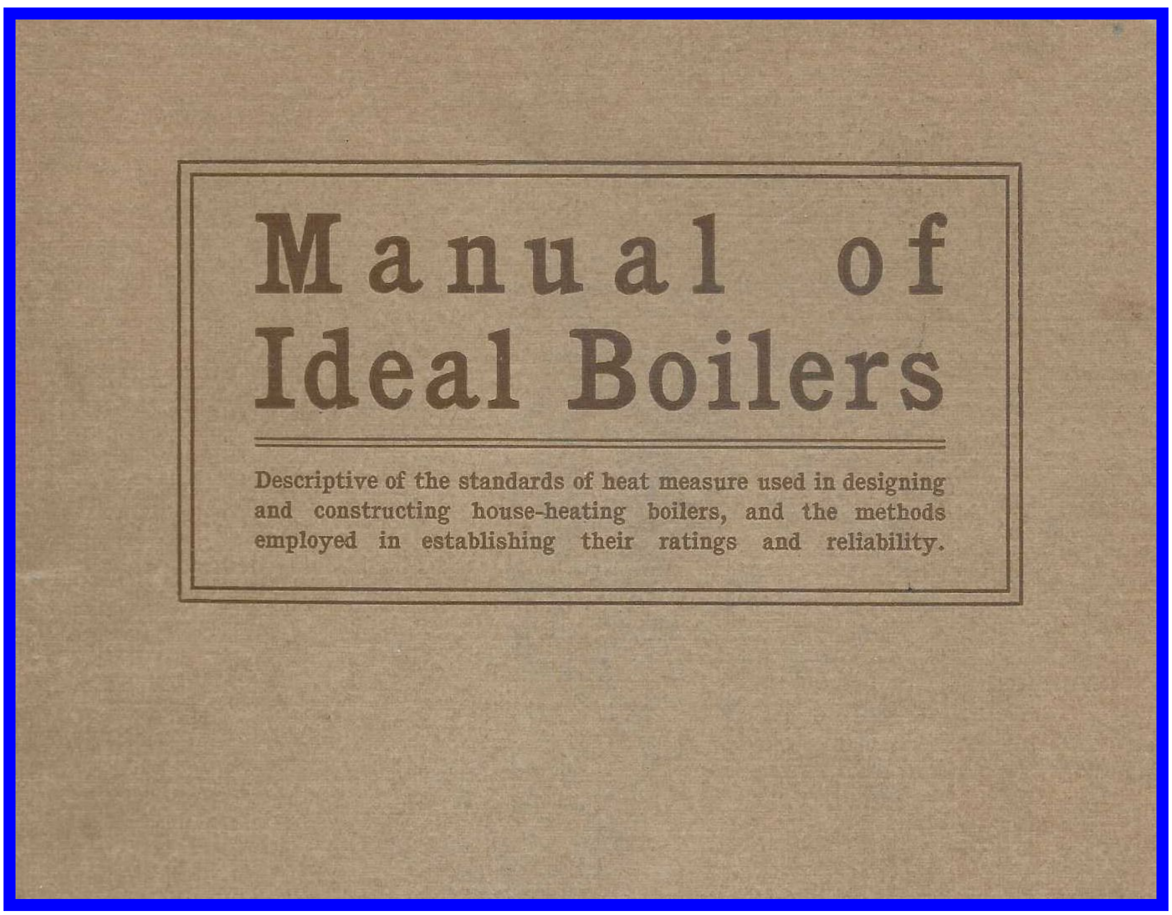
STEAM & HOT WATER BOILERS
1840-1930

Technical Publications



Manual of
Ideal Boilers

Descriptive of the standards of heat measure used in designing and constructing house-heating boilers, and the methods employed in establishing their ratings and reliability.

1909

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Compiled from Tests conducted by the Department of Thermal Research at the Laboratories of

AMERICAN RADIATOR COMPANY

THE BOYHOOD OF JAMES WATT

When he observed the chattering of the teapot's lid, and watched the drops of condensation as they fell, from the teaspoon he held at the kettle's spout, into the cup he had placed below.

Introductory

THE rapid growth of the steam and hot-water heating industry in the last few years, and the complex problems which constantly arise in the installation and use of these methods under widely varied conditions, have brought about a demand for more complete and exact knowledge and tables for convenient reference.

It is perhaps but natural that of late the Trade is freely demanding from our sales representatives reliable, scientific data, as the fact has gradually come to be known that the American Radiator Company is the sole manufacturer in this line of industry which maintains a Department of Thermal Research, or Physical Laboratory.

The aim of this Department has of course been chiefly directed toward advancing the efficiency and reliability of our product, and we have hesitated somewhat—despite these frequent requests—to put into type these excerpts from our elaborate tests, feeling that the time may not as yet be ripe for spreading their results broadcast before the Trade.

We have therefore thought that for the present it will be desirable to place this preliminary publication in limited edition in the hands of such members of the Trade only who hold themselves as students and are seeking authentic, laboratory-proved facts.

Upon the following pages concise answers will be found to many of the questions which more frequently arise. There will also be found much other valuable information, perhaps not as often requested, but for which the progressive heating engineers are liable to call.

The correctness of our method of tests has been rendered all the more clear and convincing through having had opportunity to compare the work of our Physical Laboratory with the laboratory experiments conducted at the leading colleges in the United States, France, Germany, and England.

Such investigations have conclusively shown that our Company has perfected a method of research by which heating laws may be studied and the causes of success or failure in heating apparatus accurately determined. Our method of tests has been endorsed and accepted by eminent authorities as being in every way accurate and exhaustive. Our present Physical Laboratory is far more complete in equipment, and the tests there made on house-heating boilers and radiators are far more exhaustive than have obtained at any institution or college. So far as we know, we are the only manufacturers in this line of industry that regularly maintain and operate a Physical Laboratory, or Department of Thermal Research.

We have exhaustively tested IDEAL Boilers, both singly and in comparison with similar types and sizes, but we have also made hundreds of comparative tests with all other makes of boilers of any market standing. Every effort has been made by us to thoroughly *know* the exact, dependable performance of our product, to enable us to compete, successfully as we do, with every other make of house-heating boilers or radiators in the world, each in its own market.

We firmly believe that the information which we are thus imparting will, more than ever, cause our Company to be regarded as true, helpful friends to the Architects and the Heating Trade.

With our splendidly equipped new Institute of Thermal Research, now in process of erection, we shall be in position to bring out, from time to time, additional heating engineering data, should our friends and patrons encourage us in so doing.

Faithfully,

AMERICAN RADIATOR COMPANY

First Issue, September, 1908.
Reissued, July, 1909.

H. RIETSCHEL

TRAITÉ
THÉORIQUE ET PRATIQUE
DE CHAUFFAGE
ET
DE VENTILATION

Guide pour le calcul et l'établissement des projets et installations

de Chauffage et de Ventilation

DEUXIÈME PARTIE

TABLES ET PLANCHES

1911

TRAITÉ
THÉORIQUE ET PRATIQUE
DE CHAUFFAGE
ET
DE VENTILATION

Guide pour le calcul et l'établissement des projets et installations de Chauffage et de Ventilation

A L'USAGE DES INGÉNIEURS, CONSTRUCTEURS, ARCHITECTES
ENTREPRENEURS, ETC.

PAR

LE D[r] H. RIETSCHEL
Ingénieur,
Conseiller intime du gouvernement,
Professeur à l'École des Hautes Études techniques de Berlin.

TRADUIT DE L'ALLEMAND SUR LA 4[e] ÉDITION
PAR
LÉON LASSON

PLANCHE 23

Chaudières en tôle
pour vapeur à basse pression.

Figure 1. Chaudière tubulaire horizontale (Rud. Otto Meyer).

» **2. Idem**, sans enveloppe de maçonnerie (Johannes Haag, Akt.-Ges.).

» **3. Chaudière tubulaire verticale sans enveloppe de maçonnerie** (Gebr. Sulzer).

» **4. Foyer fumifuge réglable à alimentation continue** (J. A. Topf et Söhne), pour chargement à la main d'une chaudière tubulaire à flamme. *a* réserve de combustible, *b* registre d'admission, *c* registre de réglage, *d* grille à gradins, *e* dispositif de réglage.

» **5. Chaudière tubulaire horizontale** avec grille à gaine (Gebr. Körting, Akt.-Ges.).

Fig. 1.

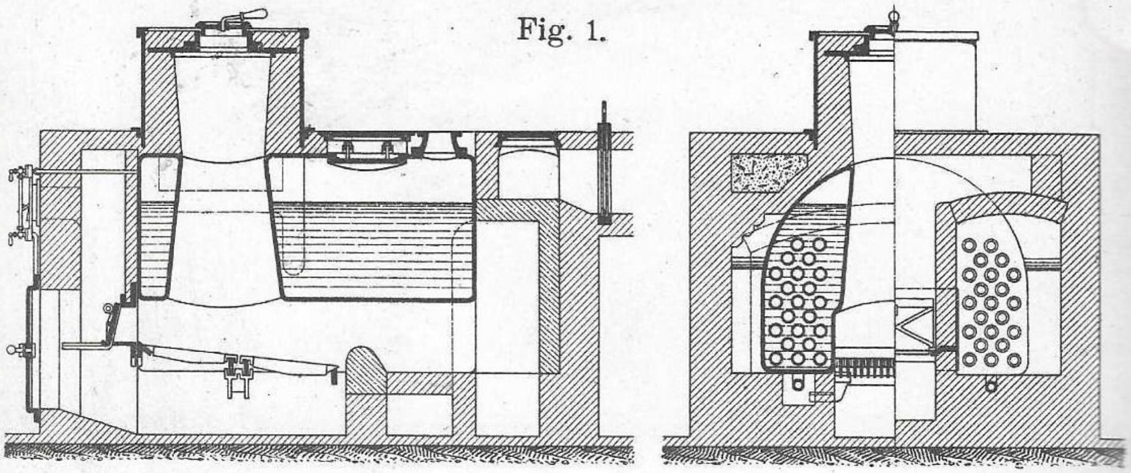


Fig. 3.

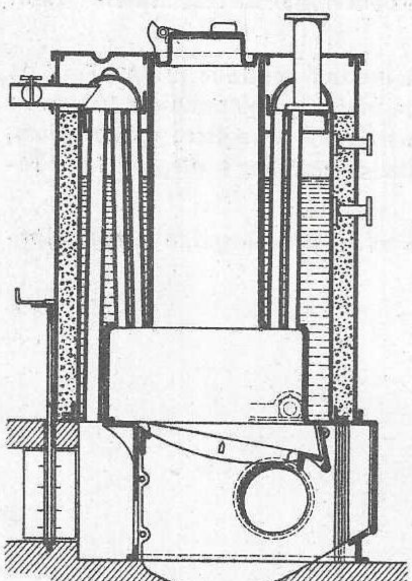


Fig. 4.

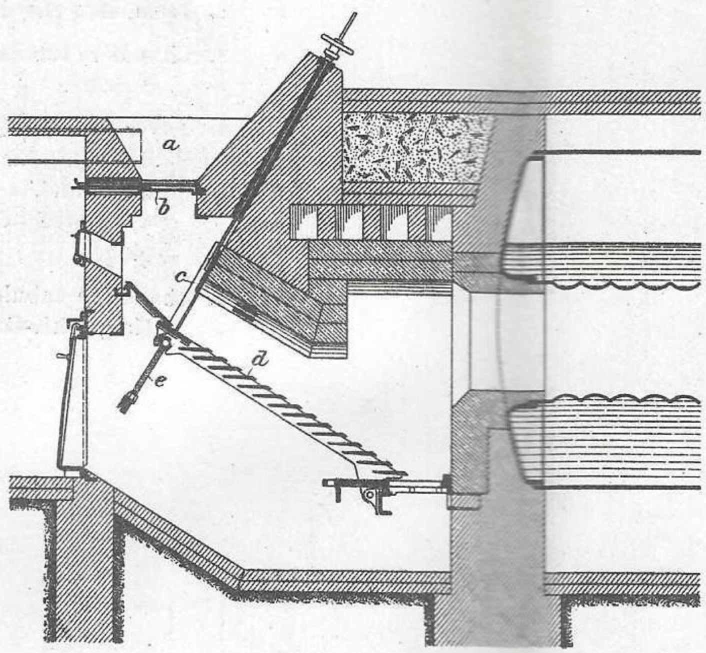


Fig. 2.

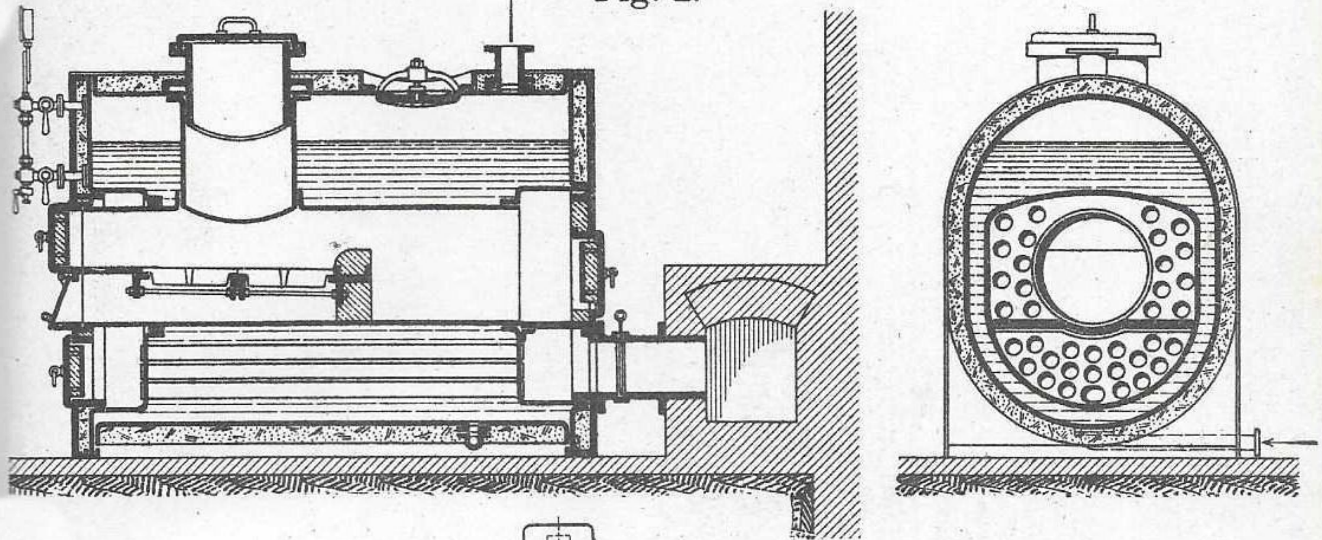


Fig. 5.

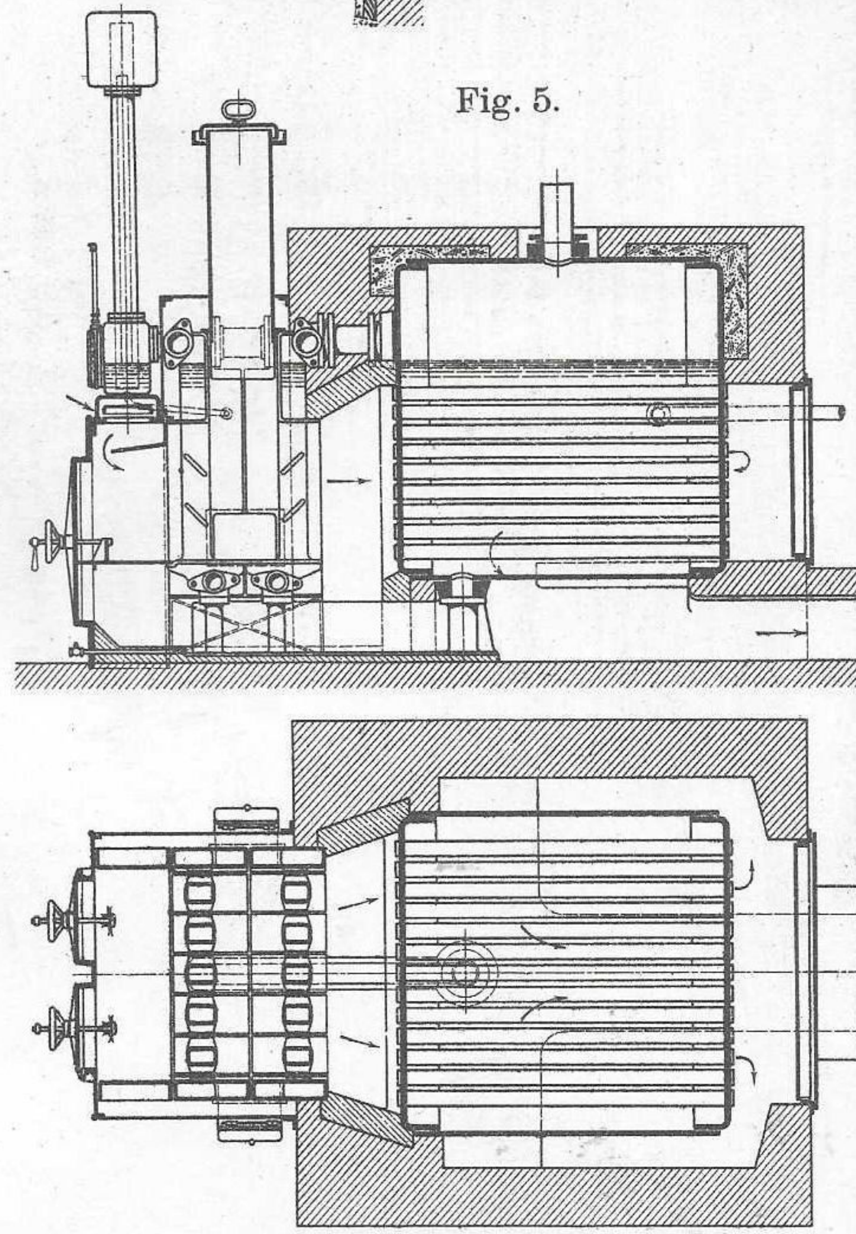


PLANCHE 24

Chaudière en fonte pour vapeur à basse pression.

Figures 1 et 2. Chaudière sectionnée en fonte de fer, de J. Strebel. (Strebelwerk, G. m. b. H.).

» **3. Idem.** (Chaudière Lollar, Buderussche Eisenwerke).

» **4. Idem.** (B. Oelrichs).

» **5. Idem.** (Eisenwerk Kaiserslautern).

» **6. Idem.** (Fritz Kaeferle).

Fig. 1.

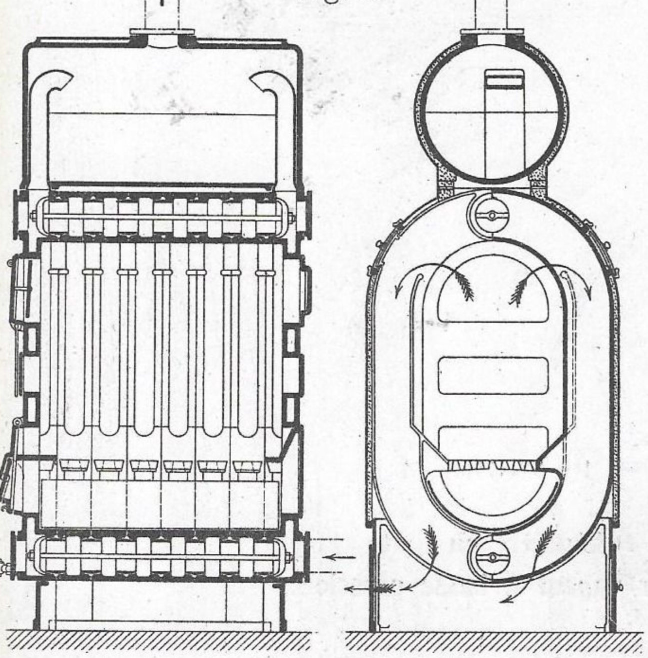


Fig. 2.

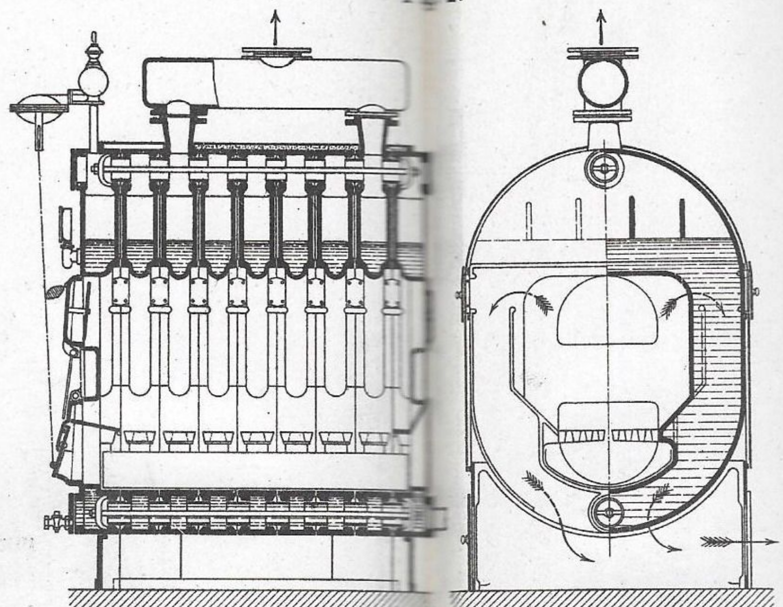


Fig. 4.

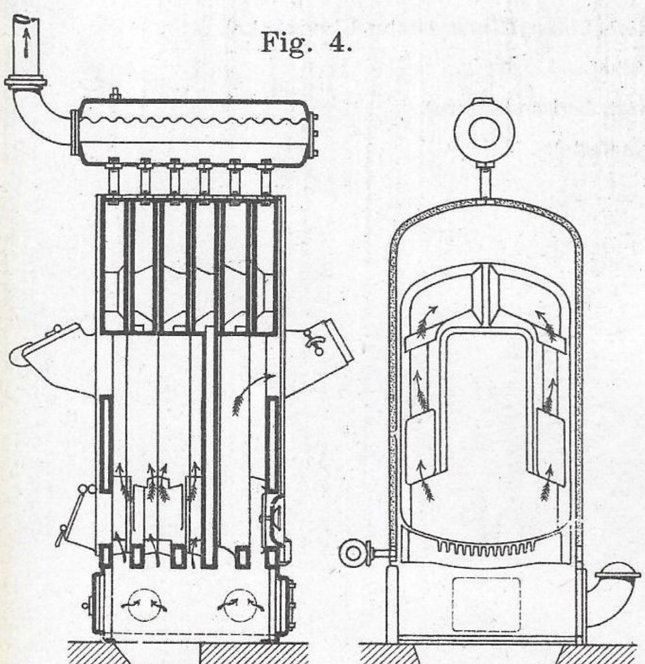


Fig. 3.

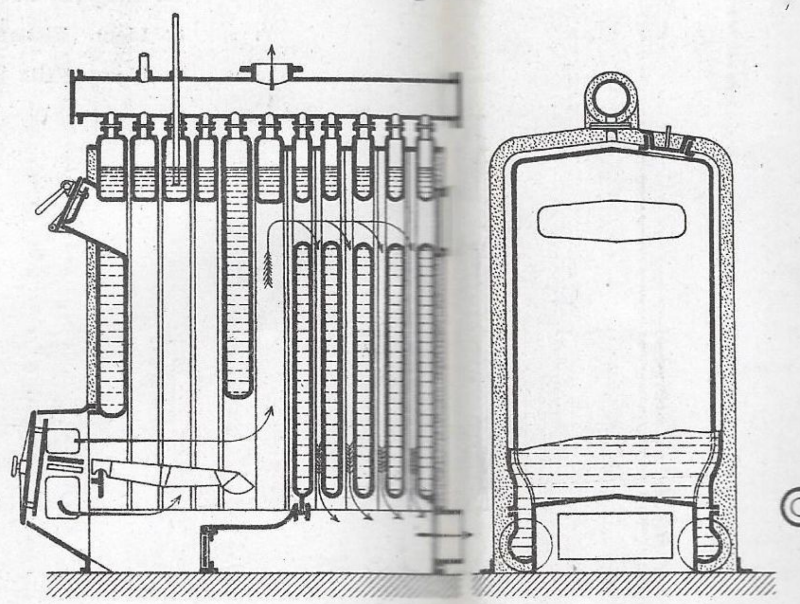


Fig. 3.

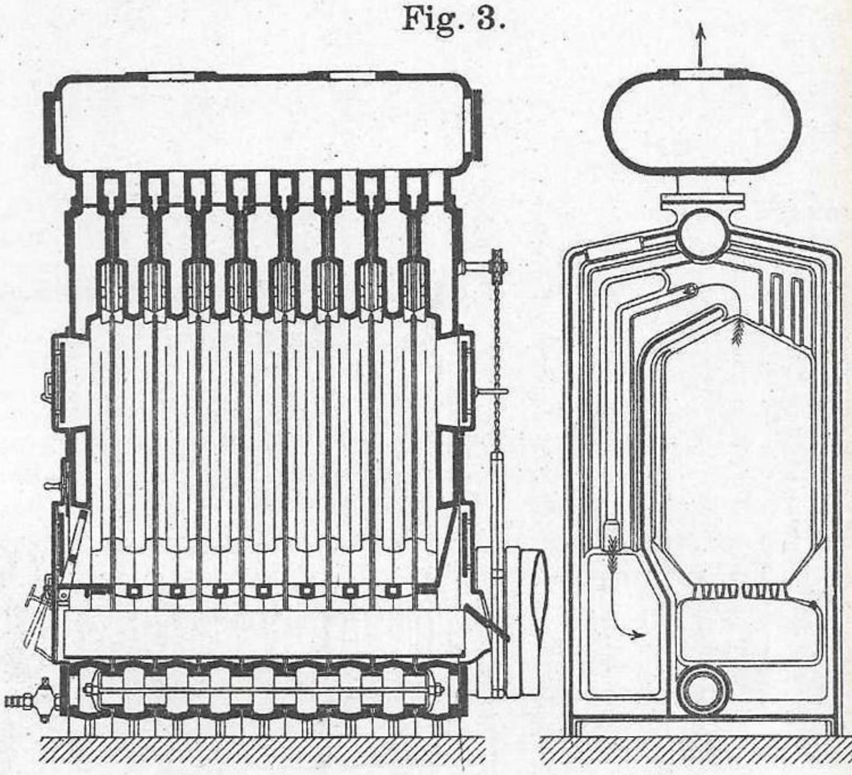
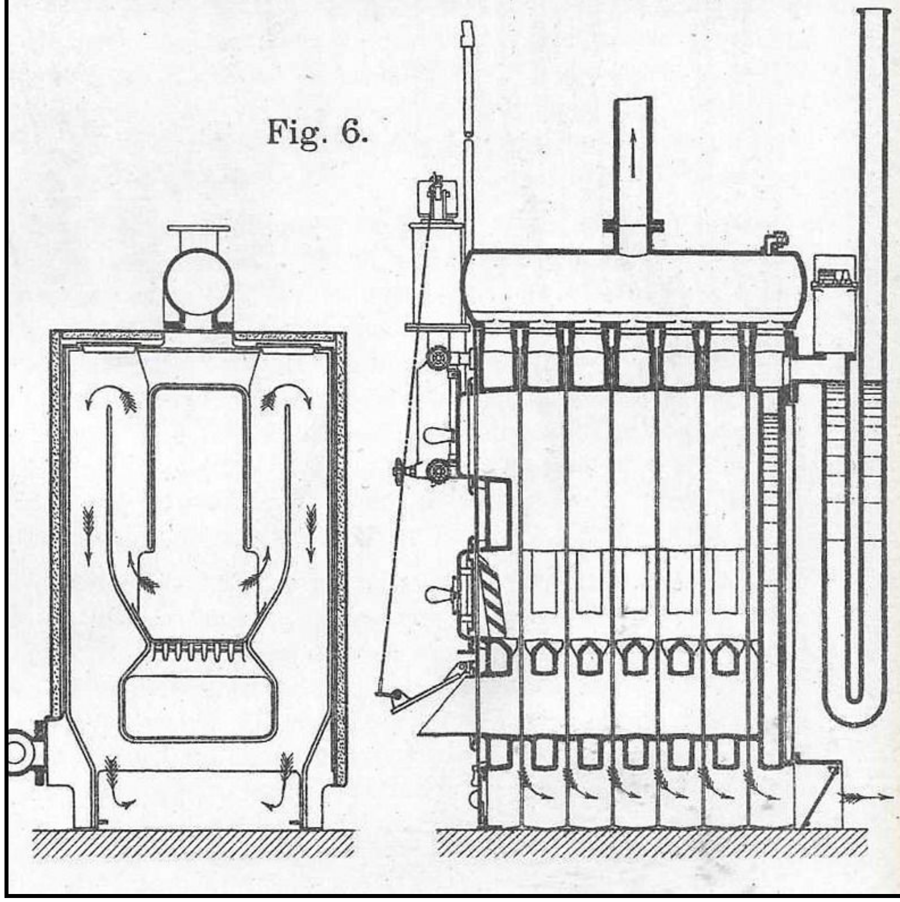


Fig. 6.



The BP Book of Industrial Archaeology

NEIL COSSONS

1975

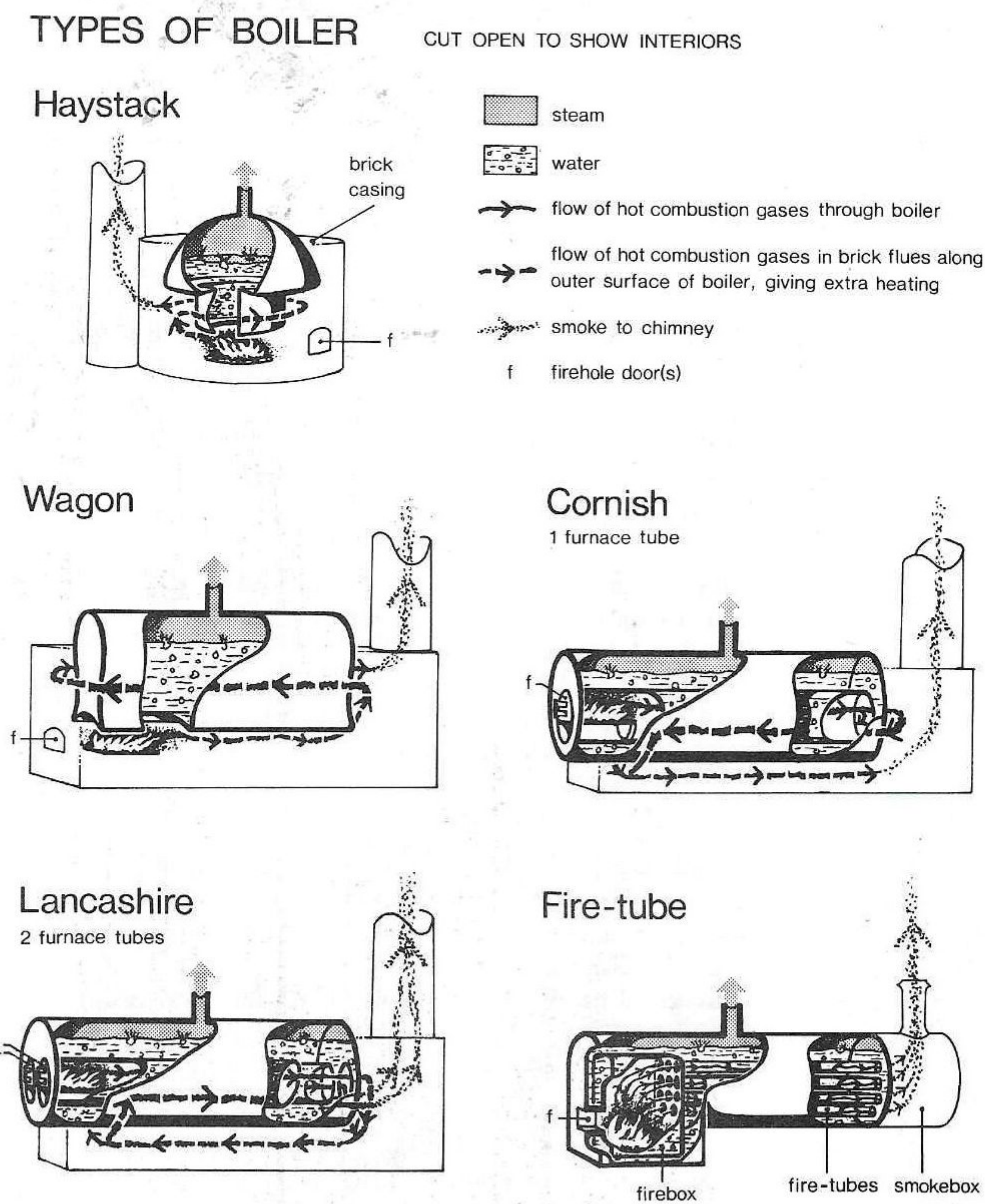

TYPES OF BOILER
CUT OPEN TO SHOW INTERIORS
Haystack
brick casing
f
steam
water
flow of hot combustion gases through boiler
flow of hot combustion gases in brick flues along outer surface of boiler, giving extra heating
smoke to chimney
f firehole door(s)
Wagon
f
Cornish
1 furnace tube
f
Lancashire
2 furnace tubes
f
Fire-tube
f
firebox
fire-tubes
smokebox

Fig 12

14 Haystack boiler, Blists Hill Open Air Museum, Ironbridge, Shropshire

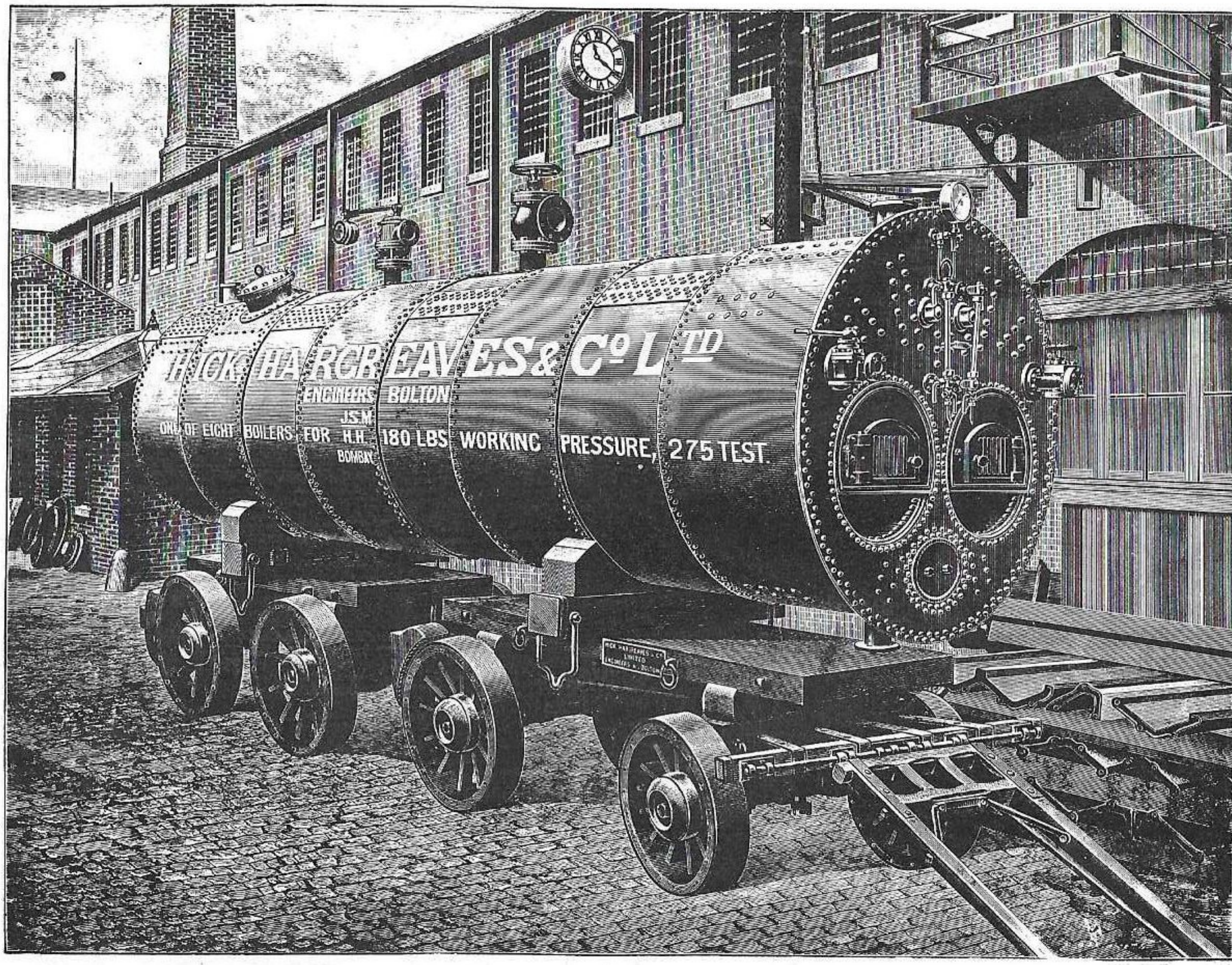
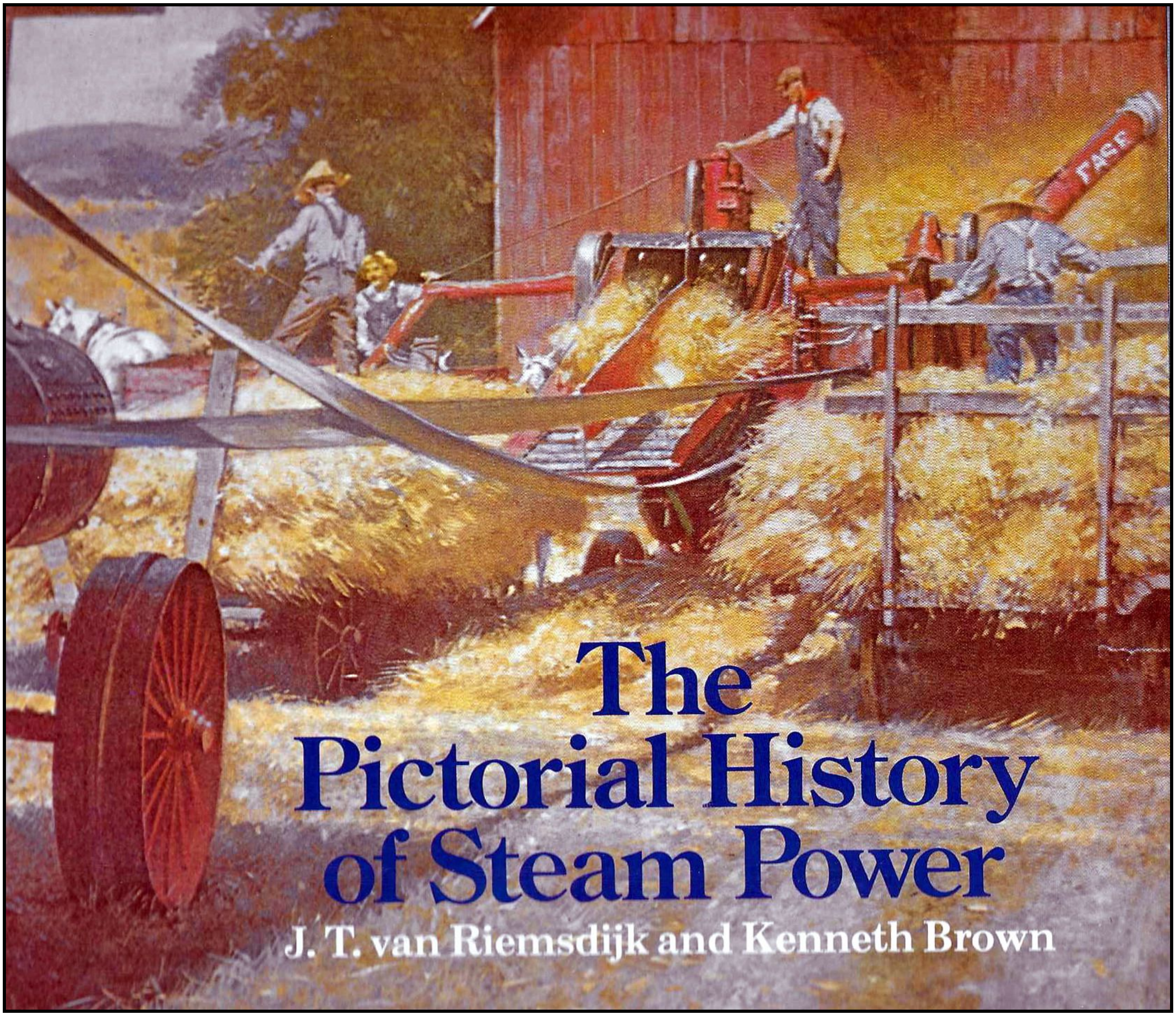


Fig 13 Lancashire boiler for 3,000 ihp triple-expansion engines


The Pictorial History of Steam Power
J. T. van Riemsdijk and Kenneth Brown

1980

Boilers and Accessories

The history of the boiler obviously goes back further than that of the steam engine, even if we use the word boiler only to describe a vessel normally closed; by a lid, plug, cork or other device. We can safely assume that the first attempts at obtaining mechanical power from steam were inspired by the apparent violence with which steam issued from confinement, or even by the explosion of a closed vessel which was closed too well. Any lidded water-boiling vessel could have demonstrated this effect, especially if it had been made of pottery.

However, the earliest boilers (those belonging to the prehistory of the steam engine) were made of copper or bronze. From all accounts and all reconstructions, Hero's aeolipile was mounted on top of a boiler in the shape of a lidded, round-bottomed, cooking pot. From experience with reconstructions of this device, one knows that it required a pressure of at least half an atmosphere or 48 kN per sq m (7 lb per sq in) to work at all convincingly, and it works much better at twice that pressure. Provided that it is not made too large, a cooking-pot boiler should be able to withstand such a pressure, even if made in Roman times.

Two remarkable Roman proto-boilers were discovered at Pompeii and are now in Naples Museum. They are clearly not pressure boilers, but water heaters, with hinged lids and elegantly shaped handles—proto-samovars, perhaps. But their construction is very sound and their shapes would be quite well adapted to withstanding internal pressure. Their truly remarkable feature is that they have water-tube fireboxes inside them. The water tubes form the grate at the bottom of the box. The box is fully water-jacketed and has a fire door in the side. One of these water heaters has a firebox which tapers upwards and curves to the side, to give a proper chimney effect, but the other, though it has a domed firebox crown, is simply provided with a small opening high at the back of the firebox, which would need to be connected to a long rising pipe to generate any natural draught. The skill evidenced in their construction makes it plain that a Roman pressure vessel was perfectly possible, provided that it was not too large.

During the revival of ideas of using steam to provide power, in the 16th, 17th and early 18th centuries, the pressure of confined steam is still the first thought in the minds of inventors such as Branca, who conceived an impulse turbine supplied from a cooking-pot type of vessel, and even the nearly successful Savery, who hoped that steam pressure would do most of the water raising in his 'Miner's Friend'. However, when it came to doing real work, pressure vessels proved unsatisfactory, because they could not be made large enough without leaking, deforming, or even bursting. For most of the first century of practical steam power the boiler was a kettle, a copper, a brewer's vat, or some other form of familiar water-heating vessel which produced steam at atmospheric pressure only, or just sufficiently above that pressure to make it flow in the desired directions. It did not even have to be made of metal.

Savery's boilers, which were intended to withstand a pressure of several atmospheres, were based on the design of the brewer's copper. They were made of copper, externally fired by a fire beneath them, and housed in brickwork which followed brewery practice in providing some sort of encircling flue through which the gases passed on their way to the chimney. This flue might even, according to one description, be spiral. A point of particular interest was Savery's use of boilers in pairs: a small boiler was arranged to be able to refill the larger main boiler whenever necessary, and for this purpose had to develop a higher pressure than that of the main boiler. Obviously, this should have been done when the main boiler pressure was rather low, and the fire damped down, so that no excessive pressure was required in the small boiler. There was always a danger of the small boiler 'blowing up' the large one if the operator was careless and there was any overheating caused by low water in the large boiler. The system was ingenious (as was the whole Savery engine) but, with the state of technology at the time, clearly contained the apparatus of its own destruction.

Newcomen's engine was quite different and only used steam to produce a vacuum. The height to which it could raise water was not directly determined by the pressure of the steam, but by the relative sizes of piston and pump, and the number of stages in the lift. The steam was kettle steam at the pressure of the atmosphere—96 kN per sq m (14 lb per sq in)—or very slightly above, and the boiler from which it came had only to provide a large water capacity and effective transfer of heat. These boilers were rather like Savery's, in that they were circular vessels encased in brickwork with an encircling flue. The bottom and sides, exposed to the fire, were generally of copper in the early years, and the top was sometimes of lead. The cylinder of the engine was above this, and secured in crossbeams of the engine house, but undoubtedly there must have been some relative movement between cylinder and boiler as the engine operated. As the two components were connected by a steam passage and valve, the use of relatively flexible lead for the boiler top probably prevented fracture, and this is to some extent borne out by the later practice, after the whole structure had become firmer, of making the lower part of the boiler of iron, but the top of copper.

Newcomen's boilers were the shape of an enormous, short, round-headed rivet. The top was hemispherical, and below was a parallel part of smaller diameter. This provided the boiler with an internal shelf, of no particular benefit except that it enabled the top of the boiler to be borne directly on the brickwork. As there was no appreciable internal pressure, the boiler could be replenished directly from a tank at a higher level. The bottom of the boiler was slightly concave.

This basic form was soon being modified by various engineers. As early as 1717 Henry Beighton flattened the hemispherical top to something more like the domed lid of a cooking pot, and turned the parallel and rather deep lower part into a shallower cooking-pan shape with flared sides and a more sharply domed bottom. The shelf was reduced in width, but was exposed to heat in the encircling flue. This boiler must have been very sensitive to changes in water level, because the wetted, heated area would drop sharply, as would the area of the water surface, if the water dropped below the shelf; but there was insufficient height above the shelf to allow much water there. Again, as the water level rose above the shelf, the area of the water surface diminished sharply and in practice this would have hindered the production of steam.

After 50 years of experience, boiler makers were using iron plates and making boilers which had highly domed tops and no shelf; they tapered down to a base ring somewhat smaller than the maximum diameter at the bottom of the dome. The lower taper might be concave, and the boiler bottom was nearly flat, being supported by internal stays. Cast-iron was also beginning to be used, and boilers were assembled from sections bolted together.

In the later part of the 18th century, James Watt was using the wagon-type boiler. Although closely identified with Watt, it was not developed by him and had earlier antecedents. Its name arose from its general resemblance in shape to a covered wagon, as it was a rectangular box with a rounded top. The flat sides and bottom were in fact slightly concave, and tied together with a few internal stays, but the ends were actually flat. The half-cylindrical top was not stayed, all the internal stays joined the more-or-less flat surfaces. These boilers were assembled by riveting quite small wrought-iron plates, large plates not being available until well into the next century.

Water feed into wagon boilers was again by gravity, because Watt was still using the near-atmospheric pressure of the Newcomen engine. An internal float could be used to open a valve in the gravity feed-pipe and thereby maintain a constant water level. This type of boiler was not particularly susceptible to changes in water level, because there was no internal shelf which would be exposed; neither did the area of the water surface change much at different heights, unless the boiler was overfilled. But there was an encircling flue reaching to about half the height of the boiler, which made it undesirable to let the water fall too low.

Plain cylindrical horizontal boilers, with no internal flue and arranged in brickwork with the fire underneath and an encircling flue (or a pair of return flues in parallel) were used for low pressures, notably in America, during the period of the popularity of the wagon boiler. This type was better adapted for higher pressures, but only became common when fitted with one or more internal flues. As it needed no stays, except perhaps to join the flat ends, it was clearly superior to the wagon type, but probably more expensive. With the adoption of higher pressures it became more attractive and was developed in two quite different ways: by the addition of internal flues, giving rise to the Cornish and Lancashire boilers with their several variants; and by the addition of extra drums, joined to the main barrel by large diameter pipes. This last type, developed especially by Arthur Woolf and exported by him to the European continent, became known as the 'Elephant' or 'French' boiler. It consisted of a relatively slim main drum, with two slimmer ones beneath. The whole was set in brickwork and the grate was beneath the lower drums at one end. The flames passed along the lower drums and then rose into a higher flue in which they passed along the upper drum. These boilers were long used and very successful, provided that the arrangement of flues allowed sufficient temperature differences to ensure a good circulation of water within the boiler.

Internal flues, and internal fireboxes, were tried many times during the 18th century, but did not become common until the 19th. Their outstanding advocate was Richard Trevithick, but he had several predecessors, notably William Smeaton, the great improver of the Newcomen engine, who produced a small, nearly spherical, boiler with an internal firebox in 1765; and Nicholas Cugnot, whose artillery tractor of 1770–1 (an example of which is preserved in Paris) incorporated a preserving-pan-shaped boiler with a firebox at the bottom and rising flues terminating in two short chimneys. This boiler worked a non-condensing engine so it must have had a working pressure of not less than 48 kN per sq m (7 lb per sq in).

Trevithick produced many boiler designs suitable for the high pressures he advocated, and the most important of these has already been described in the section dealing with the first locomotives. Whether he could be regarded as the originator of the 'Cornish' boiler is open to doubt, though this type has frequently been attributed to him. A Cornish boiler is a horizontal cylindrical boiler with a single internal flue along its length, the grate being in one end of this flue. Hot gases emerging from the other end pass beneath the boiler and return along the sides, before ascending the chimney. (The great height of factory chimneys was commonly needed to produce an adequate draught to draw the fire through arrangements such as this.) The weakness of the design lay in limited water capacity, because the flue had to be large and its upper surface was not far from the top of the boiler. Water level had to be held within narrow limits: too high a level would reduce the water surface and restrict liberation of steam from it, and too low a level would expose the flue crown and risk its burning.

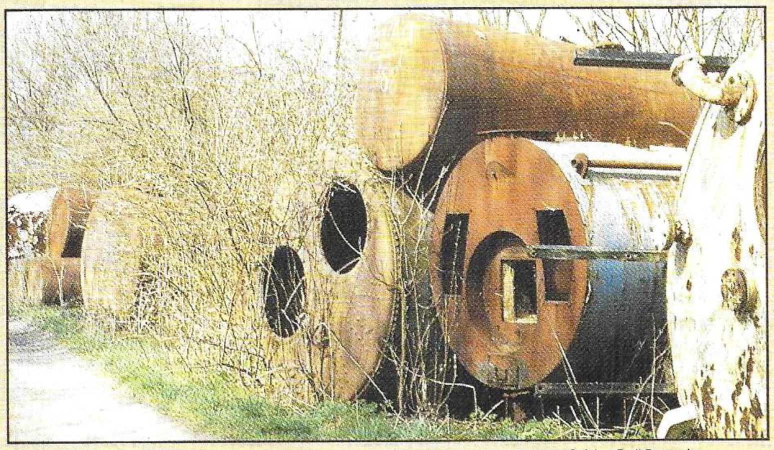
LANCASHIRE BOILERS

Lancashire boilers have two flues of smaller diameter, offering a greater heating surface and a lower flue crown, though at the expense of reduced flue cross-section, of little significance in their usual applications. The two flues were sometimes united at the firebox end, providing a large grate area, but complicating the design and construction, requiring the use of stays. Both flues led the gases to external flues in the brick setting of the boiler, as in the Cornish type. The Lancashire type was patented by William Fairbairn in 1844, and has remained in use ever since. Both these types of boiler could be fitted with water tubes within the flues, and this practice was common with later Cornish boilers. The Lancashire boiler formed the basis of some short-lived freak designs, such as one with the two flues united into a single flattened shape, with vertical water tubes acting as stays. This sort of thing made it far more difficult to withdraw the flues for overhaul, and even to climb inside them for inspection.

Though the cylindrical boiler appeared early and was in use for a long period, it must be remembered that a great number of the early internally fired boilers were operated at very low pressures and so could be rectangular boxes with labyrinthine flues inside them. Such boilers were very common on land, and almost universal at sea for the first half of the 19th century. They had large rectangular flues through which a cleaner could pass, and these turned back and forth to fill a large part of the space inside the boiler shell. The shell itself was not exposed to the fire anywhere, so it could be made of flat plates caulked with lead, and if it leaked at the seams it did not matter, because scale would soon build up and seal the gaps. The shell had only to be strong enough to contain the weight of water, and it did not have to be made of iron, or indeed of metal at all. Wooden boxes served the purpose on occasion, notably in America at the turn of the 18th and 19th centuries, and there were also a few boilers made of stone in England.

Hubble-bubble, boil and trouble

The foundation stone of the mechanical side of the building services industry is the boiler, but not many people know of its early history or of the names of its pioneers. *Paul Yunnie* takes us back to the days when guides and catalogues didn't exist.



Above: Today, the final resting place for a great chunk of our industrial heritage: a field at Bell Broughton, Worcestershire.

There is nothing new about boiling up large quantities of water, and the idea of using boilers to produce steam as a means of power goes back to the 17th century.

The need to provide power for draining mines, powering mills and for water supply occupied the minds of many people during the 17th century; men such as Denis Papin (1647-1712), Edward Somerset, later the Marquis of Worcester (1601-1667), and Thomas Savery (1650-1715).

Thomas Savery took out a patent in 1698 for "....raising of water...by the impellent force of fire..." This engine was, however, very limited in its use as it was only capable of lifting water about 20 ft and therefore only useful for small domestic water supplies. The limiting factor was the boiler construction which was very basic and followed known construction techniques.

Then, in 1712, along came Thomas Newcomen. Newcomen (1663-1729) was an ironmonger from Dartmouth who supplied the Cornish tin miners. As the mines were driven deeper water became more of a hazard. With his partner, John Cawley, Newcomen produced a practical design for the construction of a steam engine for the purpose of mine drainage.

It can be reasonably claimed that Newcomen not only invented the first practical steam engine but also, in around 1712, the first practical boiler. History records his steam engine, but the fact remains that this would have been useless without his invention of the boiler that went with it.

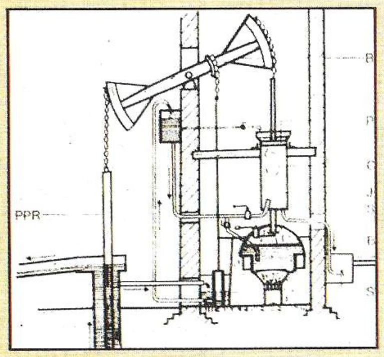
Because of its shape, this boiler became known as the Haystack boiler. It owed much of its design to a brewer's copper. Made of small copper plates and circular in plan, it was able to provide steam at only a little over atmospheric pressure. The boiler was brick-set allowing waste-flue gases to pass around the outside of the boiler before reaching the flue.

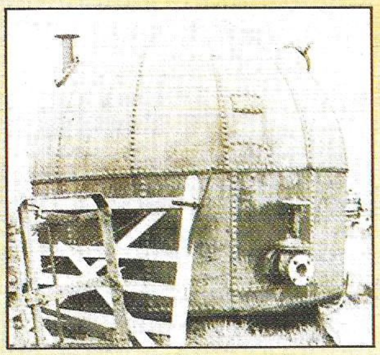
The Haystack boiler was developed by others over the following years. First a lead top was provided and then, in 1725, Stanier Parrot of Coventry used wrought iron plates for the bottom of the boiler. It is unlikely that he actually made a complete boiler out of iron, but it is known that such a boiler was made by Smeaton for an engine at Long Benton in 1772.

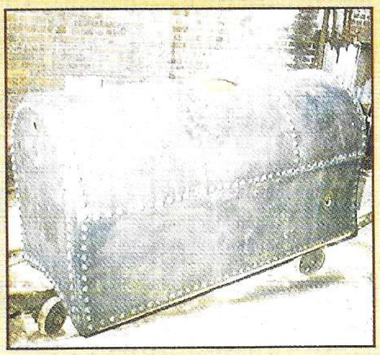
Development continued until boilers with domed bases 20 ft in diameter were made. You could still see Haystack boilers in use at the end of the last century. Different places and makers referred to these boilers as Haycock, Beehive, Balloon or even just plain round boilers.

With the demand for more powerful steam engines came the requirement for larger heating surfaces. An elongated version of the Haystack, called the Wagon boiler, came along in about 1780. This boiler is often attributed to James Watt (1736-1819), but there is no conclusive evidence of his being involved in any boiler design.

Below: The simplicity of the Haystack boiler provided the key to beam engine technology.
Right: The fate of most Haystack boilers was to become a water tank. This one ended up in a field in Ironbridge.
Far right: The Wagon boiler followed on from the Haystack. This one was found at Coldharbour Mill in Devon.







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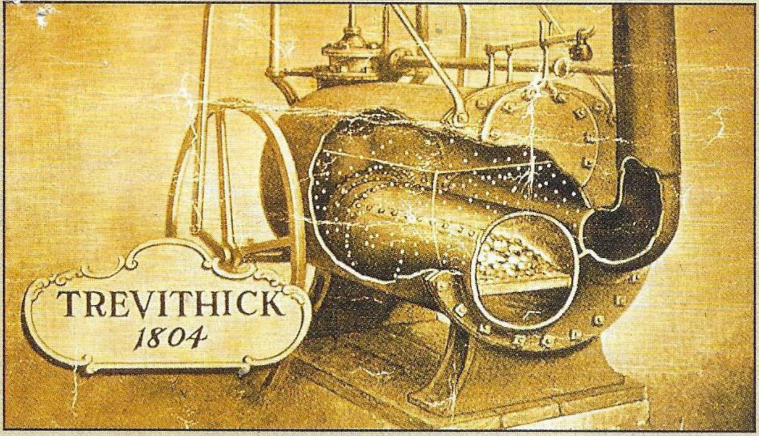
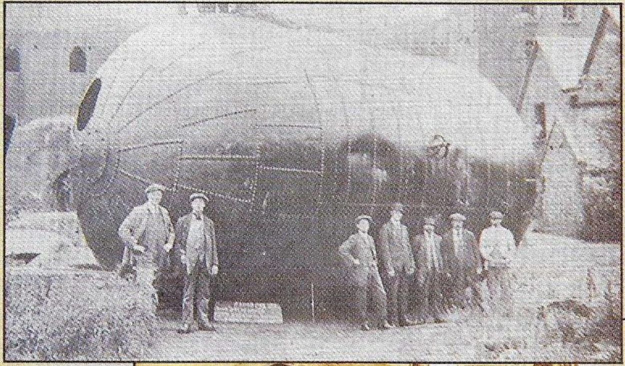
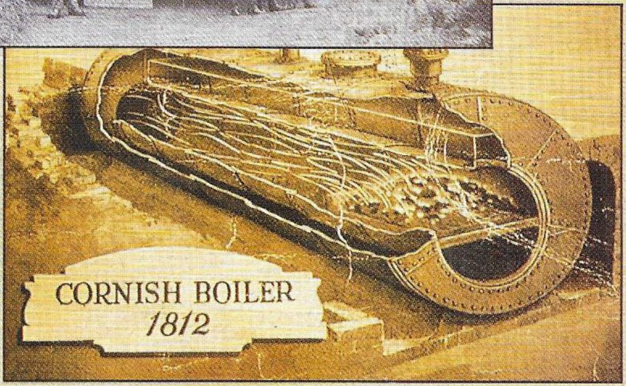


Left: Trevithick became the true revolutionary of boiler design when he put the fire inside the boiler casing.
Centre: Some of Trevithick's egg-ended boiler designs took size to the limit of available technology. This one was at Bliss Hill, Ironbridge, while ***below***, Trevithick's Cornish boiler was a terrific breakthrough in power availability. A few are still operational today.
Bottom: Cornish boilers at Middleton Top, Matlock, Derbyshire.





These boilers were made of riveted wrought iron plates with a similar external flue arrangement as the Haystack, with internal fire box and smoke tubes being added some time later.

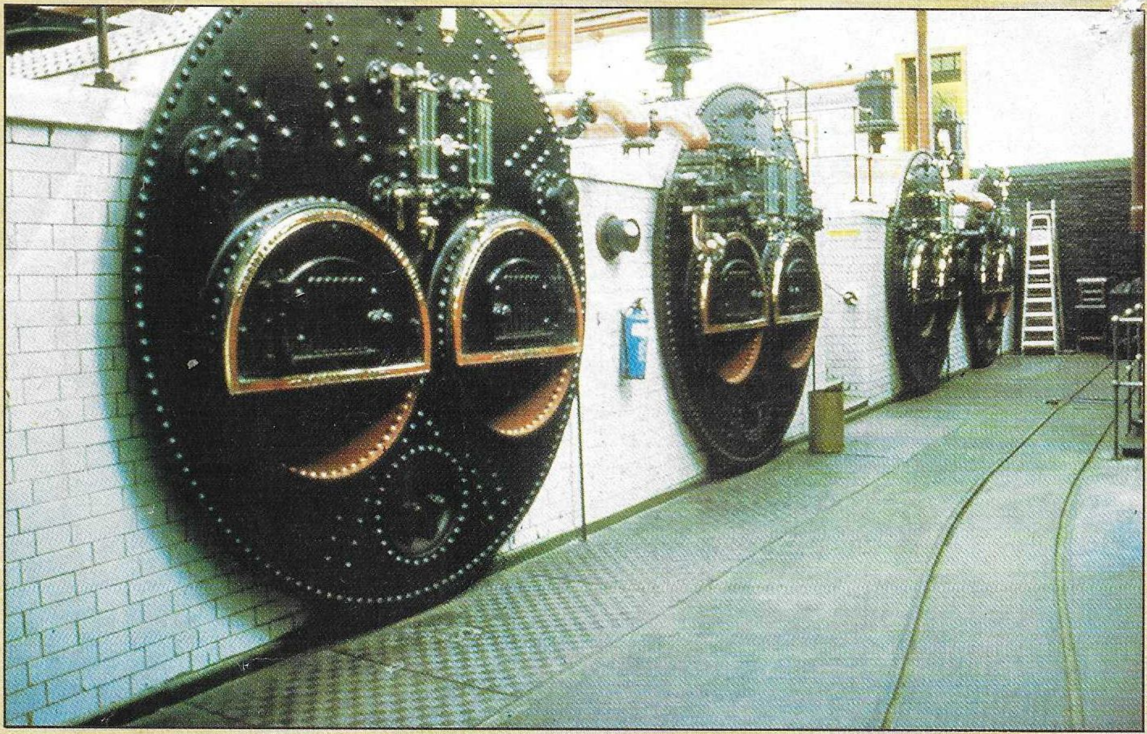
Both these early Haystack and Wagon boilers were usually made by blacksmiths, but by 1790 a definite boiler making industry was established in the Midlands. It was at about this time that Messrs Boulton and Watt began buying their boilers from John Wilkinson of Bradley, Tipton (also at Bersham, Wrexham) and from John Horton of Great Bridge, West Bromwich.

The trouble was that these boilers could achieve little better than atmospheric pressure. Better construction and retaining stays allowed pressures to increase to about 10 psi but, inevitably, the need for better fuel economy (especially in areas such as Cornwall which were remote from the coalfields), and the move towards high pressure engines, led to a new design of boiler.

And so it was that one Richard Trevithick (1771-1833) produced a boiler, in 1802, that was globular in shape, externally fired and made of cast iron. Then in 1805 he developed his high pressure engine and boiler which was cylindrical with a U-shaped furnace table. The egg-ended boiler was developed at about the same time and achieved a maximum pressure of 70 psi. This, however, remained externally fired.

Then, in 1812, while the politicians and armies were having their day, there came true revolution in the form of the Cornish boiler. This is attributed to Trevithick but, in all fairness, a similar boiler was also being developed at about the same date in the USA by Oliver Evans (1755-1819). Although there was correspondence between Trevithick and Evans, it appears that the design of the boiler was reached independently.

The Cornish boiler design, however, is still in use today, although in much reduced numbers. The boiler is made of a riveted outer shell with a single internal furnace. The boiler was able to withstand an incredible pressure (for those days) of 120 psi.



The mill owners of Lancashire were not impressed, however, and demanded even greater heating surfaces and capacities. Hence it was, in 1844, that William Fairbairn (1789-1874) and John Hetherington of Manchester developed the Lancashire boiler. This boiler had a much larger diameter than the Cornish boiler and had two furnace tubes, originally intended for alternative firing.

In 1851, Galloway increased the heating surface and improved the efficiency by introducing tapered water tubes that bisected the furnace tubes. This also gave better circulation and added an element of strength to the boiler. In the same year, Adamson improved the seams of the flues and these were further improved by Hill in 1860 and by Paxton in 1885. The greatest improvement was by Samson Fox of Leicester who, in 1876, introduced hammered corrugated flueways.

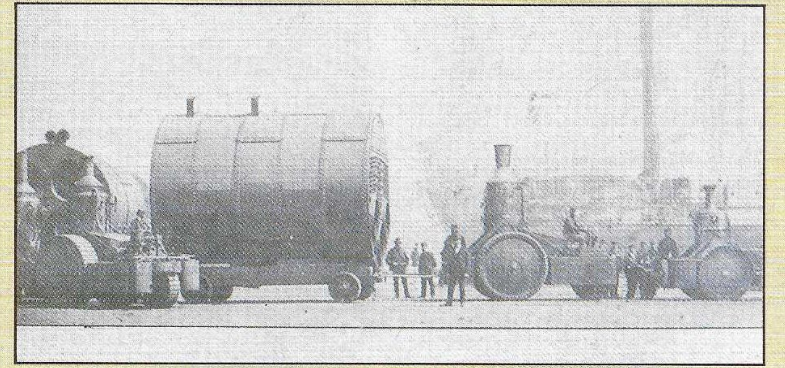
It is still possible to strip to the waist and shovel coal into one of these hungry beasts but their days are now numbered as modern upstarts in the way of water tube and fire tube boilers have come along. But that, as they say, is another story.

Paul Yunnie is the divisional manager, Water Heaters for Andrews Industrial Equipment. He is also a member of the CIBSE Heritage Group. He has tracked down many old boilers and is constantly on the lookout for more.

Further reading

☐ *Building services engineering*, Billington et al 1982.
☐ *A short history of the steam engine*, Dickinson, 1938.
☐ *Early applications of engineering to the warming of buildings*, Dufton, 1941.
☐ *Steam boilers*, Fowler.
☐ *The development of the factory*, Tann, 1970.

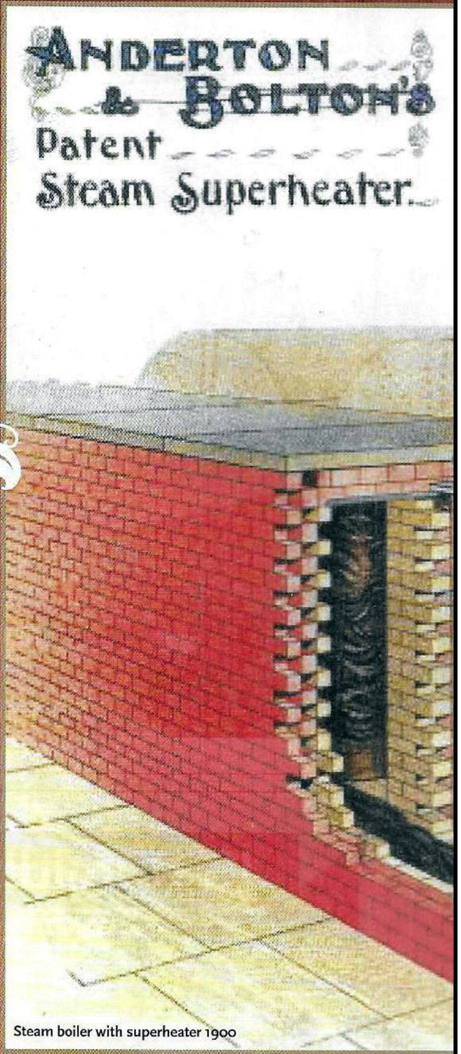
Thanks to John Powell of the Ironbridge Gorge Museum, Salford, for his assistance.



Top: The all conquering Lancashire boiler became the ordinary man's picture of what a boiler looked like. Here, in their prime, are four Yates and Thompson boilers of 1934 of 3500 gallons capacity and producing 6000 lbs steam per hour each.
Centre: Transport of large boilers provided huge problems. This artist's impression gives some idea of the task. No tarmacadam roads, nothing but horsepower; long distance travel took a long time.
Above: By 1890 these boilers on Glasgow docks were being pulled by steam engines.

Steam was fundamental in heating some of Britain's most famous buildings during the Victorian age. **Laurie Brady** and **Derek King** argue that the 19th Century technology still has a role to play in providing cost-efficient energy for hospitals today

Return of the STEAM AGE?



Steam boiler with superheater 1900

Steam may be old-fashioned, but, even in this day and age some hospitals still use it and industry experts consider it to be 'proper engineering'.

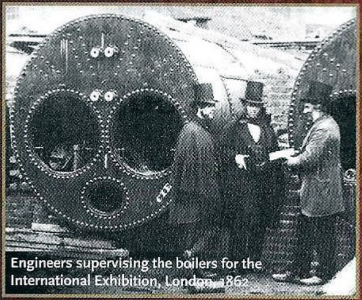
But is steam a viable way to convey heat energy from the central boiler plant in modern district heating systems, or is it just a Victorian hangover? Some would argue that pressurised hot water systems are the more modern option. They do the same job as steam, more efficiently, and without all those technical headaches, don't they? Maybe...

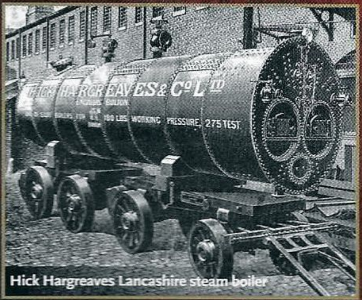
Perhaps a way to assess the feasibility of steam, is to make a technical comparison with pressurised hot water systems. Steam has a higher heat capacity than hot water, so is capable of conveying a lot more heat energy in smaller pipework. Thinner pipes not only reduce capital cost but also normally mean lower heat emission losses. But it's not quite as simple as that; the higher temperatures of steam may reduce – or even eliminate – this benefit, though steam enthusiasts would always point out that the high standard of modern insulating materials and techniques make this point largely moot.

Another advantage is that, in steam systems, the pressure differences caused by condensing steam provide sufficient energy to propel steam through the pipework, so a circulating pump is not required – although, in reality, steam systems cannot be entirely pump-free. Condensate must be returned to the boiler via the hot well tank, and boiler feed water must be pumped to overcome boiler pressure. Condensate return flow rates are, however, smaller than those for hot water systems and this means lower pump duties.

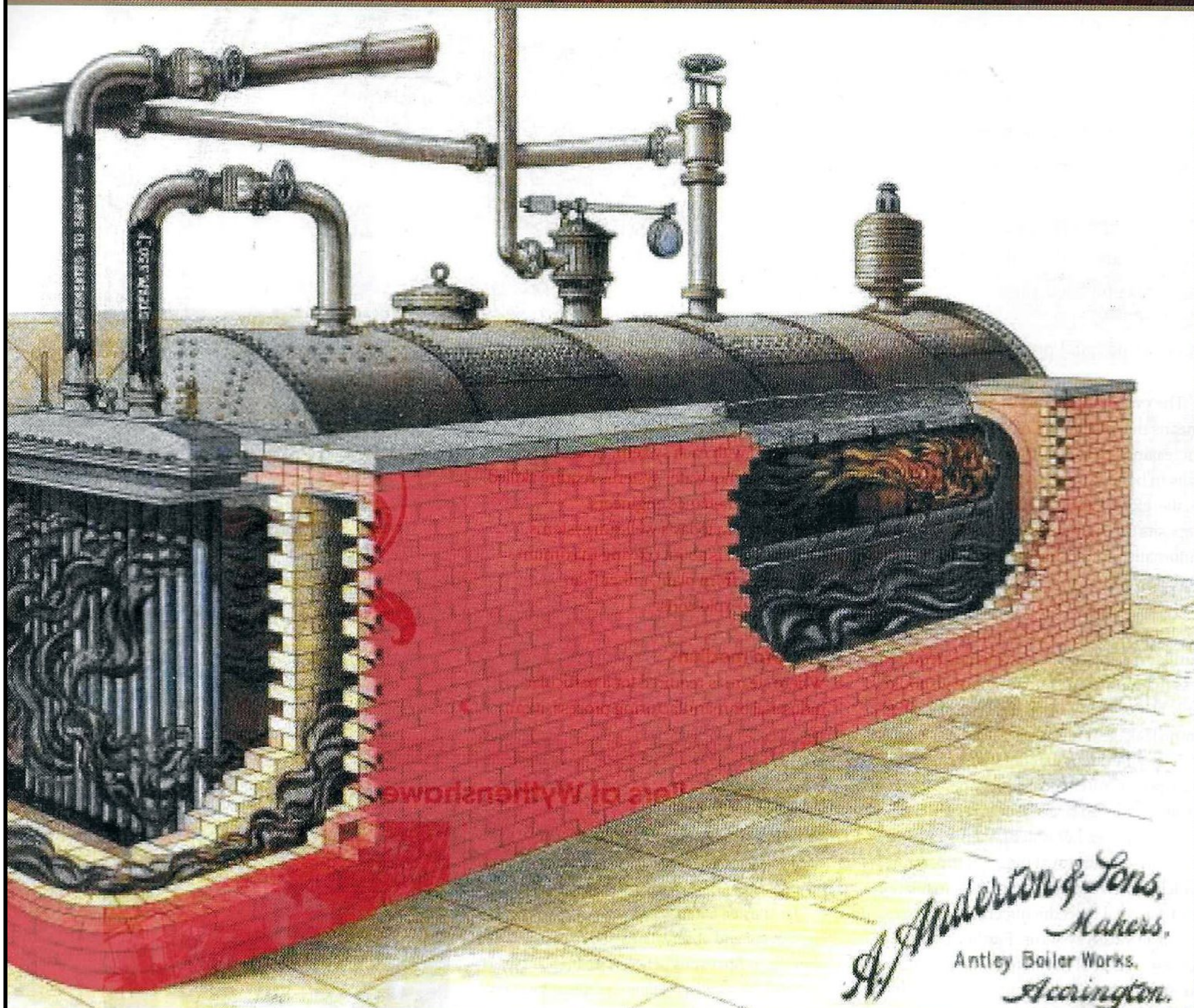
Condensate tends to bring its own technical challenges into the mix, though. In poorly designed or incorrectly functioning systems, condensate can cause water hammer (when a fast-moving fluid or gas is made to stop or change direction suddenly) in steam pipework, and this is one reason why it must be captured by strategically located steam traps before being returned to the boiler.

These are a critical factor in the efficiency of steam systems – it is important that they are carefully maintained. Depending upon its


Engineers supervising the boilers for the International Exhibition, London, 1862


Hick Hargreaves Lancashire steam boiler

2013



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pressure, condensate can contain significant amounts of energy, which can prove awkward to manage. For instance, if pressurised condensate is delivered into a vessel that allows the liquid to evaporate, flash steam can result, though this can be utilised for low pressure applications.

The efficiency of steam systems is enhanced by its potential to deliver large amounts of heat energy by condensing and releasing latent heat. A correctly functioning steam trap controls this process by only opening once steam has condensed. Traps passing live steam will waste energy and can create problems in condensate lines. Nowadays, however, traps can be monitored via wireless technology and a building management system (BMS) can raise an alarm if a trap fails.

RECORDING THE PAST

The CIBSE Heritage Group, which supplied the pictures for this article, is celebrating its 40th anniversary this year.

The group, which was established in 1973, aims to discover and record all aspects of building engineering services history, including information and pictures on pioneers, companies, services and equipment.

The committee is made up of representatives from CIBSE, English Heritage and the National Trust.

Visit **www.hevac-heritage.org** to see more.

> In poorly designed or incorrectly functioning systems, condensate can cause water hammer in steam pipework

The main differences between steam and pressurised water	
Steam	**Pressurised hot water**
High heat content (latent heat approx. 2100 kJ/kg)	Moderate heat content (specific heat capacity 4.19 kJ/kg K)
Extensive water treatment required	Less extensive water treatment needed
No circulating pump needed (though condensate pumps are required)	Circulating pumps needed
Smaller pipe sizes	Larger pipe sizes
Steam traps and condensate handling techniques required	No condensate handling required
Less complicated zone controls – that is, two port valves are sufficient	More complex zone controls, such as three-way mixing/diverting valves needed
Certain hospital processes require steam	

The evaporation process for steam systems means that distillation of the water occurs, increasing the concentration of dissolved salts in boiler water. Feed water treatment is, therefore, vital to prevent corrosion and deposits on heat transfer surfaces, but automatic monitoring of total dissolved salts and blowdown can minimise heat energy and water losses. Of course, while hot water systems also require chemical treatment for similar reasons, such treatment is required less than in steam systems, since it should only be necessary when the system is filled – some leakage is always expected.

It is self-evident that hot water cannot transport as much heat energy per kilogram as steam can, so larger pipe sizes should be used. However, hot water systems that are pressurised can run at higher temperatures, which means that the integrity of insulation is just as vital for reducing emission losses as it is in steam systems. Furthermore, pressurisation of hot water systems requires supplementary equipment such as gas-filled vessels, pressurisation pumps, expansion tanks and circulating pumps.

Temperature control in steam systems can be achieved by exploiting the thermodynamic relationships between temperature and pressure, whereas hot water systems tend to require a mixing and/or diverting valve arrangement, or two port valves linked to variable speed pumps.

Direct energy comparisons between the two systems hinge on emission losses and pumping costs. Steam systems can use steam generated on site for pumping, whereas pressurised systems rely on electricity, which – if generated in power stations – results in the use of more primary energy. Of course, if combined heat and power (CHP) is available, the balance of the primary energy comparison changes.

Bearing all of the above in mind, it is evident that direct technical comparisons are inconclusive. A more significant factor for specifiers might be the maintenance associated with each system. Both steam and pressurised hot water systems require skilled, trained maintenance engineers.

However, in today's well-run systems, maintenance is about coaxing maximum efficiencies from plant, rather than preventing explosions.

Modern medium

Where steam is required for a particular industrial or manufacturing process, it can

Steam boilers at Wythenshawe hospital

Some interesting and useful work has been performed recently by Ken Eaton, a hospital engineer at Wythenshawe Hospital in Manchester. Eaton was able to carry out some first-hand observations and make working comparisons between steam plant at Wythenshawe and a medium temperature plant at the Royal Derby Hospital.

Eaton found that the maintenance requirement in terms of man-hours was similar for the two types of system. Both require regular boiler strip downs and inspections, though the medium temperature hot water (MTHW) boiler plant has additional pressure vessels, which must also be inspected, while the steam system incorporates steam traps that come with their own maintenance needs. Domestic hot water and plate heat exchangers for both systems again had similar requirements for strip down and inspection.

For condensate return pumping at Wythenshawe, a comparison study was carried out between electrically driven and steam-driven pumps. The electric pumps were found to handle greater quantities of fluid and could be conveniently arranged in duty/standby mode. However, the electric pumps required more maintenance because of mechanical seal


Modern steam boiler at Wythenshawe

problems and tended to suffer from cavitation problems if steam traps were not operating correctly.

No cavitation problems were reported for the steam-driven pumps, which reliably operated for long periods without developing faults. The Wythenshawe engineers described them as 'maintenance-free'. The steam supply to power the piston/drum, which propels the condensate, is supplied through a valve operated by a float arrangement. When the condensate fills the pump to a prescribed level, the steam forces the drum to deliver the condensate into the condensate line. This type of pump provides a steady flow, which tends to limit the cooling effect that can occur if pumping is intermittent.

be beneficial to provide the primary energy for the heating and hot water requirements of associated or nearby buildings. Hospitals, of course, have particular processes where steam is a requirement, particularly for the sterilisation of equipment and materials, and some hospitals also include large laundries. If we add absorption chillers to the mix, then the economic and energy arguments can stack up in favour of steam on hospital sites.

The choice between pressurised hot water and steam requires a careful analysis of the capital and running costs for the particular installation. Each situation will have unique factors, and it is important that decisions are not based solely on the preconceptions that steam is 'old-fashioned' or technically problematic. Design, installation techniques, and equipment have advanced considerably.

In addition, there are several advanced technologies that can greatly enhance the viability of steam in modern installations. These include: the injection of steam into feed water tanks to remove oxygen, so reducing water treatment requirements; the use of virtually closed systems to reduce water losses; blowdown heat recovery techniques; and the intelligent use of flash steam.

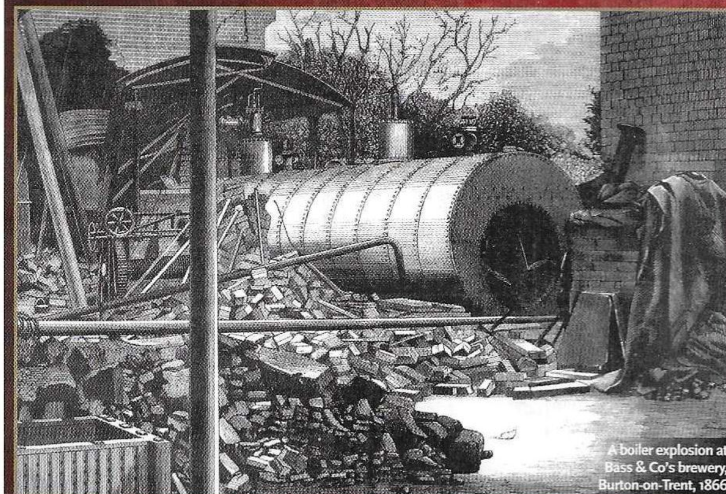
Another vital factor is to draw on the knowledge and experience of the facilities managers, who will eventually operate and maintain the system. Not only can this beneficially influence design, but it also enables engineers to balance the sophistication of the design with the facilities management resource available.

CIBSE Knowledge management committee is preparing guidance on the design and operation of steam systems, which is due to be published next year.

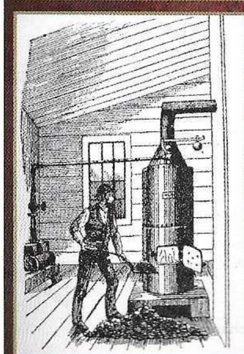
LAURIE BRADY MCIBSE and **DEREK KING MCIBSE** are senior lecturers in building services engineering at Liverpool John Moores University
Technical adviser: **KEN EATON**, Wythenshawe Hospital

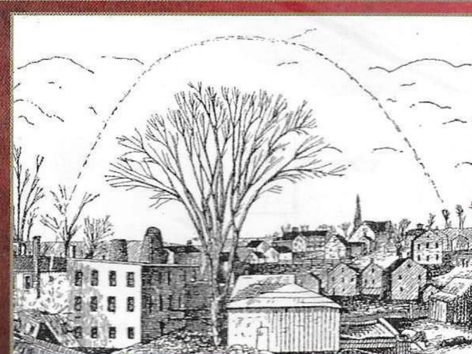
VICTORIAN BOILER DISASTERS

Between 1882 and 1893 in Britain, there were 660 boiler explosions resulting in 313 deaths. Essentially, the reason that boiler explosions no longer occur is because of enhanced engineering knowledge and properly planned maintenance regimes, using appropriately skilled maintenance technicians. Boiler explosions would often have been due to poorly planned maintenance, coupled with unskilled maintenance fitters.



A boiler explosion at Bass & Co's brewery, Burton-on-Trent, 1866





Before and after... the disastrous effects of a boiler explosion c1890 – right, the path taken by the boiler