9-year-old son John. The boy had suffered ‘Concussion of the brain…& other internal injuries not ascertained without Post-mortem inspection’ as a result of an unexplained accident. The elder Hannan is recorded as ‘Steam Engine Indicator Manufacturer’, living at 163 Holm Street, Glasgow.

Grief or guilt may have proved too much for John Hannan to continue to work effectively, and Buchanan, who may have been more of a financier

⁴ Hannan was illegitimate, born at least two years before his parents married in 1834. His life is still difficult to summarise, as he seems to have lived apart from his wife in the 1860s, lodging elsewhere in the city; the 1871 census records Elizabeth McMillan as ‘head of the household’ of five surviving Hannan children, but co-habitation had returned by the time of the entry ‘John Hannan, Smith & Machine Maker, 28 Cook Street’ in the 1881/2 Post Office directory. Only Douglas Hannan had children (three daughters).
⁵ ‘Hannan & McDougall’ were listed only in 1869/70 as makers of steam engine indicators, pressure and vacuum gauges. The links with John Hannan, if any, have yet to be established.
Plate 14. A composite view of Richards indicator no. 6760, made c. 1885 by Hannan & Buchanan of Glasgow. Note the similarity to Plate 10, but also how the curve of the front standard differs.
than an engineer, could simply have bought as a commercial speculation a business perceived to be in trouble. A family link which would have allowed Buchanan to support Hannan financially is another unexplored possibility.

No Richards indicator can yet be ascribed to John Hannan. The agreement between Charles Porter and Elliott Brothers still had several years to run, and the reluctance of Hannan (and then Hannan & Buchanan) to mark indicators other than by placing a label in the case-lid is a hindrance.

Yet Hannan & Buchanan undoubtedly did make Richards indicators in considerable numbers, probably from the early 1880s onward. Some of these instruments incorporated the ‘Patent Lubricating Piston,’ with a special filler and holes drilled radially into the two circumferential cannelures to allow lubricating oil to seep out between the hollow-bodied piston and the cylinder
Plate 15 and 16. Ephemera associated with the Richards-type indicators made by Hannan & Buchanan. The case-lid labels (left) contain misspellings of Richards’ name, a mistake Elliott Brothers never made; in addition, the maker’s name and address are absent. A page taken from an advertising leaflet published in 1889 (above) shows a spelling error in the text. The patent detent consisted of a riband spring on the platform acting as a pawl when engaged with the ratchet-ring at the base of the indicator drum. John Walter collection.
walls. Others incorporated the 1887-vintage “Buchanan’s Patent Detent”. At least one indicator survives with the riband-spring described in the patent specification, set horizontally on the edge of the platform, which can be pressed into engagement with the ratchet-ring at the base of the drum.

The Glasgow City Post Office Directories were still including references to Richards indicators in Hannan & Buchanan entries as late as 1911/12, alongside the McInnes pattern (q.v.). Unfortunately, the story is complicated by the inclusion in directories from 1895/6 to 1906/7 of Buchanan Brothers, ‘steam engine indicators and gauge manufacturers’ at 16 Carrick Street.

It is probable that Richards indicators were sold (perhaps even made) by this business; one has been reported, but evidence for the attribution is still sought. Similarly, a suggestion that Hannan & Buchanan concentrated on the ‘marine trade’ and let Buchanan Brothers handle other sales, made on the basis of one particular directory entry, cannot be verified. It is, however,

Plate 17, above. Richards indicator no. 10411 was undoubtedly the product of Hannan & Buchanan of Glasgow, probably in the first few years of the twentieth century. Note the position of the platform in relation to the cylinder. Canadian Museum of Making collection.
worthy of consideration in the absence of any other explanation of the links. In 1889, Hannan & Buchanan published testimonials from the Rosamond Woollen Company of Almont, Canada, and Maybury, Marston & Sharp of Perseverance Iron Works, Pendleton ('Near Manchester'), in addition to the Donaldson Line of Steamers, and Muir & Houston of the Harbour Engine Works, Kinning Park. Yet there is nothing to suggest that this situation remained the same after 1900, when John Buchanan retired to leave the company in control of Robert and Duncan Buchanan.[6]

6. Said to have been his sons, though there is some evidence from census and associated records that Duncan Buchanan may have been his nephew.

Plate 18. Richards indicator no. 10411 in its box; the instrument is in excellent condition Note the misspelling “Richard’s”. Canadian Museum of Making collection.
A quirk of Hannan & Buchanan’s operations—shared with McInnes—can sometimes identify their indicators: the habitual misspelling Richard’s (not Richards’) found on box labels and in directory entries and catalogues alike: a mistake which Elliott Brothers never made.

In addition, the front standard of the rotating collar (supporting the amplifier) usually had a flatter under-edge and a more pronounced concave curve at the lowest part of the upper edge on Hannan & Buchanan Richards indicators than on their Elliott-made equivalents.
Plate 21, right.
The Hannan & Buchanan ‘High Speed Richards’ indicator in its wooden case. The fit is sufficiently poor to question the provenance of this particular container.

Plate 22, below right, shows the unusual handle and key escutcheon on the indicator case. This particular design was not officially registered in Britain until 1895.
Hannan & Buchanan often claimed that their Richards indicators could be used with the triple-expansion engines that became fashionable in the late 1880s. Some advertisements also refer specifically to “Buchanan’s Patent Steam-Engine Indicator for High-Pressure…Engines” (the small-scale Richards derivative?).

Hannan & Buchanan often claimed that their Richards indicators could be used with the triple-expansion engines that became fashionable in the late 1880s. Some advertisements also refer specifically to “Buchanan’s Patent Steam-Engine Indicator” for high-pressure and triple-expansion engines. This could identify one surviving ‘high speed’ derivative, about two-thirds the size of a standard instrument (and accepting short, stiff springs).

The small indicator has been tentatively ascribed to Hannan & Buchanan or Buchanan Brothers, but, frustratingly, is completely unmarked. The extraordinary box-key escutcheon—almost Egyptian in style—bears a Registered Design mark granted in 1895, whereas indicators of this pattern would have been introduced no later than 1889. However, the indicator does

7. The attribution of the small-size Richards indicator to Hannan & Buchanan, somewhat tentative, relies entirely on accompanying scale rulers (which match the ratings of the special half-size springs).
Plate 24. ‘Improved Richards’ indicator, no. 244 was the work of the Scottish instrument-maker Thomas Struthers McInnes. The case-label suggests that it was sold by his successors after McInnes died in 1893, but it is more likely to date from the mid/late 1880s and to have been transferred as part of the assets of the estate. Location unknown.
not fit particularly well in its compartment and it is arguable if the box is original. High-speed steam engines were comparatively scarce in Britain, even in the 1890s, and Hannan & Buchanan may simply have experimented with the reduced-scale Richards indicator to compete with Crosby. But the project was clearly unsuccessful, as the manufacturer turned to McInnes and then Thompson-type indicators in the first decade of the twentieth century.

Richards-type indicators were also made in small numbers by Thomas McInnes (1857–93), better known as the patentee of the indicator which eventually became the ‘McInnes-Dobbie’ after its inventor’s comparatively early death. Plate 80 shows one of the few surviving McInnes-Richards indicators, with the comparatively minor improvements that allowed it to be “T.S. McInnes’ Patent”. The most obvious of these alterations is the pivoting paper-retainer, which snaps into place over the top edge of the drum. The piston, which has two cannels, also has features in common with that of the 1887-patent McInnes indicator.

Dating the McInnes-Richards indicators is still handicapped by a lack of information. The example pictured, no. 244, was marketed by ‘T.S. M’Innes & Co. Limited’, a trading style adopted only after the business had been acquired by John Dobbie. The ‘& Co. Ltd’ name lasted independently until 1903. In addition, the base of the limited company had been moved from Waterloo Place to Clyde Place in Glasgow, and the box-lid label displays a telephone number. Yet it seems more likely that the indicator had been part of the McInnes assets than newly-made in the period from 1893 to 1903. McInnes began trading on his own account c. 1881 and it is probable that ‘Improved Richards’ no. 244 actually dates from much the same era as the earliest-known McInnes instrument, no. 237.

Paul Garnier of Paris and Duvergier of Lyon both made Richards-style indicators in France. Little is known about them, though the Conservatoire nationale des art et métiers has a Richards indicator (of uncertain provenance) which has a distinctive rib around the top of the drum—unknown elsewhere—and an inverted paper-retainer held by three screws in the top of the drum body. Many French-made instruments were fitted with continuous-recording drums, as they were seen largely as scientific-research tools.

Philip Rosenkranz, in Der Indikator (1893 edition), includes a drawing of a Duvergier-Richards in which the drum is rotated not by a cord-and-pulley system, but instead by a pinion driven by a worm-gear on a transverse lay-shaft at the tip of the platform. An essentially similar indicator has been reported with an integral reducing wheel set in a bracket beneath the platform directly under the drum.
Though Richards instruments are said to have been made in Germany by Dreyer, Rosenkranz & Droop of Hannover, no mention is made by Philipp Rosenkranz in *Der Indikator* (even the 1893 edition) of anything other than the Elliott-made type. The principal German manufacturer was Schaeffer & Budenberg of Buckau bei Magdeburg, better known for derivations of the Thompson design. Production began either in 1869 or 1870, several being used in the trials undertaken in 1874 by Professor Berndt.

Most of the survivors prove to date from 1895–1910. Only two Schaeffer & Budenberg-made Richards indicators could be traced for examination,

*Plate 25.* A fine-quality Richards indicator by Schaeffer & Budenberg of Buckau bei Magdeburg, Germany, sold through the British subsidiary company in Manchester. This nickel-plated instrument, no. 20888, probably dates from 1908/9. The design is entirely conventional, excepting the steam-relief holes. *Canadian Museum of Making collection.*
no. 14052 and no. 20888, dating c. 1900 and c. 1908 respectively. The older of the two is brass, with evidence of nickel plating on the paper-keeping fingers and their four-screw collar, but nowhere else; the newer is beautifully nickel-plated in its entirety.\textsuperscript{[12]} Most constructional features are duplicated, with a horizontal line of five exhaust ports in the rear of the body. The markings differ considerably: No. 14052 has \textsc{schaeffer & budenberg ltd} above \textsc{manchester, london over glasgow} and the serial number; \textsc{made in germany} appears on the lower edge of the front standard. No. 20888 has a small steel plate displaying ‘\textsc{schäffer & budenberg ltd}’ on the edge of the platform between the drum and the cylinder. The number lies on the front standard of the rotating collar.

Richards indicators were still being offered for sale as ‘new’ in the late 1920s, and it is worth considering if the Schaeffer & Budenberg instruments

\textsuperscript{12.} The combination of brass and nickel-plated parts was uncommon in Britain or the U.S.A., but much more popular in Germany. Schaeffer & Budenberg and Dreyer-Rosenkranz & Droop indicators are regularly found with nickel-plated drums, even though the indicator body is lacquered brass.

\textbf{Plate 26.} The history of the indicators made by the American Steam Gauge Company of Boston, Massachusetts, remains uncertain. Better known as a maker of Thompson-type instruments, ASG evidently commenced making the Richards pattern in 1869. This example is numbered ‘599’ on the rear standard; it is assumed to date from the mid 1870s. \textit{Photograph by courtesy of Bruce Babcock, Amanda, Ohio, USA.}
made early in the twentieth century were specifically intended for sale in Britain, where a reluctance to change to improved designs was all too evident. The Richards pattern made by Crosby (q.v.) may have had a similar genesis.

Very little is currently known of the history of the Richards indicators made in the U.S.A., excepting the testimony provided by Charles Porter in his reminiscences. By publishing details of trace-cards, Porter reveals that a prototype indicator was in use as early as 1861 and that drawings were given to the Novelty Iron Works to guide manufacture of the improved version.
This was not only taken to England in 1862 but also formed the basis for the illustrations accompanying the application made to the U.S. Patent Office at much the same time. Among the most obvious features were the guide plate or standard attached to the serpentine arm anchoring the front link, the singling of the links, and the way in which the amplifying mechanism mounted on a rotating collar was held against the drum by the pressure of an ‘S’-spring attached to the body by a screw.

Intriguingly, Porter says nothing, neither in his reminiscences nor in the textbooks that accompanied the indicators, concerning manufacture outside Britain. Elliott Brothers of London began to make the instruments in 1863, and there is a distinct possibility that a licence had been granted to Kraft & Sohn of Wien (Vienna) shortly before the 1867 Paris international exhibition; but there is no incontrovertible evidence of production in North America prior to 1869. The absence of surviving indicators makes it easy to believe that the Novelty Iron Works made no Richards-patent instrument other than the single exhibition specimen completed in 1862.

The advent of the American Civil War turned the company’s interests to war matériel—including the ironclad steamship Monitor—and the demand for indicators may have abated. Even in these circumstances, however, it is equally easy to conclude that production of McNaught indicators continued; they were eminently suitable for the low-power marine and stationary engines of the day, and the enlargement of the railway system (the transcontinental line excepted) had come to a halt. One among many victims of post-war recession, the Novelty Iron Works ceased to trade in 1869 and was finally liquidated in June 1872.

The earliest of the surviving ‘American Richards’ instruments display constructional features that resemble those of the Novelty-made McNaught. However, indicator no. 436 is marked as a product of the American Steam Gauge Company. This may give a clue to the development of the US-made Richards indicator. No Novelty-marked instrument has ever been found, and it is suggested, therefore, that none had been made. Instead, the American Steam Gauge Company began work on them c. 1869 and ceased (in favour of the Thompson) in the mid/late 1870s after making at least six hundred. The persuasive similarity between some of the parts of the Novelty McNaught and the ASG Richards could be explained simply because the American

**Plate 28.** An advertisement placed by the American Steam Gauge Company in the 1869 edition of *A Treatise on the Richards Steam-Engine Indicator with Directions for its Use*. The company was formed in 1854 to manufacture the Ashcroft (Bourdon) gauge.
AMERICAN STEAM GAUGE COMPANY,
44 Congress Street, Boston,
SOLE PROPRIETERS AND MANUFACTURERS OF
BOURDON'S PATENT STEAM GAUGE
(Formerly known as the "Ashcroft Gauge"),
AND OF
LANE'S IMPROVEMENT ON THE BOURDON.
ALSO OF
"E. G. ALLEN'S PATENT" STEAM GAUGES,
Formerly made and sold by the "National Steam Gauge Co."
AND OF THE CELEBRATED
WATER GAUGES,
Formerly made by the "American Water and Alarm Gauge Company."

HIGH PRESSURE, LOW PRESSURE, BACK PRESSURE, LOCOMOTIVE,
AND VACUUM GAUGES, OF EITHER OF THE ABOVE PATENTS.
Water Gauges, Steam Whistles, Gauge Cocks, Oil Cups, etc.
THE AMERICAN STEAM GAUGE COMPANY are the Sole Proprietors and Manufacturers of the
RICHARDS PARALLEL-MOTION INDICATOR.
☞ The particular attention of engineers is called to this
Instrument, by the proper use of which the power of an en-
gine may be ascertained, its valves accurately set, and any
defects in the working of the engine discovered.

ALSO,
SEWELL'S PATENT SALINOMETER.
Orders for PYROMETERS, a new and useful instrument for
ascertaining the heat of Blast Furnaces,
FILLED AT SHORT NOTICE.
H. K. MOORE, Superintendent.

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Steam Gauge engineers, with no experience of indicators, simply took the McNaught as their point of departure.

The American Steam Gauge Company of Boston, Massachusetts, was formed in 1854 to manufacture steam-pressure gauges in accordance with rights acquired to the Ashcroft patent. An advertisement included in the first
of 1869 edition of Charles T. Porter's *A Treatise on the Richards Steam-Engine Indicator with Directions for its Use* ('with an Appendix...by F.W. Bacon, M.E., Member of the American Society of Civil Engineers') claims that ASG 'are the *Sole Proprietors and Manufacturers* [my italics] of the *RICHARDS PARALLEL-MOTION INDICATOR*', alongside the Bourdon or 'Ashcroft' steam gauge and other steam-related items. A brief review published in the U.S.A. in *The Manufacturer and Builder*, in January 1870, vol. II no. 1, drew attention to the published treatises on the Novelty-made McNaught (an 1864 edition of Stillman's booklet) and the American Steam Gauge-made Richards (the 1869 edition of Porter's book). The engraving of a Richards indicator accompanying *The Manufacturer and Builder* review is identical with the general-arrangement illustration found in the Porter book. The only major difference between surviving ASG Richards instruments and the engraving—if the latter is to be trusted—concerns the body cap, which is noticeably deeper than that fitted to no. 436.

Suggestions that parts were imported from England are easily refuted, as virtually no single individual part may be compared directly with that of an Elliott-Richards indicator. The differences are especially obvious in the design of the amplifying linkage, which is singled instead of doubled, and in the design of the barrel.

A typical early Elliott Richards has a flush-fitting rotating collar on the body, and the barrel cap and base ring are finely knurled. The ASG Richards has an oversize collar retained by a projecting circumferential lip on the barrel and the barrel cap; and, unlike the Elliott design, the platform collar can slide vertically on the barrel surface. The double-pulley fairleads also differ—the upwardly curved bracket of the Elliott, and the double curve (or 'recurve') of the American Steam Gauge pattern.

The two ASG Richards indicators identified to date, no. 436 owned by Bruce Babcock and no. 599 in the collection of the Knox County Historical Society Museum of Mount Vernon, Ohio, differ much greater in detail than two numbers less than 200 apart would usually suggest. The most important change concerns the alteration of the amplifying mechanism to approximate to the Elliott Richards double-link design. The original single link system may not have been sufficiently rigid, or, perhaps more plausibly, excessive weight concentrated in the central trace-link may have created too much inertia to provide satisfactory diagrams as running speeds rose.

ASG Richards no. 599 also shows machining differences; and the fairlead, for example, differs from that of no. 436. These changes may have been due to a change of sub-contractor, but could equally to have been due simply to
the march of time (particularly if no. 599 was made after the introduction of the Thompson). The construction of ASG Thompsons no. 114 and no. 229, notably the design of the barrel, the liner, the union and the platform, bears a greater resemblance to Richards no. 436 than it does to no. 599.

An unexplained part of the story of the Richards-type indicators made in the U.S.A. is provided by those made by Crosby. To date, two have been reported, no. 28 and no. 174 (with some parts marked ‘73’), and it is assumed that the quantities involved were never large; the serial-number series is undoubtedly separate from the standard Crosby indicators. Both Crosby-Richards instruments are nickel-plated brass. They have distinctive fairleads, though the retainers are different: no. 28 has a knurled disc-like nut, but no. 174 has an elongated wing-nut with an oval head. Five exhaust ports are bored through the back of each body. Both indicators are clearly marked CROSBY STEAM GAGE & VALVE CO. BOSTON in two lines over CROSBY–RICHARDS on the front of the body, above the serial number, with patent date-claims for 2nd September 1879 and 1st June 1880 at the base. A third claim, for 20th December 1887, appears on the drum.

The history of the Crosby-Richards is a mystery, as too few have been found. The date on the drum shows that they were made long after the better-known form of Crosby indicator had been introduced, undermining a theory

Plate 30. Nickel-plated no. 174, sold by eBay in 2013, is one of only two known examples of the Richards indicators made by the Crosby Steam Valve & Gage Company of Boston, probably in the 1890s (though evidence is lacking). Note the design of the fairlead-retainer nut, which differs from that of the other survivor.

Present location unknown.
that the Crosby-Richards pre-dates Gordon Crosby’s first design. It is more plausible to suggest that they were made in the early 1890s specifically to answer requests from the British subsidiary, perhaps to promote business by providing an alternative to the standard 1882-type instrument. Though the latter was gradually accepted for use with high-speed engines, and then only grudgingly, many British commentators attempted to characterise the Crosby as ‘too lightly built for normal use’.\[13\]

**IMPROVEMENTS ON THE RICHARDS INDICATOR**

Richards indicators were still being used into the twentieth century, and were still being advertised by many suppliers of steam accessories (e.g., W.F. Stanley & Co. Ltd of London) into the 1920s. For slow-speed installations they were as reliable as any of the later, lighter and usually more delicate designs, and were eminently suited to the comparatively ill-trained engineers to whom many manufactories, waterworks and similar installations entrusted them. They were also commonly used at sea.

The success of the Richards indicator naturally inspired many other inventors, but the strength of patent protection dissuaded copyists. However, it did not stop the inventors who were determined to provide something different, and many other methods of indicating engines were soon being suggested: as early as the mid 1850s, for example, the Scottish locomotive engineer Andrew Barclay had proposed using the expansion of caoutchouc tube as the basis for an indicator and John & Joseph Hopkinson of Huddersfield introduced a new parallel-axis indicator commercially c. 1870. The former never reached production, and the latter, made in considerable numbers, has been described in the previous chapter.

The advent of the Thompson indicator threatened the supremacy of the Richards type, particularly in high-speed applications. This was largely due to the lightweight amplifying mechanism, and many designers reasoned that something similar, fitted retrospectively, could raise an otherwise unaltered Richards indicator to similar levels. Charles Richards made one final contribution to the design of the indicator, apparently made for exhibition in Paris in 1878. Built on the general lines of an Elliott-Richards instrument,

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13. This reflected badly on the abilities of the average British ‘engineer’, whom society regarded as only one step removed from a labourer, and on the primitive nature of many engines still being used in industry in 1900. The Richards indicator had gained such a reputation for robustness and reliability that establishing rivals could be difficult—particularly in districts where individual distributors exercised a stranglehold.
but in steel instead of brass, it had a pantograph-type amplifying mechanism inspired, no doubt, by the emergence in the U.S.A. of the Thompson design.

The status of the improved Richards indicator has been questioned many times, and claims have even been made that it is the original form of the design—preceding the demonstrations in London in 1862. This is quite wrong. The prototype made by the Novelty Iron Works in 1861 was essentially similar to 1863 patent drawings. The reminiscences of Charles T. Porter, published in the American Machinist, contained a letter written to Porter by Charles Richards on 9th October 1903, ending: ‘Enclosed is a card taken in 1878 with the “pantographic” indicator for which a silver medal was awarded me at Paris in that year. This particular indicator...is in the Museum of the Conservatoire des Arts et Métiers’.

No award would have been made for an old design—the original Richards indicator had been exhibited in Paris in 1867 and again in Vienna in 1873—and there is no doubt that the pantograph design was new. The instrument is still in the museum collection in Paris, inventory no. 09416. It was donated by the inventor after the exhibition had ended and is marked appropriately ‘Presented/to the/Conservatoire/des/Arts et Métiers’ and ‘C.B. Richards’ over ‘1878’ on the body.

The amplifying mechanism is a simple pantograph system comprising a link, pivoted on the serpentine standard protruding from the body, which is connected at its tip with the elongated pencil arm. A link from the top of the piston rod to the pencil arm is connected to the rear link, at approximately its mid-point, by a short double-pivoting bar. This maintains a proper straight-line motion, but the efficiency of the design was never matched by commercial success; indeed, it seems that only the prototype was ever made.

Despite its strength, simplicity and mathematical perfection, the Richards pantograph was never exploited, though it may be no coincidence that the later Elliott-made Simplex ‘tong-spring’ indicator also used a pantograph amplifying system. Jacques Buchetti, writing in his book Guide pour l'Essai des Machines à Vapeur et la Production Économique de la Vapeur (1887?), even gives a diagram of the Richards pantograph mechanism.

A different approach was taken by George Maximilian Borns (1852–93), who developed one of the last concentric-cylinder indicators that could trace their lineage back to McNaught. Patented in Britain in 1884 and in Germany on 3rd January 1885 (DRP 32145, granted to ‘Georg Max Borns in Wimbledon (Surrey, England)’ to protect a Kolben-Indicator für Dampf- und andere Motoren), this design had a pantograph, anchored to a pillar within the oscillating drum, operated by a collar attached to the tip of the piston-rod.
Plate 31. Taken from the British Patent of 1880, these drawings show the Casartelli-Darke indicator, essentially a Richards-type body with a lightweight pantograph.
extension. Diagrams were taken with a sheet of paper held to the drum by two pivoting fingers. The Borns indicator was exceptionally compact, but the fragility of the pantograph and the limited vertical movement of the collar restricted it to low-pressure uses. In addition, changing the spring was not as simple as more conventional designs.[14]

Elsewhere, attempts were made to provide hybrid designs by at least two manufacturers: the American Steam Gauge Company in the U.S.A. and Casartelli in Britain. ASG advertised what could be construed as a standard Richards body fitted with a Thompson-type linkage, though the details of this transformation are unclear: no example is currently known to survive. The Casartelli indicator, conversely, was made in some numbers.

The basis of the design was a patent granted to Edward Darke, which included the so-called ‘Darke Detent’ exploited on Richards indicators made by Elliott Brothers in Britain and on Thompson-type indicators made in Germany by Dreyer, Rosenkranz & Droop. Darke is better known for his later high-speed indicator, patented in 1880, which had a tracer sliding in a vertical channel. However, a few years earlier—on 25th October 1875—Edward Thomas Darke of ‘No. 1, Brecknock Crescent, Camden Road, in the County of Middlesex’, had received British Patent no. 3702 to protect ‘Improvements in Indicators used for Ascertaining the Power of Steam Engines’.

The printed specification does not refer specifically to Richards, but the accompanying drawings show an Elliott-Richards indicator modified to accept a pantograph-type amplifier system. The upper bar of the pantograph (extended backward to pivot on a standard attached to the body collar) and the front link, carrying the tracer, form the sides of an isosceles triangle. The long (front) and short (rear) intermediate links complete the lower sides of the pantograph, with a mutual pivot in the cap of the piston rod.

14. Borns had an interesting life. Born in Stettin on 18th May 1852, the son of a mail-steamer captain, he was educated in Halle an der Salle and then apprenticed to an engineer. Borns was forced to abandon his education in the summer of 1873 and came to England, working first for Allen Ransome & Company and then Maw, Drege & Hollingsworth, consulting engineers of London. He married Marion Thomas in 1882 and had four children, but moved to Australia in 1891 (shortly after being proposed as a Member of the Society of Mechanical Engineers) and then to New Zealand in search of a cure for what was probably tuberculosis. George Borns died in Masterton, New Zealand, on 27th September 1893. Several spurious lineages have been created for Borns, largely because his gravestone in New Zealand apparently states his place of birth as ‘Canada’! It has been suggested that the stone was not erected until the death of his son Frank Fairford Borns, killed in action in Flanders in 1917, and that putting ‘Germany’ would have been regarded as inappropriate at that time. But why ‘Canada’ was chosen is still a mystery…

15. An earlier attempt had been made to protect the invention, leading to the grant of British Patent no. 1211 of 20th March 1880. However, the printed Specification is countermarked ‘(This Invention received Provisional Protection only.)’; the information was re-submitted to become Patent no. 1557/1880.
The 1875-type Darke indicator was undoubtedly made by Casartelli of Manchester. Joseph Casartelli and William Potter then sought protection for an improvement of its pantograph system and were rewarded with British Patent 1557 of 16th April 1880.¹⁵ The accompanying Provisional Specification notes that the invention ‘…relates principally, and in the first place to steam

**Plate 32.** One of the few surviving Casartelli-Darke indicators, made in Manchester to a patent granted in Britain in 1880. *Canadian Museum of Making collection.*
engine indicators of the “Richards” type, wherein the movement of the tracer is multiplied or increased in relation to the movement of the piston. The principal object of the first part of our Invention is to render more accurate the parallelism of movement of the tracer… We prefer to make the multiplying lever of the same proportions as the corresponding part in the “Richards” indicator, partly in order that such indicator may be more readily altered to correspond with our Invention.’ The patent also protected a method of locking the driving cord in the fairlead by a radial lever in the pulley block, and an improved detent set in a cap on top of the drum-spring spindle.

It is suspected that Casartelli numbered all the indicators in one series, and so the number of the 1880-type Casartelli-Darke pictured, ‘2481’, should not be taken as a guide to the success of this particular design; the numbers are a better clue to date. The amplifying mechanism of no. 2481 agrees in detail with the patent drawing, comparison with the 1875 design revealing that the layout of the pantograph has been altered so that a link anchored in the piston-rod cap now extends above the lower arm that pivots on the standard. No. 2481 retains the standard two-pulley Casartelli fairlead and an external Darke detent, though the high-speed Casartelli described in greater detail in Book Two, which dates from much the same era as 2481, has both the clamping fairlead and the Casartelli & Potter internal detent.

Other modifications of the Richards indicator included the use by Elliott Brothers of the Darke tracer-and-slot mechanism, patented in 1880, though the design had been conceived for use specifically with high-speed engines and was comparatively unpopular in its larger guise. These indicators were apparently numbered into the regular Elliott-Richards series, which makes their success difficult to judge. They are now extremely uncommon.

Henry Lea of Birmingham, ‘Consulting Engineer’, developed one of the first integrating indicators. The drawings accompanying British Patent no. 785 of 26th February 1877 show a typical Richards instrument, adapted by the substitution of a collar supporting the integrating head (replacing the tracer) and the counter unit registering power replacing the rear standard.

Though the French inventors had been responsible for some remarkably sophisticated indicators made in the mid-nineteenth century, the advent of the Richards design appears to have stifled much of the development of indigenous designs. Exceptions were provided by the work of Marcel Deprez. Based on McNaught and then Richards patterns, Deprez indicators were novel. The most obvious feature was usually a large crank handle on the cylinder body. Patented in France in 1870, the mechanism could be turned to alter the pressure exerted by the spring, acting in conjunction with
a limiting collar to create a diagram of closely spaced lines. These showed where resistance was overcome on each stroke as a turn of the handle steadily increased the pressure applied by the spring on the piston.

After about twenty strokes, the Deprez indicator had constructed an ‘average’ but otherwise conventional diagram. The lining system, inspired by the work of Gustave Hirn some years earlier, was subsequently used by John B. Webb in the U.S.A. and by Farnum & Bodley and then Moses Wayne in Britain. It enabled surprisingly smooth traces to be obtained from railway locomotives or the fast-running stationary engines that were prone to vibration. Perfected Deprez indicators, in use by 1881, also had a unique parallel motion system relying on a pivoting arm and three toothed wheels.

**DISCS, TUBES AND TABLETS**

The advent of the Bourdon tube and the Schaeffer & Budenberg diaphragm revolutionised the design of the pressure gauge, which had soon become a universal fitting on boilers and similar pressure vessels. It was only a matter of time before the principles were applied to indicators. One of the earliest patents to be sought was British no. 2545 of 12th November 1855, which ‘did not proceed to the Great Seal’ (i.e., was never granted) even though a Provisional Specification had been left by Andrew Barclay ‘of Kilmarnock in the County of Ayr, North Britain [Scotland], Engineer’.

Barclay subsequently became better known as a railway engineer and his indicator did not proceed past the trial stage. According to the printed specification, the apparatus consists of a tube of caoutchouc [indiarubber], which is closed at one end, whilst the other end is in communication with the boiler pipe or other container of steam, the presence of which is to be indicated. The tube is enveloped by a helical spring of metal wire, for the purpose of preventing the lateral dilation of the tube, and for aiding its reaction or contraction. This tube may or may not be contained in a larger tube, in which it works with perfect freedom; an index pointer, fixed or connected with the tube in any convenient way, is made to traverse over a scale…being suitably divided to indicate the pressures corresponding to the different positions of the pointer.’

One of the problems of the design was the poor resistance of caoutchouc to high temperatures, a factor which Barclay readily acknowledged (‘It is preferred to fill the elastic tube and a portion of the communicating pipe with water’) — but probably soon realised that it also inhibited commercial exploitation of the design.
Bourdon allegedly made a pressure-tube indicator in the 1850s, but a better design was protected by British Patent no. 2249 granted on 3rd August 1869 to Arnold Budenberg ‘of the Firm of Schäffer and Budenberg, of Manchester, in the County of Lancaster, for the Invention of “Improvements in Apparatus for Indicating and Registering the Pressure of Steam in Steam Generators, and the Pressure in Hydraulic Presses and other Vessels or Chambers, which Improvements are also applicable to Indicating and Registering Pressure and Vacuum in Condensing Apparatus; also to Indicating and Registering the Combined Pressure of the Steam or other Power employed to give Motion to an Engine, and the Speed of such Engine or other Machinery; also to Indicating and Registering Barometrical Variations”’

Plates 33 and 34. A drawing of the perfected Schaeffer & Budenberg Bourdon-tube indicator of the late 1880s, and example no 1912290 dating from 1897. Drawing from The Practical Engineer, 28th February 1890; photograph by courtesy of Pieter Knobbe, the Netherlands.
The patent papers also reveal that the information was ‘A communication from abroad by Bernhard August Schäffer and Christian Friedrich Budenberg, of Buckau, Magdeburg, in the Kingdom of Prussia’. The drawings reveal that the essence of the design was a conventional Bourdon-tube pressure gauge, connected to a toothed sector to rotate the pointer and a vertical rod to actuate a Richards-like amplifying mechanism. The pointer recorded pressures directly onto paper around the drum, which could be driven by clockwork to provide a permanent record, but could also be operated by ‘the motion of the engine or other machinery to cause by band and wheelwork or otherwise a cylinder to revolve and complete…one revolution in a given time… For indicating and registering pressure and vacuum in steam engines part of the apparatus may work as an apparatus known as McNaughts’ and other similar steam engine indicators, but instead of a piston and a spiral spring the hollow tube…is applied to effect the relative motion.’

Indicators of this type were made in the late 1860s, and an improved design, introduced c. 1889, was described by Charles F. Budenberg during a lecture given to members of the Owens College Engineering Society on 4th February 1890. Budenberg noted that ‘Another type of indicator which has come into use to some extent…is that which was patented by the late Mr. Kenyon, of this city [Manchester], the invention of which, however, had been anticipated by the firm with which I am connected, who had constructed an indicator of this type, and abandoned the same, long before Kenyon patented it. In this indicator the piston and spiral spring are replaced by a Bourdon tube, which is identical with that very generally used in pressure gauges…’

“A supposed advantage of this arrangement is that the difficulty of leakage past the piston is overcome—a difficulty which, however, in reality has no existence. The instrument itself is large and unsightly, and, in addition to other disadvantages, it suffers from the fatal objection that its indications are seriously affected by variations in temperature, and also by the weight of condensed water accumulating in the tube… The principle of this indicator has…recently found a new practical application by the construction of a high-pressure indicator, which can be used for indicating pressures up to and from five to ten tons per square inch… In this instrument the brass is replaced by a steel tube, which is bored and turned out of a solid piece of steel, and afterwards flattened and bent, the tube being, in fact, identical with those used in the steel-tube pressure gauges. This indicator is chiefly employed for hydraulic work…”

16. Budenberg’s lecture was published, apparently in its entirety, in The Practical Engineer: 14th, 21st and 28th February, 7th, 14th, and 28th March 1890.
Plates 35 and 36. This Kenyon pistonless indicator, no. 111, was made by Isaac Storey & Sons of Manchester, c. 1882. Canadian Museum of Making collection.
The subject of British Patent no. 1278, granted on 1st April 1878 and sealed on 13th September 1878 to 'John William Kenyon, of Manchester in the County of Lancaster, England, Engineer, for the invention of “Improvements in Steam-engine Indicators, Partly Applicable to other Apparatus for Promoting Economy in the Consumption of Fuel”…', the Patent Pistonless Indicator was made in small numbers by Isaac Storey & Sons of Manchester, using a modification of the standard Richards-type parallel motion. It was easily recognised by the Bourdon Tube, bent into a semi-circle, which replaced a conventional piston and cylinder. The tube expanded in relation to pressure, and, as the upper or ‘free’ tip of the tube was connected to the upper link bar, the pointer operated in the usual manner.

The Schaeffer & Budenberg and Kenyon indicators excited controversy when they first appeared. However, though they seem to have worked quite well when new and were at least the equal of a standard piston-type indicator, problems developed with age. Bourdon tubes in pressure gauges had to cope only with gradual changes in pressure; in an indicator, however, the change was sudden, violent and subject to rapid change. Perpetual stressing

Plate 37. Drawings of the indicator patented on 26th December 1876 by Thomas Minor and John Rae (no. 185773). Note the flattened pressure tube, and the pointer working in a slot in the mounting plate. By courtesy of the U.S. Government Patent Office, Washington DC.
of the brass caused the ‘work-hardening’ that altered the rate at which the tube responded to stimulus and degraded accuracy. In addition, though the pistonless indicator had advantages, including the isolation of corrosive or poisonous gases from the atmosphere, it seems to have been unusually susceptible to vibration.

Plate 38, left. Drawings from the U.S. patent granted in 1886 to Walter Brown. Note the large-diameter diaphragm and the unusual adaptation of a Thompson amplifier.

Schaeffer & Budenberg and Storey & Son were the best-known exploiters of the tube-type indicator, but other attempts were made. They included the indicator protected by U.S. Patent no. 185773, granted on 26th December 1876 to Thomas Minor and John Rae, which had a simple amplifier with a pointer sliding in a vertical channel cut in the mounting plate.

The failure of Bourdon-tube designs opened the way for the diaphragm indicator, made in several patterns. The idea was simple: the ability of a thin metal diaphragm to act as a spring, assuming that the limits of elasticity were never exceeded, could be harnessed to operate a tracer mechanism. Among the first to make a mechanically-actuated indicator of this type were Dreyer, Rosenkranz & Droop of Hannover, who introduced a variant of the Thompson originally intended specifically for ammonia-type refrigerators (*Linde’s Eismachinen*). Dating from the mid 1880s, the indicator could be

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**Plate 40.** A drawing of the Hädicke indicator, developed in Germany some time before 1893. Note how the diaphragm is reinforced with a conical coil-spring; the pantograph amplifying mechanism is also unusual. *By courtesy of the Deutsches Patentamt, München.*
distinguished by the broad disc-like housing beneath the platform. Made in two cast-iron parts, screwing into the body above and the steam cock below, the housing contained a sealing washer above a corrugated diaphragm with a central hollow boss in which the ball-tip of the actuating lever could ride. The lever in turn elevated the trace arm as pressure rose beneath the diaphragm. The limited vertical movement of the diaphragm, only a fraction of that of a conventional spring, presented a major drawback: to obtain a usable diagram, the pivots of the back link and the ‘piston rod’ (attached, of course, to the diaphragm) were so close that they almost abutted. Necessary to obtain an eightfold or tenfold enlargement, this system was prone to excessive inaccuracy caused by play in the joints.

A later attempt to provide a diaphragm indicator was made about 1890 by Hädicke, relying on the interposition of a conical coil-spring between the diaphragm, which was shallowly corrugated, and the rod that operated the pantograph-type 6:1 multiplier. The advantages of the system proved to be illusory, and Hädicke indicators were never sold in quantity.

Interest in Bourdon tube and diaphragm indicators rapidly waned in Europe, and work ceased. John Rae and Walter Brown continued work in

**Plate 41.** General-arrangement drawings of the Sweet/Halsey moving-tablet indicator, from a brief review published in the British periodical *Engineering*, 8th August 1879.
the U.S.A., patenting several improved designs as late as 1887, but there is no evidence that large-scale distribution was ever undertaken; no surviving specimen of Rae's or Brown's later indicators has been traced. They resemble the Kenyon pattern superficially, though the amplifying mechanism usually proves to be a pantograph (Rae) or a Thompson (Brown). The Clarke and Clarke & Low optical indicators of the 1880s and 1890s, included in Book Four, also relied on diaphragms to rock a mirror to deflect a beam of light.

**THE TABLET REVISITED**

One of the earliest attempts to resurrect moving tablet systems was reported by John Sweet to a meeting of the American Institute of Mining Engineers held in Chattanooga, Tennessee, in the summer of 1879. John Edson Sweet was born in October 1832 in Pompey, New York State. Apprenticed first to a carpenter and then to an architect, he went to London in 1862, during the Civil War, to work for the International Patent Office. After returning to Syracuse, New York State, in 1864, he patented a nail-making machine in collusion with his brother William, designed the typesetting machine—a forerunner of the better-known Linotype—exhibited in Paris in 1867, and produced the first micrometer caliper to be marketed successfully in the U.S.A. He became a professor of mechanical arts at Cornell University, Ithaca, in 1872, resigning in 1879 to manufacture the ‘Straight-Line Engine’. He was also a founding member and the third president of the American Society of Mechanical Engineers (‘ASME’).

Even at this early stage in the development of high-speed engines, a need had been identified, said Sweet, for efficient indicators which dispensed entirely with parallel motion. The Thompson indicator (then regarded as the most modern design) had dramatically reduced the weight of the parts in the pointer linkage, but engineers such as John Cooper of Philadelphia were already predicting that running speeds of 1000 rpm would be achieved. No indicator available in 1879 could provide legible diagrams at this speed.

The indicator promoted by Sweet, which he credited to F.A. Halsey, was built on a Richards instrument made by Elliott Brothers of London. The drum had been replaced by a frame supporting a sliding tablet, and the pointer had been replaced by a copper wire sliding within a pivoted hollow
STEAM ENGINE INDICATOR.

No. 535,152. Patented Mar. 5, 1895.

Inventor
Moses John Wayne.

By Knight Bros.

Attorneys.
arm. The piston moved the arm radially between angles of $-7\frac{1}{2}$ and $+52\frac{1}{2}$ degrees, relying on a narrow leaf spring to keep the pointer in contact with the recording board, which had an appropriately concave surface. The pointer was connected to the piston by a short intermediate link, and to supports on the rear of the piston cylinder with a transverse rod.

Sweet claimed that the Halsey indicator had worked very well, providing diagrams as good at 330 rpm (the highest speed that could be obtained) as they had been with the Thompson instrument at 270 rpm and the original Richards machine at only 220 rpm—though the rigid connection between the reducing gear and the sliding tablet undoubtedly explained part of the improved performance.

The most sophisticated moving tablet indicator to be introduced prior to 1914 was the work of an Englishman, Moses Wayne, who acknowledged the prior existence of instruments (such as the 1879 Sweet/Halsey design) working on similar principles. Comparatively little is known about Wayne, who, if nothing else, was prepared to offer indicators that departed from commonly accepted ideas by developing, in addition to the tablet-type instrument, the Simplex (q.v.)—with a pantograph amplifier and a unique tong-like spring. He was born in Enfield in 1849, the son of a gunmaker, but had moved to Birmingham by the time of his marriage in 1867. The 1871 English census records Wayne as a 'Military Gun Actioner', residing in the London district of Bethnal Green; by 1891 he had become a 'Optical and Mathematical Framer' [sic], and an absence from the 1901 census suggests he had gone abroad. After marrying for a second time in 1906, Moses Wayne died in Chesterton in the summer of 1919.

British Patent 8247 of 1893 was granted on 14th April 1894 to 'Moses John Wayne', an 'Engineer' of 'Louisa Cottages, East Street, Prittlewell, in the County of Essex'. U.S. Patent no. 535152 of 5th March 1895, sought in December 1893, is broadly comparable. Made in small numbers by Elliott Brothers of London, the Wayne indicator was marketed commercially from 1894 onward. The manufacturer was sufficiently convinced of its merits to include an addendum to the 1894 edition of Charles Porter’s *A Teatise on the Richards Steam-Engine Indicator*, though ultimate success is difficult to judge. Only one indicator of this type is currently known to survive.

The Wayne design offered some very interesting features, including a lightweight moving tablet and a rotary piston controlled by an externally-mounted helical spring. Steam from the engine cylinder entered by two channels through diametrically opposed admission ports, twisting the piston by its vanes against the pressure of the control spring. The steam or water
that leaked past the piston simply dissipated through two escape ports. The pointer was a radial arm attached directly to an extension of the piston spindle, drawing its trace on a piece of paper attached to the concave mounting plate. The plate was moved forward and then back by the connection with the crosshead or suitable reducing gear, producing a conventionally shaped indicator diagram.

The Wayne instrument could also be fitted with a detachable limiting mechanism (later known as a ‘liner’), enabling it to be used in circumstances—on railway locomotives running at speed, for example—where vibration often hindered the creation of a single diagram. Similar in principle to the mechanism developed in 1870 for Richards type indicators by Marcel Deprez and the indicator developed by Burkitt Webb (Chapter Eight), Wayne’s design depended on a crank and worm to rotate a sector or bar curved concentrically with the piston. A pin through the piston spindle usually restricted the radial movement of the piston unit to no more than a quarter inch.

Instead of taking a single diagram, the limiting mechanism allowed the operator to produce a continuous line-by-line summary of performance as the tablet reciprocated. The movement applied to the piston by the worm gear ensured that each line was drawn at slightly greater than its predecessor. The piston, however, could be moved from its ‘off’ position—when the cylinder pressure was less than that the opposing spring—to ‘on’ when the pressure
finally overcame the spring. Though the absolute pressure was not shown, the point at which it rose above the controlling spring was clearly marked on each line and allowed the points to be joined to provide continuity. Experience soon taught the operator how fast to turn the limiter crank handle, until the individual lines were no more than a twentieth of an inch apart. At this spacing, the pressure line became all but continuous.

The 1894 addendum to Porter’s book suggests that the Wayne indicator had many advantages over conventional drum-type instruments. They included the lightness of the moving parts; minimal movement of the parts attached to the tracer; the piston and tracer made as a single piece; the absence of loose joints or parallel motion; bearings that were free from friction; an externally-mounted spring; and the ease with which the spring and the paper could be changed. Elliott Brothers offered a wide variety of springs, in two series: an ‘Imperial’, ranging from ⅙ (‘No. 1’) to ⅙ of an inch (‘No. 12’), and a ‘Metric’ from ⅜ (‘A’) to ⅛ of an inch (‘V’) for each lb/sq.in of pressure.

Instruments of this type were still being offered in 1914, though they are unlikely to have been anything other than old stock. The familiarity of conventional rotating-drum patterns relegated the Wayne design largely to experimental or laboratory use, even though the ease with which legible ‘lined’ traces could be obtained from engines running at 1000 rpm was greatly in its favour. By 1899, Elliott had turned instead to the Simplex (q.v.), with its detachable ‘tong’ springs and pantograph-type amplifier.

The Wayne indicator, though the only one of its kind to achieve any commercial success since the days of James Watt, was not the last tablet-type indicator ever to be devised. Joseph Thompson, better known for the conventional internal-spring design patented in 1875, developed a radically different instrument towards the end of his life. Patented in the U.S.A. on 28th April 1908, no. 886021, the indicator has a stationary convex platen attached to a frame. The tracer is linked to a vertically-moving bar engaging the piston rod, to record changes of pressure, and the changes in time are indicated by oscillating the tracer carriage horizontally to complete a conventional pressure/time diagram.

As the drawing shows, the instrument was large, clumsy and complicated compared with a standard 1875-type Thompson. The amplifying system was not only exposed but also comparatively weakly made; and the carriage-return springs seem to have been poorly conceived. Though the indicator

allowed the diagram to be drawn in such a way that its construction was easily observed, there is no evidence that anything other than a prototype was ever made. Series production was never attempted.

Closely linked with the tablet-type recorders was a disc-like system patented in Germany in May 1917 by Dr Kochmann & Co. of Charlottenburg (DRP 359322). Not published until September 1922, the specification reveals that the indicator was intended for use with internal-combustion engines. It consisted of a body containing a conventional piston and had an external spring, anchored to a bridge, which extended as the piston rose.

Teeth cut into the stem of the bifurcated piston rod rotated the splined shaft of a vertical pinion anchored in the bridge, and the pinion in turn moved a toothed rack laterally. Amplification was controlled by the ratio of the number of teeth on the splined shaft to those on the pinion. As pressure rose and fell, a trace-point on the tip of the rack marked a paper disc attached to a table rotated mechanically by a lay shaft and bevel gears.

The unconventional diagram was to be drawn on paper pre-printed with radial lines, but gave an accurate record of events in the cylinder without the need of complicated timing- or reducing gear. However, introducing any idea which was at variance with ‘accepted practice’ courted disaster—particularly in wartime—and the Kochmann design disappeared into history.

**Plate 45.** Drawings from the patent granted in 1917 to protect the Kochmann indicator. *By courtesy of the Deutsches Patentamt, München.*
The advent of the Richards indicator was one of the important landmarks in the analysis of engine performance, though the comparatively slow spread of fast-running high-pressure engines (railway locomotives excepted) allowed the makers of the old direct-recording instruments not only to continue lucrative production but also denigrate the performance of the amplifying design. The skill with which the Richards patent had been drawn initially prevented the development of efficient competitors, despite the ingenuity of individual ideas; once the Richards patent had neared the end of its course, however, the desire to defend it receded.

The Richards indicator was sturdy, efficient and reliable. But it had two major weaknesses: the individual parts of the parallel motion were heavy, and the Watt-type or ‘lemniscoid’ parallel motion did not ensure that the pen moved in straight line. Once the central range of the lemniscoid curve had been exceeded, the pen began to trace an arc, and although the error was comparatively small—reckoned to be 0·8 per cent for a ‘large’ example—many people reasoned that it was avoidable. In addition, the inertia inherent in the amplifying mechanism promoted excessive vibration once engine speed rose much about 250 rpm. Though usable diagrams were occasionally obtained at high speed, they were the exceptions to the general rule.

THOMPSON INDICATOR
U.S.A., PATENTED IN 1875
A major advance was made by an American engineer, Joseph W. Thompson. The U.S. Census returns and some fascinating Ohioan history studies reveal that Thompson had been born in Virginia in 1833 and had moved with his family to Salem, Ohio, in 1851. There he had been apprenticed to Samuel Taylor, who owned the Eagle Foundry.

Before the apprenticeship had been completed, Thompson went to work as a machinist in the Sharp, Davis & Bonsall factory. This particular combine had made a blowing engine in 1863, to the designs of Joel Sharp, but the patterns were destroyed in a disastrous fire in 1865. Thompson was instructed
J. W. THOMPSON.
Indicator for Steam-Engines.

No. 167,364.
Patented Aug. 31, 1875.

Fig. 1.

Fig. 2.

WITNESSES:
W. W. Hollingsworth
Amy W. Hart

INVENTOR:
J. W. Thompson

BY

ATTORNEYS.
to design new patterns and a handful of engines had been made by the time Sharp, Davis & Bonsall metamorphosed into the Buckeye Engine Company in 1871. By 1875, Thompson had developed a horizontal single-cylinder engine with an automatic cut-off, a design perfected in 1876—gaining an honourable mention from the judges of the 1876 Centennial Exhibition—and thereafter made in quantity.

Work on the steam engine appears to have persuaded Thompson of the limitations of the Richards indicator, and he had soon produced a design that was more suited to high speeds. It is also assumed that his prototype was built on a Richards body; the principal claims to novelty lie not in the overall layout, but in the detail of the amplifying gear.

Thompson replaced the Watt-type parallel motion, with its distinctive serpentine ‘wings’, with the superior “Evans’ Parallelogram”, also known as the ‘Scott Russell’, ‘Grasshopper’ or ellipsoid method. The arrangement of links and pillars took the general form of the letter ‘M’. Thompson’s design was lighter than its predecessor, and had the merits of being mathematically perfect: the pressure-trace line was straight throughout its entire vertical movement. The piston rod extension often incorporated a universal joint, not only to allow proper movement of the parallel motion but also to combat wear. The piston rod extension pushed upward on the pointer or ‘tracer’ bar, which was attached to one link attached to a fixed post and another pivoted on the cylinder body. The amplifying assembly, therefore, consisted of two fixed pivots, two moving pivots and three levers (or four if an auxiliary link was used to attach the piston rod extension to the pointer bar).

The history of the Thompson indicator is still uncertain. An interest in the patent was assigned to the Buckeye Engine Company, and so, for many years, attempts have been made to find an indicator with Buckeye markings. These have been notably unsuccessful. Instead, it is more probable that Buckeye, with no experience of small-scale precision engineering, subcontracted manufacture to the American Steam Gauge Company (‘ASG’) of Boston, Massachusetts.

ASG had been making Richards-type indicators since c. 1869, which themselves showed some of the production characteristics of the McNaught-
Plate 47. ASG Thompson indicator no. 229. Drawing by courtesy of Bruce Babcock, Amanda, Ohio.

type instruments made (or perhaps only marked) by the Novelty Iron Works of New York. The bodies of the earliest ASG Thompsons reported to date—no. 99 owned by Larry Parker and no. 114 owned by Bruce Babcock—both resemble those of the ASG-made Richards indicators. The amplifying mechanism is very different, but the way in which the body (with steam vents), the platform and the steam-cock union are made is very similar.
And the springs are exchangeable, though the pistons are different—the Thompson has the shaft hollowed to accept a ball-jointed inner rod. The recording drums each contain a helical spring, though the components of the Thompson are stronger. The design of the fairleads and the method of retaining the drum with a hexagon nut are also much the same.

The original Thompson indicators had a tapering pillar-type standard anchoring the front link and a decorative back link composed of what could be described as a ring between two opposed half-rings with extended jaws. The back link pivots on a small bracket formed on the rear of the body collar.

A trial in Boston Navy Yard in 1879 was undertaken with an instrument made by the American Steam Gauge Company. In March 1885, the Bureau of Steam Engineering ordered the commandant of Boston Navy Yard to test the ‘Improved Thompson Indicator…submitted by the American Steam Gauge Company…provided said test is made without cost to the government’. A report submitted on 10th April 1885 helpfully lists the alterations that had been made since 1879: ‘…The features of the instrument for which it is designated the “Thompson Improved Indicator” consists of one patented invention, a modification of some of its parts, and several additional devices. They are as follows:—

“First. The improvement for which a patent [U.S. no. 280256 of June 1883] has been granted is a mechanical contrivance for guiding the cord on the paper cylinder, the imparted motion being from any possible direction…It is apparent that the adjustability of the guiding pulley will give a smooth and regular rotation to the paper cylinder, no matter from what direction the motion may be imparted. The improvement is in keeping with the rest of the details of the instrument, and is an invaluable adjunct where the indicator motion is not a permanent fixture. It has no special advantage…for use on naval vessels, as the indicator motion is permanent and direct; but it will greatly facilitate the taking of cards from the air and circulating pumps.

“Second. There is a modification of the pencil-carrying levers, whereby they are lightened, stiffened and harmonized. Their principle and action, however, remain unchanged… The instrument without the improvements has a quaint, ungainly and ancient look in comparison with the newer design…

“Third. This improvement consists in the ratcheting of the base rim of the paper cylinder carrier a short distance on its circumference at the limit

Plate 50, next page. Taken from Cassier’s Magazine, August 1894. Note the claim that five thousand American Thompkins had been made by this date. Author’s collection.
AMPLICATION: INTERNAL-SPRING PATTERNS

CASSIER'S

INDICATORS

INTEGRAT 1884.

American
Steam Gauge Company
(ORIGINAL STEAM GAUGE CO.)
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Adopted by the United States Navy for use on all the
New Cruisers and Gunboats to be built.

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logue.

PATENTED.
of its rotation; this, in combination with a spring pawl, holds the cylinder when desired, and enables the user to take off the card and renew, without unhooking the cord. This will save trouble and much annoyance, which will be fully appreciated by every user of the instrument.

“Fourth. There is a device to regulate the pressure of the pencil on the paper when tracing a diagram, and consists of a steel wire post riveted to
the base plate of the paper cylinder, and a delicate handle of suitable length, tapped through the movable arm, by which means a light line may always be assured… This will be duly appreciated by those who have to use it in naval vessels, as the pencil can be adjusted before taking the instrument to the generally dim lighted and hot place it is used in.

“The instrument has been lighted by lowering the spring drum, thus shortening the spindle; also by reducing the length and thickness of the material of the cylinder. A cap is brazed on the cylinder having a central orifice through which the spindle of the spring drum passes for strengthening and steadying the cylinder.

“It has been lightened in every part that would admit of it.

“Tests were made with several different classes of engine, ranging in speed from 50 to 150 revolutions,—no higher speed could be found,—the steam varying in pressure from 60 to 90 pounds. The tests were more than satisfactory, the improvements proving to be…sensible.

“The senior member of the present board [Chief Engineer F.A. Wilson] was senior member of a board to test the Thompson Indicator in 1879. The board reported favourably, and recommended its use in the United States Navy, since which time it has been in general use in naval vessels… The improvements have added greatly to its accuracy, delicacy, sensitiveness, and durability, making the instrument about, if not wholly, as near perfection as can be obtained, and we have no hesitancy whatever in recommending its use in naval service…”

The report drew attention to changes in the lengths of the links in the amplifying mechanism, and a significant reduction, calculated to be 51.6 per cent, in the weight of the ‘trunk, piston rod and levers in the parallel mount’.

A catalogue published by the American Steam Gauge Company in 1896 or 1897—the newest testimonial dates from May 1896—lists the ‘American Thompson Improved Indicator (The Original Thompson Indicator)’, noting the improvements over the older type to be:

“…lightening the moving parts, substituting steel screws in place of taper pins, using a very light steel link instead of a large brass one, reducing the weight of the pencil lever, also weight of squares on trunk of piston and lock-nut on end of spindle, and increasing the bearing on connection of parallel motion. By shortening the length and reducing the actual weight of the paper cylinder just one-half, and by shortening the bearing on spindle, also lowering the spring casing to a nearer plane to that in which the cord runs, we have reduced the momentum of the paper cylinder [which had gained a closed top] to a very small amount.”
The change to the fairlead of the Improved American Thompson was distinctive. The contours of the pulley bracket were notably squared, and there was only a single pulley, capable of being rotated laterally and locked by turning a finger-wheel screw protruding from the base. This accorded with U.S. Patent no. 280256, granted on 26th June 1883 to ‘Ladislav Staněk, of Prague, Bohemia, Austria-Hungary, Assignor to the American Steam Gauge Company, of Boston, Mass.” The bracket was usually marked patented/JUNE 26./1883 in three lines which, owing to the width of the mark, were placed to read diagonally upward.

The instruments were usually supplied with a .798-diameter piston, giving a surface area of half a square inch, which the maker claimed to suit it to pressures of up to 250 lb/sq.in when fitted with a 100lb-rated spring. For higher pressures, a special .564-diameter piston (area: one quarter of a square inch) could be supplied, either ready-installed or as an optional extra. This suited the instrument to pressures as high as 500 lb/sq.in. A special all-steel indicator was made for use with ice-making and refrigerating machinery, owing to the corrosive action of ammonia on brass components.

American Thompsons were originally made in ‘handed’ versions, left or right; though each could be adapted to reverse their operation, true left-hand indicators had a left-hand thread on the drum-spring adjuster. Accessories included an optional pivoting detent, which attached to the platform and intercepted a short ratchet on the base of the drum, and a three-way cock.

An ‘electrical attachment’ made to Sargent’s patent and the Ideal reducing wheel, patented by Snow & Pierpont in 1894, could be supplied with a variety of stroke-adjusting bushes. Owing to the similarity of reducing gear available in 1900, despite differing brand names, it is suspected that the Snow & Pierpont design was either made by one manufacturer for supply to several or had been licensed to several indicator-making businesses concurrently.

American Thompsons bear a variety of markings, depending on their age. A typical example from c. 1900 acknowledges the original patentee on the body—J.W. THOMPSON/PAT'D AUG 31, 75.—beneath the manufacturer’s mark (AMERICAN/STEAM GAUGE CO./BOSTON) and a large ‘110’, which is sometimes assumed to be the serial number but identifies the pattern or style. The actual serial number, ‘NO 4047’ will be found on the rear edge of the platform, with PAT D’ JAN 31, 1899 [sic] along the front. This acknowledges U.S. Patent 619420, granted to Amos Kinney and Earl Vaughan of Boston, protecting a small pin that can engage a recess in the underside of the drum to stop the motion when the operating lever is moved radially. Three large gas vents are bored diagonally upward through the rear of the body-cylinder.
Plate 52. A later ‘Improved American Thompson’ indicator, no. 6167, made by the American Steam Gauge Company of Boston in the 1890s. The changes evident in the preceding illustration have been maintained. Bruce Babcock collection, Amanda, Ohio; photograph by Joe Ruh, University Photographer, Northern Kentucky University.
The catalogue also reveals that each Improved American Thompson instrument, unless the purchaser specified otherwise, was supplied ‘...with one spring, in the instrument, one scale, two cocks, all necessary wrenches to use on the instrument, one screw driver, one bottle watch oil, and Pray’s “Twenty Years with the Indicator,” all enclosed in a neat mahogany box.’

A comparison between the American Steam Gauge Company catalogue American Thompson Improved Indicator. Original Thompson Indicator (most probably published in 1896 or 1897, as the newest testimonial is dated 8th May 1896) and A.C. Lippincott, “In a Nutshell” (published by Hine & Robertson
prior to 31st December 1896), reveals that the price of an Improved American Thompson was then $85—expensive compared with the Hine & Robertson indicator, which cost only £40. The differential was still being maintained in 1910, when advertisements published in the US periodical *Power and the Engineer* on 24th May asked $55 for the external-spring Thompson and $50 for the internal-spring Robertson-Thompson; the latter, however, was accompanied by a Victor reducing wheel ($15 if purchased separately).

The Ashcroft Mfg Co. had claimed the U.S. Navy among the purchasers of the Tabor indicator, but the quantity was probably small. The instruments may simply have been supplied by the shipbuilders as part of the equipment of warships, and, therefore, were never adopted officially. This was not true of the Thompson. The 1896/7 American Steam Gauge Company catalogue reproduces a testimonial from the U.S. Navy Bureau of Steam Engineering, noting the results of a test undertaken in Boston Navy Yard in February 1879: ‘…Believing that this instrument is a reliable and sensitive one, we respectfully recommend its adoption in the Naval service…’ The manufacturer added a rider stating that, after another test had been made in the Spring of 1885, the Thompson Improved Indicator ‘has been adopted by the United States Navy department as the standard indicator’. This it remained until the Crosby and then the Bacharach (Maihak-type) instruments became pre-eminent.

Joseph Thompson lived long enough to enjoy the success of his indicator, retiring from the Buckeye Engine Company in 1895 (though he retained a shareholding), and vigorously pursued his ideas virtually until his death in 1909. He was also responsible for an odd-looking tablet indicator patented in April 1908, which is described in greater detail in Book One.

**TABOR INDICATOR**

**U.S.A., PATENTED IN 1878**

Though the Thompson was to have long-lasting effects on indicator design throughout the world, the instrument designed by Harris Tabor enjoyed greater short-term notoriety in North America. Tabor was a prolific patentee of moulding machines and equipment, employed as the General Superintendent of the Hartford Engineering Company of Hartford, Connecticut, in December 1883 (according to *Manufacturer and Builder*). He became the principal of the Tabor Manufacturing Company of New York in 1885, and died in Long Branch City, New Jersey, on 1st August 1898.[1] An

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1. According to the Red Bank Register for Wednesday 10th August 1898. No trace could be found of Harris Tabor in the US Census of 1891, but it is assumed he was abroad—possibly in England.
intriguing potential relationship with an indicator patentee of the 1920s, Harry Tabor (whom the specifications list as English) has yet to resolve.

Harris Tabor ‘of Corning, New York’, was the recipient of US Patent no. 210643, sought in October 1878 and issued, with surprising alacrity, on 30th December 1878. Tabor sought to ‘reduce the number and weight of the reciprocating moving parts of the instrument, and consequently render it more accurate and better adapted to record the action of steam when the engine…is running at a high rate of speed’. A prototype shown to Charles Porter proved to run efficiently at 450 rpm and was soon interesting the Ashcroft Mfg Co. of Bridgeport, Connecticut.

The first few hundred Ashcroft-made Tabor indicators, despite statements that have been made to the contrary, were made in close accord with the patent drawings. The essence of these instruments—which were being made in quantity by 1883—is a small cam-plate elevator attached directly to the piston-rod extension. An early review of this design, published in the U.S. periodical *The Railway Age* on 1st July 1880, said: “The most striking feature, and in fact the main point of novelty in design…, is the parallel motion. It will be noticed that the piston rod, which is jointed to the piston and the pencil lever, as usual, is slotted. This slot is curved and works over a guide roller set into the cylinder cap. The rear end of the pencil lever is pivoted to the usual radius link.

“The slot curve is that peculiar curve, which would be described by the guide roller as a scribing point while the pencil was being moved in a straight line. This, it will be seen, insures an absolutely correct parallel motion to the pencil.

“The guide roller is journalled in a free collar, held in the cylinder cap. This allows all the motion work to be freely revolved.”

The reviewers were also intrigued by the lightness of the Tabor amplifying mechanism, which proved to weigh merely 1.427oz compared with, or so *The Railway Age* claimed, 2.125oz for a Thompson indicator and 2.875oz for the Richards pattern. All the figures included a standard ‘40lb’ spring. The review continued: “The whole instrument is very much lighter and more portable than any others we have seen. Its weight, complete with cock attached, is three

Plate 54, next page. The drawings from the U.S. patent granted to Harris Tabor in 1878. They show clearly how the motion of the slotted tracer bar was controlled by a curved section of the piston rod. The system proved to be effectual but too weak, and was changed in the mid 1880s to the familiar vertical plate attached to the body cap. *By courtesy of the U.S. Government Patent Office, Washington, DC.*
Plate 55. This photograph of Ashcroft-made Tabor indicator no. 443 shows how the first-pattern instruments retained the comparatively weak amplifying system shown in Harris Tabor’s 1878 patent. This was superseded by the familiar vertical plate. The two-pulley fairlead was also soon changed for the single-pulley Calkins design. *Photograph by Bruce Babcock, Amanda, Ohio, U.S.A.*
pounds, six ounces... The diagrams produced are admirable. A seventy-five pound card, taken with a thirty spring, at two hundred and sixteen revolutions, and retracing its lines continuously for fifty revolutions, shows a clean, sharply cut, unvarying card of the most delicate accuracy. A seventy pound card, taken with a thirty-two spring, at three hundred and eighty-five revolutions, gives results so perfect as to almost lead to the conclusion that high speed need not interfere with accurate indicator work.

“The construction of this instrument seems to open up a way for high pressure diagrams made with low tension spring, even at the highest of modern high speeds…”

One of the most important features of the Tabor indicator was the spring, patented in the U.S.A. on 27th September 1881 by Allen Sill of Boston, ‘Assignor to the Ashcroft Manufacturing Company, of Same Place’, the first to be made from separate wire coils. In the words of the designer, ‘a tendency of either to bulge when compressed will be counteracted by the others, and a direct and simultaneous movement of each coil [is] transmitted…’ Where Ashcroft led, virtually everyone followed.

In 1886, however, after at least 443 of the first-type indicators had been made, Ashcroft replaced the flimsy elevator with the more familiar amplifying mechanism: a sturdy standard, attached to the cylinder cap, containing a curved track to ensure that the pencil arm moved vertically. Links pivoted at both ends joined the pointer bar to the piston rod extension and the cylinder body. Series production began in 1887, and continued for many years.

The following description of the Tabor indicator is taken from John Musgrave & Son, Illustrated Catalogue of Vertical Quadruple Expansion Engines, Horizontal & Vertical Triple Expansion Engines... (undated, but apparently published in 1892):

“...the most noticeable peculiarity of the Tabor Indicator is the means employed to communicate a straight line movement to the pencil. A plate containing a curved slot is fixed in an upright position and secured to a swivel plate on the cover of the steam cylinder. This slot serves as a guide, and controls the motion of the pencil bar.

“A pin which carries a roller is fixed on one side of the pencil bar, and this roller is fitted so as to roll freely from end to end of the slot. The position of the slot is so adjusted, and the pin attached at such a point on the pencil bar, that the curve of the slot compensates the tendency of the bar to move in a circular arc, and the end of the bar, which carries the pencil, moves up and down in a straight line, when the roller is moved from one end of the slot to the other. It will be apparent that there is little chance for friction in this
movement, and also that the lightness of the bar and connections insures that inertia will not exert a disturbing influence on the movement of the pencil.

“Of the general features of this Indicator it will be noted that the base of the paper drum and the steam cylinder jacket are made in one piece. The steam cylinder is a straight tube inside of the jacket, with an air space around the sides, and is attached to the jacket by means of a thread cut on the bottom

Plate 56. A section of the standard post-1885 Tabor indicator, showing the major revision to the amplifying mechanism. From A.G. Brown, The Indicator and its Practical Working (c. 1887).
of the cylinder. The cylinder being thus left free to expand or contract without affecting other parts of the instrument. Slots are cut in the top of the cylinder for the insertion of a key for screwing it in or out, and it may be easily and cheaply renewed if damaged when working.

“The pencil mechanism is carried by a swivel plate fitted to the cylinder cover, on which it can be freely moved. The pencil movement consists of three pieces—the pencil bar, the back link, and the piston rod link. The two links are parallel to each other in every position they may assume. The lower pivot of these links and the pencil point are always in the same straight line. If an imaginary link, parallel with the pencil bar, be supposed to connect the two, the combination would form an exact pantagraph, and would serve the purpose of making the pencil point move in a straight line, but the friction and wear of the pencil movement would be greatly increased. The slot and roller serve the purpose of this imaginary link to much better advantage. The connection between the piston and pencil mechanism is by means of a steel piston rod, hollow at the upper end where it passes through the cylinder.

Plate 57. This Tabor indicator, no. 3220, is typical of the instruments made by Ashcroft in the late 1880s/early 1890s. The Calkins-patent fairlead (held by a hexagonal-head nut) and the improved amplifying mechanism can be seen clearly, as can the high quality of the nickel plating. Indicators of this type are often found in excellent condition, as they were comparatively free of structural weakness. Canadian Museum of Making collection.
cover, but solid below, with a reduced diameter, and having a ball formed on the lower end.

“A ball and socket joint forms the connection of this rod with the piston. This prevents the slightest tendency to bind either rod or piston while working, a fault which causes considerable error in other indicators where solid connections are used.

“The socket is an independent piece which fits into a square hole in the piston, and is fastened with a thumb nut below. The piston is light but strong,
and has a number of shallow grooves cut upon the outside to serve as water packing, and is practically steam-tight when working.

“The springs used…are of duplex type, being made of two coils of wire fastened exactly opposite each other on the fittings. This arrangement equalises the side strain on the spring, and keeps the piston central in the cylinder, avoiding the excessive friction caused by a single coil spring forcing the piston against the side of the cylinder.

“The maximum pressures to which the springs for this Indicator should be subjected, to give good results, are given in the following Table [not reproduced here]… These springs are always kept in stock.

“The paper drum turns on a vertical steel pin secured to the frame of the Indicator. The drum, which is very light, has a closed top, with an inside sleeve fitting the steel pin and serving to guide the top. The bottom rests on and is guided by the drum carriage, which has a long bearing on the central pin. Stops are provided on the drum and corresponding openings for them on the carriage, arranged so that the position of the drum may be reversed, in order to take diagrams from the opposite side.

“The pencil movement is made to correspond, so that in two or three minutes time the Indicator may be changed from a right to a left hand instrument; this is a great convenience in many cases. The pressure of the pencil on the paper is regulated by a screw which passes through a projection on the guide plate and strikes against a pivot on the frame. This screw is operated by a handle which also serves for turning the pencil mechanism to and from the drum when taking diagrams. Steel clips are attached to the drum for holding the paper. It will be noticed that one of these is shorter than the other, and this slight alteration makes it vastly more convenient for putting on the paper.

“The drum carriage projects below the drum and is grooved for the reception of the driving cord, the groove being wide enough for two complete turns of the cord. The drum spring, which furnishes the returning force for the drum, consists of a flat spiral spring placed in a cavity underneath the drum carriage and encircling the bearing. One end is attached to the frame below and the other to the carriage. A stop is provided on the frame, to prevent the carriage unwinding the spring when released. The tension of the spring may be regulated by unscrewing the knurled nut above, which holds the carriage in place, lifting the carriage clear of the stop, and winding or unwinding the spring as may be desired.

“A simple form of carrier pulley, at the end of a swinging arm placed below the paper drum, serves to guide the Indicator cord from any direction.
A circular plate carrying a single-grooved pulley, is mounted in a clamp at the end of the swinging arm, and this plate and clamp are so arranged as to swivel to any position; while the groove on the pulley being central with the driving cord at all times, leads the cord in any desired direction.

“The cord provided with this instrument is specially braided, and is stretched by the manufacturers until its elasticity is eliminated. This cord will not stretch in use under ordinary circumstances, and in extraordinary cases cord should not be used.

“A ratchet is cut on the edge of the drum carriage, and a pawl is so arranged as to engage in it wherever it is desired to stop the motion of the drum without unhooking the driving cord. This is a great convenience in many cases.

“The outside of the Indicator in all its parts, excepting the pencil bar and links, is nickle-plated. The pencil movement is of spring steel hardened and finished blue. The excellence of manufacture of the parts of the Tabor Indicator is a marked feature of the instrument, and particular attention is directed to this matter because, from an engineering point of view, excellent workmanship in an instrument of this kind is of great importance. The perfection that is reached in its mechanical construction is revealed not only by a general examination, but by a close inspection of every part.

Plate 59. An Ashcroft advertisement from Cassier’s Magazine of August 1894, showing the perfected Tabor enclosed-spring indicator. Ephemera of this type often gives a surprising amount of information about the manufacturer. John Walter collection.
These Indicators are sent out in polished walnut boxes with nickle-plated mountings, each box containing, besides the Indicator, two Indicator cocks (nickle-plated), one spring and scale (any pressure), a shank of special Indicator cord, cord adjuster, package of Indicator cards, Treatise on the Indicator, hyperbolic curve, extra drum spring, bottle of special oil, box of leads for pencil arm, set of keys and screw driver.

Tests conducted by the U.S. Navy in Brooklyn Navy Yard, in 1886, with Richards, Thompson, Tabor and other indicators, revealed that the moving parts of the Tabor instrument were thirty per cent lighter than the nearest rival and had 24.3 per cent less friction. This undoubtedly led to the official purchase of Tabor indicators to equip the latest warships.

In addition to the standard indicator, a very rare high-speed version with a small-diameter drum (1.5in instead of 2.06in) and an all-steel type for use with ammonia, Ashcroft also made a Navy Pattern ‘in use on nearly all ships of the U.S. Navy, ocean, lake, and sound steamers’. This was a minor
variation of the standard Tabor, with a large hexagonal-head nut at the base of the cylinder and a rotating collar with three small oval vents on the large-diæmeter body; the sprung drum-intercepting detent was also standardised.

A catalogue dating from the 1890s states that, for $85, each indicator in its ‘neat black walnut box with nickel-plated trimmings’ was accompanied by ‘one spring, one scale, two cocks, 100 plain cards, Treatise on the Indicator, one screw driver, one bottle [of] oil, one extra drum spring and the necessary
wrenches’. Additional springs were $5 apiece, scales were 50¢ (boxwood) or $1.50 (steel), a nickel-plated three-way cock was $7, and an electrical attachment (Sargent’s patent) was $25. A fixed-arm Amsler planimeter cost $15, and the ‘Coffin averaging instrument, in morocco case’ was $30.

The most popular attachment, judged by the frequency of survivors, was the reducing gear ($35 if acquired with the indicator) protected by a series of patents granted to William Houghtaling. This was a notably compact European-style reducer relying on a transverse helically-geared shaft engaging with a toothed rack on the lower wedge of the drum to transmit the motion of

2. On 28th March 1893, Houghtaling received US Patent 494482 to protect the basis idea of his reducer. He was also granted British Patent 3627/1894, describing him as a ‘Machinist’, and then US Patent 538043 of 23rd April 1895 to protect an improved reducer. His patents were assigned to the Ashcroft Manufacturing Company of Bridgeport, Connecticut.

Plate 62. The lid tray from the case of Ashcroft Tabor indicator no. 1951, which was sold in Britain in the late 1880s. Note the cards showing the name of the principal English distributor at this time. John Walter collection.
the engine. Indicators made after application had been made in March 1894 for what became U.S. Patent 538042, issued on 23rd April 1895, also often had a clutch in the form of a knob protruding from the top of the drum to throw the system out of engagement.

With the American Steam Gauge-made Thompson, the Tabor was the undoubtedly the widest distributed indicator to be made in the USA prior to 1890, but thereafter lost much of its pre-eminence with the emergence of the 1895-type Crosby, the Robertson-Thompson and a host of Thompson-type derivatives. The story was similar in Britain, where surprisingly large numbers of Tabors were sold in 1885–95 through the efforts of the Globe Engineering Co. Ltd of Manchester (publisher of A.G. Brown, The Indicator and its Practical Working, which was little other than a Tabor promotional vehicle), John Musgrave & Son of Bolton; and Hodgson Hartley & Co. Ltd of Manchester. None of these distributors, however, marked anything other than printed material.

**CROSBY INDICATOR**

**U.S.A., PATENTED IN 1879, 1882 AND 1895**

Perhaps the most successful of the pre-1914 indicators were made in Boston, Massachusetts, by the Crosby Steam Gage & Valve Company, the first pattern was protected by U.S. Patent 219149, ‘Improvements in Steam-Engine Recorders’, sought on 24th December 1878 and granted on 2nd September 1879 to George H. Crosby of East Somerville, Massachusetts.

However, the 1879-type Crosby was an awkward-looking design, with the links of the amplifying mechanism offset so that the pointer lay in the same vertical plane as the piston rod. Another identifying characteristic was provided by the lattice construction of the back link, which was pivoted on the rear of the platform. There was also a method of pivoting the drum carriage so that the pointer could make contact with the drum-card.

The first Crosby was not successful, and sales were few and far between. One remains in the care of the Smithsonian Museum in Washington DC, but few others are known survive. However, the Museum of Making collection contains no. 134, and it is evident that, though the instrument conforms in most respects to the patent drawings, changes had been made as a result of experience. The most obvious change concerns the design of the links, as the lattice structure has been superseded by solid links pierced with holes—easier

**Plate 63**, next page. The Crosby patent of 1879, showing to original form of the indicator. *Courtesy of the U.S. Government Patent Office, Washington DC.*
G. H. CROSBY.
Steam-Engine Recorder.

No. 219,149. Patented Sept. 2, 1879

Fig. 1.

Fig. 2.

Fig. 3.

Witnesses:

S. H. Piper
M. Sullivan

Inventor:

George H. Crosby,
by attorney.

R. H. E.
to make, and probably also stronger than the original form. The body is marked ‘— N° 134 —’ over CROSBY, down-curving over STEAM GAGE & VALVE CO. above up-curving BOSTON over PATENTED over SEPT. 2, 1879 & JUNE 1, 1880. The lettering is hand-engraved in a distinctive ornamented style, with short cross-strokes on many of the individual letters. The patents acknowledge U.S. Patents 219149 and 228179, the latter granted to George Crosby on 1st June 1880 to protect the design of an improved tubular piston rod.

The failure of the first Crosby design soon led to a review of progress, and additional protection was sought in the early 1880s. This included U.S. Patents 256294 and 256295, granted on 11th April 1882 to protect not only a simpler and more conventional design (with a slotted upper rear guide) but also the now-familiar Crosby instrument. The mechanism was essentially similar to the Richards pattern in general layout, but the two fixed pivots, four moving pivots and four levers bore a greater resemblance to the 1875-vintage Thompson—though the short anchor link was pivoted to the piston-rod extension link instead of the tracer arm. Production of the new indicator began almost immediately.

Characterised by simplicity and exceptionally light construction, the 1882-type Crosby could be identified by the pencil motion—an ultra-light pseudo-pantograph, just one of several alternatives proposed in the patents—and a back link in the form of a curved ‘I’ strut. The Crosby was the first high-speed indicator to employ a coil spring to rotate the drum, which was soon accepted as an improvement over the conventional helical spring within the drum base. This feature was widely copied once Crosby’s 1879 patent lapsed.

Judging by illustrations in engineering periodicals of the mid 1880s, the original 1882 Crosby had a short body, a platform with a noticeable step on the underside (immediately ahead of the body), and an open-topped drum. The earliest examples possibly also incorporated a detent to interrupt recording when required; one of the claims on the body of the 1882 instruments refers to the patent granted in the U.S.A. in September 1882 to Gilman W. Brown of West Norbury, Massachusetts (see below), which included a similar detent or latching system. Brown was also responsible for the distinctive Crosby spring, counter-wound from a single coil with a ball at the centre of the base to seat between the piston and the base of the hollow piston rib. This was protected by U.S. Patent 256281 of 11th April 1882, ‘Spring Connection for Indicator Pistons’, assigned to the Crosby Steam Gage & Valve Company.

The stepped platform gave way to a more elegant form, with a radius between the body and the underside of the platform, and the open-top drum was rapidly superseded by a closed-top type, though it continued to appear
on individual indicators for some years. In addition, drums have been found with struts across the open top or, alternatively, part of the top surface cut away in the shape of a cross. Too few individual indicators have been examined to detect any obvious pattern to these changes: for example, no. 581 and no. 1052 now have open-top drums; 833, 1501, 1561, 1657 and 1658 have closed-top drums; and 2670 has cruciform cut-outs in the top surface of the drum.

The Crosby indicators were taken by Gilman Brown, ‘Assignor to the Crosby Steam Gage & Valve Company’, as the basis for patents granted in the U.S.A. on 5th September 1882 (263843) and 21st April 1885 (316111, ‘Steam-Engine Pressure-Recorder and Speed-Indicator’). The earlier patent allowed a modification of the Crosby indicator of 1879 to record the speed of the engine piston or register the number of piston strokes; the later patent, on the basis of the 1882-pattern indicator, relied on a pawl-and-spring escapement—a ‘ratchet ring or annulus, divided into convenient number say 100, divisioned

Plate 64. This matched pair of 1882-type Crosby indicators, no. 1657 (left-hand) and no. 1658 (right-hand), were once part of a ‘pair of pairs’. They are believed to have been the property of the Municipal Technical College in Brighton (England), opened in 1897, but were already more than ten years old and may have come from the original School of Art & Science. Canadian Museum of Making collection.
in tens—to achieve the same purpose. Neither of these modifications was made in quantity.

The Crosby instrument was very popular, allowing its manufacturer to maintain prosperous offices in Boston, New York and Chicago. A branch was also operated for many years at 147 Queen Victoria Street, London. A review published in *Engineering* in 1884 stated that ‘to obtain the necessary rapidity and delicacy of action, the weight of the moving parts has been kept as small as is consistent with the necessary strength, and the space over which they move has been reduced… At the same time a number of improvements of details have been introduced… One of the chief novelties in the instrument lies in the construction of the springs… These springs are made of the finest quality of steel wire, and are so designed that that the strains are transmitted from the centre of the piston, the connexion between the piston and the spring being by a kind of ball-and-socket joint. Each spring is made of a single piece
Plates 65, 66 and 67. This 1882-type Crosby, no. 1501, found in France, has ‘INDICATEUR CROSBY’, ‘Henry CHAPMAN Ing.’ and ‘10, Rue Lafitte, Paris’ engraved on a brass plate on the box-lid. It is accompanied by seven boxwood rules (and four appropriate springs) graduated in the metric equivalent of standard Anglo-American pressures. It is tempting to speculate that this was one of the instruments exhibited in the 1889 Exposition Universelle, Paris, where Crosby indicators won a gold medal. Canadian Museum of Making collection.
of wire wound from the middle into a double coil. The two ends are confined to the head by screwing them into four wings, and the final adjustments are made by screwing the spring in or out of the head until it is of exactly the right strength… The foot of the spring, which has the greatest movement, is simply a small steel ball brazed in place on the wire, and replaces the heavy brass head usually employed, thus effecting a great reduction in the weight of the moving parts. The bead has its bearing in the centre of the piston, so that any lateral movement which the spring may have in being compressed is not communicated to the piston, which moves up and down without any twisting or canting strain being thrown upon it…

‘The piston rod…is hollow, and its lower end screws on to a brass nipple on the piston, this nipple being split to receive the cross wire at the lower end of the spring. A collar at the lower end of the piston rod is undercut, so that when the piston rod is screwed into its place it clips the upper end of the split nipple, and closes the latter on the screw cut on the piston rod… The hollow piston rod is connected to the pencil movement by means of the swivel which is screwed on it…

‘The piston rod runs through a long bearing in the cap; the piston is made as light as possible and is provided with chambers in its outer surface; and the steam entering them prevents the piston from touching the sides of the cylinder…’

The review then described in detail a spring-testing rig designed by Gilman Brown, and the way in which a trace of the amount of strain on the cord could be used to show the uniformity (or otherwise) of the performance of the drum spring during the ‘out-and-back’ recording stroke. The review claimed that the Crosby indicator, with its coil-type spring, outperformed both the Thompson and Tabor indicators in this respect. A diagram taken from a Brotherhood three-cylinder engine running at 615 rpm was shown, and the reviewers concluded ‘that the Crosby indicators…are admirably finished, and trials we have made with one of the instruments have shown it to be exceedingly handy to use’.

However, as the years passed, criticism mounted. Typical were comments made by Charles Budenberg in a lecture given to members of the Owens College Engineering Society, in Manchester, on 4th February 1890. The Crosby indicator, he said, had been ‘received with great favour. The principal difference between the parallel motion of the Crosby indicator and the Thompson consists in the manner of connecting the small guide rod, which in this case is attached to the piston connecting rod instead of to the main bar. The stroke of the piston in this indicator is only three-eighths of an inch.
against five-eighths of an inch in the small Thompson, and this is multiplied in the proportion of 1 to 6, giving a diagram 2¼in. high, a correspondingly stronger spring being used. The disadvantages of this motion as compared with the Thompson are, that the links, being so short, the motion is less stable, and the effect of any play in the joints is far more serious... The angle of motion of the short links being also very large, the friction and wear are considerably increased, and the motion being multiplied in so large a ratio, the effect on the diagram of any play...is greatly enhanced.

‘The method of attaching the spring to the piston appears somewhat insecure and delicate, and, indeed, the general objection to the instrument is that throughout it is too delicate for ordinary practice. This remark applies with special force to the parallel motion and to the piston, the walls of the latter being kept so thin that it is most easily...damaged. The paper drum is also made exceeding light, and a very light helical [sic] spring is used for actuating the drum. The method of holding the guide pulley disc is unsatisfactory, as the bearing surface of the disc is too small, and considerable force is necessary to securely fasten the same.

Plate 68. The first sheet of drawings from the 1882 patent protecting the first true form of the Crosby linkage. Note the curved back link and the way in which the front link attaches to the piston rod. By courtesy of the U.S. Government Patent Office, Washington DC.
“The workmanship of the instrument as made by the Crosby Steam Gauge Company is excellent throughout, and the indicator is designed with a careful regard to the requirements of an accurate instrument; but the indicator is so lightly built that it is very liable indeed to damage, and consequent error, and at high speeds the diagrams are frequently found to be affected even by the mere vibration of the engine.

Whether this opinion withstands scrutiny is questionable. Budenberg was directly involved in the importation of Thompson-type indicators made in Germany by Schaeffer & Budenberg, despite the ‘Manchester’ address that
appeared on many of them. His lecture often focuses on perceived strengths of the Thompson system and dismisses its weaknesses; for example, the potentially weak attachment of the connecting rod to the hollow piston rod, ‘by means of a small double ball joint’ is qualified merely as being ‘somewhat delicate and necessitates excellent workmanship’—making it seem more of a strength than a drawback.

More telling, however, were claims (often made by German researchers) that the 1882-type amplifying mechanism was not mathematically perfect. Finally, Crosby gave way to pressure and introduced the perfected 1895 or Hall-type type internal-spring indicator, protected by U.S. Patent 538515, ‘Steam-Engine Indicator’, sought on 25th May 1894 and granted on 30th April 1895 to ‘Albert Francis Hall, of Boston, Massachusetts, Assignor to the Crosby Steam Gage and Valve Company, of same place’. Though this was externally similar to the 1882 pattern, the new straight back link was shorter and sturdier than its curved predecessor, and was pivoted on the upper rear edge of the body collar instead of half-way down its back.

The Hall-type Crosby was extremely successful, remaining in production until shortly after the First World War had ended. In Britain, prior to the standardisation of the Dobbie McInnes Design No. 1A indicator in 1908, the Royal Navy used Crosby indicators to test the multi-cylinder engines fitted to torpedo-boats and destroyers, which ran exceptionally fast but were also noted for their excessive vibration.
Major changes were made to the design of the body and platform in the early 1900s when the unsightly vents bored into the rotating collar—eleven of them—gave way to four vents bored diagonally upward into the piston chamber through the projecting shoulder that had been added to the rear of the body. But few other adaptations ever proved to be necessary.

Enclosed-spring Crosby indicators were often supplied in a single box as matched pairs, triples or even quadruples. The instruments were originally offered in right- or left-hand versions, selection being left to the purchaser though the most popular sets were matched pairs. After no. 3737, which may give a clue to the change from the 1882 pattern to the 1895 improvement, the design was changed so that each indicator could be converted simply by relocating the drum and altering the direction of the recording pointer.

A Crosby catalogue dating from 1897 claimed proudly that: ‘The superior qualities of the Crosby Steam Engine Indicator were duly recognized at the Paris Exposition of 1889; at the Columbian Exposition in 1893, and at the Cotton States and International Exposition at Atlanta in 1895, where it received the highest awards… A report of indicator tests, made at the Brooklyn Navy Yard, now on file in the Engineer-in-Chief’s Office at Washington, D.C., shows the great superiority of the Crosby Indicator over that of all the others… The Crosby Indicator is approved and adopted by the United States Government. It is the standard in nearly all the great Electric Light and Power Stations of the United States. It has been approved and adopted by the principal
navies, the government shipyards, and the most eminent technical schools…’ Subsequent promotional literature—e.g., *Practical Instructions for Using the Steam Engine Indicator* (first edition, 1905)—amplified these claims: a gold medal gained in Paris in 1889; a medal and a diploma from the 1893 World’s Columbian Exposition and the Cotton States and International Exposition in Atlanta in 1895; a gold medal and diploma of honour from the Russian Exposition held in 1896 in Nizhny Novgorod; and the Grand Prize from the 1904 Louisiana Purchase (St Louis) in 1904.

The 1897 catalogue not only features the 1895-pattern indicator and its accessories, but, in addition, special gas-engine and ‘Ordnance and Hydraulic’ versions. The gas-engine indicator had an elongated piston chamber that

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**Plates 71 and 72.** Another 1895-type Crosby indicator, no. 15469, dating, perhaps, from about 1910. This particular indicator has an unusual matted finish on the body and drum. *Canadian Museum of Making collection.*
Plate 73. A cutaway view of the 1895-type Crosby indicator, from the manufacturer’s promotional literature, showing the delicacy of the amplifying system and the distinctively ball-ended spring. *John Walter collection.*

could accept either the short steam-engine piston, with a cross-sectional area of half a square inch, or the long gas-engine piston. The area of the latter was a quarter of a square inch, half that of the steam-engine type, to allow the higher pressures generated in an internal combustion engine to be measured with standard springs. All that was necessary was to remember to double the actual rate of the springs to get true readings. The engraving shows a heavyweight pointer arm, fluted to increase rigidity without adding unnecessary weight.

The ordnance and hydraulic indicator had a piston chamber of normal length, but could be readily identified by the heavy pointer arm (shown as
flat-sided), a vertical rod to prevent the point jumping too far off the paper in the event of a sudden shock, and a screw-valve protruding from the base of the cylinder above the union. The indicator had a tiny rod-like piston with a cross-sectional area of a fortieth of a square inch, reaching down through a small-diameter hole bored through a piston-chamber extension. However, if the indicator was required to measure comparatively low pressures, the bypass valve could be opened to give access to a full-size piston.

Fascinating details of Sargent’s Electrical Attachment and circuit-closer are also included (see Book Five). Catalogues and handbooks also identify the many accessories that were considered to be standard. In 1905, ‘One nickel-plated Crosby Steam Engine Indicator’ came ‘with fittings complete, viz.: 1 spring, 1 scale, 2 straight cocks, 1 hollow wrench, 1 screw-driver, 1 bottle of oil, 1 hank of cord, 100 metallic-faced cards, and one copy of “Practical Instructions for using the indicator”, all securely mounted in a velvet-lined mahogany case’ cost $85.

MAIHAK-CROSBY INDICATOR
GERMANY, INTRODUCED ABOUT 1903
Hugo Maihak was born in 1858 in Myslitz, Oberschlesien (‘Upper Silesia’). After attending one of the few local Gewerbeschulen, where he soon showed promising technical skills, Maihak’s family sent him in 1877 to the Bauakademie in Berlin (subsequently the Technische Hochshule Charlottenburg). There he stayed until 1883, fascinated by such things as the electro-magnetic telegraph, refinement of measuring techniques, and the carbon-filament lamp.

Maihak determined to make his mark in precision engineering, entering into partnership with mechanical engineer Georg Klug in 1885. An office in Rödingsmarkt in Hamburg promoted the importation and distribution of valves, gauges and precision-measuring instruments. Maihak took full control of the business in 1890, expanding it to include manufacturing capabilities, and his wares—which included vibratometers and gas analysers—won a series of prizes culminating in a gold medal from the 1897 Paris Exposition Industrielle. Among the most successful of the imports were the U.S.-made Crosby indicators, which sold so well that Maihak sometimes advertised as ‘H. Maihak Crosby-Warenhaus’.

Early in the twentieth century, Hugo Maihak began to make indicators in a workshop in Grevenweg, Hamburg. A group of largely unsuccessful external-spring patterns paved the way for the designs of Stauss (1903) and Lehmann (1906). The latter was destined to be exceptionally successful not merely in Germany, but also, ultimately, throughout the world.
The Maihak company—‘H. Maihak Aktiengesellschaft’ from 1910—moved to a new factory in Geibelstrasse, where 125 people were soon at work. A design bureau was created in Semperstrasse, but Maihak lived only to lay the foundation stone, dying in November 1912 at the age of 54.

Plate 74. Maihak-Crosby indicator no. 2027. In addition to the cylinder lubricator, this instrument also has a detent system: the knob on top of the drum is simply pulled upward to isolate the drum from the oscillating base. Canadian Museum of Making collection.
The business survived him by many years, becoming involved after the end of the Second World War in the development of amplifiers and recording equipment in addition to the indicators, torsion meters, production-control equipment and gas-analysers. But profitability declined greatly in the 1970s, and the indicator-making part of the business was sold to Leutert in 1983.

In addition to Stauss- and Lehmann-type indicators, Maihak also made Crosby derivatives ranging from a surprisingly faithful copy to distinctive adaptations. A few Rosenkranz-Thompson indicators were also made in the first decade of the twentieth century.

The earliest Maihak-Crosby instruments were based on the 1895-patent U.S.-made enclosed-spring pattern. It is not yet clear if Maihak copied the design with benefit if not of licence, at least of Crosby’s blessing; the indicators may simply have been blatant copies. Patents granted in the U.S.A. were not recognised in Germany in the early 1900s, partly because no international agreement to protect intellectual property existed at the time.

The first Maihak-Crosby indicators may be difficult to distinguish from their U.S.-made prototypes, unless the drum has an integral detent mechanism and Stauffer screw-feed lubricators are fitted. Their boxes reflect differing

Plate 75. Maihak-Crosby no. 2827 probably dates from 1910-11, as it has the ‘improved’ design of fairlead with two unequal pulleys. This particular example also has a screw-feed piston lubricator on the body side. Canadian Museum of Making collection.
Plate 76. This Maihak-Crosby indicator, no. 12283, dating from the late 1920s, represents the rarely-seen ‘high speed’ variant that was unique to this particular manufacturer. Note the greatly shortened platform and the curved tracer bar. This instrument also has a small-diameter piston. Canadian Museum of Making collection.
traditions; Crosby invariably used American walnut, Maihak almost always used oak, and the accessories were never the same.

The ‘High Speed’ Maihak-Crosby, however, was unlike any American prototype. The Crosby indicator had built an unrivalled reputation in the 1890s for the precision with which diagrams could be obtained from fast running high-pressure engines, but engine development rapidly proceeded until speeds and pressures were too high even for the Crosby.

In an attempt to improve the amplifying mechanism, partly so that stiffer springs could be used and partly to prevent the trace-bar vibrating, Maihak developed a short tracer arm with a distinct curve. The length of the platform was also greatly reduced to enhance rigidity.

It is assumed that comparatively few of these Crosby-type indicators were made by Maihak, but, as they seem to have been numbered in the same series as the Rosenkranz-Thompson, Stauss and Lehmann-type instruments, an accurate assessment of rarity is very difficult to deduce.

**CASARTELLI-CROSBY INDICATORS**

**BRITAIN, INTRODUCED IN THE 1890S**

The Manchester-based instrument manufacturers J. Casartelli & Son had experimented in the late 1870s and early 1880s with Darke, Casartelli-Darke
Plate 78. An engraving of the Casartelli internal-spring indicator, taken from Pickworth's *The Indicator. A Manual for Engineers* (1916 edition). Note the Crosby-like amplifying linkage, the ball-joint between the piston rod and the piston head, and the slot cut vertically in the body wall.

*Courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.*
and guide-slot indicators without encountering success. Little is known about the progress—or otherwise—of Casartelli’s indicator designs in the 1890s, and it seems that reliance was still being placed on the ‘Improved Richards’ pattern described in greater detail in Book Two.

The advent of a Crosby-type instrument, which is presumed to have occurred in the late 1890s, was a step forward. It is likely that the copy post-dates 1896, when the influence of Crosby could no longer be protected in court, but there is a possibility, in the absence of evidence, that the Casartelli pre-dated the Hall patent of 1895 protecting the improvement to the Crosby

Plate 79. The Casartelli ‘High Speed, High Pressure’ indicator appeared c. 1912. This illustration from The Indicator shows a slender slot cut through the insulator and the small-diameter drum.

Courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
linkage. It must be admitted that the original Casartelli-Crosby has a very long back link with a slight curve.

The original ‘Casartelli Special Gas Engine Indicator’ had a plain brass body, with a large round-edged cutaway immediately beneath the transverse bracket for the back link. The piston, fitted with a universal joint, slid in a liner within the body, but the top of the liner was exposed at the top of the cutaway to allow blow-by to escape to the atmosphere. A portion of the spring was also visible, but the cooling effect would have been negligible.

A typical all-brass instrument, no. 2804, is marked SPECIAL GAS ENGINE OVER INDICATOR above J. CASARTELLI & SON and MANCHESTER in four lines placed vertically on the outside of the body. Its features include a fluted nut around the base of the body; a fairlead (with two small pulleys of equal size) retained by a butterfly nut with two short straight wings; and parallel-sided paper fingers of unequal height, held to the drum by three small screws in triangular formation.

After small quantities of these indicators had been made, the expiry of the McInnes patent of 1887 (in 1901) allowed the body to be sheathed in vulcanite. The large port was cut through the sheath and the body wall to expose the liner and the spring. Instruments of this type are considered to be external-spring design, and are described in detail in Book Three.

Casartelli also made ‘High Speed, High Pressure’ indicators in small numbers. Apparently introduced about 1912, these instruments lacked the quick-release piston system. They were characterised by their small-diameter recording drums, stiff springs, and a narrow slot cut vertically through the insulated body. The Atkinson suppressor sometimes associated with the dual-purpose external-spring patterns had been abandoned.

Indicators were still being offered by Casartelli & Son long after the First World War had ended, but there is no evidence that they were still being made in quantity even though a Casartelli-Richards instrument has been reported with a serial number in the low 5000s—which would date it to the mid 1920s. A suspicion lingers that these indicators were being assembled from parts which had been in store for some years.
The Richards indicator had reigned supreme until the master patent expired in the mid 1870s, allowing better designs to be based on the same general principles. Though the Richards-type instruments were robust, tests often showed that oscillations began to affect the accuracy of its diagrams above 200 rpm, and rival promoters considered that details of the basic pattern—e.g., the pointer linkage—could be improved to reduce both friction and inertia. This left the field open to speculation. The most successful American-made indicators made prior to 1914 were the Thompson, the Tabor and the Crosby, described in the previous chapter, but several other instruments were also marketed commercially.

American engine makers, in particular, habitually sold their products on the basis of indicated (or ‘real’) horsepower instead of the arbitrary nominal horsepower system so often favoured in Europe. Consequently, many inventors and precision-engineering businesses turned their attention to steam-engine indicators. The sheer size and vibrant nature of the engineering industry in the U.S.A., still underpinned in the last decades of the nineteenth century by the pioneer spirit that had opened up vast tracts of the Wild West to settlement, created a ready market. Though trade was not particularly outward-looking, a ready grasp of the principles of standardisation and series-production methods encouraged many entrepreneurs to seek their fortune. It is possible that the output of indicators in the USA in 1880–1900 exceeded the combined output of all the European manufacturers, though evidence in the form of production figures is difficult to obtain.

The situation in Europe differed greatly from that found in the U.S.A. A handful of engineering businesses had been able to monopolise the supply of indicators, but even these were unable to stem the large-scale importation of the Tabor and Crosby patterns, in particular, in the 1890s. Elliott Brothers of London, the original licensee of the Richards pattern, remained the principal promoter of amplifying indicators in Britain until the emergence of McInnes of Glasgow in the late 1880s. Casartelli of Manchester made small quantities of Richards and ‘own brand’ indicators prior to 1914; and Richards...
Plate 80. Taken from the Dreyer, Rosenkranz & Droop catalogue published in 1899, this shows a variant of the Rosenkranz-Thompson indicator fitted with an adaptation of the Richardson continuous recorder. Note the great height of the drum! Author’s collection.
and Thompson patterns were made in Glasgow by the interrelated Buchanan businesses—John Buchanan, Buchanan Brothers, Hannan & Buchanan—together with Hall-Brown, Buttery & Co. and Whyte, Thomson & Co. Ltd.

In Germany, Schaeffer & Budenberg of Buckau bei Magdeburg, Dreyer, Rosenkranz & Droop of Hannover, and even Maihak of Hamburg made indicators with Thompson-type linkages. Kraft & Sohn and Victor Lefebvre made them in Vienna and Paris respectively, but the Austro-Hungarian and French markets were soon dominated by imports from Germany and the USA. No indicator manufacturers have yet been identified in Italy or in tsarist Russia.

**RICHARDSON INDICATOR**

**BRITAIN, PATENTED IN 1878**

British Patent 2814/78, ‘Indicator for Steam and other Engines’, was granted on 13th July 1878 to the philosophical instrument maker John Richardson of Camden Town, then on the outskirts of London (see Chapter Two). The principal goal was to protect a system of rollers and a roll of paper within the drum to allow diagrams to be taken successively (see Chapter Nine), but Richardson was also keen to ensure that the amplifying system of his indicator was mathematically correct. The drawings accompanying the specifications show two alterations of the Richards motion, one involving a vertical slot. It is likely that a few of these guide-slot instruments were made by Elliott Brothers. Elliott Brothers, Schaeffer & Budenberg and Dreyer, Rosenkranz & Droop all exploited the Richardson paper-feed system commercially.

**DARKE INDICATOR**

**BRITAIN, PATENTED IN 1879**

The simplicity of the Tabor system influenced Edward Darke of London, whose minimalist design was patented on 21st November 1879 (4888/79). Made exclusively by Elliott Brothers, the Darke Patent High Speed Indicator had only one fixed pivot and a swivelling link connecting the piston rod extension to the pointer bar. The role of the other fixed pivot was taken by a vertical slot cut in a plate on the cylinder body. The pointer was allowed to slide back along its bar as a guide pin rose in the slot. However, though this was claimed to promote accuracy—the Darke and a properly regulated Tabor were among the few indicators of their day to be mathematically perfect—it was also susceptible to excessive friction in the slider unit.

Some greeted Darke’s ideas enthusiastically. A typical review, published in *Engineering* on 26th March 1880, remarked that reduction in the weight of
the individual parts was a great improvement over the Richards patterns then most commonly encountered, and that ‘the pencil motion, which is made of one piece of steel fitted at the one end to a crosshead, which crosshead is supported and moves upon steel centres, and at the other carries a little sliding block through which the pin (or pencil as it may be called) passes; the pin moves upon the paper drum through a slot or guide (which is a part of the swivel top of the indicator cylinder); the little sliding block upon the arm moves the lever as the pin moves in a straight line in the slot or guide. The piston-rod head carries a jaw in which moving also on centres is a light sleeve through which the pencil arm passes, sliding in this sleeve as the angle of the pencil arm varies with the stroke of the piston.

‘An examination of this instrument will show that every possible care has been taken to avoid “back-lash”… The theory of this motion is perfect, and in practice it is found to be much more simple to manufacture, lighter and more accurate than the Richards motion’. Other commentators were much less convinced, concerned that excessive friction in the slider was likely to degrade accuracy.

Typical of these views was that of Professor Robert Smith of Mason College, Birmingham, England, whose department had replaced Richards

Plate 81, right. A page of engravings of the small Elliott-Darke indicator, from the British periodical Engineering (1880). John Walter collection.
indicators with “Darke’s High Speed Indicator” some years prior to lectures given in 1885 to the Institution of Civil Engineers.\footnote{1} Though describing the design as ‘far from perfect’, Smith had praised the lightness of the moving parts compared with those of the Elliott Richards. But he had found by experiment that though there was negligible friction in the lever joints at the mid-stroke position, when the trace arm was horizontal, the forces not only increased as the extremes of the diagram were approached but increased much more obviously at the bottom than the top of the vertical guide slot. This problem could have been unique to one particular Darke indicator (no comparisons had been made), but was an obvious weakness in the basic design not only of the Elliott Darke but also of the others that incorporated slots.

In an earlier British patent, granted in 1875, Edward Darke claimed ‘an invention for giving motion to the paper drum by means of rods, &c, in rigid communication with the engine, with means of stopping and starting

\begin{figure}
\centering
\includegraphics[width=\textwidth]{plates82and83}
\caption{Two small or high-speed Elliott-Darke indicators, no. 30 (left) and no. 565 (right). Both display the ‘Darke Detent’ on the side of the cylinder above the platform. The brightly-polished and lacquered brass instrument was regarded as ‘Second Quality’: the nickel-plated version was its superior. Canadian Museum of Making collection.}
\end{figure}

\footnote{1} ‘On the Theory of the Indicator and the Errors in Indicator Diagrams’ by Osborne Reynolds (19th May 1885), and ‘Experiments on the Steam-Engine indicator’ by Arthur W. Brightmore (10th November 1885). Smith relayed his remarks by letter as part of the discussion of the controversial findings.
Plate 84, left. This small or high-speed Elliott-Darke indicator, no. 30, is one of the oldest to survive. The mahogany case differs from the design subsequently accepted as standard, which may simply reflect ‘early production’ status. There is no evidence to suggest that the indicator has been re-cased.

Plate 85, below. Small Elliott-Darke indicator no. 565 in its walnut box. Dating from the early 1880s, this is the standard wooden case.

*Museum of Making collection.*
Plate 86. A typical large Elliott-Darke indicator, no. 8618, probably dating from c. 1881-2, showing clearly the design of the trace arm and its guide plate. The sliding 1875-patent ‘Darke Detent’ and its stop can be seen on the side of the cylinder above the platform.
the paper drum in a very simple and effective way. His sprung pawl-type detent could be activated simply by engaging a spring-steel plate that slid horizontally around the cylinder body. This allowed the operator to stop the movement of the drum if required to do so.

Small high-speed Darke-patent indicators—but not large Richards-type adaptations—generally had a helical riband-spring in the base of the drum, freeing the interior for a continuous roll of paper. The paper clip was a hinged two-bar pattern instead of the customary Richards spring fingers.

It is very difficult to assess how many Darke indicators were made. At one time, it was assumed that the small ‘high-speed’ instruments were numbered in a special series, but that the large version (which seemed to be less common) had been numbered with the Richards indicators.
Plates 87 and 88. An Elliott-made Darke indicator, no. 8700. This particular instrument (unusually for a ‘large’ example) was sold with a supplementary small-diameter piston, intended for use with high-speed or high-pressure engines. *Museum of Making collection.*
This is now known to be mistaken. The Elliot-Darke indicators were not marketed commercially until 1880, by which time the numbers of the Elliott-Richards type had reached at least 13000. Among the known ‘small Darkes’ are numbers ranging from 30 to 2579; but the larger ones include 8618, 8938, 8700 and 11367.

This shows unequivocally that the ‘large Darkes’ and the Richards indicators were numbered separately. It also suggests that, unless separate number-blocks had been allotted, the large Darke was produced only after production of the small ‘High-Speed’ version had ceased. The most likely
explanation is that enthusiastic promotion of the Crosby indicator in Britain, and its adoption by the Royal Navy for use with the engines of the torpedo destroyers (which tended to vibrate excessively), reduced sales of the small Elliott-Darke to a point where they became uneconomic.

It also seems probable that though efficient enough in theory, with a mathematically-acceptable ‘straight line’ tracer, the Darke had weaknesses. Labels pasted into the case-lids draw attention to the necessity to keep the guide-slot for the tracer free from oil. In the hot, damp and steamy confines of an engine-house, any clogging—or, worse, rusting—of the comparatively crudely-made tracer head would have a disastrous effect on accuracy.

THOMPSON-TYPE INDICATORS
AUSTRIA AND GERMANY, INTRODUCED ABOUT 1877
The earliest Thompson-type indicators to be made in Europe were the work of Kraft & Sohn of Wien (Vienna), sometimes spelled ‘Krafft’. No survivor of these could be traced, and so identification relies largely on engravings in Rosenkranz’s and Buchetti’s books of 1893. These show a conventional Thompson amplifying mechanism, with a fretted back link comprising a central oval flanked at each end by a half-oval; the front support for the trace arm is a ball-headed pillar. The paper-retainer plate has two parallel-sided fingers of equal height, held at the base by two small screws.

The engraving, if it can be trusted, shows that the Kraft-Thompson had unusual features: for example, the fairlead bracket was integral with the platform, set at an angle to allow the cord tangential access to the drum. Though the pulley could be tipped laterally, it could not be moved outwards. The French illustration suggests that the steam cock was part of the indicator body, but this, which would be unique, was a misunderstanding. The German sectional drawing shows quite clearly that the parts were separate.

Nothing is known about the production history of these instruments. The dearth of survivors suggests that comparatively few of them were made, and possibly also that Kraft & Sohn failed to prosper. This may be due to the introduction in Germany of essentially similar indicators by Schaeffer & Budenberg of Buckau bei Magdeburg. The strength of the newly-created German manufacturing base by the late 1870s, after an uncertain start (and a crisis of confidence), rapidly eclipsed Austria-Hungary; consequently, it is possible that Kraft was simply unable to handle the competition.[2]

2. A few Austro-Hungarian industrial businesses prospered. However, excepting Škoda, many were subsequently controlled by German capital. Österreichische Waffenfabriks-Gesellschaft of Steyr, the leading maker of small-arms, became part of a cartel promoted by the backers of Waffenfabrik Mauser.
Schaffer & Budenberg, with branches in Britain and the U.S.A. in addition to Germany, was originally formed in 1850 to exploit a riband-spring pressure gauge patented a year previously by Bernhard Schaeffer. The original partners were Schaeffer himself, Christian Friedrich Budenberg, and Franz Primaveri, a master mechanic. Budenberg proved to be the driving force. Born on 21st
December 1815 in Neuenkirchen, near Osnabrück, the son of an importer of ‘colonial ware’, he had learned his trade in Bielefeld. There he saw the commercial potential that lay in steam engines and was quick to see potential in Schaeffer’s reliable spring-operated pressure gauge to replace the mercury gauges that were then in general use.

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.[3] Work 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. The first affiliated 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 also enlarged at this time.

By 1895, the company, though still making most of the items in Buckau (an administrative district of Magdeburg from 1887), was claiming to support affiliated businesses in Glasgow, Hamburg, Liége, Lille, London, Manchester, Milan, New York, Paris and Zurich-Seebach. Depots were being maintained in Wien (Vienna), Prague, St Petersburg, Stockholm and Berlin.

Schaeffer & Budenberg made a variety of indicators, beginning with the Richards pattern before proceeding to the Thompson. There is no evidence that the Thompson amplifying mechanism had been protected in Germany and so the earliest Schaeffer & Budenberg Thompson was virtually a facsimile of the American Steam Gauge version, with a vertical pillar supporting the front link and the decoratively fretted back link. Indicators of this type were made until the introduction of the improved Rosenkranz-pattern amplifying mechanism (q.v.), apparently in 1893.

Plate 91. A French-language catalogue printed c. 1895 for Schaeffer & Budenberg’s Swiss subsidiary.

*By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.*
Typical of the Schaeffer & Budenberg Thompsons is no. 7049, dating from 1886 or 1887, a standard or large-size instrument with a conventional amplifying mechanism with the lower end of the link between the piston and the trace arm pivoted at the base of a hollow piston rod immediately above the piston-head—in exactly the same manner as the original U.S.-made indicators. The platform is clamped to the body by a split collar and adjusting screw, the cylinder cap is knurled with short vertical lines, and the Staněk-type fairlead is held beneath the platform by a butterfly nut.

The nickel-plated drum, contrasting with the lacquered brass of the body and the platform, has a paper-retainer—held by four small screws placed horizontally—with two parallel-sided fingers of unequal height. The cylinder sleeve screws into the base of the body, with the assistance of an integral collar with four small recesses accepting the head of a special spanner, and the union attaches with the assistance of a large hexagonal nut.

Plate 92. Schaffer & Budenberg Thompson indicator no. 7049, in its fitted wooden case. The upper tray has been removed (see next page). John Walter collection.
Marks on the indicator are confined to SCHAEFFER & BUDENBURG over BUCKAU MAGDEBURG on the outer edge of the platform, with ‘No 7049’ on the edge of the base-plate of the amplifying mechanism. Most Schaeffer & Budenberg Thompsons were marked in this way. Plate 47 shows a pair in the collection of the Dutch Maritime Museum, no. 2810 of c. 1879 marked
'H.D.' ('high pressure') on the body and no. 4786 of c. 1883 marked 'L.D.' (low pressure). Both are marked similarly to no. 7049, with the maker’s mark on the platform and the number on the base-plate of the amplifier.

No. 7049 was owned by Wright & Marvin of High Orchard Engineering Works, Gloucester, a business which was acquired by the Gloucester Railway Carriage & Wagon Co. Ltd c. 1909 and remained independent into the 1950s. It had been imported in Britain before the Merchandise Marks Act was passed to ensure the country of origin was included in the markings. Indicators dating after 1887, therefore, customarily bore the name of Schaeffer & Budenberg Ltd of Broadheath, Manchester, which was deemed to be British in the eyes of the law.

Once numbers had reached about 10000, Schaeffer & Budenberg elected to copy the short-link Rosenkranz amplifier and abandoned the classical Plate 94. Schaeffer & Budenberg Thompson indicator no. 7049 is shown here on top of the removable tray carried in the case. This instrument was used by a Gloucester engineering business from the 1880s until the 1930s, perhaps even into the 1950s. John Walter collection.
Thompson. Indicator no 10752 of 1894 amalgamates the new design with the older pillar-type front standard, though the old fretted back link was replaced by a forward-curving standard, not unlike a diminutive of the old Richards component, carrying the short ‘I’-strut that connected with the tracer bar. No. 11010 of 1894 or 1895, conversely, is of entirely ‘new’ type.

The indicators were supplied in wooden cases, with brass hinges. Standard accessories, apart from the springs and their scale-rulers, included a gas cock, a spanner for the hexagonal nut above the union, a spanner-like tool for the collar retaining the cylinder liner, an oil bottle, and a wiper. However, the case for 7049 has an additional tray in the lid, not unlike the Tabors (which were popular in Britain in the 1880s and 1890s), and it is assumed that changes could be made to order.

**LYNE INDICATOR**

**U.S.A., PATENTED IN 1880**

The origins of this indicator are still in doubt. Surviving examples were undoubtedly made in Germany by Schaeffer & Budenberg of Buckau bei Madgeburg, apparently in the same serial-number series as all other indicators from this source. This, together with the Staněk-type fairlead bracketand
general constructional features, would appear to date them to the mid-1880s. It is assumed that they were made for distribution in the U.S.A., where, on 26th August 1880, Lewis Lyne of Jersey City applied for protection for a ‘Piston-connection for Indicators and Steam Gauges’. This was duly issued as U.S. Patent 235791 on 21st December 1880. Unfortunately, this patent seems to have no relevance to the Lyne indicator, which has a much more conventional piston head than the patent drawings depict. Nor has any trace of protection for the amplifying system been found; it bears a considerable resemblance to the Richardson pattern, which it may have infringed.

Plate 96. The Lyne indicator was made only in small numbers, apparently by Schaeffer & Budenberg under contract from the promoters. Note the distinctive shape of the trace-arm guide plate. Courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
Plate 97. Drawings of the first Dreyer, Rosenkranz & Droop indicator, a modification of the Thompson design. From The Engineer, 15th December 1882.
ROSENKRANZ-THOMPSON INDICATORS
PATENTED IN GERMANY IN 1880
Thompson-type indicators were made in Germany in many differing forms, but, excepting those made by Schaeffer & Budenberg prior to 1893, almost all of them embodying a significant modification of the Thompson linkage patented by Philipp Rosenkranz. Son of Karl Rosenkranz and Laure Gruson, Philipp Hermann Rosenkranz was born on 17th February 1836.[4] He subsequently studied engineering in Berlin and Magdeburg, specialising in the construction of instruments and machinery, before joining Schaeffer & Budenberg of Buckau. Rosenkranz had soon been promoted to Oberingenieur (‘senior engineer’), but became disillusioned and left to participate in a new venue—Dreyer, Rosenkranz & Droop, formed in Hannover in 1870. The engineer among the partners, he was to be responsible for a variety of improvements in the design of pressure gauges and engine indicators.

The principal change to the indicators concerned the ball-tipped strut connecting the piston with the tracer arm. The American Steam Gauge

4. Karl Rosenkranz and Laure Aspasie Adeline Cecile Gruson (1808–73), his cousin, had three children: Otto Henri (1834–68), Philipp Hermann (1836–1925) and Anna Maria (1837–1924). Philipp Rosenkranz married Caroline Stoy (1833–1926) in 1864 and had three children, all of whom may have died young. Laure Gruson had links with the steelmaking business that became Grusonwerke of Magdeburg, and it is probable that the links between Rosenkranz and Schaeffer & Budenberg were also due to family ties.
instruments relied on an elongated strut that pivoted in the hollow piston rod just above the piston itself. Rosenkranz reasoned that this was too delicate and unnecessarily complicated manufacture; his improvement, therefore, used a short strut pivoting in the piston-rod cap. This probably reduced accuracy, owing to the restricted length of any rod which could be inserted between the piston-rod cap and the tracer bar, but exemplary fitting seems to have overcome much (if not all) of this particular restriction.

DREYER, ROSENKRANZ & DROOP TYPE
The basic mechanism was protected by DRP 13663, granted on 8th August 1880 to Dreyer, Rosenkranz & Droop to protect Neuerungen in der Zeichenstiftgeradführung, sowie in der Einrichtung des Papiercylinders bei Indicatoren—'Improvements in the trace-point guide, and in the operation of the paper cylinders of Indicators'.

The first instruments, to be retrospectively known as the ‘Old Model’ (Veraltete Ausführung) once better versions had appeared, could be identified principally by a narrow body which flared outward to fit the hexagonal head of the plug to which the captive union was attached. The platform was forged integrally with the body; a steam port was bored diagonally upward into the spring chamber through the inner angle of the platform/body joint; and the rotating collar carried a serpentine standard supporting the front link. The rear link was a flat plate, with concave sides and semi-circular cuts at the tips, pivoting on a lug formed in the rear of the collar. The piston had a single circumferential cannelure and a hollow face. A small turned wooden handle projected from the base of the standard to allow diagrams to be traced.

The simplest form of this indicator had a two-pulley fairlead with a curved shank, similar that of the Richards, placed between the platform and the drum. A more sophisticated variant, probably dating from 1885 or later, had a one-pulley Staněk patent fairlead pivoting on a linear extension of the platform; it also usually had a detent copied from that of the English Darke indicator, relying on a sliding spring-leaf plate mounted on the body to engage a toothed block pivoting on a short vertical pillar with a rack cut part-way around the lower edge of the drum.

Indicators of this type were offered in two sizes, large and small. The former was designed to give a diagram measuring 130 × 75mm, and could accommodate engine speeds as high as 350 rpm (restricted to 250 rpm if the detent mechanism was fitted); the smaller or high-speed version, giving 90 × 50mm diagrams, was rated for 600 rpm (300 rpm with the detent). In 1893, twenty counter-wound springs were available, all intended to allow use with
condensing engines (which often created a vacuum in the cylinder) and rated from the weak ‘No. 1’ to the stiff ‘No. 20’.

The numbers referred to the pressure needed to compress the spring to the optimal diagram height: 50 or 60mm above the atmospheric line for the large indicator, 30 or 40mm for the small version owing to the differences in the cross-sectional area of the indicator piston. The ‘No. 1’ spring gave a pointer movement of 50mm or 30mm per kg/sq.cm, in the large and small instruments respectively. With the ‘No. 20’ spring, each kg/sq.cm of pressure moved the pointer by 3mm (large) or 2mm (small).

Tables showed that a large indicator fitted with the ‘No. 4’ spring would give a 75mm-high diagram: 60mm deflection above and 15mm beneath the atmospheric line. Small Dreyer, Rosenkranz & Droop indicators similarly fitted would give a 50mm-high diagram—4 × 10mm above the atmospheric line plus 10mm below it. It was left to the skill of the operator to select the appropriate spring for a particular pressure.[5]

Dreyer, Rosenkranz & Droop also supplied a wide variety of indicators tailored to individual demands. Some had steam-jacketed piston cylinders or double ball-jointed piston/piston rod constructions, and others, intended to record high pressures, had the reduced-diameter pistons that included elongated Riedler-patent designs seating in a reduced-bore union plug. Pistons rated at ¼ (quarter-area) were suitable for pressures up to 60 bar, and those at 1/10 (one-tenth area) for 60-150 bar.

Ultimate expressions of this trend were made in 1890 for Bochumer Verein fur Bergbau und Gussstahlfabrikation, apparently to test hydraulic accumulators and high-pressure pumps running at more than twenty strokes a minute. Indicators with 10mm-diameter pistons could handle pressures as high as 500 at; those with the tiny 4mm pistons, however, could extend the range to 800 at. At the other extreme, pistons with diameters as large as 40mm were used in conjunction with light springs to record the performance of blowing engines.

A few Rosenkranz-Thompson indicators were fitted with a variant of the Richardson-patent continuously recording drum, containing a roll of paper and a receiving spool; others had a drum which moved vertically to separate individual diagrams; and at least one type of difference indicator was made, though it was neither as efficient nor as successful as the Prussmann-patent rival offered by Schaeffer & Budenberg.

5. This quirky system of spring classification seems to have been unique. Rival manufacturers in Germany preferred one in which the numerical designation of the spring showed how many millimetres the pointer would move for each kg/sq.cm of pressure. This had become universal by 1914.
Plate 100. Taken from the 1899 Dreyer, Rosenkranz & Droop catalogue, this shows variations of the Rosenkranz-Thompson indicator. Note the straight-arm standards supporting the front tracer-bar link. Archiving Industry collection.
Modifications to the Dreyer, Rosenkranz & Droop Thompson were soon made. The most obvious change to the new-pattern (Neuerer Ausführung) large indicator concerned the standard supporting the front link, which became straight-sided instead of serpentine, but the back link was strengthened and the design of the drum spring was refined.

The piston springs were counter-wound, the paper-holder was retained by four screws in an extended collar, and the trace point was held in an adjustable screw. A second groove was added to the base of the drum to drive another indicator when necessary. The turned wood handle on the collar became the shank of a threaded rod which projected through the base of the standard to impinge on a small pin projecting from the body. The piston seems to have been plain-surfaced, though the face remained hollow.

The small indicator gained a parallel-sided body, the hexagonal head of the plug anchoring the captive union giving way to a plain collar, and the back link became a solid ‘I’ bar. All these instruments were fitted with an angular two-pulley fairlead, held beneath the platform by a butterfly nut, and the projecting parallel-sided handles of the union were bored to receive a
tommy bar. These features may also be found on old-style indicators made during the period of transition from old to new.

The Dreyer, Rosenkranz & Droop indicators of the 1890s were supplied in a box measuring $235 \times 255 \times 110$mm (large size instruments), with a variety of accessories: a spanner for the cylinder cap and the piston springs; a spanner for the cylinder-cap screw, with two small projecting pegs; a short ‘tommy bar’ fitting the hollow arms of the union nut; a steam cock and a $\frac{3}{4}$-inch Whitworth die; a jointed parallel divider or Teillineal; a wooden piston-chamber cleaning rod with the head wrapped in lambs’ wool; a small turn-screw; a container for tracer leads and points; an oil bottle; a spare drum spring; and 25 sheets of recording paper.

By the early 1900s, the Rosenkranz-Thompson indicators, large and small sizes alike, had gained a piston that could be removed simply by turning the cylinder cap through sixty degrees to release a bayonet coupling. The piston had three external cannelures and, in the larger patterns, a rod projecting downward through a seat in the body to prevent lateral movement. The ventilating holes in the body could be exposed simply by rotating a collar beneath the cylinder cap, and the improved Staněk-type fairlead had two small superimposed pulleys.

Plate 102. Schaeffer & Budenberg Rosenkranz-Thompson indicator no. 13372 dates from about 1899. The accessories include a small-diameter bronze piston, suited to higher pressures than the standard pattern, which can be seen clipped into the case-lid. Museum of Making collection.
Plate 103. Accompanied by a spare small-diameter piston, this standard-size Schaeffer & Budenberg Rosenkranz-Thompson indicator, no. 11010, dates from 1894 or 1895. The combination of a nickel-plated cylinder and brass body is commonly encountered on indicators of this type.

Canadian Museum of Making collection.
SCHAEFFER & BUDENBERG TYPE

The 1880 Rosenkranz patent protecting alterations to Thompson’s amplifying mechanism expired in Germany in 1894. Almost immediately, Schaeffer & Budenberg began to make essentially similar indicators, replacing those of conventional Thompson pattern by 1895. The new S&B [Rosenkranz-] Thompson was distinguished by the design of the piston-extension rod, which pivoted in the piston-rod cap instead of inside a hollowed piston-rod shaft. The front link was supported on a serpentine standard (smaller than the Richards type, but clearly based on it), and the ‘I’-type rear link pivoted on a short incurving standard which was also forged integrally with a collar that could be rotated with the assistance of a small handle on the side, the precise position being adjusted by the tip of the handle-shaft bearing on a short pillar screwed into the platform. The design of the linkage was otherwise a straightforward Thompson pattern. The piston, which moved within a liner, was hollowed at the front and had a single cannulure. The cylindrical body flared at the base and had a circumferential rib. The union nut was held by a large hexagon-head nut.

Held to the underside of the platform with a butterfly nut, the Staněk-type fairlead had a single pulley. The two short arms of the union nut were bored to accommodate a tommy-bar. Two spring-steel fingers of unequal height, attached to the drum by four widely-spaced screws through an extended collar, held the paper in place.

The indicators were made in two sizes, *Grosse Ausführung* (‘large type’) and *Kleine Ausführung* (‘small type’) for speeds of up to 400 rpm and 600 rpm respectively. Apart from size, there were very few differences (though the paper-retainer of the small instrument was usually held by only three screws). The standard piston had a diameter of was 20·3mm, though an optional 14·4mm version—which seems to have been popular—allowed the pressure range to be doubled. A 40mm-diameter piston was offered for use with low-pressure blowing engines. The Schaeffer & Budenberg indicators were accompanied by a range of fifteen springs, rated in kg/sq.cm, though those of the smaller instrument gave commensurately smaller movements. Large diagrams measured 130 × 72mm; small, 90 × 45mm.

In 1900, the design was changed. A combination of increased running speeds and greater steam pressures made obtaining a smooth trace on a diagram much more difficult. One way of improving the quality was to increase the pressure-rating of the spring, but this reduced the height of the diagram in the same proportion. The recording mechanism of the Schaeffer & Budenberg indicators amplified the movement of the piston 4:1, the same as...
**Plates 104 and 105.** The 1900-pattern small or 'high speed' Schaeffer & Budenberg Rosenkranz-Thompson indicator. Note the counter-wound spring, and how the bottom of the intermediate link between the piston and the trace bar is anchored to the tip of the piston-rod above the body cap. The line drawing shows a later pattern with an insulated vulcanite cylinder cap and improvements to the piston-chamber liner.
the Richards indicator had done. The ‘Model 1900’ increased this to 6:1, and changes were made internally to facilitate changes of piston-diameter; it was merely necessary to unscrew the lower part of the body, allowing the liner to fall out (it had been held in place only by the body), then detach the piston and its spring. A new piston was attached, an appropriate liner inserted, and the body could be screwed back together. A double-pulley fairlead replaced the single Staněk type, and the paper-retainer was held by three screws. The most obvious feature was the position of the link between the trace bar and the piston-rod, which lay approximately midway between the front and back links on the 4:1 amplifier and noticeably towards the back link in the 6:1 pattern. Model 1900 indicators were sold with a range of thirteen counter-wound springs, rated from 0·5 to 20 kg/sq.cm.

Plate 106. The distinctive design of the links and standards of this ‘Improved Thompson’ indicator shows that, though unmarked, it was the work of Schaeffer & Budenberg. No. 21275 may date from 1913 or 1914: eve of the First World War. Museum of Making collection.
Though the new indicator was successful commercially, instruments with 4× amplification were still being offered for sale when the First World War began. In addition, the increasing sophistication of rival designs persuaded

Plate 107. The position of the link between the piston and the trace-bar shows this Schaeffer & Budenberg Rosenkranz-Thompson, no. 18838 of c. 1909, to be a ‘Model 1900’ with a 6× amplifier. Courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
Schaeffer & Budenberg to improve to their internal-spring designs. Changes included simplying the machining of the body (with the advent of a straight-sided standard on the large indicators) and the addition of a vulcanite-clad independent retaining collar to the body cap. The control handle was still placed on the side. Offered in standard (large) or high-speed (small) patterns, the indicators were often fitted with spring-operated detents, though this reduced the maximum speeds at which they could be run.

The last instruments, introduced in 1920, had pistons hollowed at the head and tail, a steam-jacketed liner, and a body with exhaust ports for blow-by cut

Plate 108. An engraving from Pickworth’s *The Indicator* of a Schaeffer & Budenberg Rosenkrantz-Thompson indicator fitted with Atkinson’s patent vibration suppressor. See Book Three for a description of the Casartelli version.
through the body and a rotating collar attached under the platform. The front standard was duplicated to allow the trace bar to pass between them, giving symmetrical support to the pivot, and the fairlead comprised a single pulley held in a pressed-steel shroud. The paper retainer, with two fingers of unequal height, was held to the drum by three screws at the base. The drums usually had a second cord-guide to allow a remote indicator to be driven simultaneously.

CASARTELLI INDICATOR
BRITAIN, INTRODUCED ABOUT 1882
The Casartelli High Speed Non Conducting Steam Engine Indicator, made in Manchester, was exhibited at the Engineering and Metal Trades Exhibition.
Plate 110. The Casartelli high-speed indicator of the early 1880s. This is currently the only example known to survive. Note the patented clamping lever on the fairlead bracket.
staged in London in 1883, but few survivors are known. Clearly influenced by the Tabor design, it offered a vertically slotted plate to guide the pointer, but had an additional moving pivot.

A review of the exhibition published in *Engineering* on 13th July 1883 suggested that ‘the new indicator presents several interesting and novel features in its construction. The body unscrews midway; the piston is very light, the piston-rod is made of steel tube instead of solid steel wire, and is attached to the piston by a universal joint, and to the pencil bar by the usual gut [sic]… The parallel motion is of the single-bar guide type with several modifications, and is jointed at the piston end to long steel levers. The piston rod is mounted directly onto the bar, but is screwed and unscrewed the same as in the ordinary Richards instrument. Between the paper cylinder and the body of the indicator there is inserted a piece of ebony to prevent the heat from the body passing to the stage.’

The total weight of the working parts was claimed to be less than one ounce, which explains why indicators of this type are rarely seen; they may well have been too lightly built to withstand hard use. The indicator may also have been deemed to have been an infringement of the Darke patent of 1879.

**Plate 111.** The Casartelli high-speed indicator in its box. Among the accessories were a steam cock and a reamer, both now lost. *Museum of Making* collection.

**Plate 112, facing page.** Drawings from the Bachelder patent of 1887, showing the original design of the indicator. There is no evidence that anything other than a prototype was made in this form. *Courtesy of the US Government Patent Office, Washington DC.*
Virtually all of the indicators promoted successfully prior to 1880 incorporated coil springs, though the individual designs (and the way in which they were supported in the steam cylinder) varied considerably. Some observers felt that there was room for other approaches. It was usually conceded that flat or ‘riband’ springs were much easier to make, and riband-spring indicators developed by the Frenchman Arthur Morin (made by Bourdon or Saulnier) had appeared as early as 1850. They were successful enough to be used for experiments, but were much too unwieldy to achieve wider distribution.

The Bachelder indicator was the first of its type to be commercially successful. The original form was protected by U.S. Patent 360644, ‘Steam-
engine attachment’, granted on 5th April 1887 to ‘Joseph H.C. Bachelder, of Meriden, Connecticut’. An application—no. 219579—had been filed on 23rd November 1886. Originally patented in 1887. It incorporated a sturdy riband spring placed horizontally beneath the drum, seeking to avoid changing springs to suit differing engine characteristics and exploiting the ease with which the effective length of the spring could be changed to provide an ‘adjustable’ indicator. The prototype, shown in the patent drawings, had an imprecisely drawn amplifying mechanism. The principal claims to novelty centred on the adjustable bar-spring and not on the amplifying mechanism.

When production began in the early 1890s, however, the indicators were made in accordance with U.S. Patent 467431, issued on 19th January 1892 to Frank Pierpont of Hartford, Connecticut, but sought a year earlier. A simple tracer bar, equipped with a roller, slid in a vertically-slotted plate alongside the recording drum. In combination with a piston-rod extension link and a curved rear link, this slot allowed the tracer to rise vertically. Large numbers of the guide-slot Bachelder were made; several survive, and most of the advertising material published prior to 1900 includes engravings of the guide-slot system.

But it is assumed that the amplifying system was too weak; after perhaps five hundred had been completed, it was replaced by a conventional Thompson-type linkage and work continued into the early 1900s. It is assumed that the slot, which could promote excessive friction if not kept clean, was also too close to the drum to avoid accidental damage.

Bachelder instruments were made firstly by Thompson & Bushnell and then by a successor, John S. Bushnell & Company of 123 Liberty Street, New York City.[6] Though the indicators are now rarely seen, production was considerable. Serial numbers suggest that at least three thousand were made, though not where the change from guide-slot to Thompson amplifiers occurred—except that this happened before five hundred indicators had been completed. Bushnell indicators are typically marked JOHN S. BUSHNELL, NEW YORK OVER PAT. APR. 5. 1887, JAN. 19. 1892 around the base of the cylindrical portion of the body. The reducer bracket is usually marked JOHN S. BUSHNELL in a curving line above NEW YORK.

6. Cassier’s Magazine of August 1894 gives the address of Thompson & Bushnell as 110 Liberty Street. The partnership split in the early 1900s: a January 1905 catalogue gives the trading address of John S. Bushnell & Company (a partnership of John Bushnell and Amos Joslin) as 123 Liberty Street, New York City, and indicators made by Richard Thompson & Company sometimes include recording-card blanks marked ’126 Liberty Street’. Bushnell continued to make Bachelder indicators for a few years, but Richard Thompson preferred a conventional ‘Improved Thompson’ instrument. Production of both types seems to have ceased by 1917.
Plate 114. The simplified Bachelder indicator had a fixed riband spring, lacking the adjustability of its predecessor. This allowed the price to be reduced, but there is no evidence to suggest that large quantities were ever sold.

By courtesy of Bruce E. Babcock, Amanda, Ohio, U.S.A.
Bushnell also offered the “Improved Bachelder Indicator With Steam Jacketed, Air Jacketed Cylinder”. Intended for use with ‘high pressure or superheated steam, gas and ammonia, this particular design was patented on 23rd August 1904 by Albert L. Williams of Brooklyn. A leaflet published by Bushnell in January 1905 explained the construction: ‘…both ends of the [piston-]cylinder are faced true with the flanges of the upper and lower sections of the case, so that when the sections are screwed together an air tight joint is made at both the top and bottom of the cylinder. These sections of the case are held from unscrewing by a set screw. The cylinder can be removed by turning the set screw back one turn… The springs for this Indicator are scaled the same as for our regular instrument…, but their range can be doubled or quadrupled by…cylinders and pistons of lesser areas.

“In producing the Bushnell piston and cylinder [as] described..., we have overcome all these objections [to the unequal expansion of cylinder and piston, with consequent increase in friction or jamming] by first producing a properly constructed steam jacketed cylinder and surrounding this steam jacket with an air tight jacket, the outer jacket, or air jacket, being a good non-conductor of heat, radiation is checked and we are enabled to keep the temperature uniform and consequently the expansion of our piston and cylinder are just alike.

“Therefore this Indicator is equally well adapted for high pressure or super-heated steam, as for medium or low pressure, the piston in all cases being a good fit so that undue leakage is obviated…”

A simplified version of the Bachelder, the ‘Outside Spring Indicator’, had a single exchangeable but non-adjustable spring held in a channel under the slender angular body. The fairlead was held under the platform, beneath the drum, by a butterfly nut.

Bachelder indicators were often accompanied by lightweight aluminium ‘Ideal’ reducing wheels, with up to seven exchangeable bushes, and also often by the ‘Bushnell Cord Take-Up’, the subject of a patent granted on 10th November 1903 to Levi Snow of New Haven, Connecticut (‘Assignor to John S. Bushnell Co., Incorporated, of New York, N.Y.’). This protected an ‘L’-shape cord guide and a small spiral spring wound around the transverse pivot to maintain slight pressure on the base of the cord-guide arm. The ‘Bushnell Improved Coffin Planimeter’ or an Amsler-type planimeter were also sometimes contained in the well-fitted wooden case.
Plate 115, next page. Drawings of the McInnes indicator, from the 1887 British patent. The production version differed from these drawings only in comparatively minor details.

**McINNES INDICATOR**

**BRITAIN, PATENTED IN 1887**

On November 1887, Thomas Struthers McInnes (or M’Innes) of ‘8 Buchanan Street, Glasgow, in the County of Lanarkshire, Watchmaker’ had been granted British Patent 16258/87 to protect the most influential of the pre-1900 British designs.

Thomas McInnes had been born in Glasgow on 2nd October 1857, son of watchmaker William McInnes (who, according to the 1861 Scottish census, was employing ‘One Boy’). The younger McInnes was originally destined to become a teacher, but was already following his father’s calling by 1881, when he was 24. McInnes was lodging in Pollock Street, Glasgow, at this time, employing ‘four men and two girls’ in what had clearly become a successful watch- and instrument-making business.

McInnes eschewed the minimalist approach taken by Tabor in the U.S.A. and Darke in England; accepting that his indicator would inevitably contain more parts than some of his better-established rivals, he simply sought to reduce friction whilst simultaneously improving the response of the pointer linkage to the changes in pressure. The greatest claim to novelty, however, lay in the adoption of vulcanite sheathing to protect the operator’s hand from heat absorbed by the piston cylinder body.[7]

It has been claimed that the earliest instruments were made McInnes & Cairns (allegedly in Edinburgh), but evidence is lacking: no trace of a partnership of the name has been found in Scottish archives either in Glasgow or in Edinburgh. By 1889, however, McInnes was trading as ‘T.S. McInnes & Company’ from 56 Waterloo Street, Glasgow.

McInnes indicators had sufficient merit to be used by Professor Kennedy in marine engine trials sponsored by the Institution of Mechanical Engineers in 1889–90. The British periodical *Engineering* of 2nd August 1889 remarked in a brief review that one instrument had been tried with steam engines running at 75 rpm and 110 rpm, and found to be ‘very convenient to handle,

7. Vulcanite, sometimes known by the later trade-name ‘Ebonite’, was created by heating raw rubber with sulphur until the resulting compound hardened. The use of insulation on indicators was not new; some McNaught indicators made during the middle of the nineteenth century had a layer of lagging between the body and a thin outer shell, and the Casartelli High Speed indicator shown at the Engineering and Metal Trades Exhibition in 1883 had an ebony plate clamped between the body and the drum platform. McInnes seems to have been the first to fit enveloping shrouds of synthetic material.
and the diagrams leave nothing to be desired in the matter of distinctness, even when taken with a comparatively light spring... The indicator with its various appurtenances is put up in a neat and convenient case, and should go far to supply the demand for a cheap and reliable instrument.

**Plate 116.** This McInnes indicator, no. 337, was probably made about 1890. Though based on the Thompson amplifying mechanism, the curved standard for the front link, the position of the tracer bar, and the rearward overhang of the collar extension are most distinctive. This particular indicator has a plain vulcanite body sleeve, but the sleeve on the union nut has an integrally moulded monogram. *Canadian Museum of Making collection.*
Plate 117. McInnes indicator no. 337 in its mahogany box, accompanied by four springs and most of the original accessories. This particular instrument has been overhauled at least once, as the box lid displays a Dobbie McInnes label. Museum of Making collection. Plate 118 shows a typical advertisement from the first (1898) volume of Pickworth’s book on the steam-engine indicator. John Walter collection.
These first-pattern McInnes indicators were still being sold commercially in 1900. Unfortunately, McInnes had died of tuberculosis in January 1893—aged only 35—and it is difficult to determine how many instruments had been sold. Yet the inventory accompanying Thomas Struthers McInnes’s will, registered with the Glasgow Sherriff Court in September 1895, makes fascinating reading. His indicator had clearly attracted the attention of the leading Clydeside shipbuilders, as among the creditors were Denny & Co. of Dumbarton, Blackwood & Gordon of Port Glasgow, Ramage & Ferguson of Leith, Fleming & Ferguson of Paisley, and William Simons & Co. of

Plate 119. McInnes indicator no. 3336, showing details of the amplifying gear and the single-pulley fairlead. Note also the fluted cylinder cap; earlier examples are usually chequered.
Renfrew. It can be assumed that each of these businesses had purchased McInnes indicators to be part of the fixtures and fittings of each new ship. Debtors under an ‘England’ heading included J.S. Whyte [sic] of West Cowes, the London & North Western Railway Company of Holyhead (the marine engineering department), R. Stephenson & Co. of Newcastle upon Tyne, the Brush Electrical Company of London, Laird Brothers of Birkenhead, and Readhead & Co. of South Shields. And ‘Gio. Ansaldo & Co.’ were listed under a heading ‘Abroad’, showing an appreciation of the export trade. The list of creditors refers to suppliers of material, including the Anglo-American Varnish Co. and Thomas Piggott & Co. of Birmingham, but is not detailed enough to allow a realistic assessment of McInnes’ output. However, the inventory also shows that offers of £320 for the ‘Plant, Tools, Furniture & Fittings’, £336.10.0d for ‘Stock of Materials and work finished and in Progress including goods on approbation, and £170 for ‘Patents and Goodwill’ had been made on 15th February 1893 by ‘J.C. Dobbie Chronometer Maker, Glasgow’. These had all been accepted by the executors of the McInnes will. Dobbie had been making clocks and watches in premises virtually adjoining McInnes’ premises in Clyde Place. A limited liability company was formed shortly afterward, manufacturing facilities moving from Waterloo Street to Clyde Place at about the same time.

**Plate 120.** McInnes indicator no. 3336, probably dating from the 1890s, has the rarely-seen pivoted paper-retaining bar. *Canadian Museum of Making collection.*
HALL-BROWN INDICATOR
BRITAIN, PATENTED IN 1889

The indicator designed and patented by Ebenezer Hall-Brown of ‘15 Moor Terrace, Hartlepool, in the County of Durham, England’, was among the most interesting of those that were made in Britain towards the end of the nineteenth century. Brown was born on 9th April 1862 in Greenock, in Scotland, the son of a master-mason of the same name. Apprenticed in his youth to the Fairfield Ship Building & Engineering Company, he was not only claiming to be a ‘Marine Engineer’ by the time of his marriage in 1886 but also affecting the surname ‘Hall-Brown’.[8]

Hall-Brown and his wife had soon moved from Glasgow to Hartlepool, County Durham. The 1891 English census reveals that he had taken the post of Assistant Works Manager of the Central Marine Engineering Works, owned by William Gray & Company, and also that the works manager, Thomas Mudd, lived next door. The ‘Central Works’ was among the most important manufacturers of marine engines in 1880–1914, and would have allowed Hall-Brown to observe the use of the autographic indicator in detail.

An application for what was to become British Patent 15924/89 was made on 10th October 1889; the complete specification was submitted on 9th July 1890, and the claims were accepted on 4th October 1889. However, the precise genesis of the design—and in particular, its commercial exploitation—is still something of a mystery.

The drawings accompanying the patent suggest an initial enthusiasm for the Crosby system, with the linkage modified to become a true pantograph, but there is no evidence that many instruments of the type were made. Yet the 1891 census also notes that Hall-Brown was a ‘Manufacturer of Steam Engine Indicators’, and lists him as both ‘employer’ and ‘employee’. The implication may be that he was operating a separate business of his own.

The 1889 patent concentrates on variants of a pantograph-type amplifier, though the Provisional Specification noted that the ‘improved indicator for fluid pressure engines consists of:— A cylinder with a piston and spring of a form similar to that ordinarily used in a “Richard’s” indicator or of other suitable form’. The indicator that entered production in the 1890s, however, adopted a Thompson-type mechanism. Novelty lay instead in the detachable pointer mechanism, cylinder cap and piston/spring assembly, which could

8. Changing surnames in this way was not unusual in pre-1914 Britain, particularly if the original name was regarded as commonplace or lacking distinction. The preferred methods included incorporating the maiden surname of a wife or a mother (though in Hall-Brown’s case, these would have been McClenaghan [sic] and Grieve), or another family name to signify an inheritance.
Plates 121 and 122. An exceptionally clean, but completely unmarked Hall-Brown ‘Type A’ indicator in its fitted manogany case. It has been speculated that the instruments were actually made by Hannan & Buchanan of Glasgow. Canadian Museum of Making collection.
be removed simply by aligning the bayonet joint with a supplementary locking collar running around the cylinder body. The spring in this design is exceptionally easy to change, but the Hall Brown system does not seem to have survived into the twentieth century; in the absence of an interlock, the readily detachable cylinder cap could have contributed to accidents if the engineer forgot to rotate the collar back to its locked position before opening the steam cock.

Hall-Brown indicators were apparently made in quantity: only four have been examined, one being marked TYPE A NO. 296 and another TYPE A NO. 1295, but it is not known if the numbering began at ‘1’ or ‘100’. No ‘Type B’ examples have yet been found, though it is possible (cf., Elliott-Simplex) that this was intended to be a small or ‘half-size’ variant. The workmanship is very good, and the boxes of the four Type A indicators reported to date are identical in size, fittings and internal divisions. Regrettably, none of the instruments bears a maker’s mark. They may even have been made in a single run in the early 1890s, and then sold, slowly, over the ensuing decade.

Two types of diagram card accompany the Hall-Brown indicators—one suggesting land use in the 1890s; the other, maritime use after 1900. But only the latter bears the ‘Hall-Brown & Buttery’ company name and neither the cards nor the box-labels give any other indication of age. Hall-Brown returned to Scotland in 1892 to become a partner in Hall-Brown, Buttery & Co., and the 1901 Scottish census places the family in Hyndland Road, Glasgow. There he is listed as a ‘Mechanical Engineer’, but as a ‘worker’ instead of an ‘employer’. Glasgow trade registers also show that Hall-Brown, Buttery & Company registered in 1893 and that the principal premises were ‘Helen Street Engine Works, Helen Street, Govan’. An advertisement placed in The Engineer in 1894 also reveals an intention to make high-speed steam engines to drive generating equipment.

It has been suggested that this highlights the earliest date on which the indicators could have been made, but it is now suspected that the work was sub-contracted to instrument-makers: perhaps Hannan & Buchanan, who made Thompson-type instruments in the early 1900s on their own account.

At the end of 1901, Hall-Brown, Buttery & Company, ‘Marine, Electrical and General Engineers’, were succeeded by A. Rodger & Co. On 20th February 1913, however, The Edinburgh Gazette published a ‘Notice of Dissolution’ confirming that Rodger & Co., ‘Ship-builders & Engineers, Port-Glasgow and Govan’, had been dissolved on 31st December 1911 by mutual consent of the partners. The notice also named the partners as James Hutchison, Anderson Rodger and Ebenezer Hall-Brown. Hall-Brown served a term as
President of the Institute of Shipbuilders and Engineers of Scotland (1911–12), but returned to England in 1912 to become general manager of Richardsons, Westgarth & Co. A long-term member of the shipbuilders’ organisations in the north-east of England, he died on 13th May 1920.

Circumstantial evidence suggests that substantial numbers of ‘Type A’ Hall-Brown indicators were acquired by the British government. Three of the examples that could be traced for examination had the ‘V [crown] R’ marks that denoted government purchase stamped into the box-lock casing. It is possible that this was due to the impressment of more than a hundred steamships to carry thousands of British soldiers to southern Africa during the South African (‘Boer’) War of 1899–1902, which could have caused an unexpectedly sudden need for indicators.

**CLARK (ARC AND STRAIGHT LINE) INDICATORS**

**U.S.A, FIRST PATENTED IN 1890**

On 17th June 1890, Frank Clark of Tilton, New Hampshire, was issued U.S. Patent 430467 to protect a ‘Pressure-Indicator for Steam-Engines’. Clark had assigned his patent (which had been sought in November 1889) to the Mechanical Specialties Company of Boston, Massachusetts, and the ‘Arc’ indicator was subsequently made in small numbers.

The patent reveals that Clark was seeking to provide ‘a simpler, cheaper, and more effective device than is now in ordinary use’. The drawings show a comparatively simple instrument, with the steam cock formed as part of the piston cylinder and a straight platform retained by a threaded sleeve. The recording mechanism, mounted on a collar provided with a handle at the rear, could be rotated against a curving-tip pillar held by a screw to the drum platform. The tip of the piston rod pushed upward through the domed cap to bear against a shoulder on a recording lever. An adjustable-pressure torsion spring ran laterally onto the forked spigot, doubling as the recording-lever pivot, that projected through a vertical standard fixed into the collar-handle shank. This spring resisted the rotation of the arm as it was lifted by the piston-rod tip, keeping the parts in continuous contact. The Clark indicator also had a cranked fairlead bracket, which could be inverted to allow the cord access to the drum from above or below the fairlead pulley, and a curiously forked drum spring with ends bent in opposite directions.

The Arc was made in quantity, the highest number reported to date being 229, but was doomed to failure. Virtually all rival designs offered trace points that moved in a straight vertical line, and anything that moved radially was unacceptable. Clark redesigned the Arc, seeking protection for the changes in
F. M. CLARK.

PRESSURE INDICATOR FOR STEAM ENGINES.

No. 430,467. Patented June 17, 1890.

The text and diagrams describe a pressure indicator for steam engines, with detailed specifications and illustrations.
January 1895, and U.S. Patent 535485 was duly issued on 12th March. One-half of the interest was assigned to William Holmes of Boston, who was probably involved in the Mechanical Specialties Company.

Christened ‘Straight Line’ to draw attention to the greatly improved tracing mechanism, the new instrument may have been made under sub-contract by Hine & Robertson of New York City. The steam cock reverted to a separate component; the platform was cranked upward between the piston cylinder and the drum; the quirky drum spring was replaced by a conventional coil; and the original amplifying mechanism was modified. Though the patent

Plate 123, previous page. Drawings from Frank Clark’s 1890 U.S. Patent, protecting the design of the ‘Arc’ indicator. The radial movement of the tracer was to be its commercial downfall. By courtesy of the U.S. Government Patent Office, Washington DC.

Plate 124. The ‘Straight Line’ indicator, though better made than the Arc, was still small and very delicate. This example is no. 512. Canadian Museum of Making collection.
shows a system of rocking cams, the production version relied on a standard which curved forward above the piston-rod, with a restraining roller to ride over a bolster or camming-block on the right side of the tracer arm. This arm was connected in turn to the two links—one rigidly attached to the piston rod and another pivoted on the base of the standard—that kept the pointer moving in a straight line.

The few Straight Line indicators that could be traced for examination all showed signs of being sold by Hine & Robertson, dating them prior to 1897. No. 512, in a velvet-lined box, was accompanied not only by reducing gear patented in 1894 by Edward Rea but also by a special Lippincott planimeter which could be anchored in a channel-plate in the box lid. Markings included
THE STRAIGHT LINE INDICATOR arched above a decorative line, PATENTED JUNE 17, 1890, another line, and then MECHANICAL SPECIALTIES MFG CO. forming the lower part of an approximately circular motif on the piston cylinder. The serial number lies at the front of the platform, immediately before the upward crank begins.

CALKINS INDICATOR
U.S.A., PATENTED IN 1890
The indicator designed by Almon B. Calkins of Bridgeport, Connecticut, protected by U.S. Patent 442102 of 9th December 1890, was made only in small numbers. Calkins was also responsible for the distinctive fairlead-pulley assembly fitted to the Tabor indicators (see Chapter Three), patented in 1885, but was an opinionated engineer who made every effort to disparage rival designs. His self-promotional A Treatise on the Calkins Steam-Engine Indicator..., published in New York in 1891, contains details not only of the indicator but also a planimeter. Unsurprisingly, the patent is complicated, verbose, and makes no fewer than twenty claims to novelty. Yet the amplifying mechanism is little but an adaptation of the ellipsoid method patented fifteen years previously by Joseph Thompson, the most obvious alteration being the addition of a short curved closed-path guide to the tip of the piston-rod extension.

Calkins duly noted that: ‘...Among the objects is the improvement of the parallel movement, perfecting thereby the ratio of movement of the pencil to the piston; also, to improve the indicator in many other respects that will add greatly to its efficiency as well as to simplify and cheapen its construction.

“To this end my invention consists; first, in mounting rigidly or forming at the upper end of the indicator piston-rod a compensating curved surface or guide to engage with the pencil-carrying bar of the parallel movement, such curved surface or guide projecting laterally from the piston-rod and in the direction or path described by the forward and backward movement of the pencil-carrying bar, and, second, a spring to preserve the contact or engagement of such pencil-carrying bar with the curved surface or guide of the piston-rod.

“My invention further consists in providing the hub of the swivel-plate, which plate supports the levers of the parallel movement, with a hub or projection, which hub operates in a recess of the cylinder-cap and is held in place by means of a flanged projection on the piston-rod guide-sleeve; also, to provide a nipple in the outer casing or shell of the cylinder and above the piston, to which a hose or pipe may be attached to provide an outlet for the
steam escaping by the piston; further, to provide means whereby the piston may be lubricated from the exterior of the cylinder-casing, such means preferably consisting of an oil-hole through such casing and a cover for such hole to exclude the dust; further, to provide the paper-carrying drum with a long sleeve mounted on the drum-stud, such sleeve being rigidly attached to

Plate 127. Calkins indicator no. 152. Despite the complexity of the fittings, it is little more than yet another modification of the popular Thompson. By courtesy of Bruce Babcock, Amanda, Ohio, U.S.A.
the top of such drum, a web rigidly attached to the lower end of such sleeve to assist in strengthening such drum in its position on the carriage; further, to regulate the tension of the drum-carriage spring by means of a ratchet-wheel rigidly attached to the drum-stud, a horizontally-placed disk attached to a sleeve of the drum-carriage spring, a pawl mounted on such disk to engage with the ratchet wheel, the carriage-spring arranged to be reversed that the instrument may be used either right or left handed, and, further, to provide the drum-carriage with a stop-pin whose head projects below such carriage and engages a stop adjacent to said carriage, and by means of which stop the maximum travel of the carriage is limited.

“My invention further consists in providing the paper-carrying drum with a compensating balance or weight, which balance or weight is placed eccentrically with the axis of such drum, such balance arranged to be shifted in any position about such axis, thus balancing such drum in its reciprocating movement, and thereby causing it at the instant or commencement of its reverse action to be identical or in time with the reverse action of the piston

Plate 128. A detail view of the amplifying mechanism of Calkins indicator no. 152, which combined a Thompson linkage with a tension spring and elements of the original Tabor (the curved guide-slot). By courtesy of Bruce Babcock, Amanda, Ohio, U.S.A.
of a steam-engine, to which engine the indicator is connected; further, to hold the drum-carriage and its paper-carrying drum in any position required by means of a stop-pin actuated by a spring, said pin and spring located, preferably, in the frame of the indicator, the projecting end of such pin engaging with the drum-carriage, and, further, in attaching a support to the paper-carrying drum in such a manner that sufficient space is left between such support and drum to receive the tongue of the paper-spring, which spring by means of said tongue is attached directly to the support instead of the drum, as heretofore constructed…

According to The Manufacturer and Builder, vol. 23 no. 7 of July 1891, Calkins indicators were made by the Brown & Sharpe Mfg Co. of Providence, Rhode Island, for the Engineers’ Instrument Company of 54 Warren Street, New York City (though the earliest instruments may have been made by the Neptune Meter Company). Production does not seem to have been substantial, and the indicators are uncommon today; no number higher than 152 has been reliably reported. The planimeters, which are even rarer, were the work of the American Watch Company of Waltham, Massachusetts.
Statistically among the most successful of the U.S.-made enclosed-spring designs, the engine indicators made by Hine & Robertson and then (from 1st January 1897) by J.L. Robertson & Sons of New York followed the improved or Rosenkranz-Thompson layout with the intermediate link anchored above the cap instead of in the base of a hollowed piston rod.

They had narrow platforms, parallel for much of the length but enlarged at the tips to accommodate the body and the drum. The body was comparatively plain, with vertical fluting on the cap and at the base directly above the union nut. The fairlead, held by a large knurled-head nut, supported a spherical boss in which a symmetrical two-pulley bracket was inserted.

The amplifying mechanism (which was claimed to be ‘the lightest moving parts of any on the market’) included a doubled rear link, pivoting in the slender rearward projection of the body collar, and a pillar-like standard at the front. The stop screw bore against a skittle-like peg projecting upward from the platform. Held by a small knurled wheel beneath the platform, the peg could be removed when required, allowing the instrument to change from right-hand to left-hand (and back again) in a few seconds.

The face of the piston was hollowed; the piston spring had a flanged collar at the top and a plain threaded boss at the base; and the tension of the helical drum spring was adjustable to counter the effects of wear. Two spring-steel

Plate 130. ‘Improved’ Robertson-Thompson indicator no. 7009, dating from c. 1907, is accompanied by an ‘Improved Victor’ reducing wheel no. 4465. Note the exchangeable wooden bushes on the post in the box interior. *Museum of Making collection.*
Plate 131. This advertising leaflet was published prior to 31st December 1896 by Hine & Robertson, to promote the Robertson-Thompson indicator and the ‘Victor’ reducing wheel. Courtesy of Bruce Babcock, Amanda, Ohio, U.S.A.
paper fingers were held to the surface of the drum by two short screws. The Robertson-Thompson indicator was made in quantity from c. 1896 into the first decade of the twentieth century. After perhaps two thousand had been made—too few have been reported to be precise—the original design gave way to the ‘Improved Robertson-Thompson’ (apparently also known as the ‘Improved Perfection’), with a rotatable blow-by vent beneath the platform, a double ring of knurling around the base of the body, and a fairlead retainer in the form of a large hexagonal-headed nut. Most will also be found with a sprung detent attached horizontally to the platform to engage a rack cut in the periphery of the drum base.

Indicator no. 7009, pictured here, is numbered on the edge of the platform as it fairs into the body. The body itself displays IMPROVED “ROBERTSON-THOMPSON” in two lines above MAN’F’D BY, bracketed by two open-‘v’-ended decorative lines, JAMES L. ROBERTSON & SONS and NEW YORK CITY. U.S.A. Among the most popular accessories were a ¼-inch piston/liner unit, and the ‘Victor’ reducing wheel (see Book Five) that could replace the fairlead.

Production of standard and improved Robertson-Thompson indicators exceeded eight thousand (the highest numbers reported to date are 8189 and 8308), together with more than six thousand Victor and Improved Victor reducing wheels (highest numbers: 6127, 6135). Though the wheels were popular accessories, included with perhaps half the indicators, it is clear from the totals that many were sold for use with indicators of other types. An association with a Crosby, for example, is not necessarily a mis-match.

A pneumatic actuator could be obtained to allow two or more indicators to be used simultaneously (patented on 14th May 1895); and a ‘Take-Up Device’, patented in the U.S.A. on 25th June 1901, promised to overcome ‘great trouble experienced when using the Detent on the Steam Engine Indicator…caused by the slack cord given up between paper drum and the reducing bushing’. The Standard, Lippincott or Improved Willis planimeters are also often associated with Hine & Robertson and Robertson indicators.

After experimenting with a variety of designs, including one with a special spring-loaded fairlead to take up unwanted slack in the cord, and a system or rings or a handguard around the body to act as an insulator (U.S. Patent 677275 granted on 25th June 1901 to James L. Robertson Jr.), Robertson introduced the ‘New Century’ in a bid to compete with newer, cheaper indicators. Though generally similar to the original version, the new instrument had a simplified amplifying mechanism with a single ‘T’-tip back link. The supplementary piston and the detachable stop-peg were abandoned, and the shape of the platform was altered. The cap and the ring above the
Plate 132. McInnes-Dobbie indicator no. D-480 (the oldest of its type yet found, bearing the marks of T.S. McInnes & Co. Ltd) probably dates from 1901. Nickel plating on the principal components marks this instrument as ‘First Quality’. The decorative shield let into the vulcanite sheath was soon abandoned. Canadian Museum of Making collection.
Plate 133. This McInnes-Dobbie internal-spring indicator, D A-12487, was probably made in 1913. The lacquered brasswork identifies it as ‘Second Quality’, selling for appreciably less than the nickel-plated version. Canadian Museum of Making collection.
union nut were knurled, and a central band, with rope-work edging, was added to display NEW CENTURY above M’FD BY/JAS. L. ROBERTSON & SONS/ N.Y. CITY. U.S.A. in three lines. Production is judged to have been small, and possibly also short-lived.

**McInnes-Dobbie Indicator**

**Britain, Patented in 1898**

On 14th May 1898, John Dobbie of ‘45, Clyde Place, in the City of Glasgow, Nautical Instrument Maker’, obtained British Patent 11026/98 to protect an improvement of the 1887 McInnes indicator. The principal claim to novelty was a readily detachable spring exposed between the underside of the platform and a threaded cap on top of the piston chamber, but among the other refinements was an alteration to the amplifying mechanism that allowed the tracer bar to operate on the centreline. The tracer bar of the McInnes and most other Thompson-type indicators introduced prior to
1900 passed vertically outside the front link, which required the latter to be cranked and the support to be asymmetrical. The new tracer-bar system was immediately applied to the basic McInnes indicator, producing the inside-spring ‘McInnes-Dobbie’ pattern and work continued. Simultaneously, a new exposed-spring Dobbie indicator entered production.

McInnes-Dobbie internal-spring indicators were made of nickel-plated brass in two types: ‘Pattern A’, with spring-steel fingers on the paper drum, and ‘Pattern B’ with independently hinged clips. Pattern A was made in three sizes, ‘Large’ (for speeds up to 250 rpm), ‘Small’ (800 rpm) and ‘Half’ (1500 rpm), but Pattern B came only in ‘Large’ and ‘Small’. Pattern A was additionally offered in ‘Second Quality’, with a lacquered polished-brass finish to keep cost to a minimum. An all-steel variant of Pattern A was sold for use with refrigeration equipment filled with ammonia, which rapidly corroded brass. The diameter of the Pattern A and Pattern B drum was usually $\frac{151}{64}$ inches
(45.6mm), but larger two-inch (Richards type) drums were “very extensively specified for ships’ use” and also often used by inspectors employed by boiler-insurance companies. However, these large drums are uncommonly found and it is concluded that the demand was not as high as Dobbie McInnes had claimed. Perfected McInnes Dobbie internal-spring indicators were still being sold in the 1920s, but were eventually superseded by the efficient outside-spring types that had been based on patents dating from 1898–9.

**LIPPINCOTT INDICATOR**

U.S.A., PATENTED IN 1900

The ‘Indicating Instrument’ designed by Alpheus C. Lippincott of Newark, New Jersey, protected by U.S. Patent 648506 of 1st May 1900, embodied a Thompson-type amplifying mechanism with a ‘T’-type back link and an offset rod-like post.

Among the many claims to novelty were a piston with a small-diameter tail rod which passed through a collar at the base of the steam chamber to give additional support; a piston head that was allowed to move laterally in relation to the piston rod; a tube, locked by a small finger wheel, that could be rotated to divert exhaust away from the operator; a compressible copper seal between the steam chamber and its jacket, allowing for differential expansion; a fairlead that automatically wound itself up with the engine motion to prevent overlaying the cord; and a winder for the drum spring, complete with pawl-and-ratchet stop.

These indicators were most probably made for the Lippincott Steam & Specialty & Supply Company ‘of Green & Columbia Streets, Newark, New Jersey’ by J.L. Robertson & Sons; and, therefore, resemble the Robertson-Thompsons externally though the mark PATENT MAY 1, 1900 (stamped on the body) provides a ready distinction. Production was considerable: serial numbers into the 3000s have been reported, and it is assumed that work continued until at least 1910. The indicators were often accompanied by reducing wheels.

**STAR INDICATOR**

U.S.A., PATENTED IN 1901

Made by the Star Brass Mfg. Co. of Boston, Massachusetts, this indicator was protected by U.S. Patent no. 687391 granted on 26th November 1901 to Charles B. Bosworth. Star claimed its introduction to have been due to ‘the indicator business… growing rapidly, and the manufacturers [having been] frequently called upon to furnish instruments of other makes of steam specialities which
they have heretofore manufactured. The new design was not intended as ‘a radical departure from existing indicators, but one that should be designed and constructed on lines that had been so well proved by long experience as to meet the requirements of those desiring a high degree of efficiency and reliability.’

The instrument was a conventional improved Thompson internal-spring design, with the intermediate link anchored in a swivel link protruding from the cap. Its claims to novelty were largely internal. The drum had a spiral spring instead of the helical pattern favoured by other manufacturers in North America, and the piston was contained in a liner that was not only vented to allow blow-by to escape but also steam jacketed to prevent unwanted expansion of its walls.

A well-designed piston was vital in any indicator, not only to minimise friction but also to avoid binding or asymmetric movement. In *The Star Improved Engine Indicator*, George Barrus described how the piston “consists of a thin cylindrical shell, open at the top and bottom, with a transverse web across the center. It is made of tool steel, hardened, ground, and lapped. At the center of the web is an opening which receives the hub of the piston. The hub is made of soft steel, and it is fastened securely to the web by a staking-tool. The hub has a threaded central opening running from end to end. To the top the piston-rod is screwed, and to the bottom, an adjusting-screw.

“The upper part of the hub is slotted so as to provide an opening for the introduction of the lower part of the spring. The slot is of slightly greater width than the diameter of the wire, so as to leave a certain amount of freedom of motion in a lateral direction. As the two parts into which the slot divides the hub have no connection at the top, they would easily be spread apart by the thread of the piston rod and thereby become insecure, were it not for the arrangement of the upper end, whereby a collar which forms a part of the piston-rod slips over the upper end when the rod is screwed into place… The lower end of the piston-rod and the upper end of the adjusting-screw are made concave so as to receive the ball on the lower end of the spring…

“The piston-rod being screwed down so that the collar bears solidly upon the top of the piston hub, and the adjusting-screw below being set so as to lightly touch the ball,…the piston and rod are free to rotate a slight amount on the axis, and still have no sensible lost motion in a direction parallel to
the axis. This feature provides a flexible connection between the piston and the spring which prevents biding produced by the strains in the spring itself that might otherwise occur; and at the same time it is sufficiently rigid in the direction of the motion of the piston to transmit the movements desired.”

Also novel was the “swivel-head through which motion is communicated to the pencil mechanism. The swivel head is a new feature in this instrument, and by its use any desired vertical adjustment of the position of the pencil can be secured without removing the cap from the cylinder. It consists simply of a delicate thumb-screw, drilled from end to end, and mounted on a light shaft to which it is nicely fitted.

“The screw swivels upon the shaft, being held in position by the shoulder of a small stud, which is screwed into the lower end of the shaft… [All] that is needed to adjust the height of the diagram above the lower edge of the card is to turn the swivel…the amount desired.’

Externally, the Star indicator had a single back link with a bifurcated tip and a small lock-screw on the tip of the collar ahead of the pillar-like standard supporting the front link. The projecting wings of the swivel-head are also
easily identified. The fairlead, held beneath the platform by a large nut with a vertically-milled edge, had a bracket with a single pulley. The outside edges of the two spring-steel paper retaining fingers, held to the drum by three short screws, tapered inward from a noticeable step at the base. Production seems to have continued until the end of the First World War, but the Class B external-spring version was subsequently preferred.

**DORAN & TAGGART INDICATOR**

**BRITAIN, PATENTED IN 1902**

On 13th December 1902, ‘Lewis Robert Doran, of Dalmuar House, Dalmuar [sic], Glasgow, Engineer, and Arthur Taggart of 30 Sutherland Terrace, Hillhead, Glasgow, Engineer’\(^9\) received British Patent 27499/02 to protect ‘a means of multiplying the motion imparted to the recorder arm and the employment of a new form of recorder’. This was exceptionally simple, consisting of little more than the recorder arm, which was attached to a standard at the rear of the pivoting carriage, and a laterally projecting pin on the piston rod that engaged a slot in the recorder arm.

Had a pencil point been attached to the recorder arm, the trace would not have been mathematically acceptable. However, Doran & Taggart fitted a marker in the form of a triangular bar, held by a small riband spring to the tip of the recorder arm. The blade bore directly on the diagram paper, but the point of contact moved along the blade (depending on the amplitude of the arm) to lift the ‘marking point’ vertically.

If the drum-diameter was sufficiently small, the paper could be attached directly to its surface; alternatively, if the diameter was large enough—to allow easily-interpreted diagrams to be taken—the paper was led under the spring-steel arm that clipped over the top lip of the drum body, then over a small-diameter roller fixed in the platform and back around the drum until its other end could be clipped in place.

A peg on the underside of the clip pierced the paper before entering an aperture in the surface of the drum. This provided a more secure fixture than clips depending solely on friction.

Indicators of this type were made in small numbers, one by Whyte, Thomson & Co. being pictured in the 1911 edition of Pullen’s *The Testing of Engines, Boilers And Auxiliary Machinery*. Pullen observed that ‘the sharp edge of the brass piece…against the paper on the roller…makes a very clean outline to the diagram, which is very free from oscillation’. He had ‘used

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\(^9\) Scottish census returns reveal that Taggart was Irish. Both men subsequently moved to London, where the 1911 Census of England & Wales records them as ‘Motor Engineers’.
this instrument on steam and gas engines and...found it a strong and useful indicator.

Yet the New Era was not successful commercially. Diverting the paper over the separate roller was clearly undesirable; the cuts made by the recording blade were actually much difficult to follow than a conventional pencil or stylus line; and the quick-detachable cylinder cap, held by a bayonet joint, may have been prone to accidental release. The production version of the ‘New Era’ enclosed-spring indicator had a simplified recorder, consisting simply of a triangular brass bar brazed to the steel arm, and the cylinder and recording-carriage caps were knurled to improve grip. The plain cylinder-cap locking handle had three circumferential grooves. The union nut had flattened lugs, drilled vertically, and the fairlead bracket was held by a butterfly nut.

Plate 138. This typical internal-spring Triumph indicator, made by the Trill Mfg Co., has Faultless reducing gear. It comes from the earliest production (1902–3), as it is clearly marked ‘PAT. APPLIED FOR’. Canadian Museum of Making collection.
TRILL INDICATOR

U.S.A., INTRODUCED ABOUT 1903

Little more than an improved Thompson, with the intermediate link pivoted on the piston rod above the cap and a single ‘U’-tip back link, the Trill is remarkable more for its reducing gear.

This was the subject of U.S. Patent 724525, granted to William L. Trill, of Corry, Pennsylvania, on 7th April 1903. Protection had been sought in February 1902, and it is apparent from marks on the earliest indicators that production had begun before the day of grant. In addition, the Corry newspaper of 14th April 1902 drew attention to an illustrated article in the periodical *Power* containing a ‘description of a new Reducing Motion, called the “Faultless”, which was invented by Mr Will Trill of this city and is to be manufactured by the Trill Indicator Company.’

The internal-spring indicator, marketed as the ‘Triumph’, with the ‘Faultless’ reducing wheel, was eventually joined by an external-spring derivative and a continuous-recording mechanism. A handbook, *The Triumph Steam Engine Indicators and Appliances*, published in 1908 soon after the external-spring Triumph had been introduced, notes that the single-coil springs were rated from ‘8’ (i.e., requiring a pressure of 8lb/sq.in to give a pencil movement of an inch) to ‘200’.
Plate 140. This ‘Model 1’ Whyte, Thomson & Company internal-spring indicator, no. 351, resembles the 1887-patent McInnes too closely to be coincidental. It is assumed that either Whyte, Thomson copied the rival design after the patent lapsed (which would date no. 305 later than 1903) or the basic components were supplied by T.S. McInnes Ltd or Dobbie-McInnes Ltd. Canadian Museum of Making collection.
A special Combined High Pressure Steam and Gas and Oil Engine Indicator was offered with an exchangeable bronze cylinder and small-diameter piston, and a Triumph Ammonia Indicator was made entirely of steel to minimise the effects of corrosion. There was also an indicator suitable for use with both steam and corrosive alkaline gases, which was made from what the manual calls 'a special composition' that did not require 'such careful cleaning to prevent corrosion of the cylinder'.

Each indicator was sold in a 'fine plush-lined mahogany case, fitted with lock and convenient carrying handle. The indicator is fastened solidly to a post, which prevents it being damaged from sudden jolts. Within the top cover is a box containing an instruction book, triangular boxwood scale with six graduations, screw-driver, 100 blank indicator cards, hank of cord, and a small envelope of pencil points. Two springs and two straight cocks are included. If desired, we will furnish one three-way cock in place of the two straight cocks…'

Trill had acquired the Engineering Power Company in 1907, acquiring a small inventory of 'Excelsior' and 'Howard-Thompson' indicators, 'Peerless' reducing wheels and a special type of planimeter. The Excelsior was renamed 'Perfection' and sold for a time alongside the Triumph. It could be identified by the rotating vent tube beneath the platform, and had a steam jacketed cylinder. The piston, hollowed front and rear, had a series of venting holes drilled into its periphery on the 'face' side of the central web. The piston rod had a locating shoulder with a slender threaded boss which protruded through the piston web to receive a retaining nut.

**WHYTE, THOMSON INDICATOR**

**BRITAIN, INTRODUCED ABOUT 1903**

Thompson-type indicators were also made by Whyte, Thomson & Company of Glasgow. Their history remains obscure; though their existence is mentioned in several pre-1914 sources, few instruments exist today and the evidence that can be gleaned from an examination of the only known survivor can only be sketchy.

Renowned as a maker of nautical instruments, Whyte, Thomson & Co. 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 particularly chequered history, including two bankruptcies, Heron relinquished 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, in 1864. Whyte seems to have taken James Thomson as an apprentice, and Whyte & Company, formed in the 1870s, became ‘Whyte, Thomson & Company’ in 1889.

Whyte, Thomson & Co. gained a silver medal at the 1886 Edinburgh exhibition, showing, according to the Official Catalogue, a variety of “Nautical instruments various, for ships’ use. Binnacle Stands and Compasses for yachts etc. Lifeboat Binnacles and Spirit Compasses… Clinometer, Salinometer, Sextants, Chronometer Clocks, Telescopes, Thermometers, etc…” Much the same was on view in Glasgow in 1911.

Whyte, Thomson & Co. 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. 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. A branch was maintained in South Shields (1902–16), and trading continued until 1934.

Plate 141. Whyte, Thompson & Company ‘Model I’ no. 351 in its box, which also bears a similarity to McInnes and McInnes-Dobbie instruments. Museum of Making collection.
and James Wilson then participated in the creation of Christie & Wilson, and William D. Whyte re-formed the original operations as ‘Whyte, Thomson & Co. Ltd’, which continued to trade until 1953.

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.

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 Environs (1891), shows that indicators were made in comparatively small numbers prior to the First World War. However, a few clues are to be found in the British patent records.

The earliest Whyte, Thomson indicator was protected by British Patent 10018/1900, ‘Improvements in Steam Engine and Like Indicators’, granted to ‘Lewis Robert Doran, of Gallowflat House, Rutherglen, Glasgow, Engineer, and Arthur Taggart of 30 Sutherland Terrace, Hillhead, Glasgow, Engineer’. The application was made on 21st May 1900, but contains no obvious links with Whyte, Thomson & Company.

The piston, a separate part, hollowed from below, was held to the bifurcated lower portion of the piston rod by a screw. This screw passed up from beneath to clamp a ball on the Crosby-like spring against the solid head of the lower piston rod. This rod in turn screwed into the tubular upper portion, which protruded through the cylinder cap and operated the amplifying mechanism. Various quick-release methods were claimed, including partially cutting away the cylinder-cap thread (to act as an interrupted screw) and the use of a nut and a spring-steel washer to hold the links bracket in place. Novelty could also be seen in the construction of the drum spring, which was to be ‘made of two helically-wound wires, the ends of which are formed into loops or eyes on opposite sides to receive screws for attaching them to the drums’.

The only indicator answering this general construction to be found to date, ‘Model I’ no. 351, has a modified form of the 1900-patent piston, using a McInnes-type spring with a collar at each end, and its Thomson-type amplifying system that is also essentially similar to the McInnes indicator that had been patented in 1887.

However, comparing design and construction of individual components reveals a total lack of similarity, and a theory that Whyte, Thomson indicators were simply McInnes or Dobbie McInnes instruments being marketed under another name is no longer tenable. It seems more likely that manufacture of certain key components was simply sub-contracted to Dobbie McInnes.
BUFFALO INDICATOR
U.S.A., INTRODUCED IN THE EARLY 1900S
Made by the Engineering Appliance Company of Buffalo, New York State, the ‘Buffalo-Thompson’ was characterised by an amplifying mechanism with a Robertson-type twin-strut back link. The parts were very lightly constructed—particularly the short taper-tip front link—and the low rate of survival is probably due as much to poor durability as limited output. The stop-screw runs directly through the extreme tip of the body cap. One of the best features was the design of the drum spring, which could be adjusted by turning a special bracket. The fairlead was a twin-pulley Staněk pattern, and the unequal paper fingers, which tapered, were held by two short screws.

HOWARD-THOMPSON AND EXCELSIOR INDICATORS
U.S.A., INTRODUCED IN THE EARLY 1900S
Essentially similar, these were made by the Engineering & Power Company of Jamestown, New York. They were conventional designs similar to the Lippincott, with a rotating steam vent beneath the platform, a strut-like yoke-tipped back link, and a special piston with a tail rod that extended downward through a bearing at the base of the body. Ports bored in the liner allowed steam to circulate between the body and the liner to reduce the chances of the piston jamming.

The instruments were made only in small numbers, and survivors are now very rarely seen even though the business was acquired by Trill in 1907. A few Excelsior-type indicators (probably assembled from parts) were subsequently sold by Trill, in a slightly improved form, as the ‘Perfection’.

OTHER U.S.-MADE INDICATORS
Among the attempts to provide continuous recording instruments was one made by Thomas Gray of Terre Haute, Indiana, whose two-drum machine with a Thompson-type pointer (protected by U.S. Patent 615161 granted on 29th November 1898) was described to a meeting of the American Society of Mechanical Engineers in 1897. Illustrations showed that it relied on an idler and a rubber roller to drive the paper roll.

Richard Thompson was a partner in Thompson & Bushnell, makers of the Bachelder indicators. When the partnership foundered c. 1903, Thompson set out to trade on his own; ‘Richard Thompson & Company, Indicator Manufacturers’ of 126 Liberty Street, New York, marketed instruments under the name ‘Twentieth Century’ (the two words on the edge of the platform are customarily separated by an arrow).
The indicator was similar to the standard Robertson-Thompson, but had a bulbous steam vent protruding horizontally from the body beneath the platform, and the tapering paper fingers were held by three small screws set as the points of an upright triangle; the Robertson-Thompson has parallel-side fingers held by three screws in inverted-triangle formation. There are also small differences in the design of the fairlead and in the shape and style of the amplifying-mechanism links, as the back link—doubled on the Robertson-Thompson—takes the form of a strut with a forked or ‘U’-tip.
MAIHAK[-THOMPSON] INDICATOR
GERMANY, INTRODUCED IN 1905
Best known for adaptations of the Crosby, Maihak of Hamburg also made a few Thompson-type indicators with internal springs. These instruments could be distinguished from similar designs made by Dreyer, Rosenkranz & Droop and Schaeffer & Budenberg by the design of the platform, with its independently rotating vulcanite collar; by the prominent ventilation slots in the body above the platform; and by the design of the amplifying mechanism, with an angular standard at the front, orientated diagonally, and a bifurcated back link pivoting on pegs on the body cap instead of a second standard at the rear. The success of the Lehmann-patent exposed-spring indicators ensured that Maihak made very few instruments of Thompson type after 1909.