Mr. Watt's Stupendous Steam Engine

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SUMMARY An account of the origins and history of a 1785 Boulton and Watt rotative beam engine in the Museum's collection, is presented. Plans for its restoration and display are outlined, and its mechanical, economic and social significance are discussed.

1 INTRODUCTION

In a recent bulletin of the International Council of Museums (ICOM), one writer described Museums as places where each object kills every other, and all of them together annihilate the visitor. This is yet one more variation on the long held perception of museums as cemeteries of dead objects.

The Power House Museum, to open in Sydney in 1988, is making a full frontal attack on this tradition. It will be a place of vibrancy, excitement and involment providing entertainment as well as education for visitors of all ages. The project I will describe epitomises this spirit, for its aim is not just the preservation but the revitalisation of an outstanding example of Australia's, and indeed the world's, engineering heritage. I refer to the 1785 Boulton and Watt rotative beam engine in the Museum's collection, which is being restored to steaming condition for its bicentenary this year, and which will be the star performer in an exhibition featuring a dozen working steam engines in the Power House Museum in 1988.
The engine has been called the world's most significant mechanical antiquity by one authority (Minns, 1980) - and even the Mona Lisa of Technology! Certainly, it is the oldest steam engine of any kind in Australia, and the oldest rotative engine in the world. In addition its mechanical features and its industrial economic and social significance give it an intrinsic interest far beyond the mere fact of its survival, although that is a fascinating story in itself.

2 PRESERVATION OF THE ENGINE

2.1 Aquisition by the Museum

The Museum's role in the preservation of the engine began almost 100 years ago, in 1887. As is so often the case, it was the result of coincidence and circumstance, rather than rational planning.

The precursor of the Power House Museum, itself a branch of the Museum of Applied Arts and Sciences, was established in 1880. Called then the Technological, Industrial and Sanitary Museum, its founding was a direct result of the sucess of the 1879 Sydney International Exhibition. Most of the fledgling Museum's collection was inherited from the Exhibition, but sadly this and its buildings too were destroyed in the Garden Palace fire in 1882. But it was this catastrophe which spurred the undaunted Trustees to begin again from scratch, and indirectly, brought the engine to Australia.

In 1887, one of the Trustees, Professor Archibald Liversidge, then Professor of Chemistry at Sydney University, travelled to England with, amongst other tasks, a commission to acquire new material for the Museum. At this point, coincidence played a strong hand. Firstly, Liversidge had previously taught at the Royal School of Science in London and so had many local contacts. Secondly, his visit coincided with the final retirement of the venerable Boulton and Watt engine that had driven Whitbread's Finsbury brewery for 102 years. It was to be replaced by a modern high pressure compound engine and again by coincidence, the engineer in charge was an ex-student of Liversidge. With his help, Liversidge suceeded in persuading Whitbread's to donate the engine to the Sydney Museum, on condition that Liversidge would "use (his) influence to have it erected, exhibited and kept in good order in the Museum." (Liversidge correspondence, 1887).

In addition the Museum was to pay the cost of packing and freight to Sydney - a total sum of £171.4.6d. Interestingly, the flywheel had to be cut in two to fit into the Ship's hold and the entire engine occupied 45 crates weighing almost 35 tons, which arrived on the wool clipper "Patriarch" on 6 June, 1888 (MAAS archives, 1888).

However, Liversidge's success in obtaining the engine (which even then was an acknowledged rarity) caused the Trustees considerable problems as there was nowhere to put it. No resources to replace the Garden Palace premises were forth coming from the government, despite repeated requests, until the building in Harris Street, Ultimo was completed in 1893 (Willis, 1982). Consequently, the engine remained in storage on the wharf until 1896, when a building to house both the Watt engine and the No.1. locomotive was erected behind the main museum building. However, the engine itself was not fully erected by 1902. When it was actually completed is not documented, but in 1930 an electric motor was installed so that the engine could be seen in motion (MAAS archives, 1895-1930).

2.2 Restoration Programme

Whether any plans were ever made to steam the engine is unclear - certainly no provision for a boiler appears to have been made. But the battle to house it safely had been won, and for 50 years the engine could be seen in operation of a kind. However, it was not very accessible to the public, and all too few visitors even knew of its existence. Now the

Power House project has finally given the Museum the opportunity to do the engine full justice, and to display it in a fashion which, I am sure, would delight the original donors.

Again, chance has played a part. The site of the hard won engine house is being redeveloped by Sydney Technical College, forcing the Museum to dismantle the engine entirely - for the second time in its life - and move it to another site. This has not only provided the opportunity to make detailed engineering drawings of every component, but to completely overhaul the working parts, carry out non destructive materials testing, and to re-erect the engine for steaming trials well in advance of its final debut in the Power House Museum.

Based on the decision to steam the engine regularly on display, conservation guidelines were established which call for replacement of components likely to be subject to heavy wear in running. (MAAS Conservation Report, 1982). After much debate it was decided to sleeve the main cylinder with an inner lining and install a new piston with modern lubrication system to prevent wear on the original components. In addition, replica steam valves have been installed, and new dash pots fabricated as the originals were for some reason removed. The air pump was found to be badly worn and pitted from corrosion. As it could not be operated effectively in this condition it was decided to skim the cylinder and fit a slightly larger diameter sealing ring to the piston, using a 70/30 nylon/cotton material instead of the original hemp rope seal. The condenser was also found to have internal pitting and corrosion, and has been abrasive blasted and treated with a high temperature waterproof surface coating. The brittle cast iron condenser tank has been fitted with an inner stainless steal lining to ensure its watertightness. The main moving parts are in good condition and apart from replacement of bearings require little treatment. It was decided not to re-weld the flywheel boss, as its current state is regarded as part of the engines life history. All original parts replaced in restoration have been retained, and will be displayed with the engine.

When the restoration programme is completed in June 1985, the engine will be in full working order once more and ready to steam on, no longer turning the wheels of industry but rather delighting and instructing generations of Museum visitors, for at least another 200 years!

2.3 Display Programme

The display programme will have two phases. First of all, on Sunday 21 July, 1985 a celebration of the 200th anniversary of the engine's first steaming (Law, Boulton and Watt collection, 1785) will take place at its current site, the Museum's storage facility at Castle Hill outside Sydney. This will be open to the public, and weekend steamings will be held until the engine is once again dismantled for the move to the Power House Museum.

This will be the engine's final resting place, and a great deal of thought and discussion has gone into the plans for its display. The engine will be set in a replica of the brick engine house - a converted stable - at the Whitbread brewery where it was first erected. One side of the engine house will be cut away so that visitors can view the entire engine at once (which has never been possible before since it stands 10 metres high) and at the same time appreciate its original context. A detached staircase and a two level viewing platform will give access to the beam and parallel motion on the higher level, and the value gear below.

Built into the rear side of the engine house will be a display on the "life and times" of the engine. This will cover its own working history, and material on the Boulton and Watt partnership, and the intellectual and industrial climate of Birmingham, especially as represented by the Lunar Society of which both were members. An audiovisual will demonstrate how the engine works, and trace the evolution of steam power from Savery and Newcomen, through Watt, to high pressure engines and turbines. These will be displayed in the main Power exhibition, to which the Boulton and Watt engine will form an introduction.

The display will maximise the visual impact of the engine itself - steaming away at 10 revolutions a minute, with the six tonne beam swinging majestically to and fro, the five metre flywheel spinning steadily at the urging of the sun and planet gear, and the parallel motion linking beam end to piston rod describing its hypnotic curves, it will be an awe inspiring kinetic sculpture. At the same time the display will enable visitors to appreciate the engines historical context and its mechanical features as well. Since the engine will be steaming for about 5 hours a day, the attendant will also provide a live interpretation, enhancing visitors' experience of the reality of the engine's working enviroment.

3 MECHANICAL HISTORY OF THE ENGINE

3.1 Original Configuration

Unlike art objects, mechanical antiquities which survive a century or more are very rarely in their original form, and this engine is no execption. As ordered by Samuel Whitbread, and as originally drawn by Watt in June, 1784, the engine had a 24 inch cylinder with a 6 foot stroke, running at about 10 revolutions a minute in a single acting cycle. Steam pressure at about 5 psi was supplied by a rivetted copper haystack boiler. The piston drove a trussed wooden beam to which it was attached by chains; while a wooden connecting rod drove the flywheel and shaft via a sun and planet gearing.

Interestingly, on these first June 1784 plans, a parallel motion linkage is drawn in pencil, and in a set drawn in November the same year, replaces the chains entirely. Watt patented this device in August, 1784, and this was the first engine built to incorporate it from the outset, though an existing engine was modified earlier.

As far as can be determined, the engine was built to the November plans, which also incorporated a modified wooden beam, laminated rather than trussed, and a cast iron connecting rod.

The plans in the Whitbread port folio in the Boulton and Watt collection also show how the engine was fitted into the stable at Whitbreads, and how it was coupled to the malt crushing mill, its primary function. This was previously driven by four horses from a 27 foot diameter horizontal wheel, attached to the shaft driving the mill stones. The mill was in a building adjoining the stable, and by means of two vertical spur wheels and a horizontal shaft across a passage way, the engine was connected to the toothed outer rim of the horse wheel. The diameters of the various gears were calculated to drive the mill shaft at about the same speed as the horses.

3.2 Modifications

In 1795, after 10 years successful operation, Whitbread decided the engine needed more power so that it could undertake additional functions in the brewery besides driving the malt mill. To achieve this, the engine was made double acting and Boulton and Watt supplied a new cylinder, piston and steam chests and valves. One source (Cauper, Liversidge papers, 1887) suggests that the wooden beam was replaced with a cast iron one at this time. There is no documentary evidence of this; however a new cast iron beam was ordered in 1830 (Foundry Order Book, Boulton and Watt Collection). Since it seems unlikely that such a robust component would have worn out or failed, it is probable that this was the first cast iron beam fitted - certainly it is the one currently in the engine.

In 1814 a third, 25 inch cylinder was substituted, requiring replacement of valve chests. In addition, the engine went through several air pumps, condensors and smaller working parts, so that the deterioration found in the current components appears to have been a common place problem. The sun and planet gears originally had wooden teeth which were a frequent cause of breakdown. These gears have brass teeth, but when they were replaced is not known.

Overall, these modifications have been made to increase the engine's power and improve its performance and reliability, as well as being due to wear and tear. In a strict sense the only original components are probably the flywheel (though cut in half), the sun and planet gears (though not the teeth), the connecting rod and the parallel motion. However, the engine as it now stands, in circa 1830 configuration, represents the evolution of a working machine, and although not entirely "original", in its components, it is the direct descendant of the original 1785 engine.

3.3 The Engine as a Catalogue of Watt's Inventions

Because the engine was built during the period of Watt's greatest inventive activity, it has the added significance of representing a catalogue of his major patents. As originally built, the engine incorporated the separate condenser (1769), the sun and planet gear (1781) and the parallel motion (1784). A major modification encompassed the double acting engine (1782) while the centrifugal governor (1788) was added whilst the engine was in service.

As it stood by 1795, the engine encapsulated all the basic principles of stationary steam power which were to remain unchanged for the next half century. In this regard, as well as in its own individual history, the engine is a living model of the early evolution of steam technology (Fairey, 1827).

4 ROTATIVE ENGINES AND THE INDUSTRIAL REVOLUTION

4.1 Receprocating versus Rotative Engines

The first steam engines of major economic significance were the Newcomen types which came into use for pumping water from mines from the 1720's onwards (Musson and Robinson, 1959). These were reciprocating engines, and the first engines built by Boulton and Watt were also of this type and for this purpose. But the applications of reciprocating engines were limited. All the machinery of the burgeoning textile industry, and most other manufacturing processes, was driven by water wheels. Matthew Boulton, a Birmingham industrialist, was one of the first to see the potential for rotative steam engines as universal industrial prime movers; and his partnership with James Watt enabled him to help fulfil it.

4.2 The Boulton and Watt Partnership

The success of Boulton and Watt as engine builders derived as much from the entrepreneurial flair of Boulton as from the engineering genius of Watt. Boulton's first coup was to obtain an Act of Parliament giving the partnership the exclusive privilege to manufacture condensing engines for 25 years from 1775. In this period the firm produced over 500 engines, or one every 2-3 weeks. This was an impressive organisational feat, given the primitive machine shop and foundry facilities available; not to mention transport difficulties as well, since much work was subcontracted. The completion of the Soho foundry in Birmingham in 1796 brought most operations to a single site and placed the firm in a dominant position even when the Parliamentary privilege ceased in 1800 (Tann, 1981).

By then, over half the firm's out put was rotative engines - a clear fulfillment of Boulton's prediction in 1778 that "the industrial owners of Birmingham and London will become steam-mill mad" (Dickinson, 1968). It was at his urging that in 1782 Watt developed his rotative engine, using initially the sun and planet gearing rather than the simpler crank mechanism to convert reciprocating to rotative motion. This was forced upon him because a patent had already been taken out by a rival for the use of the crank in steam engines (Muirhead, 1859). When this patent was disallowed, Watt engines used the crank, and with their superior efficiency, workmanship and reliability soon led the field.

One of Boulton's most important contributions to the firm's success was his marketing strategy. He picked key figures in various industries to become a vital link in introducing his engines to their colleagues; men like Arkwright in the cotton industries, Wedgwood in pottery and Whitbread amongst the brewers (Tann, 1978).

4.3 Samuel Whitbread and the Brewing Industry

In many ways Whitbread was the most important of Boulton's targets, because the early rotative engines were best suited to a fairly robust application like mill grinding. One apprehensive prospective cotton mill customer wrote to Boulton and Watt in 1786, saying that he had heard that their rotative engines were "very liable to go the contrary way in setting on or stopping the engine, which is very hurtful to the machinery of the mill". In addition, early models without governors were liable to run irregularly, which could be equally hurtful to delicate spinning frames. So for a long time, steam engines were only used in cotton mills to pump water back up to the header pond of water wheels, which ran more steadily, and always the right way. Arkwright, for example, did not buy his first rotative engine until 1792, by which time it had been tamed in less demanding applications like brewing, and flour milling.

Brewing was an ideal proving ground for this new technology for other reasons. With the rapid urbanisation of Great Britain in the late 18th century, a large concentrated market for beer was generated.

At the same time, a new kind of beer was developed called porter which was very strongly hopped and highly fermented, giving it excellent keeping qualities. Both these factors encouraged brewers to expand their capacity, which in turn led to greater mechanisation and generated economies of scale and higher profits. Brewing became highly capitalised and highly competitive; an ideal market for relatively expensive but in the long term, cost-effective machinery. Whitbread himself was already a leading brewer by the 1780's and anxious to stay ahead of his rivals. He was thus an ideal target for Boulton's marketing strategy, for no sooner had Whitbread's engine been installed, than his competitors were clamouring to follow suit. By 1796, Boulton and Watt had sold eleven similar engines to London brewers, who almost always asked specifically for an engine identical to Mr Whitbread's. The Whitbread engine was therefore a significant catalyst in the diffusion of rotative steam power in the brewing industry, and this in turn was a catalyst in its wider adoption in other industries. As the third rotative engine built by Boulton and Watt, it stands at the watershed of the industrial revolution; the application of steam as a universal industrial prime mover.

5 CONCLUSIONS

Although the acquisition by the Museum of the 1785 Boulton and Watt engine from Whitbread's brewery may have owed much to fortunate circumstance, the value of the engine is now inestimable. The restoration and display programme will ensure that it remains at the height of its power for many years to come. At the same time, it will demonstrate to millions of visitors not only the engineering achievements of James Watt, but also the intricacies of the relationship of steam power in general, and this engine in particular, with the industrial revolution form which our present economy and lifestyle are derived.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

BOULTON AND WATT COLLECTION, unpublished papers, Birmingham Reference Library, Birmingham, U.K.

DICKINSON, H.W. and JENKINS, R. (1927, reprinted 1981). James Watt and the Steam Engine. London, Hartington.

FAIREY, J. (1827). A Treatise on the Steam Engine. London.

LIVERSIDGE CORRESPONDENCE, (1887-1896). University of Sydney Archives, unpublished

MINNS, J. (1980). A report on the Transport and Engineering collections of the Sydney Museum of Applied Arts and Sciences. Unpublished

MUIRHEAD, J.P. (1859) Life of James Watt with selections form his correspondence. London

MUSEUM OF APPLIED ARTS AND SCIENCES ARCHIVES, (1888-1930), unpublished.

MUSEUM OF APPLIED ARTS AND SCIENCES. (1982). Conservation report on object #18432, Boulton and Watt beam engine. Unpublished

MUSSON, A.E. and ROBINSON, E. (1959). The early growth of steam power. Econ. Hist. Rev., pp 418-439.

TANN, J. (1978). Marketing methods in the steam engine market: the case of Boulton and Watt. J. Econ. Hist, pp 38-51.

TANN, J. (1981). The selected papers of Boulton and Watt, Volume I, The engine partnership. (1775-1825. Cambridge, MIT Press.

WILLIS, J.L. (1982) From Palace to Power House: A hundred years of the Museum of Applied Arts and Science. Unpublished.