The reconstruction of a mine pumping engine at Sovereign Hill
PETER McCARTHY and BARRY DAVIS

INTRODUCTION
In 1983-84 the Sovereign Hill Historical Park in Ballarat constructed a mine pump of a type widely used on the Victorian goldfields in the 19th century and early this century. As major components of the pump recovered from a mine and restored, along with the steam engine, the project is best described as a reconstruction rather than a replication. While the reconstruction was not on the site of the salvaged pump parts, it was on an abandoned mining lease which had at least three similar pumps in the last century.

THE MINING MUSEUM AT SOVEREIGN HILL
The Mining Museum at Sovereign Hill is a reconstruction or replica of the surface installations and underground workings associated with a Ballarat quartz mine of the period 1880-1916. A quartz mine was a mine which worked quartz reefs containing gold. Hard-rock mining methods were used and the quartz ore was crushed in a stamp mill, or battery, to liberate fine particles of gold for amalgamation with mercury. Although the Mining Museum has been assembled since 1966, the site is an original quartz mining lease of local significance, and original mining equipment has been restored and used wherever possible.

The Mining Museum is divided into surface and underground areas. The surface buildings and structures are open to all Sovereign Hill visitors, while the underground area is accessible only as a guided tour, which takes about 45 minutes to complete.

The weatherboard buildings on the surface include the boiler house, changehouse, engine house, mine blacksmith's shop, and battery house. The engine house contains the winding engine, air compressor and now the pumping engine. The battery house contains the complete ore treatment plant. The poppet heads, or headframe, the pitman's hut and the mine office complete the scene. Seven steam engines are fully restored and operational, with much ancillary plant.

Sovereign Hill is a 'living history' museum or theme park which portrays life on the Ballarat goldfields. It has standards of conservation, research and interpretation which are similar to those of the more formal, government-funded museums. The history and operation of the museum was described in a recent paper (McCarthy & Conder, 1985). When the construction of a mine pump was first proposed in 1980, an investigation was begun into the history of pumping on the Sovereign Hill site, and into the historical development of mine pumping in Victoria and elsewhere.

MINE PUMPING ON THE SOVEREIGN HILL SITE
The site of the Sovereign Hill historical park was mined continuously from the early 1860s until 1911. The history of the major mines can be followed from the mine manager's reports, available in public archives. The Sovereign Quartz Mining Company was established in 1869, with its shaft initially sunk using a horse-whim. Two gold-bearing quartz reefs were passed through, but a third reef at 372 feet connected with a source of underground water which poured into the shaft. The contractor fell behind schedule and the work was completed by employees on wages.

1870 was a year of general economic depression in Victoria, with the value of gold shares being particularly affected. The subject of 'deep sinking' became the theme of letters to the editors and of public meetings, as Ballarat's businessmen...
sought to confirm that the gold lodes continued at depth and that their investments in the city were secure. At a public meeting in February, the Sovereign shaft was proposed as the site for a deep sinking experiment. A plan was developed to sink the Sovereign shaft to a depth of 1000 feet, but finance was not available and the mine failed.

The Sovereign mine was sold in 1871 to Christoph Luth, who had a grocery shop nearby in Victoria Street, Sebastopol, and the deep-sinking plan was revived. As mine pump was required, tenders were called. The pitwork components were described as a '...complete set of plunger and draw-lift workings with pipes to make 480 feet, from 8 to 10 inch diameter. Also rods, plates, sweep rods, bob and all connections and from 10 to 40 feet of 7 inch shafting'. (The Star, 5 June 1871). To install the pump, tenders were called '...for excavating bob pit, crank horse pit. Also, tenders for cutting ground for plunger lift, fixing the same with draw lift...'. (The Star, 14 June 1871).

The pump operated satisfactorily until one day in 1876 when '...something was heard to go wrong with the pump overhead, and immediately a mass of timber and centreing came thundering down on top of the cage'. (The Star, 1 August 1876). Two men were killed, and at the subsequent inquest Stevens, the engine-driver, testified that 'the gib had broken, and the second stroke of the bob had forced the pump rods down the shaft. He could not account for the gib breaking. There had been an old flaw in it for 18 months'. (The Star, 11 August 1876).

The mine never recovered from this disaster, as the bank lost confidence in the management and foreclosed on outstanding debts. Thus the beginning and the end of the deep-sinking venture were seen to depend on the Sovereign mine's pump.

Other mines on the Sovereign Hill site included the Speedwell Quartz Mining Company, the Normanby North Company and the New Normanby Company. Similar pumps were employed at these mines.

HISTORICAL DEVELOPMENT OF MINE PUMPS

The world's first steam engines were built for pumping water from mines during the reign of Queen Anne (1702-14). Those first 'fire engines' were built by Thomas Newcomen, and the design was improved over the next 60 years by John Smeaton and then James Watt. The mine pumping engines were adapted for pumping domestic water supplies and emptying dry docks, and in Watt's time were first applied as industrial engines in non-pumping duties. (Crowley, 1982). The Watt design of separate condenser beam engine continued to be important in mine dewatering until the end of the 19th century, by which time it had become popularly known as the Cornish engine.

In Australia as in Britain and elsewhere, industrial technology followed the need for mine dewatering. Development in mining in South Australia during the 1840s led to the importation of beam engines and the rise of a local foundry and engineering industry (Auhl and Marfleet, 1975). The illustration shows a Cornish pumping engine from Williams' Perran Foundry, Cornwall, which supplied similar engines to the mines at Surra and Moonta.

A similar situation arose in Victoria, with sudden industrial development occurring in Melbourne and in provincial centres following the rise of the gold-mining industry. This development is well documented for Ballarat by Bate (1978).

In shallow gold mining, shafts were bailed out with rawhide buckets or iron 'kibbles'. Shaft-sinking contracts usually included a clause terminating the contract at an agreed depth or inflow rate of water. For example, Richard Pope's contract at Mount Egerton, near Ballarat, was terminated because the inflow increased to 400 gallons per hour (Pope, 1869). Deep mines in some areas were able to keep down the water using bailing tanks alone. This was the practice at the Central Deborah Mine, Bendigo, until it closed in 1954.

The first steam pump on the Victorian
Goldfields was installed on the Gravel Pits Lead, Ballarat, in 1854. Some of the miners took a Luddite view of the use of machinery. 

Wood (1869) records that 'a body of men proceeded to the claim for the purpose of smashing the engine, but were prevented from doing so by Mr Talbot...who had provided himself with firearms, and threatened to shoot the first man who approached'.

Until the late 19th century, all mine pumps employed Cornish pitwork. This comprised a strong timber rod which moved up and down in a compartment of the mine shaft, transmitting the power of an engine on the surface to the pumps at various levels of the mine. A draw-lift or 'suction' pump worked in the shaft-well or sump at the bottom of the mine. Water from the draw-lift supplied the main force-pumps through a header tank. In deep mines several stages of pumps at locations up the shaft acted off the one pump rod. The rods were typically 12 inch square oregon, but could be larger. A section of 24 inch square rod can be seen at a mine site at Beaconsfield in Tasmania.

On the few Victorian mines where water became a serious problem, Cornish condensing engines were used. The building housing such an engine was an integral part of the engine itself. Very massive and expensive construction was required. A detailed series of articles on the design and history of Cornish mine pumps was published in The Engineer in a series beginning on 7 January 1870. The engines listed in Table 1 are probably the only Cornish engines to have operated in Victoria. The list is compiled from contemporary unpublished reports, from site visits by the authors where the remains were measured, and from notes provided by Ken Brown of the Trevithick Society. (Brown, 1984).

The majority of Victorian mines used a simpler and less expensive above-ground installation. This was a horizontal rotative steam engine driving a crank-arm through reduction gears, with a large balance-bob set in a pit beside the shaft collar. While archaeological reports are available on Cornish engine sites (such as Whitmore, 1982) and on pitwork (see Wingfield, 1984), nothing seems to have been published on the horizontal-engined bob pumps.

Fortunately a derelict pump bob can be inspected at Hill End in New South Wales, and a poorly presented pump bob has been relocated behind the office of Kalgoorlie Mining Associates in Kalgoorlie, Western Australia. The indoor machinery for such a pump is on display at Zeehan Mining Museum in Tasmania, and the surface foundations complete with timberwork exist at the North British mine site in Maldon, Victoria. During 1985 the pitwork and an intermediate balance bob have been exposed in the Long Tunnel mine workings at Walhalla, Victoria.

Records reviewed by the authors suggest that more than 100 horizontal-engined bob pumps may have existed in Victoria. In the 20th Century, electric ram pumps and centrifugal pumps replaced the Cornish design.

**TABLE 1: CORNISH CONDENSING ENGINES ON THE VICTORIAN GOLDFIELDS**

<table>
<thead>
<tr>
<th>MINE</th>
<th>LOCATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band of Hope</td>
<td>Ballarat</td>
<td>90 H.P. with 22 1/2&quot; pumps</td>
</tr>
<tr>
<td>Great North West Co.</td>
<td>Ballarat</td>
<td>40&quot; dia. cylinder</td>
</tr>
<tr>
<td>Band and Albion No. 9</td>
<td>Sebastopol</td>
<td>60&quot; dia. cylinder</td>
</tr>
<tr>
<td>Star of the East No. 2</td>
<td>Sebastopol</td>
<td>70&quot; dia. cylinder, 70 H.P.</td>
</tr>
<tr>
<td>Duke of Cornwall</td>
<td>Fryerstown</td>
<td>25&quot; dia. cylinder, rotative</td>
</tr>
<tr>
<td>Grand Duke</td>
<td>Timor</td>
<td>80&quot; dia. cylinder</td>
</tr>
<tr>
<td>Duke Extension</td>
<td>Timor</td>
<td>30&quot; dia. cylinder</td>
</tr>
<tr>
<td>Moolort Gold Estates</td>
<td>Moolort</td>
<td>70&quot; dia. cylinder</td>
</tr>
<tr>
<td>Berry No. 1</td>
<td>Allendale</td>
<td>70&quot; dia. cylinder</td>
</tr>
<tr>
<td>Hepburn No. 1</td>
<td>Allendale</td>
<td>70&quot; dia. cylinder</td>
</tr>
</tbody>
</table>
A NOTE ON TERMINOLOGY

The choice of a generic name to describe the reconstructed pump at Sovereign Hill caused some difficulty. As previously stated, a Cornish engine is a condensing engine of the type which has a beam or bob pivoting on a strong masonry wall. Some Cornish engines were of the rotative type, with a very large flywheel. The North Roskear engine in Cornwall was rotative, (Trounson, 1979) like the Duke of Cornwall engine in Victoria.

A beam engine is any any steam engine which employs a rocking beam to transfer motion from the steam cylinder to a crank or pump rod. An example is the Boulton and Watt engine which is soon to be installed in the Powerhouse Museum at Ultimo, NSW. Thus a Cornish engine is a particular type of beam engine. A Cornish pump is the simple plunger pump located in the mine shaft, forming part of the Cornish pitwork which includes pump, rods, balance bobs and shaft fixtures. Sometimes a Cornish engine is also described as a Cornish pump.

The type of geared bob pump used in Victoria and reconstructed at Sovereign Hill did not have a unique name. It appears in an early Fraser and Chalmers catalogue as a Cornish pumping plant, but use of this name in early discussions at Sovereign Hill caused considerable confusion. A suitable description would be 'a rotative-engined bob-pump with Cornish pitwork'. The name 'beam pump' was chosen for the project by resolution of the Sovereign Hill board because of its simplicity. In the author's opinion 'bob pump' may have been more appropriate.

PRELIMINARY PLANNING

With the historical justification outlined above, the reconstruction was intended to complement and complete the above-ground mining plant of the museum, and to provide an activated link between the surface machinery and the underground mine. The completed display would be instructional for visitors and would be given wide publicity. A five-page submission was prepared which included cost estimates totalling $55,000 in 1982.

At the time of preparing the submission, none of the components needed for the project had been located. However some of the extant sites had been visited and working drawings of at least 10 pumps had been located in the Sovereign Hill collection. Sovereign Hill also had a very accurate scale model of the surface components of a pump, which had once belonged to the School of Mines, Ballarat.

It was planned that the reconstruction would take place in three stages:

1. The installation of a horizontal steam engine and gearing within the engine house building. This would require construction of foundations, building modifications, engine restoration, steam pipework, and the machine-shop work associated with reduction gears, shafting and bearings. The steam engine could be activated after Stage 1.

2. Excavation of bob pit and crank-horse pit, with construction of retaining walls. This included broaching the concrete shaft collar beside the pumping compartment. Construction of the bob would require heavy timber and special castings. The horizontal crank rods and vertical pump rods would be installed, and the entire above-ground display activated.

3. Installation of the plunger pump at the Plat level, some 20 metres below the surface. Installation of the rising main and drainage flumes, with water recirculating to the shaft sump, would complete the project.

The responsibility for research and design was given to the authors. Fabrication and construction would be carried out as far as possible by Sovereign Hill staff, with some outside machine-shop work done by a local engineering firm.

PROJECT DESIGN AND CONSTRUCTION

The old adage 'reckon it out then double it' has some place in historical reconstruction, especially when major components have to be procured or fabricated. Restoration of an existing machine such as a steam engine can be costed out accurately after inspecting
TABLE 2:

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ESTIMATE 1982 DOLLARS</th>
<th>ACTUAL 1984 DOLLARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine and crankshaft foundations</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>Purchase of steam engine</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Pit excavation and retaining walls</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>Timber for beam and rods</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>Assembly</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>Underground drains and plumbing</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>Stage 1 sub-total</td>
<td>22500</td>
<td>54000</td>
</tr>
<tr>
<td>Restoration of steam engine</td>
<td>6000</td>
<td></td>
</tr>
<tr>
<td>Steam plumbing</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Restoration of gears and bearing</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Manufacture castings</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>Stage 2 sub-total</td>
<td>17000</td>
<td>15000</td>
</tr>
<tr>
<td>Building alterations</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Shafting and crank</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Construct flume</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>Rising main in shaft</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Construct plunger pump</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>Stage 3 sub-total</td>
<td>15500</td>
<td>17000</td>
</tr>
<tr>
<td>Grand total</td>
<td>55000</td>
<td>86000</td>
</tr>
</tbody>
</table>

The state of wear of components and determining which parts are missing. When the machine or components are not to hand at the time of estimation, a cost estimate is much less certain. Table 2 shows the detailed estimate that was made in 1982, as compared with the actual cost two years later.

A statement was included in the proposal outlining the difficulty of estimating such a project, because almost every component might be obtainable as a donation, or at scrap price, or it could be very expensive to reproduce as a casting or a fabrication. The project proceeded following receipt of a grant from the Buckland Foundation to cover stage 1 construction cost estimates.

Detailed engineering drawings were produced for each component, and stress analysis was carried out for critical members. The design work had to proceed in parallel with construction, because original components were obtained as work proceeded and the design could not be fixed in advance.

The major components were obtained as follows:

1. The steam engine, a Ruston made in Lincoln, England, was purchased from a machinery dealer at a location about 300 km from Ballarat (Figure 1). It is a single-cylinder horizontal engine of 10-inch diameter cylinder and 24-inch stroke, with a bed length of 13 feet six inches. The
Figure 1: Restored Ruston engine before installing gearing and flooring

Figure 2: Flywheel, main gear and crank installed
The flywheel diameter is 8 feet four inches (Figure 2). The manufacturers in England were able to advise that this engine, number 7739, was shipped in 1886 to Armidale, New South Wales, for use in a sawmill. A photocopy of the shipping docket and an olive-green paint sample were also supplied. When the engine was obtained, the Ruston variable cutoff valve gear was missing, but this would have been unsuitable for pump duty anyway so a new valve assembly was designed.

2. The large gear for the crank was purchased at scrap price from a mine where it had driven the winch on a Marion power shovel. Although lacking the external web which strengthened the teeth of 19th century cast gears, it was otherwise very similar to specification.

3. A spur gear to suit the large gear was purchased at full price from the spare parts inventory of a mining company. It also came from a Marion power shovel.

4. The major bob castings were donated by a mining history enthusiast. He had recovered them many years before from the Last Hope mine, south of Majorca near Maryborough in Victoria. The authors inspected the area but recent bulldozer activity by the Mines Department had destroyed almost all evidence of the site. By using a metal detector in the area of the bob pit it was possible to locate, but not to recover, the bolts which had held down the bob pivot bearings. No other information was gained at the site.

The screw-adjustable tension straps from the front of the bob had been recovered by a farmer and converted for use as adjusters on a bulldozer blade. Careful restoration enabled the entire straps to be reassembled, with welds disguised and painted over. The straps were proof-tested before they were put back into service.

5. The timber parts were made from Oregon pine, the same as the originals. No timber was available to suit the bob sections, so a suitable tree was felled in the Bullarook Forest near Ballarat and milled to size. The main beam measured 26 feet by 20 inches by 12 inches when installed.

6. Bluestone blocks for lining the bob pit were recovered from a demolished railway bridge. The back of the bob pit was corbelled to follow the sweep of the balance-box.

7. One pivot bearing for the bob was obtained as a donation, and a second one cast using it as a pattern.

8. Bearings for the crank shafting were obtained from a Queensland sugar mill.

9. The pump used at the shaft-bottom was fabricated to our design by a local engineering firm, and employs rubber-faced clack valves with detachable valve-chests. Welded construction was used but the external appearance of a Cornish pump was maintained.

All other components were new fabrications. Because of the high cost of pattern-making, large components which were originally cast were fabricated from steel plate by bending and welding in the Sovereign Hill workshop. Sections were built up and filled to resemble castings, and after painting the difference was only evident upon close inspection.

The use of original bob castings gave the project credibility as a reconstruction, but created a problem. The castings were for a bob nearly double the size of the one which had been estimated, and the cost of excavation and lining the bob-pit in bluestone masonry was well in excess of budget. A decision was made to proceed, accepting the inevitable overrun in this area. In retrospect, the decision was an excellent one as the massive size of the bob, combined with its silence in operation, is what impresses the visitors who gain an insight into Victorian engineering. The final dimensions of the bob were 26 feet long at the base and a height of 14 feet six inches at the apex, while each of the two horizontal arms connecting the geared crank with the bob is 30 feet long (Figure 3).

The connecting rods in the shaft are of 12-inch sawn Oregon, and the rising main is 12-inch diameter flanged pipe. The pump stroke is seven feet six inches and it operates at about eight strokes per minute.
The water is recirculated to conserve the water supply as the pump is installed in a visible position at a level above the natural water table. Open drains return the water through the mine to the shaft, and add to the feeling of activation.

While the scaling-up of the bob and ancillary timework was a fairly easy decision, if an expensive one, the treatment of timber presented problems. In the 19th century the timber would have had no treatment and would have been replaced when necessary, but modern preservative methods can greatly extend the life of softwoods. The treatment process gives the timber a bright green hue which fades after some months, and is decidedly un-historic. In the end the timbers were treated with preservatives in the interest of longevity.

OPERATIONAL ASPECTS

Safety is a prime concern in the design of projects at Sovereign Hill. Fortunately, many of the hazards we recognise today were also acknowledged 100 years ago. The bob pit and crankhorse areas are fenced in a style depicted in photographs of the period. A common story on the goldfields is that of small boys 'riding the bob', and while it would be an amusing sight, the danger is obvious.

Inside the engine house members of the public are kept clear, at greater than arms' reach, from all moving or hot parts. Visitors are confined to an elevated viewing area, and steam pipes are lagged.

Visibility must be given attention - it is no good restoring and operating equipment which is poorly illuminated or obscured. Illumination is achieved in the engine house through the use of skylights. A long-term problem with bird droppings was solved through use of a proprietary compound applied to all perching surfaces.

People want to stop and talk to operators. In an ideal world, every visitor could have an extended chat or a personalised guided tour. When the area is noisy or when demanding work is being undertaken, no contact is possible. Fortunately the engine house operation, and the pump as a whole, have a low noise level, and visitors have a good opportunity to converse with operators. A free brochure is available describing the background to the pump exhibit, and its working.

Staff operating boilers and steam engines must be qualified to do so, and must be particularly aware of the public risk. To operate on a seven-day basis requires a minimum of three engine drivers if holidays and sick leave are to be covered. When simultaneous working of more than one display area is required, this number rises. It also rises if operating staff are also the skilled staff who are depended upon for restoration and construction of new exhibits.

At Sovereign Hill, three engine driver/boiler attendants are currently employed on a rotating roster. One of these was trained on the job and a second has improved his qualifications there. A fourth is in training and soon to sit his exams. This number of staff is proving inadequate as new displays are developed and as projects require construction expertise.

CONCLUSION

The design and construction of the beam pump presented many problems, often exacerbated by delays in obtaining components and by not knowing until the last minute whether a particular item could be obtained as original or should be fabricated 'from scratch', which required detailed drawings to be prepared. Despite this, most problems were minor in nature and the construction schedule was maintained.

The project would not have been possible without the skill-base already established at Sovereign Hill in the 19th century application of trades such as carpentry, blacksmithing, and steam engineering. The progress of construction was remarkable when it is considered that most of the work had no contemporary example available for comparison. To the authors' knowledge, there is no mine pump of this type operational anywhere in the world.
Figure 3: Main beams lying next to completed bob pit

REFERENCES


