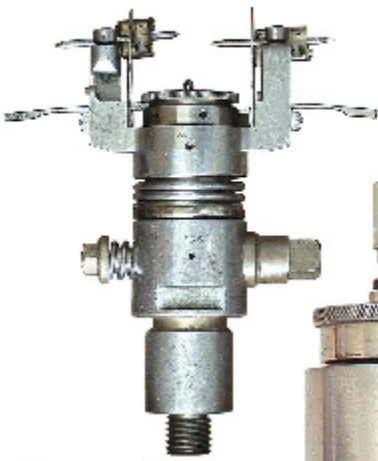
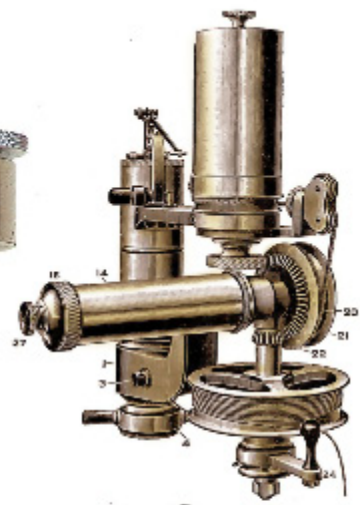
THE ENGINE INDICATOR

A short history of the autographic patterns, from 1800 to the present day

John Walter





CHAPTER EIGHT

First published in 2011 by
THE CANADIAN MUSEUM OF MAKING
www.museumofmaking.org

with the assistance of
Nevill Publishing & Design, Hove, England

Updated to 25th October 2011

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PEAK-PRESSURE TYPES

The conventional autographic indicator was, by the standards of its day, a highly sophisticated tool. It was also expensive. Among its greatest advantages was an ability to record the changes of pressure within a pressure-vessel (e.g., an engine cylinder) throughout an entire stroke. However, indicators were not particularly easy to install and operate; and the problems increased when the numbers of cylinders began to multiply.

Most steam engines with three or more cylinders were large and costly, and comparatively little additional expense was incurred by providing not merely three springs, but separate indicators. The situation changed with the rise of internal-combustion engines prior to the First World War, when comparatively small engines with four, six or eight cylinders appeared.

Among the most important goals of the design of internal-combustion engines was consistent performance, particularly when several cylinders were operating continuously and near-simultaneously. Analysing the performance of these with a conventional autographic indicator, preferable though it may have been under laboratory conditions, was often extremely difficult under normal circumstances. An easier way of checking performance was to ensure that each cylinder was achieving the same level of compression and the same amount of power when the compressed charge was ignited. The maximum-pressure indicator was developed specifically to ease the task of ensuring consistent ignition in multiple-cylinder engines.

Some of the first continuously-recording indicators recorded maximum pressures only, but were out of step with the comprehensive pressure/time traces provided by the Watt, McNaught and Richards instruments. Yet though the latter group was well suited to the needs of the steam engine, the internal-combustion engine demanded something different; a simple and sturdy instrument that could show the maximum pressures generated in the cylinder during the firing process was often all that was needed.

It is assumed that instruments of this type were inspired by the work of Mathot, but the earliest patents that could be traced were filed in Switzerland in September 1905 and in France in October 1905 by Albert Peloux ‘(‘résidant

RSPUBLIQUE FRANÇAISE.

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BREVET D'INVENTION.

XII. — Instruments de précision, électricité.

3. — Poids et mesures, instruments de mathématiques, compteurs et procédés d'essai.

N° 358.422

Indicateur de pressions et de dépressions.

M. Albert PELOUX résidant en Suisse.

Demandé le 11 octobre 1905.

Délivré le 18 décembre 1905. — Publié le 15 février 1906.

(Demande de brevet déposée en Suisse le 2 septembre 1905. — Déclaration du déposant.)

Lorsque l'on veut relever les pressions maxima dans les cylindres des moteurs à explosions, l'on se sert d'indicateurs du genre de celui de Watt, mais dès que la vitesse dépasse cinq cents tours à la minute, ces indications ne donnent plus d'indications exactes, par le fait de l'inertie des pièces en mouvement. En outre, ces appareils sont très coûteux et très délicats et ne peuvent rester longtemps en fonctionnement car le petit piston tend à gripper par suite de la température élevée à laquelle il est soumis et de la rapidité de son monvement.

L'indicateur de pressions, qui fait l'objet de cette invention, évite ces inconvénients, car l'inertie du piston est complètement annulée, ce qui permet d'obtenir des indications rigoureusement exactes, quelle que soit la vitesse du moteur; le piston ne peut gripper, son mouvement étant nul. En outre, la construction simple et la robustesse de cet appareil en font un instrument peu coûteux et peu sujet à se déranger.

Dans le dessin ci-annexé, donné à titre d'exemple :

Fig. 1 indique une coupe de cet indicateur de pressions, lequel est composé d'un piston E, ajusté très exactement à la partie inférieure d'un cylindre C. La partie supérieure de ce cylindre C renferme un ressort D placé entre la vis A et le piston E.

En vissant plus ou moins la vis A, le ressort D serre plus ou moins le piston E. L'appareil étant vissé sur le cylindre moteur, de façon à ce que la face inférieure du petit piston communique avec l'intérieur du cylindre moteur par le conduit I, le fonctionnement de l'indicateur est le suivant : Sous l'influence des pressions développées dans le cylindre moteur à chaque explosion, le piston E est refoulé contre le ressort D, lequel rejette le piston E en avant; ce dernier prend donc un mouvement de va-et-vient. Mais si l'on presse le ressort D au moyen de la vis A contre le piston E jusqu'à ce que celui-ci n'ait plus qu'un mouvement imperceptible, il est certain que la pression exercée par le ressort D contre le piston E sera égale à celle exercée par l'explosion contre la surface du piston E en communication avec la chambre d'explosion.

Il suffit donc, pour connaître la pression maximum dans la chambre d'explosion (en supposant que la surface du piston E soit de un centimètre carré) de mesurer la pression du ressort D en kilogrammes pour chacune de ses positions. Ce tarage se fait très facilement en exerçant des pressions connues sur la sur-

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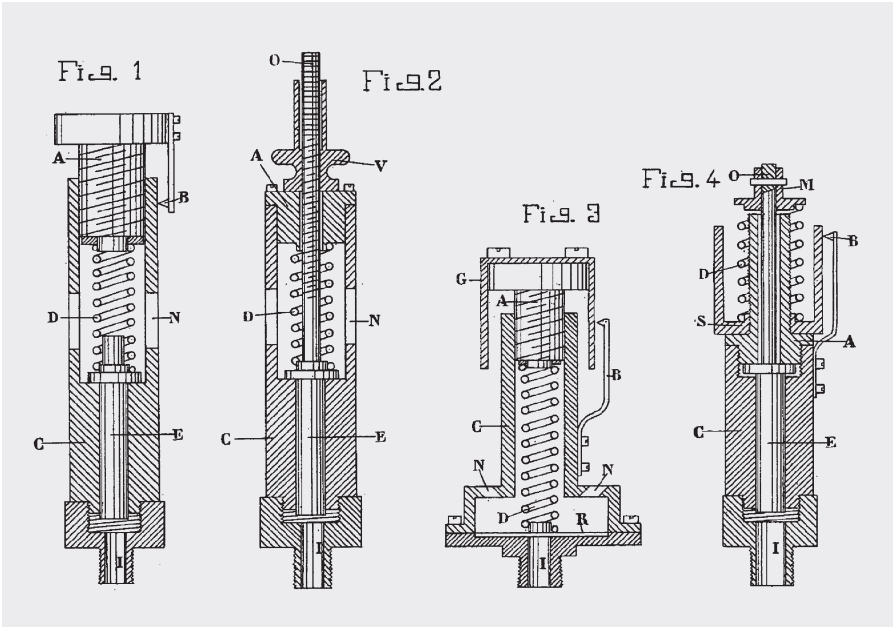


Plates 8–1 and 8–2. The title page (left) and drawings (above) of the French patent granted to Albert Peloux, which, perhaps, is never accorded the recognition it deserves. *By courtesy of the French patent office, Paris.*

in Suisse').[1] French Patent 358422 shows a variety of methods of showing the pressure, including rapid-pitch screws raising pointers against scales and graduated rods protruding through collars. There is no evidence that the Peloux peak-pressure indicator was made in quantity. However, it was cited by many subsequent patentees and it is likely that the influential Swiss Züblin design of the late 1940s was a direct descendant.

The first to offer a truly successful peak-pressure indicator was Englishman John Okill, who obtained the protection he had sought for 'An Improved Pressure Indicator for Internal Combustion Engines' in May 1907 as British Patent 12158/07, accepted on 27th May 1908. Born on 8th June 1875 in Wavertree, now a suburb of Liverpool, the son of a joiner, Okill was

1. Attention has been drawn to US Patent 323992, granted on 11th August 1885 to Stephen Wilcox of 'Brooklyn, Kings county, in the State of New York, doing business in New York City'. This protected a dial-type pressure gauge with a special valve set in the stem of the gauge to 'show the highest and lowest pressures when the pressure is variable'. Wilcox intended it 'more particularly for situations where the pressure alternates rapidly, as in the cylinders of steam or air engines, pumps, and analogous apparatus'.

apprenticed in 1891 to the engineering workshops of University College, Liverpool. He remained in the employment of the university until retiring in December 1941, having risen first to Assistant Lecturer and Demonstrator in 1917 and then Lecturer in Mechanical Engineering in October 1923.

Made a Master of Enginering ('M.Eng.') *ex officio* in July 1922, Okill died in June 1947. He is best known for *Autographic Indicators for Internal Combustion Engines*, published in 1938, which rapidly attained a reputation as an ideal guide to its subject. The title page of the book records that 'John Okill, M.Eng., M.I.A.E.' was a 'Lecturer in Engineering and Superintendent of the Laboratories of Mechanical Engineering, The University of Liverpool'.

The drawings accompanying the 1907 Okill patent specification showed several ways of achieving a balance between pressure in the cylinder, acting upward through a valve against a constrained piston, and that of a sturdy spiral spring. A finger-wheel allowed the pressure of the spring to be altered until a balance point was found, when the piston stopped vibrating. This could be seen either through a sight hole cut in the instrument body or by a vibrating pointer attached to the body side. The pressure could be read off scales engraved on the outside of the body. Not surprisingly, the pointer was much more convenient to use; even if any of the 'sight hole' indicators were made, no survivors have yet been found.

Okill indicators had been made in substantial quantities by the time the First World War began, though survivors are rarely seen. However, sufficient evidence exists to show that there were several manufacturing patterns of the 'Old Model'. It is not yet known when Okill began development of the indicator, but the similarity of the patent-specification drawings and the earliest known production variant suggests that the work had been completed by the time the provisional application for the British patent was made on 27th May 1907.

Some time elapsed before Okill could turn his ideas into reality. The earliest known advertisement—in 'Some More Flight Accessories', published in *Flight* on 16th July 1910—states that the 'Okill pressure indicator, which has been placed on the market by Brown Bros., is a simple and compact device for ascertaining the compression or firing pressure in the cylinders of an engine. It consists of a cylindrical box, furnished with a screw fitting at one end and a screw-cap at the other. The screw fitting serves as a means of attaching the indicator to the cylinder, while the screw cap enables a spring contained inside the indicator-casing to be tightened down. On the outside of the indicator-casing is a small lever, which vibrates…until the screw-cap is turned down to such a position as to bring the lever to rest. On the outside of the indicator-

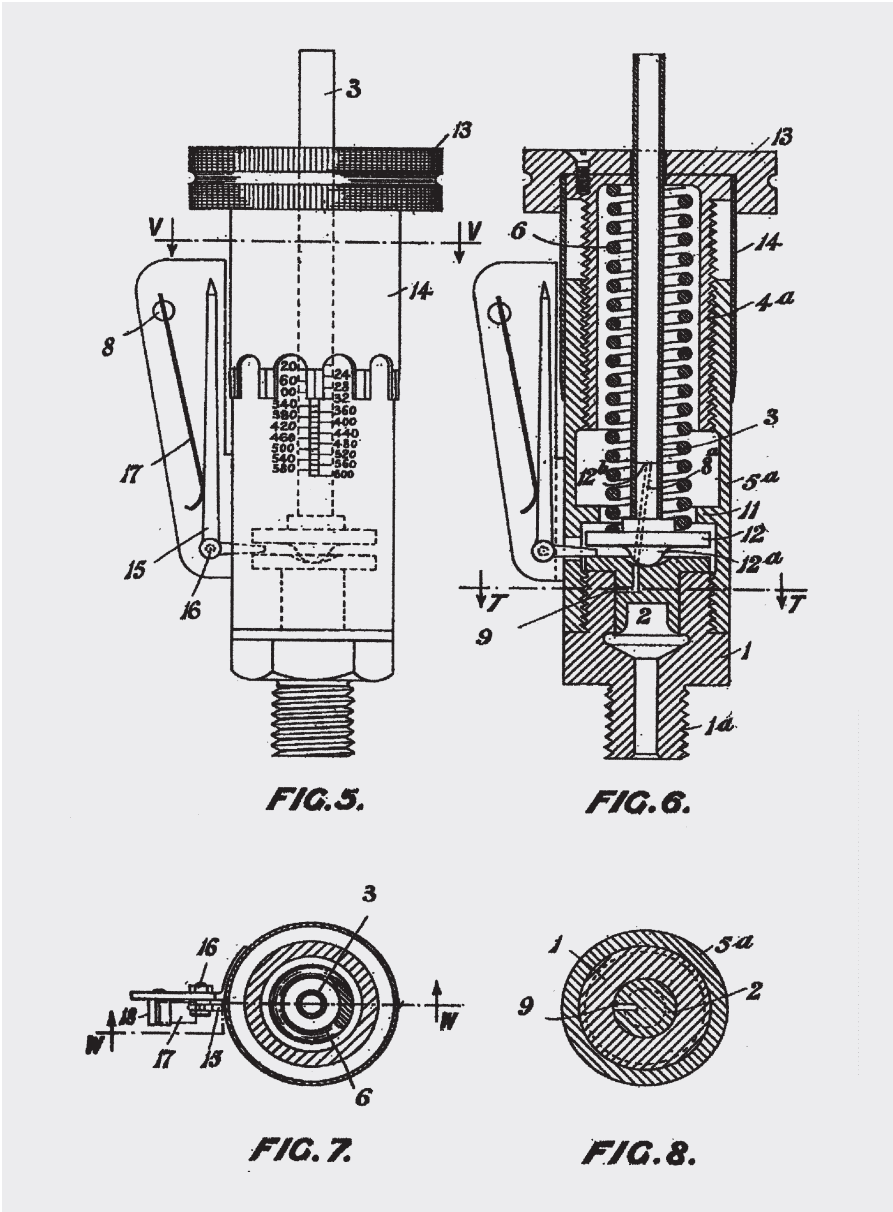


Plate 8–3. The first Okill maximum-pressure indicator, from drawings accompanying British Patent 12158/1907 granted to John Okill on 27th May 1908. *By courtesy of the UK Intellectual Property Office, London.*

case a scale is engraved, and on the cap is a pointer that moves over the scale. When the lever has been brought to rest, the pointer on the cap indicates the maximum pressure in the cylinder by the reading on the scale.' Brown Brothers Ltd of Great Eastern Street, London EC ['also at Manchester and Paris'] initially held the sole concession for the Okill indicators. The actual manufacturer was listed in 1915 as 'Taylors (Brass Founders) Ltd, Bolton, Lancs.', but it is not at all clear if Brown Brothers had commissioned Taylors to make the instruments, or if Browns were merely selling the indicators that Taylor was making.

The illustration accompanying the paragraph in *Flight* shows an indicator which is virtually identical with the patent drawings, except that the length of the angle bracket supporting the vibrating pointer (and, consequently, the pointer itself) is considerably reduced. A single oiling hole is cut through the sleeve and the body.

Later illustrations suggest that alterations were made. It is probable that Taylor made the body castings in batches, perhaps fifty or even a hundred at a time, and also that the opportunity was taken to test possible improvements. An illustration accompanying 'The Okill Pressure Indicator. An instrument for use in tuning up aeronautical engines', a review published in *Flight* on 30th October 1914, shows an otherwise standard Okill with short axial slots arranged circumferentially around the sleeve and the body, which could have been intended to promote cooling or merely save weight.

By 19th November 1915, an entry in a *Flight* supplement for 'George Taylor (Brass Founders), Ltd., Bolton' featured a drawing of an indicator with a row of circumferential holes directly beneath the sleeve-cap and another two rows around the centre of the body. The 1915 pattern seems to have been standardised for the remainder of the First World War, though a change to a knurled brass cap was made c. 1917 to conserve supplies of vulcanite for more important tasks.[2] The graduations that had been engraved above the pointer were abandoned at about the same time. The instrument shown in Plate 8–4 is a 1917-type Okill, marked as the product of TAYLORS LTD/MAKERS /BOLTON. on the lower front of the body and is numbered 'P 515' on the cap. The pressure is read simply by combining the marks engraved around the base of the cap with the vertical scale on the body, set in the illustration to 19lb/sq.in. The highest pressure that can be measured is 400lb/sq.in.

2. It has also been suggested that this change could reflect a request from the military authorities, to prevent unwanted breakages of vulcanite in the field. The absence of military marks on P515 neither supports nor rejects this possibility, as details have yet to be found of any relevant contracts (which probably did exist owing to the rapidly-growing use of internal-combustion engines during the First World War).

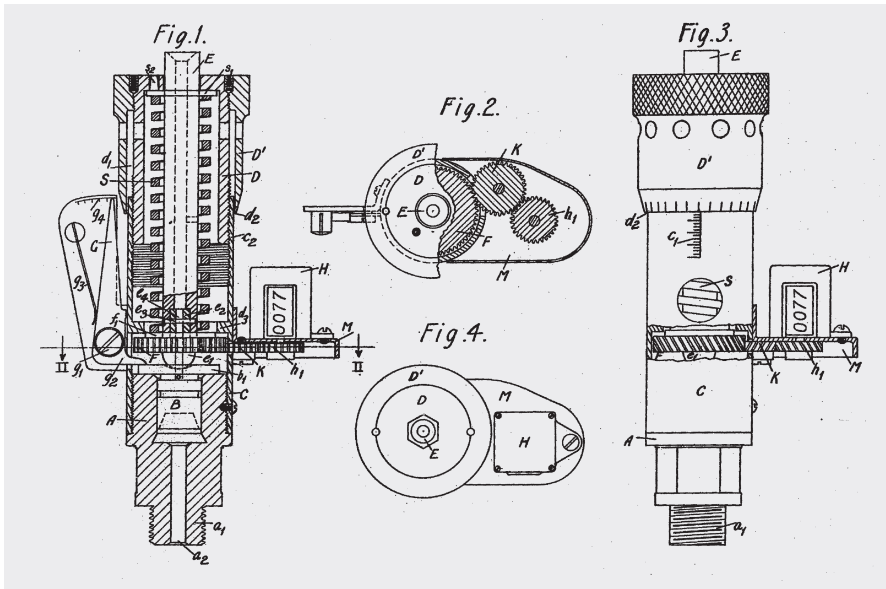
Plate 8–4. The 1907-type Okill recorder is very rare, as comparatively few were made. Note the pressure-scale engraved on the front of the body of this example (no. P515 dating from 1917–18), the multiplicity of vents, and the riband spring pressing on the pointer.

By courtesy of Bruce Babcock, Amanda, Ohio, USA.

Protection for an improved version of the 1907 indicator was sought in Britain on 23rd April 1919, British Patent 144034 being duly accepted on 10th June 1920 (a comparable grant in the USA, no. 1467558, was delayed until 11th September 1923). The British specifications name the applicants as 'John Okill, of 8, College Drive, Woodhey, Rock Ferry, in the County of Cheshire, Engineer, and John Robinson Tate, of 589, Chorley Old Road, Bolton, in the County of Lancaster, Brassfounder'; Tate, born in 1869, was the owner of George Taylor (Brass Founders) Ltd, manufacturer of the Okill indicators. An improved form of the vibrating-pointer system was fitted with a counter, driven by a gear train, so that the pressure setting could be seen at a glance. This was hailed as a great step forward, as it was undoubtedly easier to read than the sleeve type, and was embodied in the 'New Type Standard' design.

Okill indicators were made by Taylor in All Saints' Street Works, Bolton, Lancashire, England. The 'New Type' range originally consisted of ND[1], ND[2] and ND[4] patterns—identified by their serial-number prefixes, and respectively calibrated for maximum pressures of 1000, 2000 and 4000 lb/sq.in. However, it had soon been extended to include the NP, a low-pressure indicator, rated

Plate 8–5. The refined Okill maximum-pressure indicator, from drawings accompanying British Patent 144034 granted to Okill & Tate on 10th June 1920. *By courtesy of the UK Intellectual Property Office, London.*



IMPORTANT

LUBRICATE the spring adjusting screw occasionally when it is unscrewed so that the threads are visible.

FREQUENTLY REMOVE THE PISTON. Clean and LUBRICATE it and clean the Cylinder Bore.

LUBRICATE the tell-tale finger pivot occasionally.

DON'T LUBRICATE the wheels in the gear box or the counter spindle. If the counter spindle is lubricated oil will find its way on to the figure rings and obscure the figures.

Release the pressure on the spring when not in use.

The OKILL Indicator is a perfect instrument for the purpose of measuring rapidly pulsating pressure of any magnitude.

Its principle of operation is beyond criticism, and in design and workmanship it cannot be improved.

A companion fitting to the OKILL Indicator for Oil and Petrol Engines is the OKILL Automatic Fuel-Measuring Tank (Patent). This is an auxiliary fitting of small size, by means of which it is possible to obtain exact measurement of fuel oil consumption of any cylinder.

N. K. D. TYPES

For pressure readings in kilograms per sq. centimetre.
N.K.D.1 Type—Suitable for pressures to 70 kg/cm.2
N.K.D.2 Type—Suitable for pressures to 140 kg/cm.2

When the N.K.D. 1 type is taken apart for cleaning and re-assembled, the arrow marks on the barrel and sleeve should be together, the counter is then set at 120 which reads 12.0 kilos. Note that the last digit on the counter is a decimal point.

With the N.K.D.2 type the counter is set at 24 which reads 24 kilos, therefore there is no decimal reading on this type.

OKILL

(PATENT)

PRESSURE INDICATORS

SPECIALLY DESIGNED FOR PETROL, STATIONARY and MARINE OIL ENGINES

Indispensable aids to the Fuel Economy and Smooth Running of Internal Combustion Engines of every type

REGISTERED OKILL TRADE MARK

Standard types for measuring the maximum pressures of Compression and Combustion in engine cylinders, up to 2,000lb. per square inch

No Operating Gear is required

Cannot be damaged in use

Will measure any pressure at any speed

Our "S.P." Super Pressure Indicator *for fuel-injection pressures to 10,000 lb. per square inch*

SEND FOR LEAFLET

For use on Stationery and Marine Type Diesel Engine —— Fuel Pipe Lines ——

SOLE MAKERS:

G. TAYLOR (Brass Founders) LTD.

All Saints Street Works . BOLTON . England

Plate 8–6. The construction of the refined Okill maximum-pressure indicator shown here was protected by British Patent 144034 of 1920. *Author's collection.*

to only 400lb/sq.in, which was probably introduced once supplies of the older version had been exhausted. The NKD[1] and NKD[2] were metric-system instruments calibrated for 70kg/sq.cm and 140kg/sq.cm. Handbooks and instruction leaflets confirm that the three-digit counters on NKD[1] indicators were to be read as 12.5kg/sq.cm when '125' was shown; counters on NKD[2] examples, conversely, were to be read directly—'125' was 125kg/sq.cm.

Another British Patent, sought in June 1928 and again in March 1929 after improvements had been made, was accepted on 16th September 1929 as no. 319253. Granted to John Okill and John Tate, it protected a variation of the basic Okill indicator which could indicate a vacuum as well as pressure. The key to this was a piston placed centrally in a chamber, which could be pressed onto the lower abutment by the spring, recording pressure, or pulled against the upper abutment to indicate a vacuum.

Developed principally for use in the laboratory, short-body indicators contained a comparatively weak spring: the patent drawing shows a range

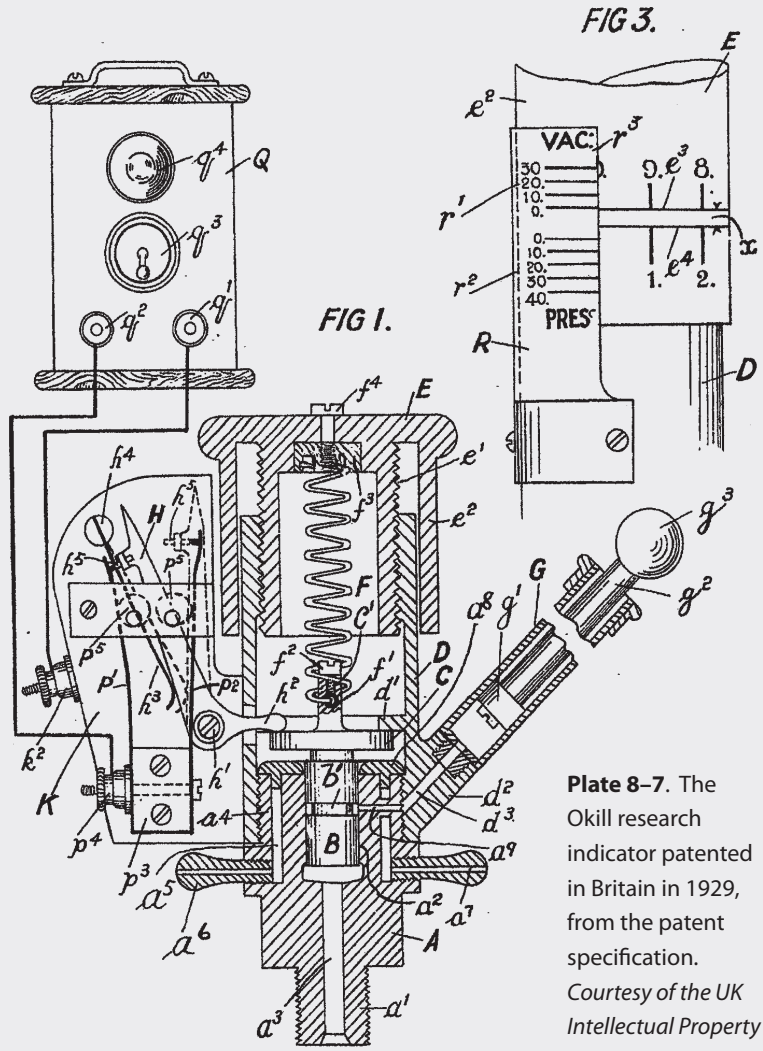


Plate 8–7. The Okill research indicator patented in Britain in 1929, from the patent specification. *Courtesy of the UK Intellectual Property Office, London.*

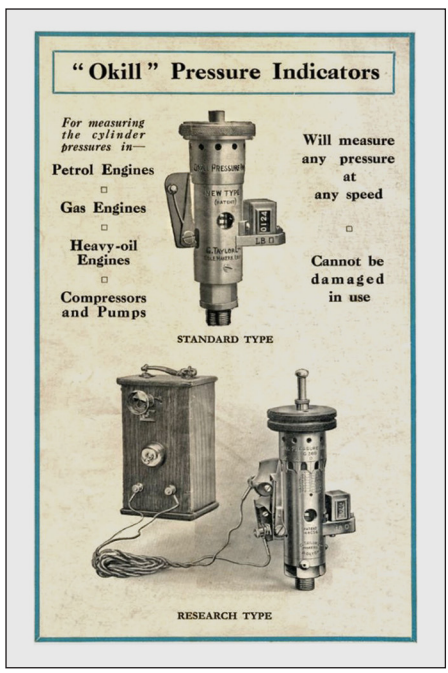
of merely 40lb/sq.in above to 30lb/sq.in below atmospheric pressure. The indicator also relied on a small bulb, contained in a separate box with its associated switchgear. When the vibrating pointer was nearly static, the bulb would begin to flash. This showed that the readings could be taken from a combination of short partly-circumferential rings engraved on a plate

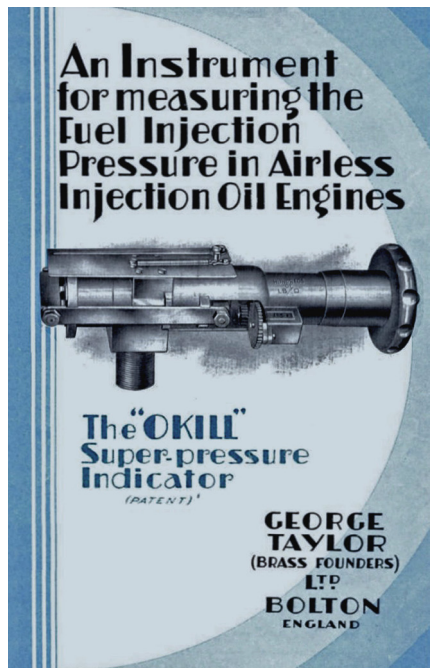
attached to the body (recording in tens) and matching rings on the sleeve (in single units). A water-cooling system was fitted in cylinder at the base of the body, and a manually operated lubricating plunger was set at an angle on the lower side of the body diametrically opposite the pointer bracket.

It is probable that a few of these instruments were made for laboratory work, but the lubricator of the 'production version' of the 'New Type Research' instrument was co-axial with the spring, and the recording graduations, if catalogue illustrations are to be trusted, reverted to one of the forms that had been patented in 1907: circumferential rings engraved on the body and arrowhead flanges projecting downward from the spring cap.

Next came the 'Super Pressure' indicator protected by a British Patent 351003, granted to Okill and Tate on 15th June 1931 (but sought in March 1930). Distinguished by its unique horizontal orientation, the 'SP' was developed specifically to record extremely high pressures without the use of

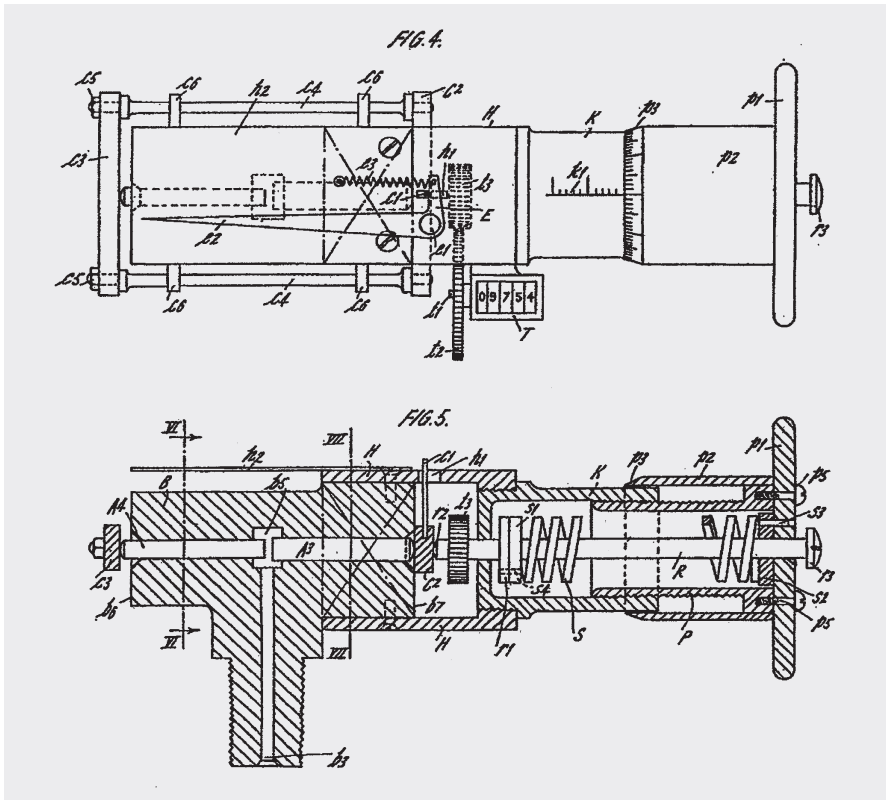
Plate 8–8, *below left*. A page of a 1920s leaflet promoting the 'Standard' and 'Research' Okill indicators. Note the separate bulb-box that accompanied the latter. **Plate 8–9**, *below right*. The title page of a leaflet describing the Okill SP or 'Super Pressure' instrument, made in accordance with a patent granted in Britain in 1931.

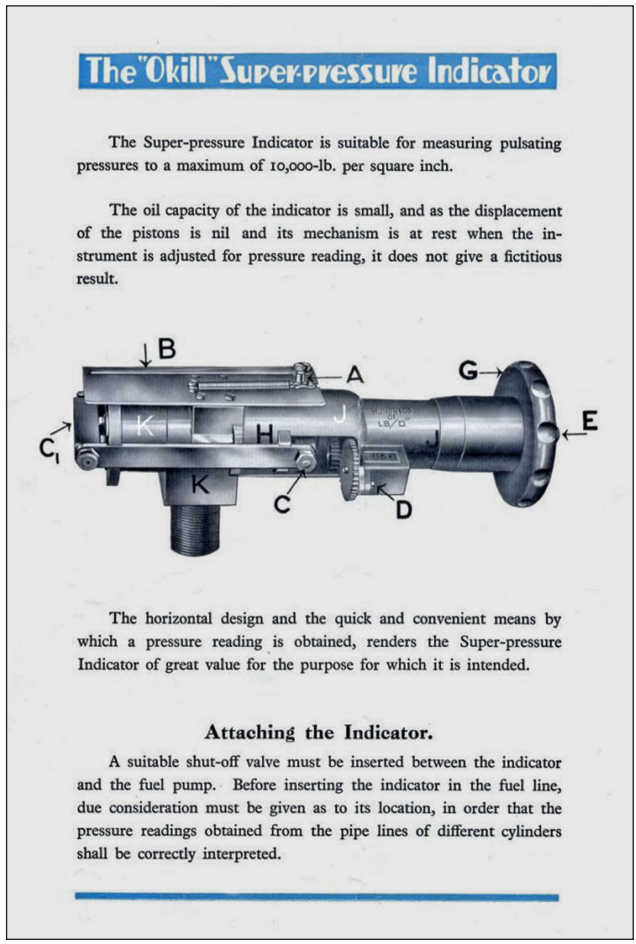




an excessively stiff spring. Among its principal goals, according to Taylor literature, was to 'measure the fuel-injection pressure in the pipelines of airless-injection oil engines…such pressures may be as high as 10,000-lb. per square inch, and the rise and fall of pressure is rapid': effectively a hammer blow to the indicator piston.

A right-angle connection between the engine cylinder and a chamber in what the Okill & Tate called the 'cylinder block' allowed pressure to be registered. Two rods entering the chamber in diametrical opposition were anchored to two crossbars which, linked with bars along each side of the cylinder block, were allowed to slide longitudinally. If their diameters were equal, the opposed rods would be 'in balance': no matter now high the pressure rose in the chamber, no movement would be detected. By making the rod connected with the spring assembly larger than its counterpart, the pressure balance was disturbed and the larger rod would move back—but only proportionately to the true pressure, the precise relationship being





The "Okill" Super-pressure Indicator

The Super-pressure Indicator is suitable for measuring pulsating pressures to a maximum of 10,000-lb. per square inch.

The oil capacity of the indicator is small, and as the displacement of the pistons is nil and its mechanism is at rest when the instrument is adjusted for pressure reading, it does not give a fictitious result.

The horizontal design and the quick and convenient means by which a pressure reading is obtained, renders the Super-pressure Indicator of great value for the purpose for which it is intended.

Attaching the Indicator.

A suitable shut-off valve must be inserted between the indicator and the fuel pump. Before inserting the indicator in the fuel line, due consideration must be given as to its location, in order that the pressure readings obtained from the pipe lines of different cylinders shall be correctly interpreted.

Plate 8–10, left. Drawings of the SP ('Super Pressure') Okill indicator, from the British patent granted in 1931. *Courtesy of the UK Intellectual Property Office, London.*

Plate 8–11, *right.* A page from a leaflet promoting the virtues of the Okill SP indicator, probably dating from the 1950s. *Author's collection.*

controlled by the rod-diameter differential. A vibrating pointer lay on top of the instrument, anchored in a fork-like collar connecting the spring chamber and the cylinder block. No other mechanical peak-pressure indicator of the day could compete with the 1931 Okill & Tate design.

The subject of British Patent 468857, accepted on 14th July 1937 (and comparable U.S. Patent no. 2130649 of 20th September 1938), the 1936-type Okill & Tate peak-pressure indicator was an improvement of the 1920 patent, with a free-floating piston and a pressure block which could move axially without twisting the spring. Alternative methods of registering pressure were proposed, and the patent drawings show an instrument in which pressures were recorded partly by a radial lever beneath a protective plate on the body

Sept. 20, 1938. J. OKILL 2,130,649

APPARATUS FOR MEASURING FLUID PRESSURE

Filed Jan. 14, 1937 2 Sheets-Sheet 1

Fig. 1.

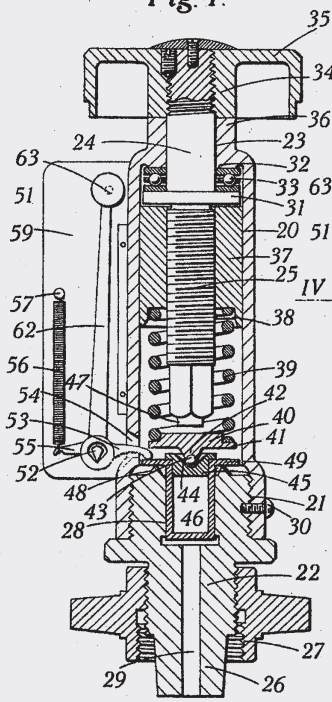


Fig. 2.

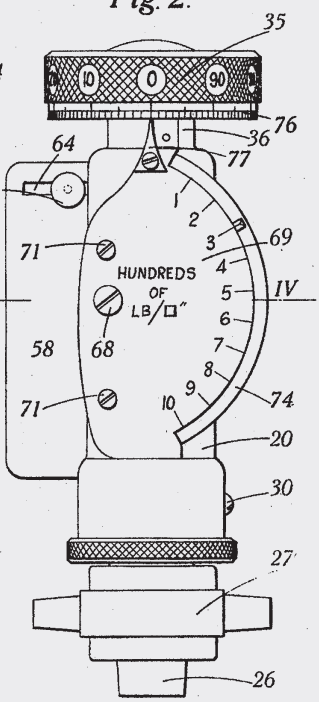


Fig. 4.

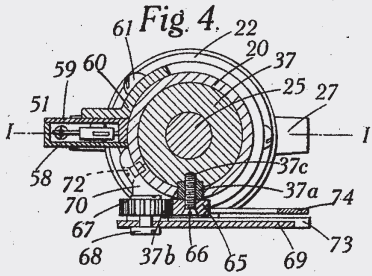
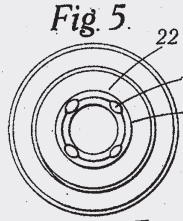


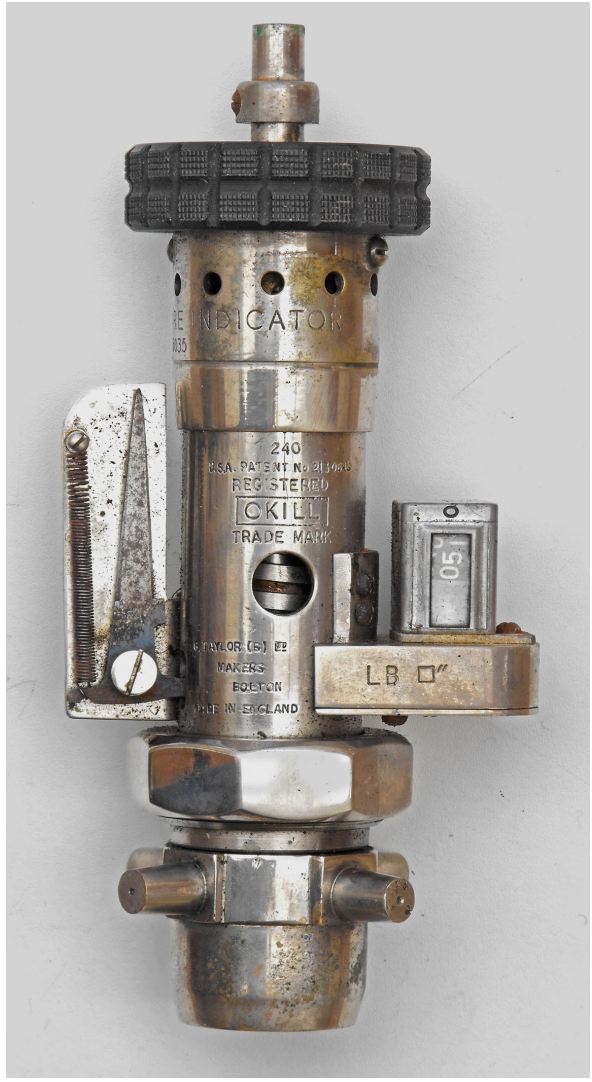
Fig. 5.



Inventor
John Okill
By J. Inwin
Atty

Plate 8–12, *left*. A page of drawings of the 1936-type Okill & Tate indicator, from the patent granted in the USA in 1938. *Courtesy of the US Government Patent Office, Washington, DC.*

Plate 8–13, *right*. 1936-type Okill indicator ND[2] 6035, capable of handling pressures as high as 2000 lb/sq.in. Note the generally sturdier construction and the coil spring associated with the pointer. This particular example was probably made after the end of the Second World War. *Canadian Museum of Making collection*.



side (recording in hundreds of units), and partly by single units engraved around the under-edge of the spring cap.

The beginning of the Second World War prevented any radical redesign of the Taylor-made Okill indicator, however, and so the series-production version—acknowledging only the 1938-vintage US Patent—retained the gear-driven counter. This instrument replaced the externally similar New Type Standard (1920) type in 1940; it was certainly made in ND[1], ND[2], NKD[1] and

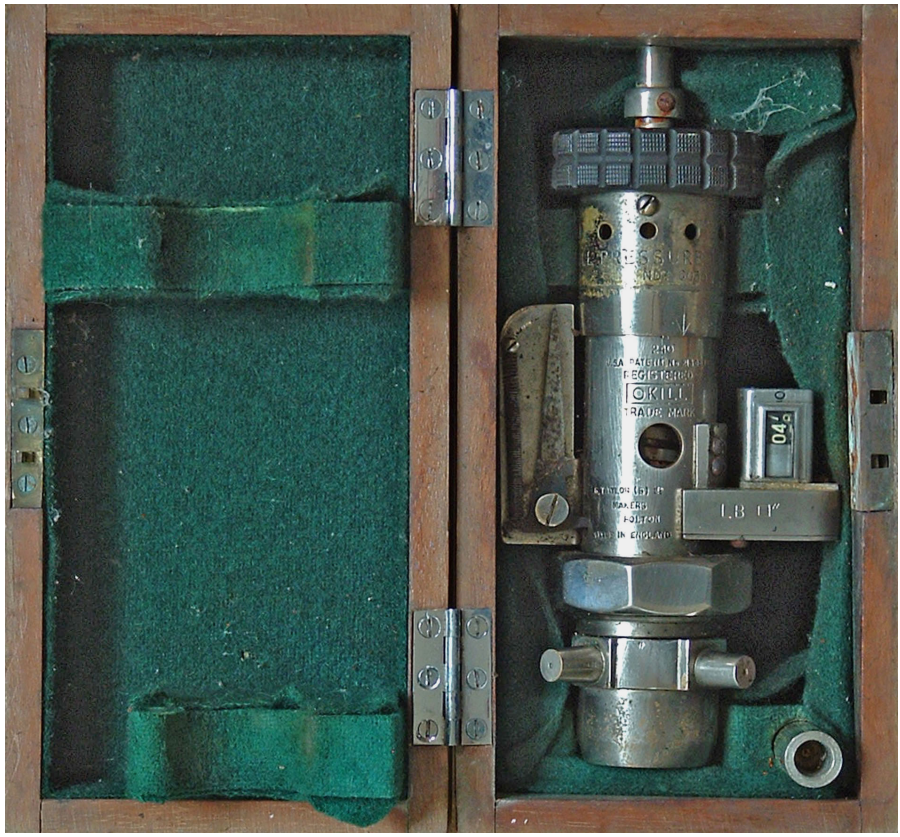


Plate 8–14. Okill indicator ND[2] 6035 in its wooden case. Many comparable indicators have been found in cardboard boxes, and it is not yet known if the case was an option or simply an 'aftermarket' addition. *Canadian Museum of Making collection*.

NKD[2] versions, though ND[4] seems to have been superseded by the SP. Work continued after the end of the war, but, even though indicators were still being sold when Taylor ceased trading in the mid 1970s, it seems unlikely that very much manufacturing had been undertaken since the 1950s. It is much more likely that the instruments being sold in the 1960s were taken out of store; and also that the last of them (e.g., ND[2] 9822) were fitted with synthetic-body Veeder-Root counters because stocks of the original metal-body pattern had been exhausted.

No surviving Okill indicator has yet been found with a five digit number, and it is concluded that production did not exceed 10,000. However, this

Plate 8–15. Taken from an October 1940 issue of the British periodical *Flight*, this page includes an advertisement for the standard Okill pressure indicators. *Author's collection.*

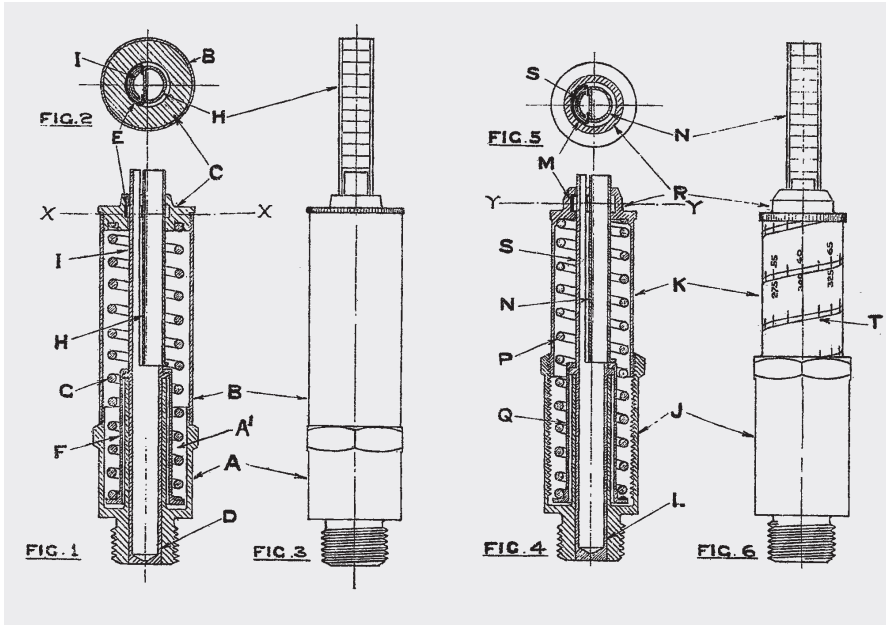


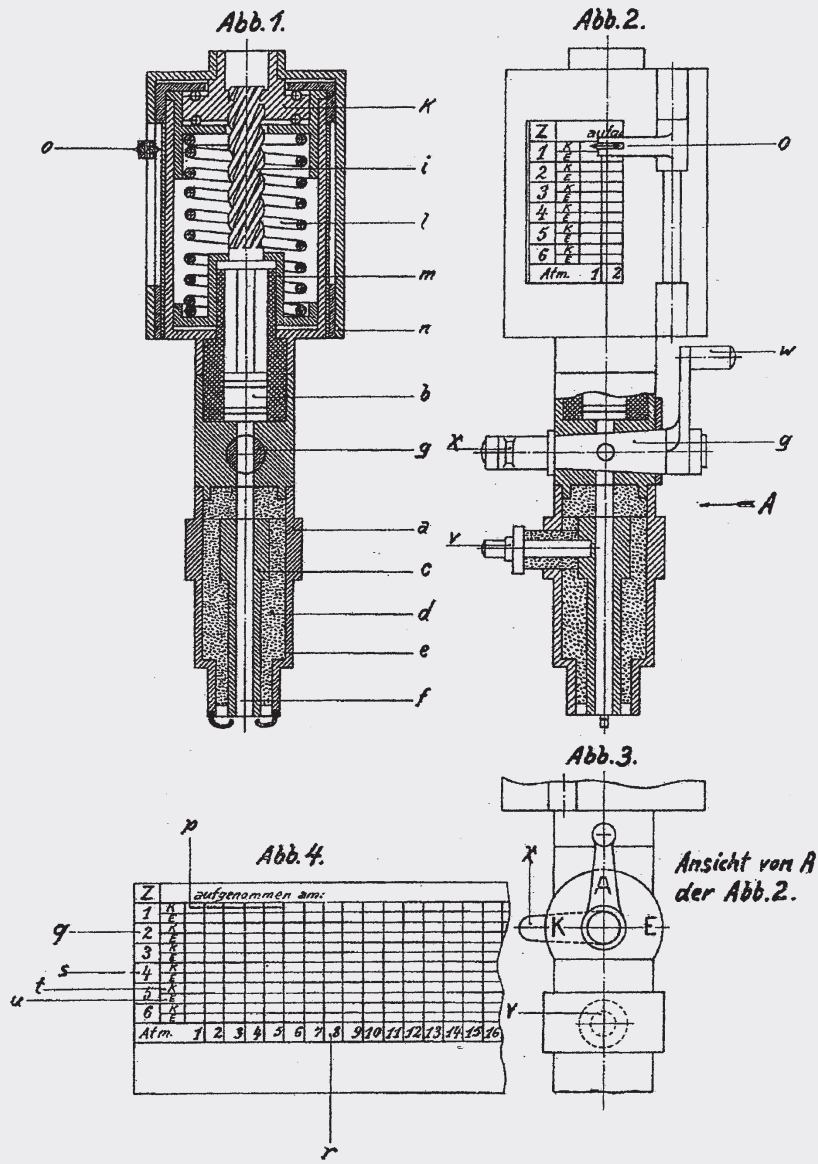
Plate 8–16. The simplicity of the peak-pressure indicators developed by John Pearson are shown in these drawings taken from his 1923 British patent. *Courtesy of the UK Intellectual Property Office, London.*

estimate is based on an assumption that the instruments were all numbered in a single sequence without regard to the 'ND' or 'NKD' pressure-range designators. With the possible exception of the rarely-seen SP, many Okills survive simply because constructional strength and unsophisticated design trumped weaker or more complicated rivals.

Others soon followed where Okill had led, though rarely with commercial success. One of the first was John Linton Pearson 'of Pensnett, Dudley, British subject', whose British Patent sought on 2nd August 1922 protected a simple indicator consisting of a spring-loaded plunger skidding vertically within its casing. The pressure was measured by the maximum height of the plunger-tip above the casing (where a sliding finger was held by a spring) or by a line engraved helically on the spring-cap.

Elsewhere in Europe, many other spring-type designs were developed. Among these was a spring-and-pointer design patented in August 1924 by Wilhelm Lehmann of Lehmann & Michels (DRP 435447), which could be adapted to show peak pressures, and another by Johannes Coenders of Traar,

Plate 8–17. Drawings of the Coenders peak-pressure indicator, from the German patent papers.



Krefeld, which used a rapid-pitch screw to rotate a drum laterally beneath a tracer point (DRP 460718 of 15th May 1926). The length of the trace, which was straight, registered the maximum pressure; but the trace-point could also be moved vertically to register another stroke. The patent drawings show a detachable card capable of recording the combustion and exhaust components of six successive cycles. There is no evidence to show that the Coenders design was ever manufactured in quantity, but peak-pressure indicators have been made by Maihak, Leutert (Maihak's successors) and Lemag to the present day. Typical of these was the *Zünd.- bzw. Spitzendruckmesser* (DPa. 1112657) designed by Hans Stüben of Morrege über Uetersen and patented by H. Maihak AG of 'Hamburg 39, Semperstr. 38' on 10th August 1961.

The 'Acrometre', patented in France by Mazellier & Carpentier, relied on a thin disc-like valve to allow combustion gases to pass until the pressures on each side of the disk were equal. The level at which this occurred could then be read on a conventional Bourdon-type gauge. This particular system was unsuccessful; the disc valve was prone to damage and, owing to the dimensions of its seat, was also improperly balanced.

An alternative approach was taken by the German inventor Robert Bosch, who set an indicator into the fuel line of the injection system. This could be adjusted against a pre-calibrated spring (by way of a micrometer thimble) until the valve began to leak.

None of these, however, were as simple, sturdy or reliable as the Okills, which remained supreme in Britain until a peak-pressure indicator was developed shortly after the end of the Second World War by Gebr. Sulzer AG of Winterthur, Switzerland. Application for the relevant Swiss patent was made in October 1948, though the grant was delayed until the summer of 1950. US Patent 2673464 (sought in August 1949 but not granted until March 1954) names the inventor as Marcel Wilhelm Züblin of 'Dumbarton, Scotland, Assignor to Sulzer Frères S.A., Winterthur'.

The specifications described and illustrated several ways that screws and springs could be used to rotate a cap against a graduated scale in response to rises in pressure. The commercially-successful version embodied expansible bellows attached to a push rod, which was in turn anchored in a conical nut. Operation was simple: when pressure was applied to the bellows, through the valve communicating with the pressure-generating vessel (usually an engine cylinder), the bellows expanded to force the push rod up against the counter-pressure of a calibrated co-axial coil spring. A conical nut was raised from its seat, but a clock-spring anchored in the cap instantly rotated the nut back again. The amount of rotation was directly proportional to the pressure being

Plate 8–18. This Dobbie McInnes leaflet, dating from the early 1960s, clearly shows the construction of the standard indicator, with vulcanite casing and a graduated thimble.

generated in the bellows, and an appropriate reading could be taken directly from a graduated thimble or cap.

Production of the Sulzer peak-pressure indicator was licensed to Haenni Präzisions-Maschinenfabrik AG (now Baumer Bourdon-Haenni AG) of Jegensdorf, Switzerland, and Dobbie McInnes Ltd of Glasgow. It was the first of its type to successfully challenge the supremacy of the Okill design, largely by offering automatic operation. All that was required of the operator was to re-set the instrument prior to each measurement and note the final reading.

The British-made instruments were offered as the 'Air Cooled Cylinder Pressure Type' used with a standard indicator cock (usually calibrated for 200–1400lb/sq.in or 15–100kg/sq.cm), with ventilation holes in its fluted vulcanite body; the steel-bodied 'Water Cooled Cylinder Pressure Type', attached directly to the engine cylinder; and an 'Oil Fuel Pressure Type', designed to be inserted in fuel lines, which could handle pressures as high as 10,000lb/sq.in.

The introduction of Okill instruments into North America persuaded Robert Wasson of Cranford, New Jersey, to develop a peak-pressure indicator that he claimed to be simpler, more accurate and more easily understood than its English antecedent. Protected by US Patent 1950532 of 13th March 1934 (sought as early as November 1925), the Wasson design used a graduated sleeve and an electric lamp to show the point at which pressure of the spring balanced that in the cylinder. Whether Wasson's distinctive indicator was ever exploited commercially is currently unknown, but it undoubtedly influenced the patent granted in July 1936 to Rudolf Ulrich of Pittsburgh, Pennsylvania (US no. 2046801). This protected another modification of the Okill principle, but incorporating a lifter attached to the piston to activate a tension spring controlled by an indexing sleeve.

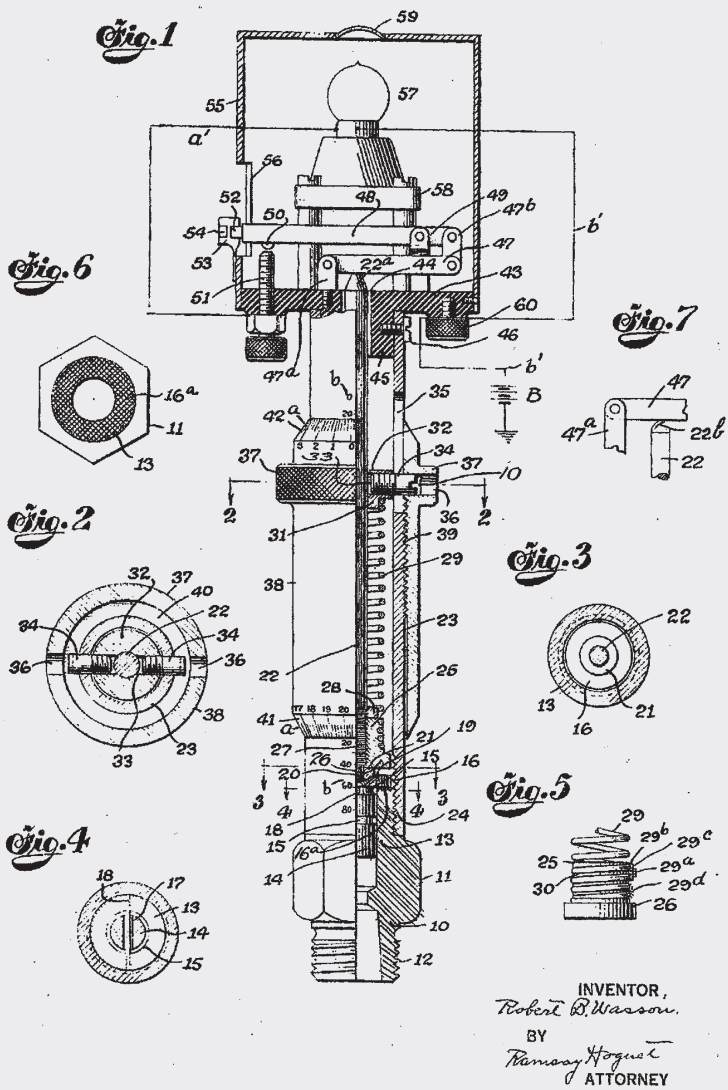
The Wasson and Ulrich patents were combined by the Bacharach Industrial Instrument Company in the 'Premax' peak-pressure indicator. Its operation was described in *Use of the Indicator for Diesel Engine Maintenance*, published by Bacharach, which stated that it was '…composed essentially of a piston exposed to the engine pressure, the helical tension spring against which the piston force acts, index sleeve, which is used to adjust the tension of the spring, and the contact of the neon circuit which gives a visual method of checking piston motion… By inspection [of a diagram] it is seen that a force upon the piston is transmitted to the spring through a pusher tube.

Plate 8–19, *right*. Drawings from the US patent granted to Robert Wasson in 1934. Note the light bulb. *By courtesy of the U.S. Government Patent Office, Washington DC.*

March 13, 1934. R. B. WASSON 1,950,532

PORTABLE PRESSURE GAUGE

Filed Nov. 20, 1925



The opposite end of the spring is connected to a micrometer sleeve so that in rotating this sleeve downward, the spring will be deflected, eventually giving a force which balances the upward thrust of the piston. A direct pressure reading can then be taken from the micrometer scales… A visual means is supplied for determining the equilibrium point and thus the compression or firing pressure. As the piston moves up due to the gas pressure, the switch closes and the neon light flashes. The circuit is broken when the cylinder pressure drops during expansion. A continuous flashing of the neon light occurs until the sleeve is rotated to stop the piston motion. When the exact point of balance between the two forces is reached, the switch will remain open [flashing ceases] and the cylinder pressure is…read from the micrometer.'

Plate 8–20, *below*. Bacharach-made Premax peak-pressure indicator no. 999, with the leads from the battery unit attached to the indicator body. *By courtesy of Bruce Babcock, Amanda, Ohio, USA.* **Plate 8–21**, *right*. Drawings from the patent protecting the Cookco peak-pressure indicator. *Courtesy of the U.S. Government Patent Office, Washington DC.*

Sept. 16, 1952 J. A. STEIN ET AL 2,610,508

PRESSURE INDICATOR

Filed Oct. 12, 1946 3 Sheets-Sheet 1

Fig. 1.

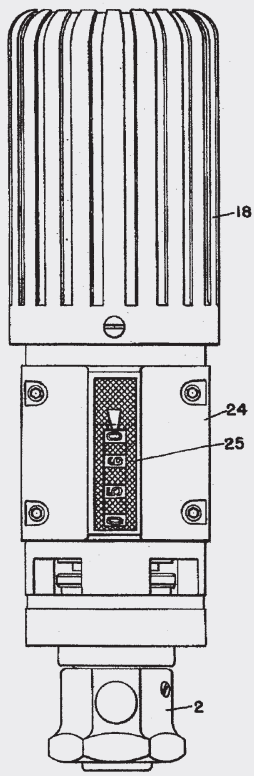


Fig. 10.

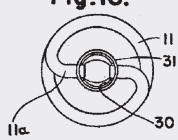
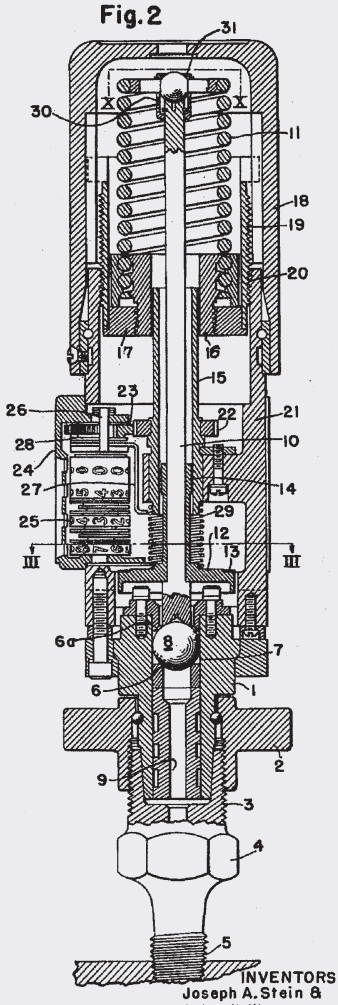


Fig. 2



INVENTORS
Joseph A. Stein &
John W. Wagner

BY J. E. Dickinson

ATTORNEY

Plates 8–22 and 8–23, *left and above*. The Cookco Ball-Check Indicator was made by Bacharach in the early 1950s for a major Chicago-based distributor. *Courtesy of Bruce Babcock, Amanda, Ohio, USA.* **Plate 8–24**, *right*. Drawings from the US Patent granted in 1932 to protect the original Kiene indicator. *By courtesy of the US Government Patent Office, Washington DC.*

Bacharach was also the assignee of a US Patent, no. 2610508, sought in October 1946 and granted in September 1952 to Joseph Stein and John Wagner, 'assignors to Bacharach Industrial Instrument Company, Pittsburgh, Pa., a corporation of Pennsylvania'. This design incorporated 'a pressure responsive device which creates an impulsive force that is utilised to act positively on the instrument to show that the peak cyclic pressure has been balanced and the value of the balanced peak pressure in terms of pounds pressure or otherwise [can be shown]'. The electrical circuitry of the Premax was abandoned in favour of a digital counter.

Peak-pressure indicators of this type were marketed in the early 1950s by the Cookco Engineering Company of Chicago, as the 'Cookco Ball-Check Indicator', though it is probable that they were actually made by Bacharach. Not only is the top cap marked MADE IN U.S.A. FOR, but the spring and the union nut are identical with standard Bacharach parts. The mark PAT. PENDING

April 21, 1942. W. J. KIENE 2,280,411

PRESSURE INDICATOR

Filed Jan. 3, 1939

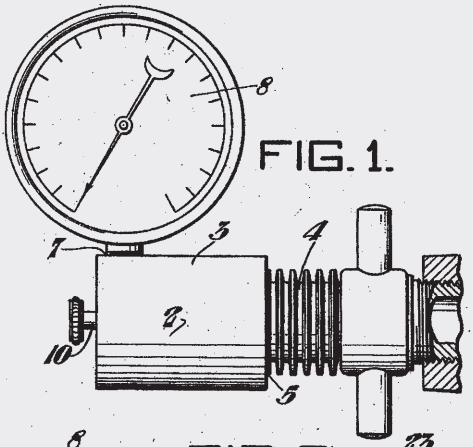


FIG. 1.

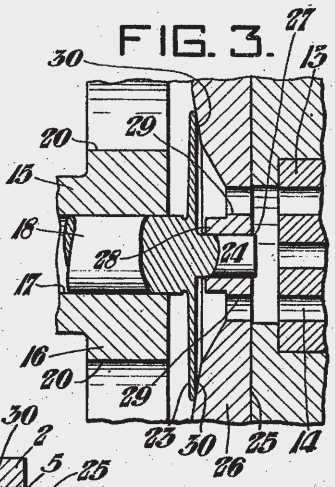


FIG. 3.

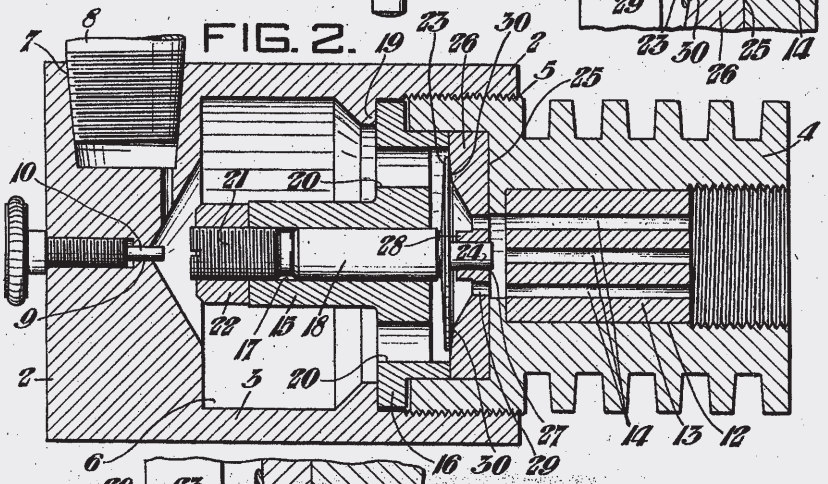


FIG. 2.

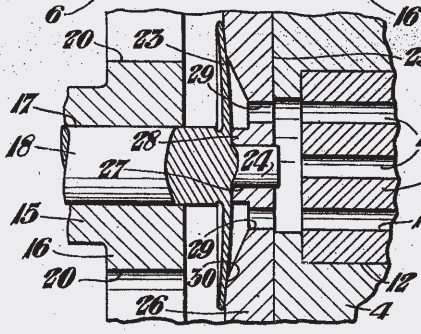


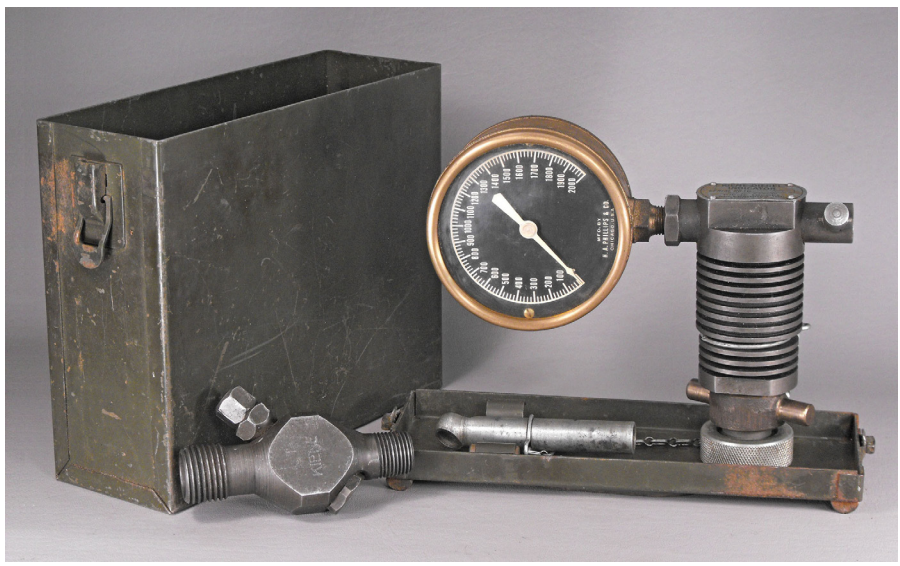
FIG. 4.

Inventor:
WILLIAM J. KIENE,
by: John E Jackson
his Attorney.

(together with an acknowledgement of the earlier US Patent 2046801) shows that the instrument was made prior to 1952.
An alternative method of analysing peak pressures was offered by William Kiene of Chicago, Illinois, who received US Patent 2280411 on 21st April 1942. In his patent, Kiene observed that various 'indicators and gages have been suggested and used for determining the maximum pressure in the cylinders of internal combustion engines, air compressors, liquid pumps, etc. The maximum pressure indicators commonly used employ pistons and springs and consequently are easily affected by dirt and gummy oil. They require careful handling and must not be allowed to overheat if they are to be at all accurate. They can only be operated continuously for short periods of time…' His solution has come to be known as a 'trapped pressure indicator'.

Kiene's instrument consisted of a cylindrical pressure chamber threaded onto the body, and a union-nut to attach the indicator to the cylinder block of the engine. The pressure in the cylinder passes through the union, then through a slotted brass filter and a copper screen to reach the adjustable

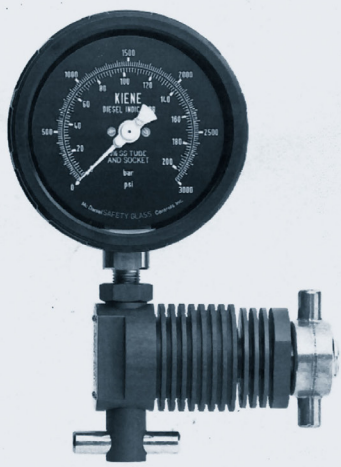
Plate 8–25, *below.* A Kiene K-100 indicator with its metal case. *By courtesy of Bruce Babcock, Amanda, Ohio, USA.* **Plate 8–26,** *right*. A page from the current Kiene advertising leaflet. The modern 'K'-series instruments are essentially similar to the 1942 patented version, but embody modern technology and materials in construction—for example, a liquid-filled Bourdon gauge. *By courtesy of Kiene Diesel Associates.*



Leaflet 100

KIENE®
DIESEL ACCESSORIES, INC.

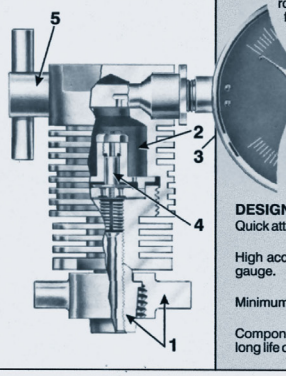
CYLINDER PRESSURE INDICATORS



(MODEL K-107 SHOWN)

INSTALLATION AND OPERATION

The indicator is installed on the indicator valve using the wing nut and plug (1). When the indicator valve is opened, the check valve (4) will rise and fall with the engine cylinder pressure, trapping the maximum pressure in the pressure chamber (2), and this average maximum pressure can be read directly on the dual scale pressure gauge (3). The gauge may be conveniently positioned for ease of reading by loosening the gauge bolt wing nut (5). The pressure in the pressure chamber (2) and on the pressure gauge (3) is removed by loosening the wing nut (5).



MEASURE FIRING AND COMPRESSION PRESSURE ON DIESEL AND NATURAL GAS ENGINES

Efficient diesel engine operation is important because it insures reduced maintenance and maximizes fuel economy and engine availability.

Diesel and natural gas engines operate most efficiently when each cylinder carries an equal portion of the total load. The most reliable method of measuring cylinder load is to measure the firing pressure of each cylinder.

The Kiene Cylinder Pressure Indicator has been the instrument of choice for engine owners and operators, engine manufacturers, and service personnel for over fifty years. By utilizing the Kiene Indicator, over and underloaded cylinders can be identified and the necessary corrective action initiated to maximize engine and/or cylinder operation.

The indicator attaches quickly and conveniently to any standard indicator valve. The "trapped pressure" design utilizes a light weight check valve, reducing the effects of inertia, insuring maintenance free operation and permitting the averaging of several pressure readings. Theliquid filled gauge provides a steady pointer for quick, accurate cylinder pressure readings in either psi or bars. The design of the indicator allows installation in a minimum amount of space, and attachment to the indicator valve in any position. The gauge can also be rotated at any point in a 360 degree arc for convenient reading.

If cylinder firing pressures are not being utilized to determine engine operation and condition, engine operation and its operating costs may be adversely affected.

Contact Kiene to learn how the Kiene Cylinder Pressure Indicator can improve your engine operation and reduce operating costs.

DESIGN FEATURES

Quick attachment to standard indicator valves.

High accuracy, liquid-filled, dual scale pressure gauge.

Minimum space required for installation.

Components designed for low maintenance, long life operation.

www.kienediesel.com

check valve. The valve takes the form of an inverted piston in a special seat, and is capable of sliding in its guide. When the engine pressure exceeds the pressure in the chamber of the indicator, the valve opens and gas flows until the pressure in the cylinder very slightly exceeds that in the engine. The valve

Plate 8–27, *right*. A page of drawings from the 1956 Schlaich patent. *By courtesy of the US Government Patent Office, Washington DC.*

then closes and the 'balancing pressure' can be read off the Bourdon gauge attached to the indicator body.

Among the advantages claimed for the trapped-pressure indicator, shared with the contemporaneous Bacharach Premax, was that the parts were all at rest by the time the reading was taken. This allowed accurate measurements to be obtained at virtually any engine speed.[3]

Kiene's design was exploited by Kiene Diesel Accessories, Inc., of Ainslie Street, Chicago, Illinois (now of Addison, Illinois), as the 'K-100'. A range of special indicator valves, 'V-10' to 'V-17' according to a leaflet dating from the late 1950s, was also made. Though copied many times, often without benefit of licence, the K-100 is still in production. According to a leaflet published in June 2006, the basic version had a liquid-filled Bourdon pressure gauge graduated 0–2000 lb/sq.in (0–140 bar); the K-107 and the K-108 were higher-pressure units graduated to 3000 and 3500 lb/sq.in (210 and 250 bar) respectively; and the K-109, for low pressures, was graduated to 600 lb/sq.in (40 bar). The indicators came in a synthetic case.

Another path was followed by the 'Moto-Meter' recorder—known in the USA as 'MoTest' or 'Mo-Test'—which was effectively a maximum-pressure indicator capable of showing the results of up to eight cylinders sequentially, or, alternatively, eight records from a single cylinder. The original patent, *Gerät zum Messen und Aufzeichnen des Kompressionsdruckes bei Mehrzylinder-Motoren* ('device for measuring and recording the compression pressures of multi-cylinder engines') was granted in Germany in September 1941 to Herman Schlaich of Elmhurst, New York.[4]

This patent has yet to be traced, but an application made in Switzerland on 1st October 1941 is undoubtedly comparable. The drawings accompanying the resulting Swiss Patent 225585 of 15th February 1943 are identical with those of the post-war German patent, with a trigger-type tablet-lifting mechanism on the side of the casing instead of the sliding plate on the rear. Schlaich received other relevant Swiss patents: 244635 of 30th September 1946, which shows an instrument with a finned cylindrical body and a pointer that was moved radially to its station and then rose vertically with pressure, and 251688 (15th

3. An improved design, with what was claimed to be a more efficient valve, was patented on 5th March 1968 (US Patent 3371537) after Kiene had retired to Miami, Florida.

4. The patent has yet to be found, but it is possible that, though granted, it had not been published by the time the Scond World War ended.

May 15, 1956 H. SCHLAICH 2,745,286

COMPRESSION MEASURING AND RECORDING INSTRUMENTS

Filed Nov. 23, 1951 2 Sheets-Sheet 1

Fig. 2

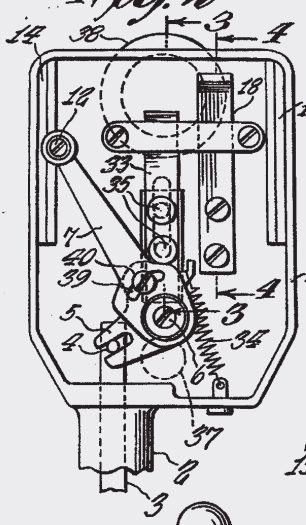


Fig. 1

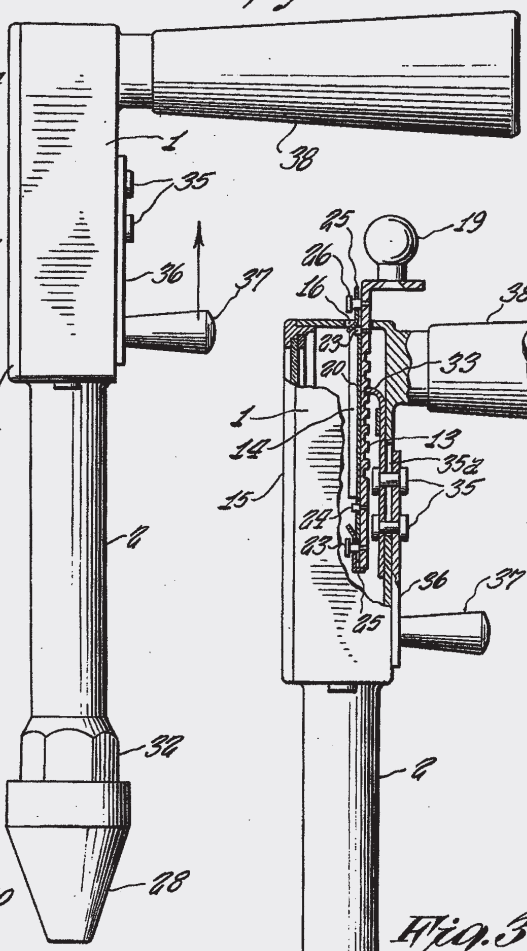


Fig. 4

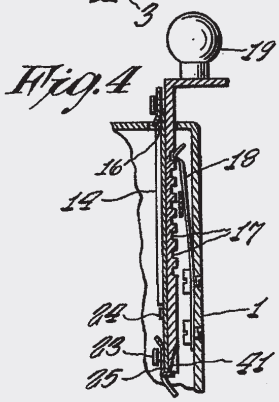


Fig. 5

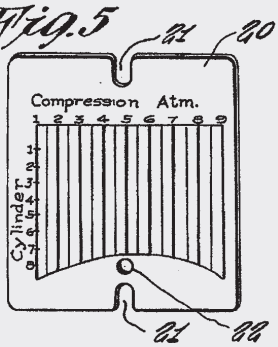


Fig. 3

INVENTOR.

Herman Schlaich

BY

Mason, Molte, Crews & Berry

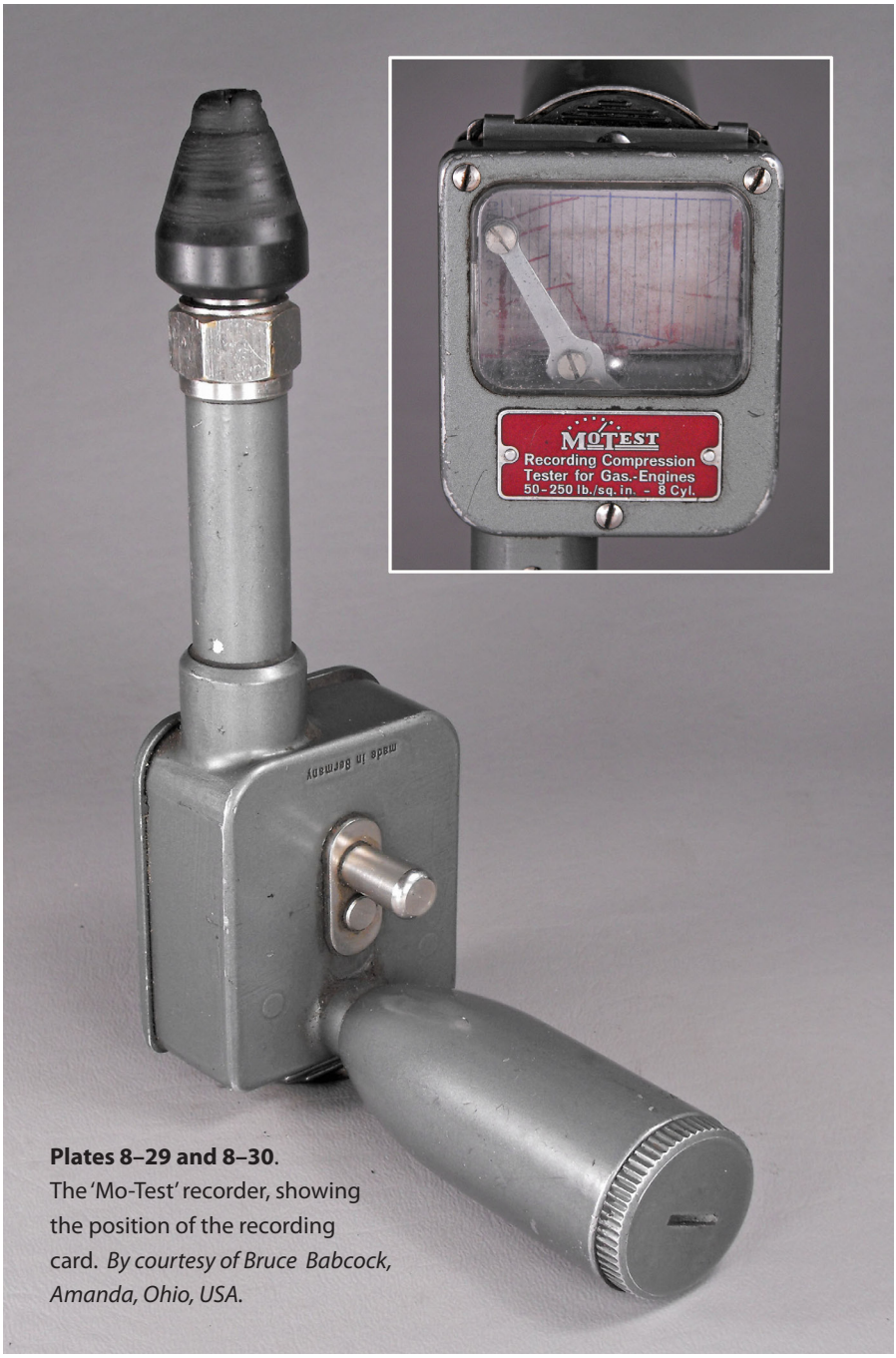
ATTORNEYS

November 1947), which protected a minor variant of the 1941 design with the sliding trigger and a 'zeroing screw' protruding from the base of the casing. At the end of the Second World War in May 1945, all German patent rights were appropriated by the Allied authorities. However, this soon caused hardship and so, in 1949, inventors were given the opportunity to re-submit claims. The specification for the Schlaich recorder was filed on 18th December 1952 and accepted on 23rd July 1953 as DBP 889078.[5] Protection had also been sought elsewhere: British Patent 741083 (filed 21st August 1951) and US Patent 2745286 of 15th May 1956, though sought in November 1951, are each broadly comparable. The latter records that Schlaich had died by the time of grant, naming his widow Lottie and his bankers as executors.

The Moto-Meter consists of a tubular body containing a piston and a box-like casing with a slot in the top. The casing contains an amplifying lever with an adjustable trace-point, and a card, attached to a tablet, which can be

5. The relevant British patent records the German application date as 25th November 1950; the discrepancy has yet to be resolved.

Plate 8–28, *below*. A typical 'Mo-Test' recorder with three of its extension tubes. *By courtesy of Bruce Babcock, Amanda, Ohio, USA.*



Plates 8–29 and 8–30.
The 'Mo-Test' recorder, showing the position of the recording card. *By courtesy of Bruce Babcock, Amanda, Ohio, USA.*

Plate 8–31, *right*. The current version of the 'MotoMeter' (the original European name for the 'Mo-Test') is shown in this leaflet, dating from 2009. The instrument is in many ways a fascinating survivor of an earlier age! *Author's collection.*

inserted in the slot. A handle protrudes from the back of the housing, above a sliding rod-like trigger which was used to lift the tablet for each successive record; a leaf spring engaging transverse grooves on the back of the tablet locked the mechanism in place.

The patent drawings show a variety of attachments between the Moto-Meter and the engine cylinder, including a small check-valve inside a rubber cone. This could be pushed into the spark-plug seat. Compression lifted the check valve, allowing air to flow through the spring chamber and up longitudinal grooves cut in the axial adjusting screw to raise the piston.[6] The short axial movement of the piston was translated into an amplified radial movement of the rocking lever, allowing the tracer to draw an arc on the card. The length of the arc was directly proportional to the compression pressure. Herman Schlaich claimed that '…a particular object [of the invention] is to provide an instrument which may be handled with one hand, moved rapidly from cylinder to cylinder and manipulated so as to make a separate record of the compression is each of the successive cylinders. Another object…is to provide a construction in which record sheets may be readily inserted and rapidly changed.' These the Moto-Meter achieved surprisingly successfully; despite its pre-war origins, the instrument is still being successfully marketed.

The earliest examples were made by Moto-Meter Hermann Schlaich GmbH, founded in Stuttgart in 1925 and registered with the local commercial authorities in 1926. The business became successively 'Moto Meter GmbH' (1969, with headquarters in Leonberg), 'Moto Meter AG' (1977) and 'MM Messtechnik GmbH' (1992). At this point, interest in the recorder seems to have ceased. However, rights to the device and the Moto-Meter trademark were acquired in 1996 by Iveka–Automotive Technologies Schauz GmbH of Mühlacker-Lomersheim and production recommenced.

The earliest Moto-Meters had a bottle-like handle, but this eventually became a tapered tube. The cases were wooden, later examples bearing the manufacturer's logo on top of the lid, but the size and internal portioning varied according to the variety of accessories—in particular, to the number

6. An additional German patent was granted on 26th March 1959 (DBP 1053817, sought on 27th August 1952) to protect the design of the extenders and modifications to their valve construction. This protedction does not seem to have been sought elsewhere.

of adaptors that were supplied. The partitioning was also generally wooden, though some of the last of the wooden boxes had vacuum-formed plastic liners; IVEKA instruments are supplied in moulded synthetic cases. Double-instrument sets are common, as the 2010 Moto-Meter catalogues offer three basic pressure ranges for 'Otto-Motoren' (petrol engines) and eight ranges for 'Dieselmotoren'.

Among the accessories are a remote-control trigger, several extenders (including one with a flexible shaft), three types of rubber cone and six threaded spark-plug seat adaptors. The current Moto-Meters also have red plastic tablets instead of the original metal fabrications, and the design of the piston housing ('body') is noticeably more angular than tubular.