4. STEAM POWER

In lecture 1 we outlined the early development. So we will now start with **Newcomen**, who is supposed to have entered partnership with Savery (who held some all-embracing patents) in 1705. It is thought that N erected a steam pump at Huel Vor in Cornwall in 1710 and that it was not very successful and that the Cornish mine captains would have nothing more to do with "fire-engines" until 10 years later when their success was well proved elsewhere. N.B. The Newcomen engine was terribly heavy on coal, and in Cornwall coal was expensive. This may be why N next tried his luck in the Midlands where coal was cheap. He had (or made) contacts in Bromsgrove Baptist circles and enlisted Joseph Hornblower from Bromsgrove as his assistant. (H later went to Cornwall with N and his son Jonathan and grandsons Jonathan and Jabez became famous Cornish engineers).

N built an engine at or near Dudley Castle in 1712 and at last achieved success - he was then 49. This was a remarkably fully-developed engine, far ahead of anything contemplated by anyone else. Included self-acting valve gear. Indeed little change was ever made in principles until Watt.

Henry Beighton, of Griff near Nuneaton, also helped Newcomen. There is a picture which shows an engine which may have been erected at Griff in a year before 1717.

There were also N engines in the north - certainly one near Newcastle-upon-Tyne by 1715, and another at Whitehaven.

Although N engines were improved in minor detail, it can be seen from the drawing of Smeaton's N engine at Long Benton in 1772 that the basic design remained. N engines were still being built a century later.

Some remains of N engines still preserved.

Sizes of N engines. (cylinder diam in inches)

Dudley 1712 - 21";	Heaton 1733 - 33";	Long Benton 1748 - 48";
5 HP	15 HP	30 HP

60" cyls became popular with 45 HP for mine drainage

Largest ever was 82" in 1810, 100 HP.

Strokes around 7 ft.

Construction of N engines originally involved brass cylinders and copper boilers.

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A brass cylinder in the early 1700's might cost £250. But (largely helped by the N engine which cheapened coal and iron) cast iron began to be available, and a cast iron cylinder by 1740 cost only £20. So in spite of somewhat reduced efficiency, CI came into use.

The next real innovation was the separate condenser of James Watt (1736–1819). Watt was a delicate, studious lad who took up mathematical instrument making, and after a year's training in London 1755 – 6 obtained a post in the College of Glasgow as instrument mechanic. One of his jobs was to repair a model of a Newcomen engine which had never worked. Watt made it work and mastered its principles. He was appalled at its terrible waste of steam and appreciated that this was mainly due to the alternate heating of the cylinder to boiling temp. and cooling to room temp. He found by experiments on a model he made specially that the volume of steam used per stroke was several times the volume of the cylinder. By discussions with his colleagues the professors at the College, he learnt of the newly-discovered principle of latent heat. He then thought of the separate condenser to avoid having to cool the cylinder. This invention cut fuel consumption by 75% – i.e. to one-quarter. Patented 1769. (N.B. Prof. Joseph Black was Watt's main adviser in all this).

The story of the next seven years is complicated, but in short Watt met Matthew Boulton of Birmingham, who was a manufacturer in a large way, in 1769 and the two men liked one another. Boulton, who was no engineer, was a first-class business man and foresaw a world market for Watt's engine. Boulton was able in 1773 to obtain the $\frac{2}{3}$ share of the patent that Watt had previously allotted to an earlier sponsor Roebuck. He then managed to get a 25 yr extension of the patent in 1775. Watt and Boulton became partners then too.

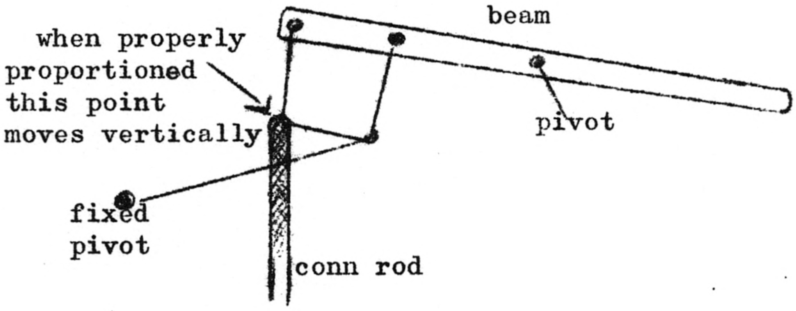
Watt preferred to develop his engine slowly, but Boulton pushed him to make a big one quickly! He made a 50" one for Bloomfield Colliery near Tipton, started in operation 1776, very successful.

The big saving in fuel meant that Watt's engine was most attractive in areas where coal was expensive. Moreover, B & W decided to charge for their engines on a basis of royalty in respect of fuel actually saved – (they took one-third of saving). So it was most profitable for them too to go to such areas. Hence Cornwall was the scene of the most intensive installation of Watt engines. (N.B. It was also under-engined before

Watt owing to uneconomic working of Newcomen engine). During 1775-1800 B & W erected 52 engines in Cornwall. B & W's competitors in Cornwall - Bull, Hornblower and others - had erected another 30 engines which were thought to evade the patent.

Rotative motion. Everyone realized the need for rotative motion from steam engines, and the water-wheel had been used as a means of getting it. Boulton realized the need for a rotative steam-engine as urgent and paramount, but Watt thought pumping more important and didn't apply himself to the problem until 1781. The crank had already been patented by Pickard in 1780/in relation to steam engines, so Watt developed the sun and planet gear. (see Fig.14 of Dickinson). This he patented in 1781 and used at least until Pickard's patent ran out in 1794.

To get double-acting cylinders, (which was not important in pumping, but desirable for rotating motion) it was necessary to change from the chain connection at the end of the beam, yet to have some means of over-coming the horizontal component of motion. For this Watt invented the parallel-motion (also shown in Fig.14 of Dickinson).



First double-acting rotative engine built in 1783

Another invention of Watt's was to use the expansion of steam, i.e. cut off steam at some point in piston stroke and let expansion do the rest. He thought about this in 1769, made experiments in 1776, but it was'nt worth applying until higher pressures came in. Patented 1782, but not used in Watt's time.

High pressure engine dispensed with vacuum and relied on steam pressure. (N.B. Watt's engines were still like Newcomen's in relying not on steam pressure but on vacuum). One of the earliest proposals for a h.p. steam engine was by Jacob Leupold (1674-1727) of Leipzig. In 1724-7 he produced a diagram of a twin-cylinder engine (see Fig.17 of Dickinson). But it was really Richard Trevithick (1771-1833) of Cornwall who pioneered a real development. 1798 experimenting, 1801 actually had his engine developed as a road vehicle, as mentioned in earlier lecture. His engines were notable for cylindrical boiler, internal flue, cylinder in boiler to keep it warm, crossheads (can't find origin of these!) (see Plate IV of Dickinson).

From here on, the development of steam engines has been smooth, with no discontinuities.

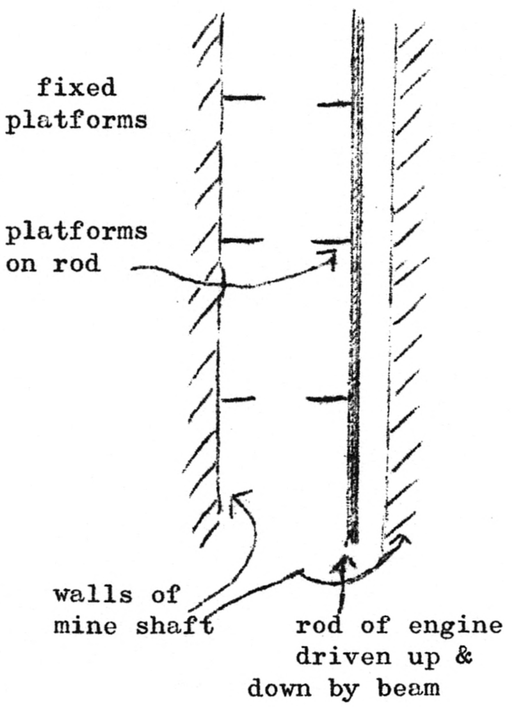
APPLICATIONS OF STEAM

1 Mine pumping was the earliest - already discussed - 1712

2 Stationary rotative engines used for mine winding in Cornwall in 1784 at Wheal Maid in Gwennap. (called "whim engines" in Cornwall and elsewhere).
Miscellaneous industrial applications followed, especially with high-pressure engines which could be made smaller.

3 Man-engines, introduced in Prussia in 1833 and Belgium in 1839 as water-wheel-driven devices.
In 1842 developed in Cornwall as a steam-driven device.
By 1843 working to a depth of 248 fathoms (1488 feet) in Tresavean mine.

Principle simple:-



One man per step, often 100-200 men could be on rod at one time.
Saved a lot of money, and also the health of the miners, who suffered greatly from heart trouble & consumption as a result of 1000 ft climb up ladder after a full day's work on poor nourishment.
Many accidents, of course, normally about 2 or 3 fatalities per year in Cornwall.
Negligible compared with benefits to health.
Worst disaster of all was the Levant Mine disaster in 1919, when the rod broke away at the top and the safety catches failed to hold it. 150 men on the rod at the time, 31 killed 11 seriously injured. Not due to age or bad

maintenance; flaw in wrought iron cap plate being found to be the cause. This was the last man-engine, and it was never re-opened.

4 Steam Hammer invented by James Nasmyth (1808 -) in 1839.

This used high-pressure steam, admitted to the underside of a piston in a vertical cylinder. This raised hammer vertically in a slide. Valve opened & hammer drops on to work piece on the anvil.

5 Railway Locomotives

6 Road Vehicles & Locomotives and Farm Engines

Trevithick's steam vehicle of 1801 already mentioned.

A number of "portable" wheeled engines developed from 1830-1850, but generally rather behind railway locos. Farming applications very important - see Fowler's ploughing engine of 1858 and his self-moving anchor (he had a terrible job to prove it saved money over horse traction, but eventually demonstrated 25% saving!)
- see Robey's engine and threshing machine 1862. Used for road haulage - circuses, fairs, etc., heavy goods generally. All sorts of variations for special purposes. Continued to be built right up to 1934 at least, when Fowler's built the last showman's engine. Powerful tractors for general purposes built by several firms right up to 1930's e.g. Robey tractor 1927 in Fig.164 of Hughes, and Marshall 1933 in Fig.166.
There were also steam lorries, e.g. by Savages of Kings Lynn and by Sentinel.

7 Steamships

A vitally important development.

First patent for a steam-boat 1736, Jonathan Hulls. Paddles driven by a peculiar arrangement from a Newcomen engine. Probably this boat was never built.

Numerous people in Britain, France and America had ideas and tried them - perhaps the most important was the steam paddle-boat of Fitch on the Delaware River, 1783-85. Rumsey 1784 demonstrated a steam-boat on the Potomac River which worked by using a steam pump to accelerate water from bow to stern and thus impel the boat along - he got 3-4 mph out of it!

In 1788 Symington applied a steam engine to paddles in a boat constructed by Miller and attained 5 mph on Dalswinton Lake in Scotland.

Symington made the first practical steam-boat in 1801 - the "Charlotte Dundas", using a Watt engine and paddles - and attained 6 mph on the Forth and Clyde canal.

Developments proceeded fast.

By 1838 Brunel's "Great Western" had crossed the Atlantic. She was still a wooden ship with paddles, 212 ft. long, 35'4" broad, displacing 2300 tons at draught of 16'8". She was highly successful.

The "Great Britain" went into service in 1843. She was of iron and screw-driven - a very courageous development on Brunel's part. She was 322 ft. long, 51 ft. broad, displacing 3000 tons at 16' draught.

Probably the most daring design of all was Brunel's "Great Eastern", which he intended for the Australian voyage, carrying its fuel for the whole journey. It was huge, 680 ft. long, 83 ft broad, 58 ft deep, 4000 h.p. applied to screw, + 2600 h.p. applied to paddles, six masts for sails (to save fuel where possible), 11,800 tons when light and 27,400 tons displacement when loaded to 30 ft draught. Provided stowage for 12,000 tons of coal and had accommodation for 4000 passengers. It was launched in 1858 (after much difficulty in getting such a large hull into the Thames) and completed in 1859. In 1860 it crossed from England to New York at 14 knots. Unfortunately it used more coal than Brunel had expected; 280 tons/day instead of 160. She was not a commercial success, from 1865 frequently used for cable-laying, scrapped in 1886.

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