Paxman's Seventy-Five Years of Diesel Engine Development (1925-2000)

Richard Carr
Paxman Archive Trust

Abstract: An introduction to the early history of Davey, Paxman & Co Ltd of Colchester and its steam engineering heritage; the Company's early work with horizontal spark-ignition engines and a semi-diesel; the development of Paxman's first compression-ignition, spring injection, heavy oil engine, in the 1920s; the subsequent introduction of turbocharging and of full pressure-lubrication, permitting higher engine speeds and longer periods of unmanned running; the innovation of welded steel engine frames; Paxman's development of indirect-injection; high-speed diesels featuring Ricardo 'Comet' combustion chambers; the introduction of vee-form engine designs, with fork and blade connecting rods and underslung crankshafts; development of the wartime 12TP engine for tank landing craft and its post-war version, the RPH, for commercial applications; the adoption of direct-injection and four-valve cylinder heads in the early 1950s; the development of the Ventura engine in the late 1950s and of its successor, the Valenta, which powered Britain's High Speed Train to world speed records; and the design of the last Paxman high-speed diesel, the VP185, featuring an innovatory two-stage turbocharging arrangement with intercooling and aftercooling.

Keywords: Paxman, oil engine, compression-ignition, large high-speed diesels, bedplate, underslung crankshaft, pressure-lubrication, indirect and direct fuel injection, Ricardo Comet combustion chamber, vee-form engines, fork and blade connecting rods, turbocharging, fabricated crankcases, railway traction.

The Founding of Paxman

James Paxman founded the Paxman business with the help of two financial backers, the brothers Henry and Charles Davey, in 1865 in Colchester, Essex. At that time the economy of north-east Essex was predominantly rural and agricultural. The Colchester area had no strong tradition of engineering or manufacturing. James Paxman was a man of considerable persuasive charm, a talented engineer and possessed of great energy and drive. He was aged only thirty-three when he set up in business but had already acquired good practical experience of steam engineering with his former employer. James Paxman quickly developed a reputation for designing and making efficient boilers. The design and manufacture of steam engines soon followed. It was on these two products, boilers and steam engines, that the early success of the business was built.

From Steam to Internal Combustion Engines

The move into internal combustion engines started relatively slowly and uncertainly, but Paxman's experience of designing and building steam engines provided a useful foundation. It is worth noting the similarities of technology and components between the two types. Both have cylinders, pistons, connecting rods, crankshafts, valve gear and speed governors. Both require a good understanding of the laws of physics applicable to the expansion of gases and the principles of thermodynamics.

Paxman did not build its first development compression-ignition (i.e. diesel) engine until as late as 1925. Yet, within twenty-five years it had established a reputation for making larger high-speed diesels, the type in which it has specialised ever since and for which it became an acknowledged world leader. Before tracing the history of Paxman's development of its diesel engines, it is appropriate to provide a brief overview of the company's earlier involvement with spark-ignition engines and an experimental semi-diesel.

In September 1903 Paxman announced its intention to commence manufacturing gas and oil engines when it advertised for 'a sound practical Engineer, thoroughly conversant with engines of this type'.[1] It is thought the company produced its first gas engine in 1904 but there is evidence to suggest that it took another two or three years to overcome problems in developing a marketable oil engine. The gas engines were designed to run on town gas or producer gas and the oil engines on 'light spirits' such as benzine, petrol or naphtha, Figure 1. The gas engines sold well and considerable numbers of the benzine variant were built. They were all horizontal types and mostly single-cylinder with magneto-ignition and 'hit and miss' governors.

In the early years of the twentieth century there was growing interest in the diesel engine and in 1903 James Paxman expressed an interest in manufacturing Diesel's engines under licence if suitable terms could be agreed.[2] Several years of discussion and negotiation followed but these seem to have collapsed finally in spring 1912.[3] The following year Paxman built a prototype semi-diesel oil engine. In a surviving copy order book there is an order dated 3 October 1913 for a 'Crude Oil Engine' for Paxman. This was for a 10¾" bore x 16" stroke gas engine to be converted to a 22 bhp crude oil engine 'for urgent completion'.[4] In an old photograph this experimental engine bears a very close resemblance to the Akroyd Stuart design on which the patents had by now expired. We hear no more about this engine. William Judd, the company's oil and gas engine expert, died unexpectedly in November 1913 and with the outbreak of war in 1914 Paxman became fully occupied with war work.

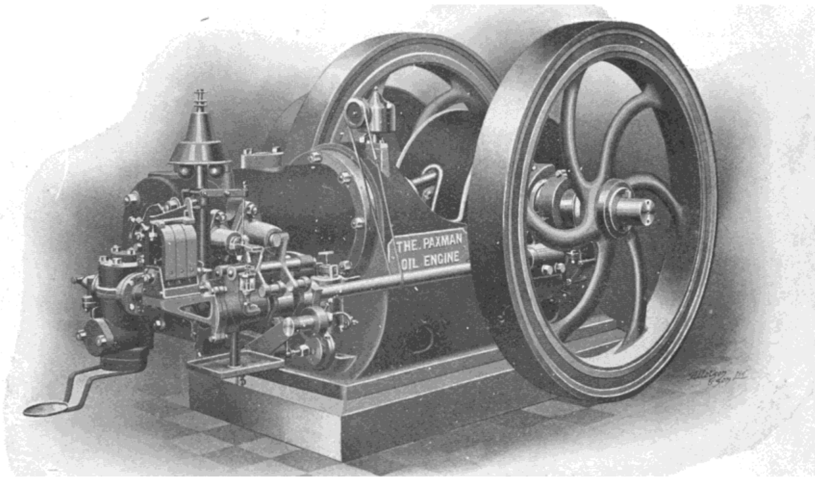

Figure 1. Early Paxman spark-ignition oil engine running on 'light spirits'.

There is no evidence of Paxman doing any work on developing an oil engine in the years just after the Great War. That is not entirely surprising. By the end of that war James Paxman was an old man of 86 and his son William, who was his intended successor, had not inherited his father's entrepreneurial or engineering flair. The company's plant and machinery was in a poor state after four unremitting years of war production. Cash was short and valuable pre-war export markets, which the company had been unable to supply during the war years, had been lost to foreign competitors. The next few years were very difficult and the management's time and energies were taken up with what must have appeared more pressing matters than the development of an oil engine.

One possible reason for the lack of any work on an oil engine in the immediate post-war years may have been the company's membership of Agricultural & General Engineers (AGE), a combine of fourteen engineering companies, mostly based in East Anglia, formed shortly after the War. At that time most of the member companies were struggling financially and they banded together in the hope that as a larger group they would be stronger to compete in international markets. In home markets it was AGE policy that member companies would each restrict themselves to making and marketing their own types of product to avoid competing against each other. One AGE company was Blackstone at Stamford which was, at that time, an established and successful manufacturer of oil engines. With AGE's policy of member companies not competing against each other, one can see why Paxman may have been dissuaded from developing its own oil engines. The irony is that Paxman's first true compression-ignition engines owed virtually everything to Blackstone technology and designs.

James Paxman's youngest son, by his third wife, was Edward, known to his family and friends as Ted. Compared with William, Edward was a man much more in his father's mould. He was a keen, able and visionary engineer, endowed with his father's friendly charm, drive and energy. After gaining a First Class Honours degree in Engineering at Cambridge in 1923, he went to acquire some industrial experience, first with Metropolitan-Vickers at Trafford Park, Manchester and then with Blackstone at Stamford.

It is possible, if not highly probable, that Edward's passion for the oil engine was fired by his experience at Stamford. At about the time he was at Stamford, Blackstone invented its patent 'spring injection' system in 1924, Figure 2. Up to that time most diesel engines employed air-blast injection in which fuel was blasted into the cylinders by compressed air. Spring injection was a solid injection technology, as are all present-day diesel engine fuel injection systems. Blackstone's spring injection system proved to be highly successful during the latter half of the 1920s. Fuel was fed by a low-pressure pump to a chamber in the cylinder head in which it was subjected to pressure immediately prior to injection. It is difficult not to imagine Edward Paxman enthusing about this new technology, and its implications for the potential of the oil engine, during home visits to Colchester while he was working at Stamford. As a young man about to join his family's firm, which he did in 1926, he would be looking to the future. He must have been acutely aware of the fact that the types of steam engine, which were then a mainstay of the Paxman business, were coming to the end of their day and rapidly being replaced by the oil engine as a prime mover. The oil engine was the direction in which his company needed to go.

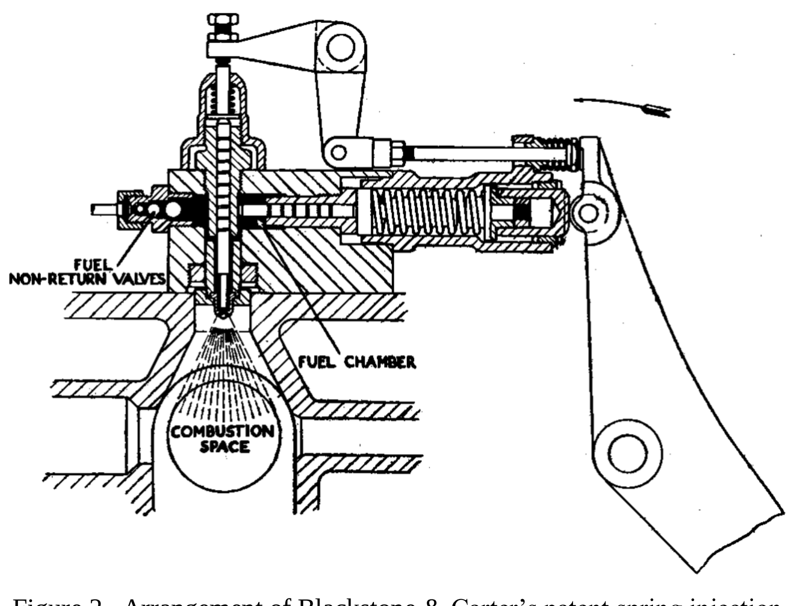

Figure 2. Arrangement of Blackstone & Carter's patent spring injection.

Cold-Starting Vertical Heavy-Fuel-Oil Engines

As previously noted, Paxman built its first true compression-ignition engine, a development prototype, in 1925. It was a vertical heavy-fuel-oil engine using Blackstone's spring injection. Those who have worked on early Paxman engines of this type and Blackstone engines of the same period say that in other respects also they are basically the same design. The only significant difference is that the Paxman was a vertical type whereas all Blackstone's were horizontal types. That raises the question of why AGE, with its policy of member companies not having overlapping or competing products, allowed Paxman to use Blackstone's designs and technology. And why would Blackstone have agreed to Paxman using its technology and becoming a competitor in the oil engine market? It is possible that Paxman had previously given Blackstone some financial support and that this was a *quid pro quo*. The author thinks that Paxman must have persuaded AGE that the vertical engine was aimed at a different market from the Blackstone horizontals and that the two companies would not therefore find themselves competing with each other. Paxman's earliest publicity brochures for its new oil engine show that, initially, it was clearly aimed at the marine market for which the horizontal type would have been entirely unsuitable.[5] Although that may have been Paxman's original intention, it was in fact land-based, not marine, applications that became the most important market for the company's first generation of diesel engines.

Paxman spent two years on tests and trials of its first oil engines before introducing them to the market in 1927. That was remarkably late in the history of the diesel engine for a company to enter a market in which it was to become a world leader.

What might be described as Paxman's first generation of compression ignition engines, launched in 1927, were described in the company's advertising literature as 'Cold-Starting Vertical Heavy-Fuel-Oil Engines'.[6] Unlike many other oil engines of the time, they could be started without using an external source of heat such as a blowlamp or initial fuelling with petrol or paraffin. They could also be started against partial load that for some applications obviated the need for a friction clutch. Like all subsequent Paxman-designed diesels they were four-stroke types, which the company argued were more economical to run, more reliable and less costly to maintain than two stroke designs.

In a 1927 catalogue this first range of engines was offered in seven different cylinder bore sizes (although the bore and stroke dimensions were not disclosed). There is only evidence of these engines being built in four different cylinder sizes. The smallest, the VF, was 8½" bore x 12" stroke with a normal power output of 25 bhp per cylinder at 360 rpm. The largest to make it into production, the VN type, was 15½" bore x 20" stroke and produced 105 bhp per cylinder at 270 rpm, later increased to 116.6 bhp per cylinder at 300 rpm, Figure 3.

The Paxman Heavy-Fuel-Oil Engine had a substantial cast-iron bedplate which carried the main bearings. The crankshaft was secured to the bedplate by

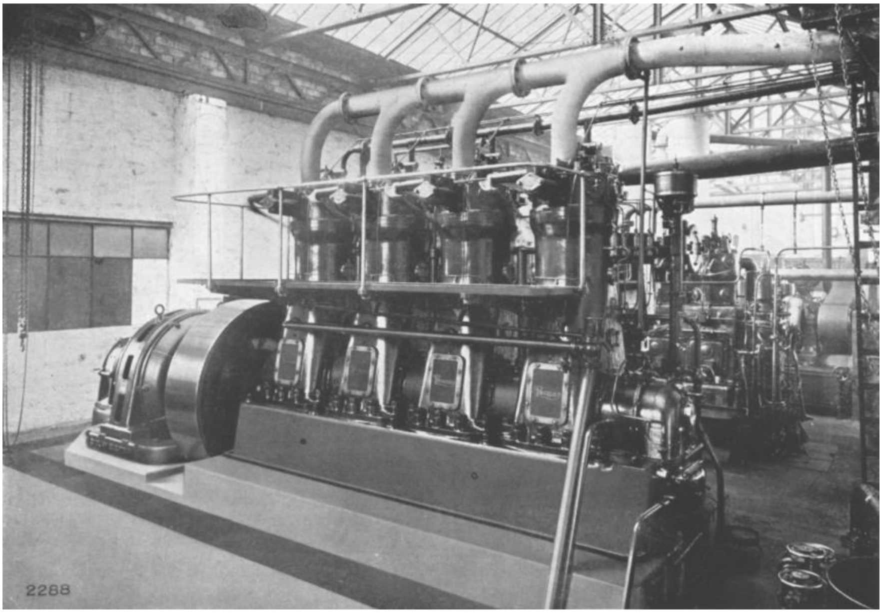

Figure 3. Paxman 4-cylinder VN engine installed at Rosyth Dockyard in 1928.

covers or bearing caps bolted down over each main bearing. Between each main bearing was an individual cylinder casting or stand, the lower part of which was an ‘A’ frame supporting the cylinder itself. The latter housed a detachable cylinder liner, the lower end of which was free to expand and contract with changes in working temperature. The lower part of each cylinder stand formed the crankcase for the relevant crank and had detachable covers to allow easy access to the big end bearing. Mounted on top of the cylinder stand was the cylinder head which incorporated the inlet and exhaust valves and the spring fuel injector.[7]

The feature of individual cylinder castings made it practical to vary the number of cylinders per engine, from one up to eight, simply by assembling the requisite number of individual castings. For each engine of a particular bore size, regardless of number of cylinders, all components could thus be standard with the exception of the bedplate, crankshaft and camshaft.

Although Paxman was a late entrant in the diesel engine business, once it got started the developments came thick and fast. In 1929 the company introduced a version of its heavy-fuel-oil engine, which was described as ‘Enclosed Type – Forced Lubricated’, Figure 4. The original engine was an ‘open’ type on which the camshaft and valve operating gear were not enclosed. The sides of the crankcase sections of cylinder stands were also open, having louvered ventilation covers. Ring oilers lubricated the crankshaft and camshaft bearings. Lubrication of cylinders and connecting-rod bearings, both big and small end, was by means of a mechanical forced drip-feed lubricator.

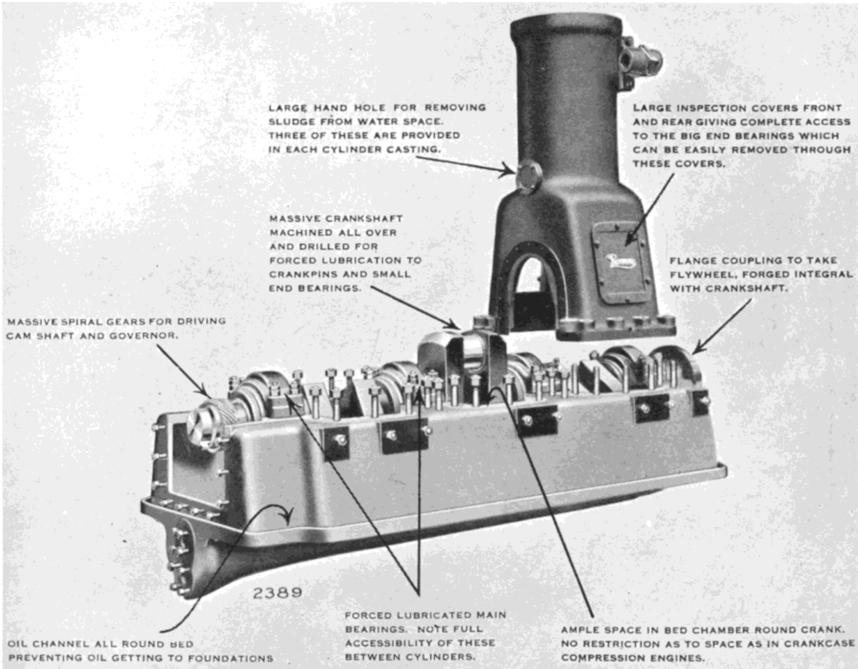

Figure 4. Bedplate, crankshaft and cylinder casting of a Heavy-Fuel-Oil Engine.

The ‘Enclosed Type – Forced Lubricated’ version of the engine featured a pump circulating oil through the main bearings and via the crankshaft to the large and small end bearings of the connecting rods. The crankcases were enclosed: a necessity with the larger quantities of oil now being thrown out from pressure-lubricated bearings. However, the camshaft remained open and camshaft bearings were still ring oiled. The improved lubrication arrangements made it possible to run engines for longer periods unattended and at higher speeds with proportional increases in power output. The enclosed version of the VF, the VFE, had a normal load of 35 bhp per cylinder at 500 rpm compared with the VF’s 25 bhp at 360 rpm: a 40% increase in power.

Another major advance in 1929 was the introduction of turbocharging. In this year two large 8-cylinder turbocharged engines were built and installed at local authority power stations, one at Basingstoke and one at Ashford in Kent. They were claimed to be the first Büchi turbocharged diesels, that is, with exhaust gas driven turbochargers, to be put to work commercially on any land installation in the British Isles. They were also the two largest airless-injection pressure-charged engines in ordinary commercial use in Britain at the time. At a retirement dinner in 1947, referring to a naturally-aspirated version of this engine installed at Basingstoke the previous year, Edward Paxman remarked ‘within three or four years of starting (*to make oil engines*) we built the largest engine in the country’.[8]

Paxman's Heavy Duty Diesel Engines

Paxman's second generation of compression-ignition engines was its Heavy Duty Diesel, launched at the British Industries Fair, Birmingham in February 1931.[9] This was the company's first 'monobloc' type. Like the earlier Heavy-Fuel-Oil engine it had a substantial cast-iron bedplate carrying the main bearings and crankshaft. The cylinder liners, however, were no longer housed in individual cylinder castings or stands but in a single cast-iron cylinder block. This monobloc was mounted on 'A' frames that sat on the bedplate and formed the crank chamber. The block was tied to the bedplate by long high-tensile through-bolts that passed through the block and the A frames to the underside of the bedplate. The bolts were tightened to a tension greater than that which could be imposed on them by the firing loads of the engine. As a result the cast-iron framing was always in compression, not in tension, which made for great rigidity of the framework and allowed the crankcase inspection doors to be of generous size.[10]

Reference has previously been made to some of the benefits of full pressure-lubrication which include being able to run engines at higher speeds, to run them for longer periods unattended, longer bearing life and better cooling of moving parts. From the start Paxman's Heavy Duty Diesel was designed to be fully enclosed and pressure-lubricated throughout. All moving parts except the flywheel were now enclosed, a feature which allowed the use of full pressure-lubrication not only for the main and connecting rods bearings but also for camshaft bearings and valve gear.

Initially the Heavy Duty Diesel was fitted with a spring injection fuel system like its predecessor. Although spring injection ha d been highly successful on the Heavy-Fuel-Oil engine it did not work so well at the higher speeds for which the new engine was designed. Very soon it was superseded by the Bosch fuel injection system which had been brought out in 1927.

The Heavy Duty Diesel was offered in three cylinder-bore sizes, Figure 5. Surviving records suggest that only six engines of the largest bore size, the 13" bore VY or VYL, were built. All other sales were of the VZ, which had a 6½" bore x 10" stroke and produced 25 bhp per cylinder at 750 rpm, and the VX of 9" or 9½" bore x 12" stroke, producing 50 bhp per cylinder at 600 rpm (normal loads).

The launch of this engine in February 1931 was not the only major landmark that year in Paxman's diesel engine development. At the Shipping, Engineering & Machinery Exhibition at Olympia in September the company displayed a welded steel frame version of its new engine.[11] Paxman was the first firm in Britain to construct diesel engines with entirely welded steel framework, using a design patented by a Mr C. H. Stevens of the Steel Barrel Company Ltd, Uxbridge, Figure 6.

The frame was designed so that all the firing stresses were taken direct from the cylinder head right down to the seating of the crankshaft bearings in continuous steel plates or slings, without any load being imposed on the welding. The vertical

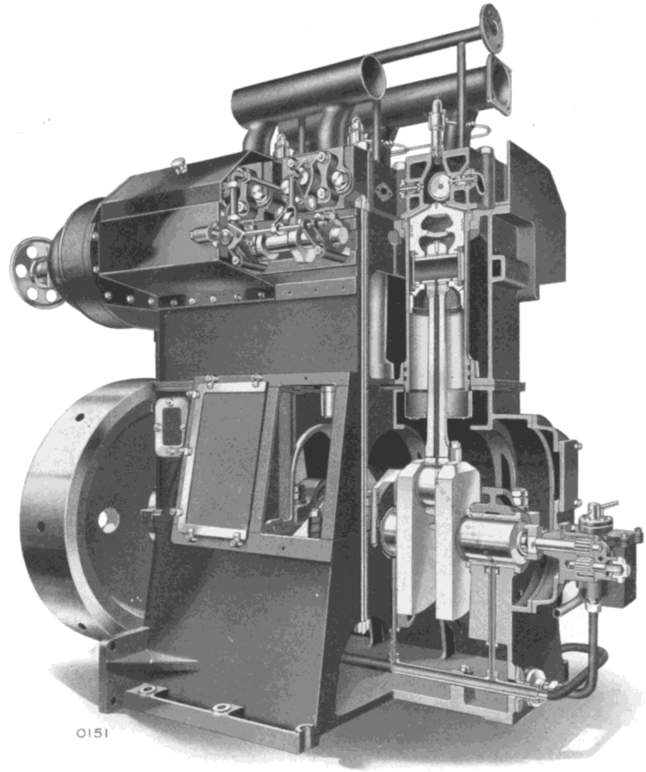

Figure 5. Sectional view of a Paxman Heavy Duty Diesel Engine

plates or slings were held together by two suitably slotted horizontal plates, which were worked into position and welded to them. The top plate acted as a seating for the cylinder heads while the lower plate served as a housing for the cylinder liners. It was claimed that the simplicity of the construction allowed access to all parts of the framework, making it possible to achieve good quality welds throughout the whole structure.[12]

The advantage of welded steel-frame construction was a major reduction in engine weight combined with great strength. The weight of the framework itself was less than half that of the equivalent cast-iron version. The much lighter weight of the steel framed versions of the engines, which retained the power output and robustness of their cast-iron equivalents, made them suitable for new applications where weight was an important factor. Perhaps the most significant of these was rail traction. Paxman supplied two steel-framed engines to the LMS Railway in the early 1930s for experimental locomotives. One was a 6-cylinder VXS rated at 412 bhp at 750 rpm, Figure 7, the other a 6-cylinder VZS rated at 180 bhp at 900 rpm.[13] Supplying diesels for rail traction was to become a major source of business for Paxman throughout the second half of the twentieth century.

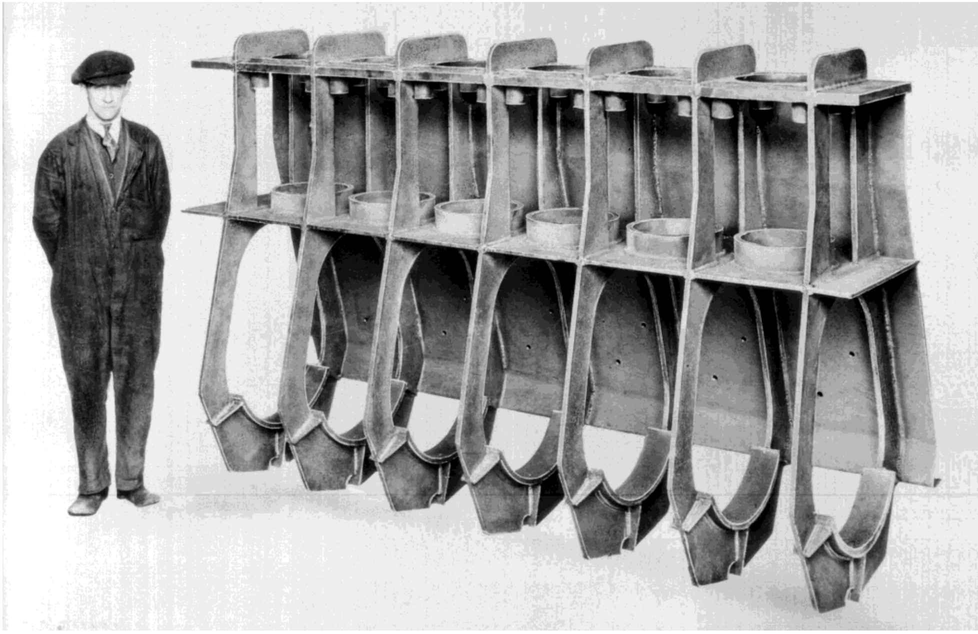

Figure 6. Stevens' patent welded steel engine frame.

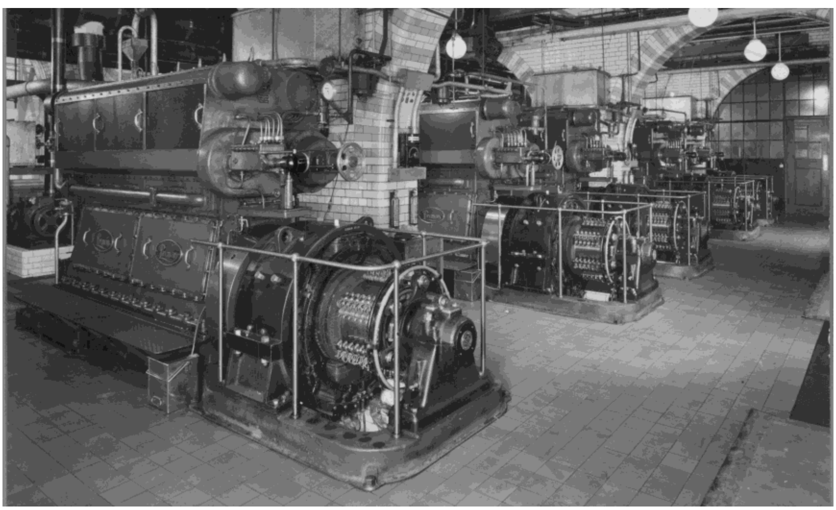

Figure 7. 6-cylinder VX engines installed at Prudential Assurance Head Office.

Many of the standard cast-iron through-bolt construction Heavy Duty Diesels were sold for electrical power generation applications in one form or another. These included land-based commercial and industrial installations, marine auxiliaries on board naval, cargo and passenger vessels, and diesel-electric marine propulsion. One prestigious contract was for four 8-cylinder VX engines for the

Bank of England and another was for five 6-cylinder VXs for the Head Office of the Prudential Assurance Company in Holborn, both for power generation.[14] Other Heavy Duty Diesels were sold for driving pumps in municipal waterworks.

Paxman-Ricardo Engines – High-Speed and Indirect Injection

In 1932 the AGE combine crashed, ending up in the bankruptcy courts and taking Paxman and the other thirteen associated companies with it. Although Paxman had been profitable before the crash, there was for some months great uncertainty about its future. Eventually a financial rescue package was put together and a new Board of Directors appointed with Edward Paxman as Joint Managing Director. Despite the enormous upheaval caused by the collapse of AGE, it was not long before Paxman embarked on the development of its third generation of diesels. These were described as high-speed diesels - high-speed relative to the speeds of other diesels of similar size at that time. The step was highly significant for the future direction of the company. It set Paxman on the path of what was to become its specialist field of designing and building larger high-speed diesels. Edward Paxman was now firmly in the driving seat of the diesel engine side of the business. He was a man who enjoyed living life in the fast lane. Among other things he was a keen participant in motor sport and speed clearly had a great attraction for him. In association with Harry (later Sir Harry) Ricardo, founder of the world famous engine consultancy, the Paxman-Ricardo range of engines was developed. The first, the RQ, was launched in 1934. A key feature of these engines was the use of indirect fuel injection via a Ricardo Comet chamber in the cylinder head, Figure 8. Fuel is injected not directly into the cylinder but into a small spherical chamber adjoining it. Combustion starts in this chamber before travelling along a small passage or throat connecting it to the cylinder.

Direct and indirect injection each has their merits and limitations. Indirect injection does not require such high injection pressures and is quieter running than direct injection. The pintle type injector nozzle used for indirect injection has a self-cleaning action, unlike the multi-jet nozzles necessary for direct injection in which the small holes are more liable to blockage. The Comet chamber arrangement also produces very good combustion, resulting in a clean exhaust with no trace of black smoke. Among the drawbacks of indirect injection are more difficult starting in cold conditions, higher fuel consumption and limited benefits from turbocharging.

The Ricardo Comet cylinder head was to remain a feature of all subsequent Paxman engines until the introduction of direct injection types in the early 1950s. The pre-World War 2 range of Paxman-Ricardo engines was expanded until it included the RQ, RW, RZ and RX/RXL types. These had cylinder bore sizes of $4^5/_8$", 5½", $6^7/_8$" and 9½" respectively. Both the RQ and RW could be run at speeds up to 1,500 rpm; the RQ producing up to 15 bhp per cylinder and the RW 28 bhp per cylinder. The RX could be run at a maximum of 750 rpm, producing 70 bhp per

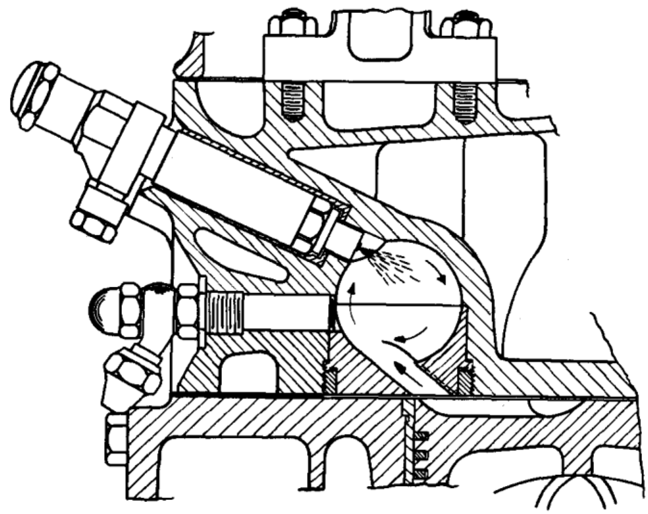

Figure 8. Paxman-Ricardo 'Comet' cylinder head.

cylinder in its naturally aspirated form. The main application for Paxman-Ricardo engines was power generation but some were sold for marine propulsion. The six cylinder RXS, constructed with a fabricated steel frame, powered some of the British 'U' Class and all of the 'V' Class submarines built during World War 2.

Paxman's First Vee-Form Engines

The next big step for Paxman came only a year after the launch of the RQ. At Olympia in 1935 the company exhibited its first vee-form engine, the 6½" bore x 7½" stroke VeeRA, Figure 9.[15] The progression from an in-line to a vee form cylinder configuration was not the only innovation in this engine. Another new feature was the use of fork and blade connecting rods. The VeeRA was the first in a line of Paxman vee form engines with fork and blade connecting rods, predominantly 12-cylinder types but including 6, 8, 16 and 18-cylinder versions.

Those unfamiliar with the fork and blade arrangement may find a brief description and explanation helpful. The simpler, cheaper and more common arrangement in vee form engines is side-by-side connecting rods. In this, the big end of a connecting rod attached to a piston in one bank (side) of the engine runs side-by-side on the same crankpin as the big end of the connecting rod attached to the corresponding piston in the other bank. As a consequence the cylinders of one bank cannot be placed directly opposite the corresponding cylinders of the other bank. The cylinders on opposite banks have to be staggered, resulting in a longer engine. The fork and blade arrangement, Figure 10, allows the cylinders of one bank to be located directly opposite those of the other bank, making it possible to design a shorter, more compact engine. The connecting rod attached to the piston

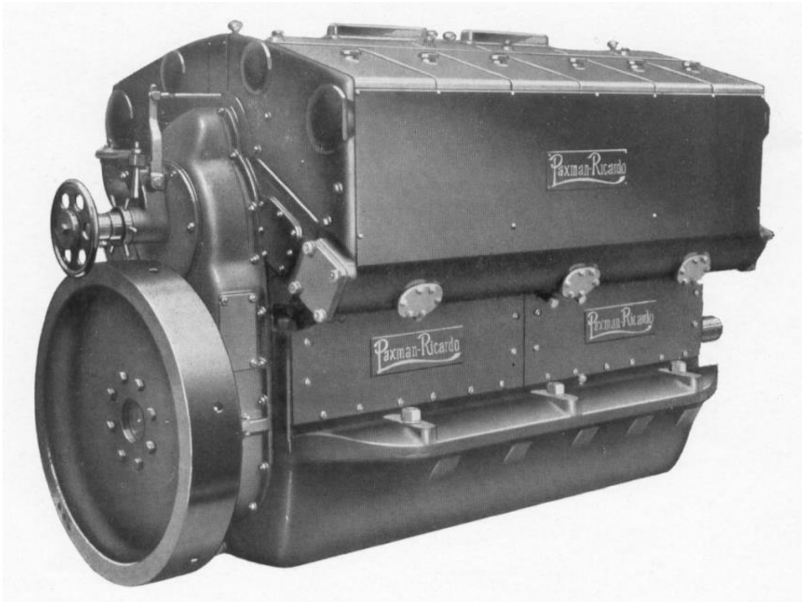

Figure 9. The 12-cylinder VeeRA engine.

of one bank is forked at its lower end, with the fork being attached to a bearing block which runs on the crankpin. The connecting rod attached to the corresponding piston of the other bank has a thin 'blade' big end which fits within the fork of the other connecting rod and runs on the bearing block, not the crankpin.

Nearly all VeeRA engines were built as 12-cylinder types but surviving Paxman records suggest that not many were made. The VeeRA does not appear to have been a great success and was soon superseded by the VeeRB, introduced in 1937. The VeeRB’s cylinder dimensions, 7" bore x 7¾" stroke, were fractionally larger than those of the VeeRA. A much greater and more important change was the move to an underslung crankshaft that substantially reduced engine weight. All earlier Paxman engines had been built on a bedplate that carried the crankshaft. The VeeRB had no bedplate, the crankshaft being carried in bearings in the main engine block, held in place by bearing caps.

The VeeRB was a far more successful design than the VeeRA and earned some fame. A 16-cylinder version had a two-hour rating of 1,000 hp at 1,750 rpm, and a continuous rating of 800 hp at 1,500 rpm. Two of these engines were installed in a twin-screw experimental motor torpedo boat “Tarret”' which set the world speed record for diesel marine propulsion in 1938.[16] Sets of three 16-cylinder VeeRBs were the propulsion engines for the triple-screw Gay Viking class of fast merchantmen which ran the German blockade of the Skagerrak to bring vital ball bearings from Sweden to the UK during World War 2.[17]

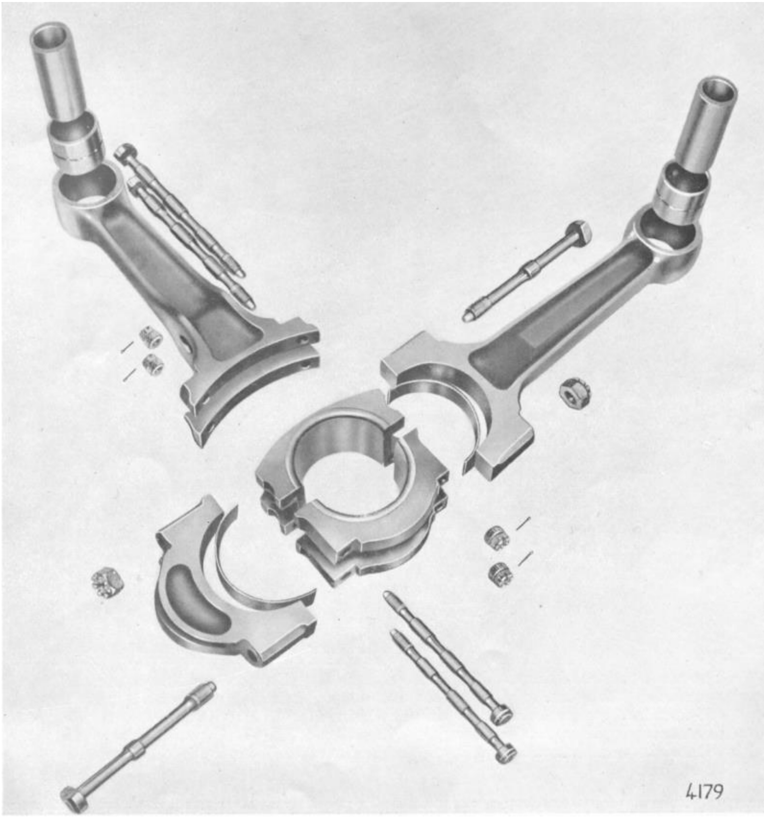

Figure 10. Components of fork and blade connecting rod assembly

The VeeRB is another notable landmark in the history of Paxman's diesel engine development, Figure 11. It was the first of a series of Paxman vee form 7" bore x 7¾" stroke engines with underslung crankshafts. Direct descendants of this engine were the wartime 12TP, the post-war RPH and the later YH.

The Wartime 12TP

In 1940, after the German Blitzkrieg which led to Dunkirk and the Fall of France, Churchill recognised that taking the fight back to mainland Europe would require large numbers of tank landing craft and suitable engines to power them. By this time Paxman was well-known to the Admiralty. In addition to its previous involvement with Tarret, the company was now building submarine engines for the Royal Navy and supplying diesel auxiliaries for power generation on board British warships. Edward Paxman was summoned to a meeting at the Admiralty to discuss how engines suitable for landing craft could be manufactured in quantity.

The VeeRB had the necessary power output for the purpose but its main block, incorporating the crankcase and both banks of cylinder blocks, was a

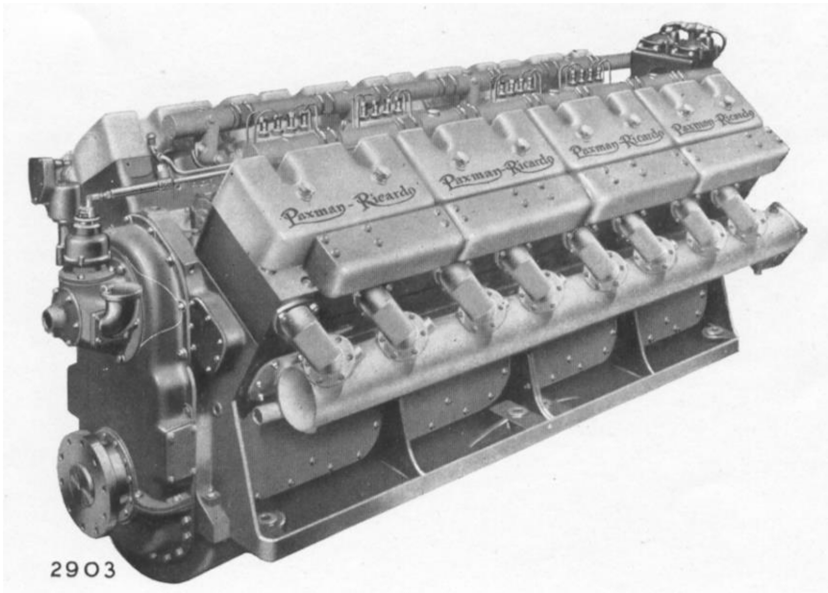

Figure 11. 16-cylinder Paxman VeeRB engine.

complex single casting and unwieldy for machining on account of its size. While being within the capabilities of Paxman, few other engineering concerns at the time would have had the necessary skills and facilities to cast and machine the block successfully or in volume. Paxman's Standard Works was already fully occupied with other vital war work and had little spare capacity. The VeeRB was therefore redesigned and broken down into more manageable elements that could be handled by small sub-contract workshops. The outcome was the 12TP, a 12-cylinder engine with a rating of 600 bhp at 1,500 rpm. It is said by some that the TP designation was short for 'three pieces', referring to the split of the original engine block into three main parts: the crankcase and two banks of cylinder blocks, or according to another opinion: crankcase, cylinder blocks, and cylinder heads. Over 400 engineering concerns, large and small, up and down the country were enlisted to manufacture parts for the 12TP. For the assembly and test of these engines the Ministry of Supply took over the then derelict Britannia Works in Colchester, not far from Standard Works. The 'Brit', as it became known, was managed by Paxman on behalf of the Ministry of Supply and employed mainly female staff. By the end of the War 2,227 TP engines had been built here and a further 1,306 at the London Renault factory, Figure 12.[18]

The Post-War RPH and RPL

Edward Paxman had been appointed Managing Director of Paxman in 1940 when Ruston & Hornsby of Lincoln acquired the controlling interest in the company. Despite the immediate demands of overseeing the heavy defence workload at

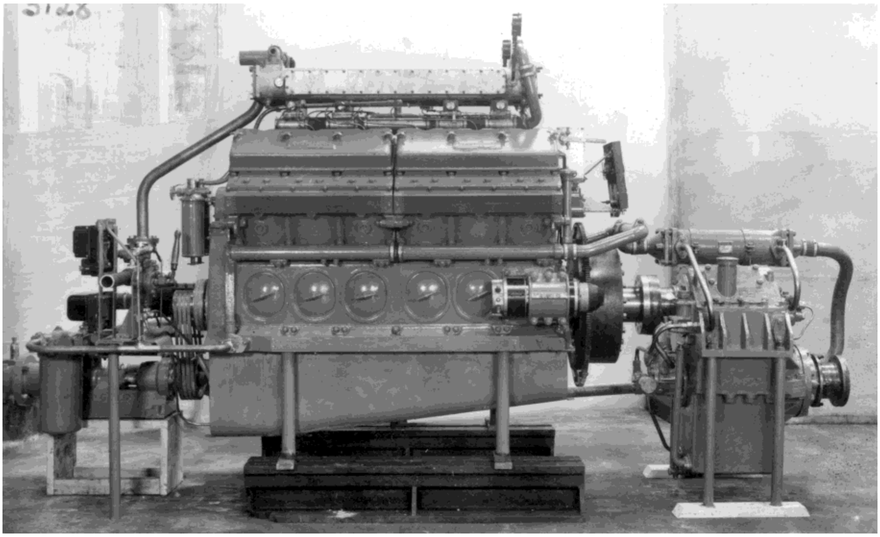

Figure 12. Paxman 12TP engine and gearbox for WW2 tank landing craft.

Standard Works and having overall responsibility for the management of Britannia Works, he was forward-looking and laid plans for the post-war future of the business. Officially the 12TP belonged not to Paxman but to the Admiralty and its manufacture was under the control of the Ministry of Supply. Edward Paxman was very conscious that when the war ended so would all the TP and other defence work which filled his factories. Board minutes reveal that as early as 1942 he already had in hand four new engine designs. One of these was the RPH, which was to become Paxman's most important post-war engine.

The RPH Series 1 was to all intents and purposes a TP for commercial applications and markets. For such uses the design had some weaknesses that only became apparent in post-war service. The application, for which the TP had been built, marine propulsion, was not a demanding one for diesel engines. Its service life was not originally an important factor. Provided the engine ran for the few hours required transporting troops across the Channel and landing them on the beaches of France, it would have fulfilled its main intended purpose. However, in immediate post-war Britain there was a desperate shortage of large diesel engines with the power output of the TP. TPs no longer required by the Admiralty were sold off and pressed into service for a variety of applications; some much more demanding than marine propulsion, involving long periods of running under heavy loads. One of these was driving oil well drilling rigs. The TPs and the virtually identical RPH Series 1 engines started to fail on a regular basis. To address the problems Paxman developed the RPH Series II. Introduced in 1951, changes included greater accessibility for maintenance and repair, increased bearing areas, gear driven water pumps, roller cam followers in place of the previous slipper followers, and a stiffer crankshaft. The RPH Series 1 and early Series 2 versions were designed to run at a maximum speed of 1,250 rpm to produce up to 41.6 bhp per cylinder in naturally aspirated form. Various modifications and improvements were made to the Series 2 during its production life, resulting in Mark 3, 4, 5, 6 and 7 versions. Marks 4 to 7 were designed to run at up to 1,500 rpm. Manufacture of the RPH continued into the 1980s and ultimately more than 6,690 were built. Applications of the RPH included standby generator sets, rail traction, oil well drilling, marine propulsion, marine auxiliaries and powering Ruston-Bucyrus excavators.

The post-war version of the RX engine was the RPL, which retained the RX's 9½" bore x 12" stroke. The in-line types initially offered were of very similar construction to the RX, having the cylinder block supported on 'A' frames and secured by long, high-tensile, through-bolts to the bedplate which carried the main bearings. In naturally aspirated form it produced up to 70 bhp per cylinder at 750 rpm. Later the RPL appeared in vee-12 and vee-16 formats with fabricated steel frames.

Direct Injection, the YH and the YL

Paxman's speciality since the mid-1930s has been the design and manufacture of high-performance diesels. Many of its customers have been those requiring an engine of high power output, compact size and relatively lightweight. The constant challenge to its design engineers has been the demand from customers for engines of ever-increasing power output without any appreciable increase in size or weight. One method of increasing power output is the use of turbocharging. It is a remarkable fact that some modern turbocharged diesels can produce up to more than four times the power of their naturally aspirated equivalents.

Indirect injection engines, like the RPH and the RPL, were not well suited to turbocharging or high-speed operation; they were less fuel efficient and could be harder to start at low temperatures. It was primarily the turbocharging limitation that led Paxman to switch from indirect to direct injection. This step was accompanied by another significant design change. To accommodate the increased flows of combustion air and exhaust gases generated by turbocharging, there was a move to a four-valve cylinder head with two inlet and two exhaust valves. Up to that time all Paxman engines had two-valve cylinder heads but since then all, with one exception, have been fitted with four-valve heads.

The direct injection version of the RPH was the YH range of engines. This was the last of a line of 7" bore x 7¾" stroke engines which stretched back to the VeeRB of 1937. Apart from the direct injection four-valve cylinder heads, the design of the YH was basically that of the RPH. Introduced in 1952, the YH was initially built as an aluminium alloy engine to Admiralty specifications and became classified as an Admiralty Standard Range (ASR2) engine. The aluminium construction gave it a low magnetic signature and many were supplied for the

Royal Navy's Ham Class inshore minesweepers. A commercial version of the YH, of cast-iron construction, was introduced in 1954. Turbocharging became standard; the non-intercooled type having a rating of up to 75 bhp per cylinder at 1,500 rpm. A variant of the YH was the ZH. A horizontal or flat 6-cylinder in-line type, it was essentially one bank of a vee-12 YH. Designed for British Railways as an under-floor mounted power unit for railcars none was actually purchased for this purpose.

The YL, which had a direct-injection four-valve head, succeeded the RPL. The bore and stroke were changed from the RPL's 9½" x 12" to 9¾" x 10½". Production of the YL, which had a fabricated steel cylinder housing and bedplate, commenced in 1953. It proved to be a good reliable engine in service and several were used for base load power generation. Marine propulsion and auxiliaries were other major applications. The turbocharged and intercooled YL could produce up to 130 bhp per cylinder at 900 rpm but some Paxman engineers have commented that it was happier running at 750 rpm.

Paxman's Air-Cooled Diesel, the Vega (YGA)

Something of a diversion from the mainstream of Paxman's engine development was the design of an air-cooled diesel. The company started investigating the feasibility of making such an engine around 1953/54. A single cylinder test unit first ran in January 1957 and an 8-cylinder development engine in June 1958, Figure 13.[19] Problems encountered with the cylinder heads and barrels led to three different designs being produced before the final one evolved. When ready to be launched onto the market the YGA, also called the Vega, was exhibited at the World Oil Fair, Oklahoma in 1959 and at the German Industries Fair, Hanover, in 1960. At that time it was the largest industrial air-cooled diesel in production anywhere. The individual cylinder heads and barrels were one-piece aluminium alloy castings with hardened and tempered cast-iron cylinder liners shrunk in. In its 12-cylinder form the 6" bore x 6½" stroke vee form engine had a maximum rating of 466 bhp at 2,100 rpm.

The Vega did not remain in production for long. An insoluble problem was that of noise. To cool a 12-cylinder engine, while keeping it sufficiently compact, the fan had to run at high speed and consumed about 60 bhp. The cylinder fins and the air ducting surrounding the engine amplified the fan's high-pitched noise. The resulting noise level made the Vega unacceptable for most applications. Two examples of this rare engine have survived and are now in preservation; one at the Anson Engine Museum in Cheshire.

The Ventura (YJ)

RPH and YH engines were used to power some classes of British Railways locomotives during the early days of dieselisation in the 1950s. Paxman began to lose out in the rail traction market to foreign competitors like MAN and Maybach who were offering engines with the higher power outputs that the railways were demanding. This spurred the development of a new series of engines, the YJ or

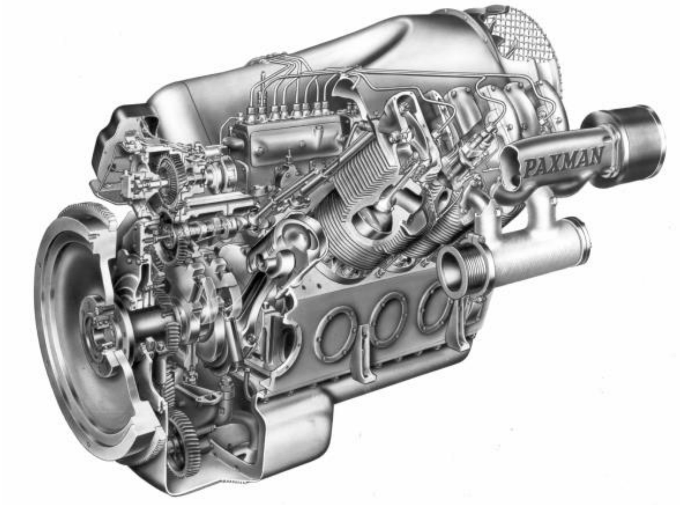

Figure 13. 8-cylinder Vega air-cooled diesel engine.

Ventura, designed with rail traction needs very much in mind. The bore and stroke were increased to 7¾" (197mm) and 8½" (216mm), giving a swept volume of 6.57 litres per cylinder. A key feature of the Ventura was its fabricated crankcase, the engine frame being fabricated using high-tensile steel plate and steel castings to reduce weight. Fork and blade connecting rods were retained, as was the block type of fuel pump, which had been used since adoption of the Bosch system for the company’s Heavy Duty Diesels in the 1930s.

Test running of the first version of the Ventura, the YJ1, commenced in August 1958. Except for the development prototype, only two YJ1 engines were built. This pair of 12-cylinder turbocharged field trial engines was installed in the Western Region’s diesel-hydraulic locomotive ‘Majestic’ (D830) in 1960 or early 1961. Experience gained from trial running in ‘Majestic’ revealed a need to increase the width of the crankshaft's bearing areas. In consequence the crankcase, as well as the crankshaft, was redesigned resulting in a slightly longer engine, the YJ2. All subsequent Venturas were basically this design, generally referred to as the YJ. By 1963 the Ventura was in full production in V6, V8, V12 and V16 formats. It was offered in either turbocharged or turbocharged and intercooled forms. The 12-cylinder turbocharged version had a maximum rating of 1,250 bhp at 1,500 rpm, increased with intercooling to 1,500 bhp at 1,500 rpm.

The Ventura was successful in the rail traction market that had prompted its design. Many were supplied also for marine propulsion, marine auxiliaries and other power generation applications. In total, just short of 1,100 were produced.

The Valenta (Y3J)

The push for increased power output continued. In about 1965 design work commenced on what was originally conceived as the Mark 3 Ventura, hence its Y3J designation. However, the changes turned out to be sufficiently major to warrant a new name, the Valenta, Figure 14. Some of the most important changes related to the fuelling arrangements. Achieving the desired increase in power required a higher rate of fuelling than could be delivered by the monobloc type of fuel pump used up to this time. The chosen solution was individual fuel pumps for each cylinder but this option necessitated another big design change. Instead of the Ventura's single camshaft, the Valenta has three. One is located in the vee between the cylinder banks and operates the valve gear. Each of the other two is located on the outer side of a cylinder bank, driving the fuel pumps for that bank. A further substantial change involved the exhaust system. In place of the Ventura's relatively conventional arrangement, the Valenta has water-cooled monobloc exhaust manifolds.

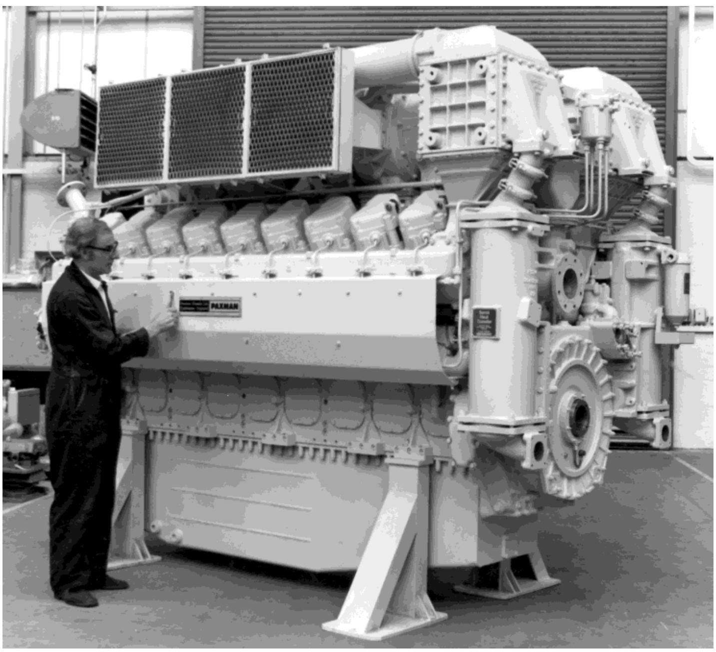

Figure 14. 18-cylinder Valenta engine.

An estimated three-quarter of all Valentas, but no 6-cylinder in-line types, were built with fabricated crankcases. The Royal Navy in particular preferred this type of construction because of its greater shock resistance and lighter weight. It can also be possible, in an emergency, to carry out a welding repair on a fabricated crankcase, which would not be possible on a cast-iron one. All engines supplied for rail traction had fabricated crankcases. As a lower cost alternative the engine was offered with an SG cast-iron crankcase.

Test running of the Valenta commenced in 1970 with the formal launch in 1972. The first Valentas were installed in the prototype High Speed Train that broke the world speed record for diesel rail traction on 12 June 1973 at a speed of 143.2 mph. This record was broken by another Valenta-engined HST, which achieved 148 mph on 1 November 1987. It is interesting to note that the first two Venturas supplied for rail traction had a rating of 1,200 bhp, compared with the 2,250 bhp rating of the twelve cylinder Valentas in the prototype and production HSTs. More than 230 Valentas were supplied for HST power cars. The Royal Navy was an important customer for the Valenta with, for example, four 12-cylinder types being supplied for each of the sixteen Type 23 frigates. Other prestigious customers have included the US Coastguard Service and the US Navy.

The Valenta appeared in 6-cylinder in-line, V8, V12, V16 and V18 formats. The later eighteen cylinder types have a maximum rating of 4,625 bhp at 1,640 rpm, equating to 257 bhp per cylinder.

The VP185

By the mid-1980s the Valenta was coming towards the end of its design life. An expensive engine to manufacture, it was facing increasingly stiff competition in the market. Furthermore, it was felt there was little or no scope for squeezing more power out of the basic design. In late 1987 the decision was made to proceed with a completely new design, effectively starting with a clean sheet of paper. Leading the project was Nigel Ramsden, then Paxman's Technical Director, a man of drive, energy and forceful personality who conceived the ground-breaking design.[20] A relatively young team of engineers led by Ian Drake undertook the detailed design work. Costing around £15 million to develop, the VP185 was the first Paxman engine to be designed using Computer Aided Design (CAD) and computing techniques for predicting performance and stress, Figure 15.

The VP185 has a maximum firing pressure of 3,000 lb/in^2 (207 bar), a giant leap up from the 1,500 lb/in^2 of the Ventura and the 2,000 lb/in^2 of the Valenta. When this high firing pressure was first proposed by Nigel Ramsden the idea was met by some in the company with incredulity and not a few doubted whether it was achievable. Perhaps the greatest innovation was the engine's revolutionary two-stage turbocharging arrangement with intercooling and aftercooling. Previously Paxman had employed only single-stage turbocharging, using one large turbocharger or two on 16 and 18-cylinder engines. The standard twelve cylinder VP185 has six automotive-type turbochargers, four low-pressure and two high-pressure, housed in a single water-cooled gas-tight casing or 'box' mounted on top of the engine. The arrangement delivers good boost pressures down to the lowest operating speeds, providing the necessary air-fuel ratios for good combustion and high engine torque. Compared with the large turbochargers used previously, the automotive-type have a low initial cost and are cheaper and quicker to replace on engines in service. The single turbocharger box arrangement used on the 12-cylinder VP185 had to be modified for the 18-cylinder version of the engine. The latter has three boxes, each housing two low-pressure and one high-pressure turbocharger. The more recent 'two-box' 12-cylinder VP185, which has better performance than the original single box type, has two boxes of the same design as those used on the 18-cylinder engine.

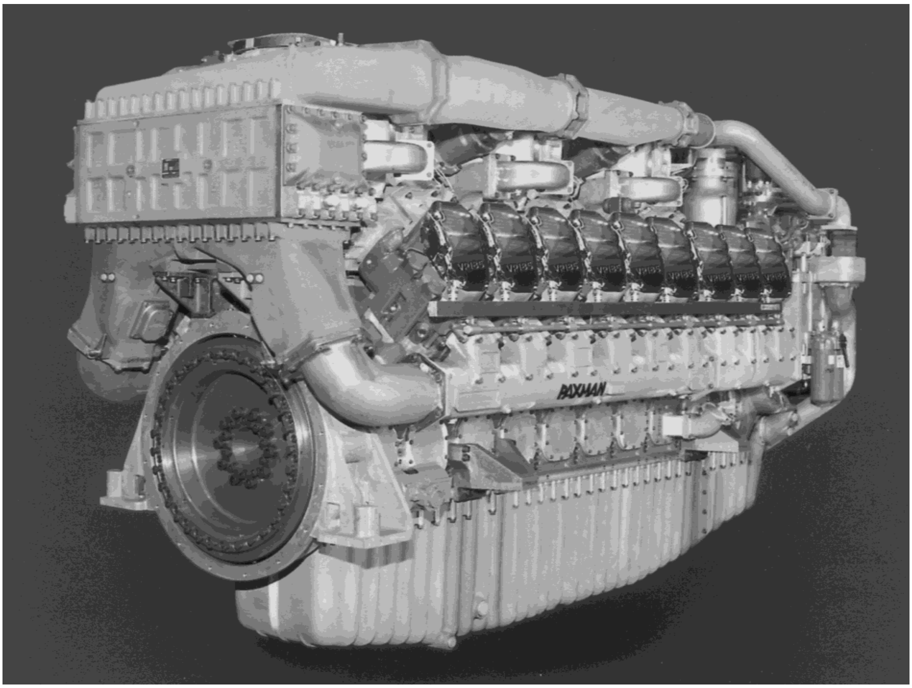

Figure 15. 18-cylinder VP185, developing up to 5,362 bhp.

The VP185 also differs from its immediate predecessors in a number of other important respects. It has a 185mm bore and 196mm stroke to give a swept volume of 5.27 litres per cylinder. The included angle of the vee was increased from 60° to 90° to achieve a flatter, more compact engine. Instead of the fork and blade connecting rod arrangement that had been used in most Paxman vee form engines since the first in 1935, the VP185 has the side-by-side arrangement. Unit pump injectors are fitted for fuel injection. These are driven by the same single camshaft which operates the valve gear, thus eliminating the need for the two additional camshafts required on the Valenta. The number of gears in the main train was reduced from ten to two, making for a much simpler and potentially more reliable arrangement with greatly reduced manufacturing costs. As might be expected, improving fuel consumption and emissions performance were important considerations in the new design.

The development prototype engine first ran on 31 August 1991 and the twelve-cylinder VP185 was officially launched in May 1993. Weighing 7.4 tonnes, this engine produces up to 3,500 bhp (2,610 kWb) at 1,950 rpm, compared with the2,250 bhp of the 12-cylinder Valentas originally fitted in the High Speed Train. The 18-cylinder version, weighing 10.2 tonnes and having a maximum output of 5,362 bhp (4,000 kWb) at 1,950 rpm, was introduced in 1998.

The Closing Chapter of Paxman's Diesel Engine Development

The VP185 is, sadly, the last chapter in the story of Paxman's diesel engine development. What is left of the Paxman business at Colchester no longer has the skills, facilities and resources that would be needed to produce a major new design. In 2000 MAN B&W Diesel, part of the MAN Group of Augsburg, Germany, acquired the business. By the end of 2002 the Development Department had been disbanded and the engineering design function reduced to a handful of people. In 2003 MAN transferred manufacture of the VP185 to the former Mirrlees Blackstone factory at Stockport, a move which proved to be an unhappy one for all concerned. The Stockport factory's experience was in the field of large slow-speed diesels. It struggled both with the standard of machining required for components of a modern high-speed diesel and with the assembly and test of the VP185. As financial losses mounted, MAN decided to stop offering the VP185 to the market. However, demands from customers for the engine persuaded MAN to relent. In July 2005 the building and testing of new VP185s was resumed at Colchester. Manufacture of small numbers of VP185s continues there but the site is now primarily a repair and overhaul facility, employing no more than about seventy people.

The story of the VP185 and Paxman's diesel engine development is not yet at an end. The VP185, a highly worthy final act in Paxman's tradition of designing high-speed diesels, remains a world-class engine that is still in demand. As at 2011, development work is well advanced on an important new enhancement of the engine. For commercial reasons, details remain confidential at the time of writing this paper.

References

1. Andrew Phillips, *Steam and the Road to Glory – The Paxman Story* (Hervey Benham Charitable Trust, 2002), p. 360.
2. Ibid.,
3. Ibid., pp. 455-7.
4. Paxman copy Order Book No. 5.
5. Paxman Marine Oil Engines, Publication No 931 (Davey, Paxman & Co Ltd, Colchester, 1927).
6. Paxman Heavy-Fuel-Oil Engines, Publication No 932 (Davey, Paxman & Co Ltd, Colchester, 1927).
7. Ibid., pp. 17-9, and subsequent issues of this catalogue: No. 952, pp. 21-3 and No. 987, pp. 22-3.
8. Paxman's World, Issue 1 (house magazine of Davey, Paxman & Co Ltd, January 1948).
9. Paxman copy Order Book No 7. See Order

No. 17703 of 9 December 1930.
10. Paxman Heavy Duty Diesel Engines, Publication No 1022 (Davey, Paxman & Co (Colchester) Ltd, Colchester, undated) p. 7 and subsequent version, Publication No 1042, p. 7.
11. 'The Davey, Paxman Welded Frame Engine', *Motor Ship* (September 1931), p. 247.
12. Paxman Heavy Duty Diesel Engines, p. 13.
13. 'Welded Steel Frames', *Engineering* (17 July 1931).
14. Paxman copy Order Book No. 7. Order No. 17847 delivered July 1932 and Order No. 18136 delivered July 1934.
14. ibid. Order Nos. 17800-17803 delivered December 1931 and January 1932, and Order Nos. 17851-17855 delivered between March and September 1932.
15. Report on the Engineering and Machinery Exhibition – VeeRA exhibits, *Engineering*, (9 October 1935).
16. Article in *Engineering* (22 July 1938).
17. 'The 'Gay Viking' Class Triple-screw Motorships', *The Marine Engineer* (November and December 1944); 'The Blockade Runners', *Marine Propulsion* (November 1979).
18. Paxman Service Department records.
19. M.F. Clover, 'The Evolution and Trend of Development of Air Cooled Diesel Engines of High Power'. *Diesel Engineers and Users Association – Symposium Paper S277* (May 1961).
20. J.N. Ramsden, 'The Design and Development of the 12VP185', *Power Engineer – Journal of the Institution of Diesel and Gas Turbine Engineers,* Volume 1 No. 2, Paper 497 (April 1997).

Notes on Contributor

Richard Carr was Senior Personnel Officer at Paxman from 1985 to 2000. He is Honorary Secretary and a foundation trustee of the Paxman Archive Trust. Since retiring from Paxman one of his main interests has been researching and recording the company's history. The results of this can be viewed on his extensive Paxman History website at www.paxmanhistory.org.uk

Comments and queries on this paper can be sent to the author at Nelmes, Mill Lane, Birch, Colchester CO2 0NG or emailed using the form on the Contact page of the above Paxman History website.