The Isabella Winding Engine
Elemore Colliery, Hetton-le-Hole, Co. Durham

by

P. ATKINSON

3rd Year Mechanical Engineering. Option B. May 1956

Dissertation submitted as part of the final examination for Pass Degree in Mechanical Engineering Option B, and reprinted without alteration except that certain diagrams and appendices have been omitted.

Acknowledgment is extended to the N.C.B. for permission to undertake this work, and for their assistance at all times.

INTRODUCTION

The Isabella winding engine installed at Elemore Colliery is a vertical reciprocating single cylinder, double acting non. condensing steam engine. (Though when originally installed the engine was condensing and the remains of the condenser sump can be seen in the cellar). The present working pressure is 30lbs. sq.in. gauge, the maximum rope speed when winding is 25 f.p.s. and the engine is capable of winding 40 tons of coal an hour from a depth of 564 ft. The exact date of construction of the engine is not known but the shaft on which it is now used was sunk in the period 1824-1827 (1)* This shaft was originally used as a ventilation shaft and it is believed that the winding engine was purchased secondhand and installed in the year 1836, when the shaft was altered to allow men to be wound in and out of the pit. It thus seems reasonable to assume that the engine was constructed about the year 1826. If this was the case then to date (February 1956) the engine has been in operation for 130 years, and the soundness of its present day mechanical condition is a fine tribute to the skill and workmanship of the early engineers. The name of the manufacturer of the engine is not known but this type of engine was installed at several pits belonging to the Lambton, Hetton and Joicey collieries and

---

* Figures in parentheses refer to the list of references at the end of the article.

it is possible that the Isabella engine was one of the earlier engines constructed by the firm of Joicey. The original shaft arrangement was one cage balanced with a counterweight and the engine was used to wind men in and out of the pit. However since 1944 the engine has been used to wind coal out of the pit, as well as men, and the present shaft arrangement is two cages, one cage being raised as the other is lowered.

GENERAL DESCRIPTION OF THE ISABELLA WINDING ENGINE

The general arrangement of the winding engine is shown in *fig.* 1 and it can readily be appreciated that the construction is very robust indeed. Full use has been made of the engine house to support the bearing for the drum shaft and to provide an anchor for the two beams. The two beams fitted to the Isabella engine are in the form of levers and their primary function is to act, through a central link, as a guide for the piston. This type of parallel motion was first invented by James Watt in 1782 and was applied to engine design by Phineas Crowther in 1800 (2). In a modern reciprocating steam engine these levers would be replaced by a crosshead and guides, obviously a much simpler arrangement.

The plain beam of the Isabella engine has two webs connected together by spacing rods and is a one piece casting of cast iron, having a very good finish. There are also two shafts both having machined diameters and these shafts would appear to have been intended for the attachment of the pump rod to pump water into the condenser sump when the condenser was originally in use. The attachments for the parallel motion links are simply two wrought iron pins pressed into position and the far end of the beam pivots on a shaft turning in two plummer blocks.

The beam carrying the plug rod is built up from two wrought iron webs. Unlike the other beam the finish is very rough and from the various markings it appears that the webs were hand forged. The difference in the manufacture of the two beams gives every indication that the wrought iron beam carrying the plug rod is a replacement for the original beam which would have been made of cast iron. The beam is pivoted as before on a shaft turning in two plummer blocks and wrought iron pins are pressed in position for the link attachments.

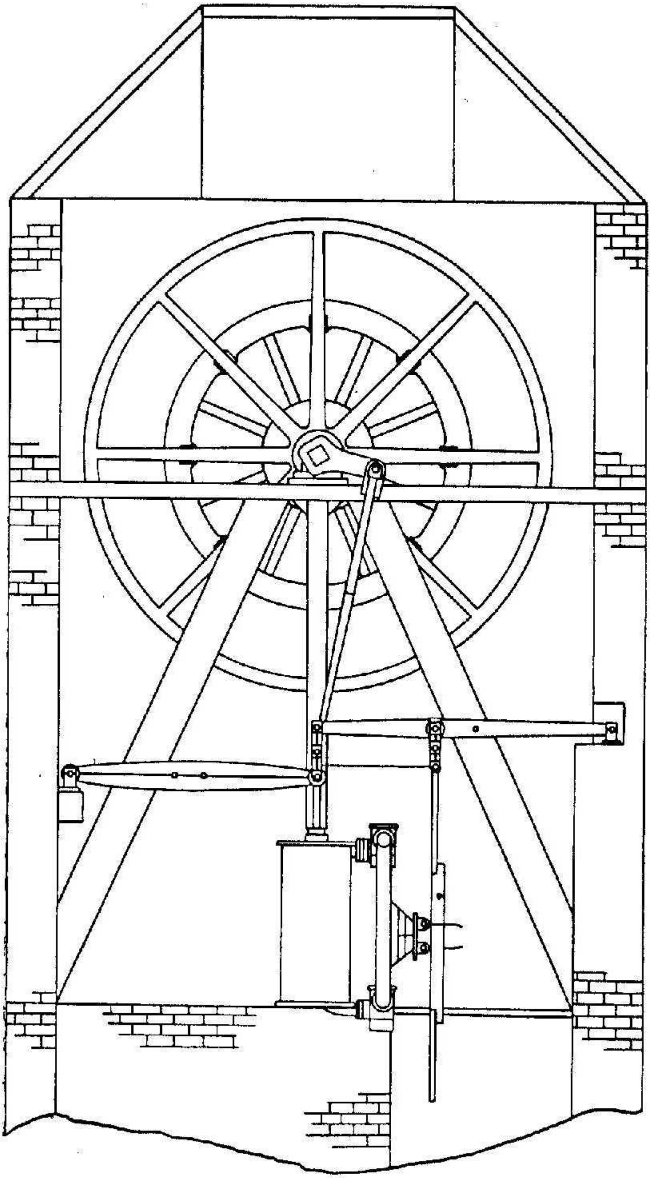


FIG. 1.
Isabella Winding Engine, Elemore Colliery.
(Side elevation, scale ½ inch ≡ 1 foot.).

The plug rod attached to this beam is forged from wrought iron and actuates the valve gear by means of two bobbins which strike the levers on the valve gear. The straight line motion of the plug rod is controlled by guide links which are attached to a crosshead on the piston rod.

An interesting theory can now be put forward to account for the disuse of the condenser. If, as is supposed, the original plug rod beam had fractured, then the primary concern of the colliery engineer would be to get the engine running again in the shortest possible time. The replacement beam was thus probably made by the colliery blacksmith (accounting for its rough finish) and once fitted it is natural to suppose that the engineer then decided to try and run the engine without waiting for the condenser to be connected up, especially if this had been damaged when the beam failed. The engine would certainly develop sufficient power and it is assumed that in view of this the condenser was never repaired and the engine operated ever since as a non-condensing engine.

The geometry of the beams and parallel motions has been investigated graphically, and at the position of inner dead centre the end of the piston rod deviates from the required straight line by approx. 1½". This means a deviation of ⅛" at the stuffing box but this error is easily accommodated by the flexibility of the packings and the play in the bearings of the connecting links. The piston also has sufficient clearance in the cylinder to accommodate this slight error. If the beams had been arranged to rotate equal amounts either side of the horizontal position then the error in the motion at inner dead centre would have been considerably reduced and the error really constitutes a fault in the design of the engine. If the engine, as is supposed was secondhand when installed at Elemore Colliery, then this fault in design could have been introduced when the engine was rebuilt.

The four links for the parallel motion systems each have three pairs of bearing brasses separated by spaces and the whole assemblies are held together by U bolts. Adjustment of the bearings is by shims and if these bearings are adjusted to a good fit then due to the inaccuracies in the parallel motion the complete system becomes very stiff and the engine has great difficulty in running.

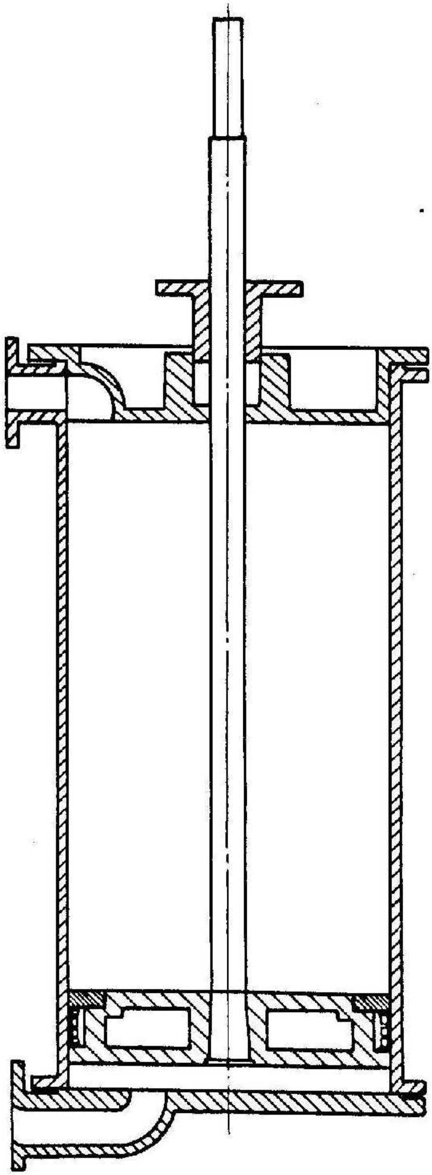


FIG. 2.

Arrangement of Piston and Cylinder. Scale $\frac{3}{4}$ inch $\equiv$ 1 foot.

Acknowledgments to N.C.B. No. 2 Area, Group 'C' Durham

The design and construction of the cylinder is simple and straightforward, see *fig*. 2, and the arrangement of the steam ports is typical of the earlier cylinders designed by James Watt. The cylinder base is made of cast iron and has the bottom steam port and valve chest flange cast integrally with it. On the top side of the base a spigot has been machined for accurate location of the cylinder. The base itself is square in shape and is firmly fixed into the foundations by four 1½" dia. bolts and concrete. These holding down bolts are of considerable length and are firmly anchored into the foundations by tie bars. The cylinder is of cast iron and is fastened to the cylinder base by 17 - 1⅛" dia. studs, the top steam port and valve chest are cast integrally with the cylinder and in addition the top 7½" of the cylinder bore has been recessed to locate the cylinder cover. The cylinder cover is also of cast iron and is fastened to the cylinder by 14 1¼" dia. bolts. A small stop cock is fitted near the top of the cylinder and is used for pouring oil into the cylinder to lubricate the piston and cylinder wall.

The piston and piston rod are replacements and at the time of fitting in 1937 conformed with standard practice in piston design (3). An interesting feature of the original piston is that it was made steam tight by packing with junk i.e. hempen rope soaked in tallow.

The piston rod is attached to the connecting rod by means of a crosshead which is keyed onto a taper fitting on the piston rod. Situated below this crosshead is another smaller crosshead to which the guiding links for controlling the motion of the plug rod are connected. Both crossheads are made of wrought iron and are machined out of solid material. The whole assembly of the crosshead, connecting rod and controlling links of the parallel motions is shown in *fig*. 3.

The connecting rod is forged out of wrought iron and is forked at one end to fit the crosshead. The connecting rod is fastened to the crank pin and crosshead by means of plain strap ends, see *fig*. 3.

The crank is forged out of wrought iron and replaces the original cast iron crank which fractured in 1949. The crank pin is made of wrought iron and is secured in position by means of a cotter pin. Lubrication of the crank pin is by means of a Stauffer box and grease.

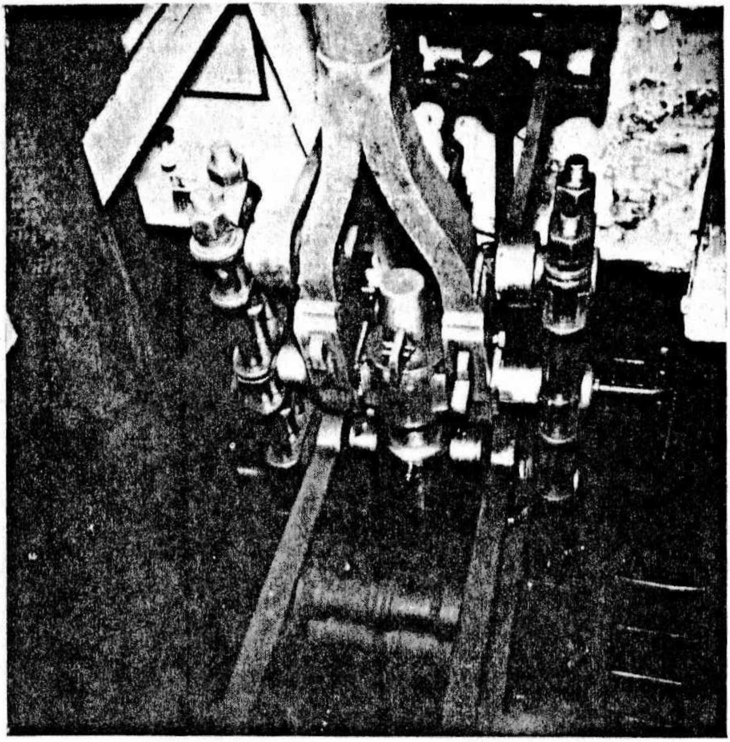


FIG. 3.
Arrangement of the crosshead and connecting rod, on the Isabella Winding Engine.

The drum shaft is made of wrought iron and is square in section. The crank has a corresponding square hole of slightly larger dimensions than the drum shaft and is fastened to the drumshaft by means of staked wedges. 16 wedges are used and are staked in, 8 from each side of the crank. The advantage of this method of fixing the crank is that no great accuracy is required in manufacturing the crank since it can always be trued in position by means of the wedges. The crank shaft has two diameters turned on it for bearing purposes and the bearings themselves are open plummer blocks, see *fig*. 4. Two light, wrought iron straps are fitted to each bearing in case the crankshaft does tend to lift but the chances of this are very remote as there is sufficient weight in the flywheel and drum to hold the crankshaft down on the bearings. A wooden A frame and cast iron pillar are used to support the bearings at the crank end of the drumshaft and the other bearing is supported by one of the engine house walls.

The construction of the flywheel and rope drum is very interesting. The flywheel is made of cast iron and is cast in two pieces, each piece consisting of four spokes, half of the rim and half of the hub. The spokes are of T section to give maximum rigidity and each half of the hub contains two sides of a square. The two halves of the flywheel rim are fastened together by wrought iron straps secured with cotter pins and the hub halves are fastened together by two pairs of wrought iron straps which are bolted round the hub, the hub thus having a square hole in it.

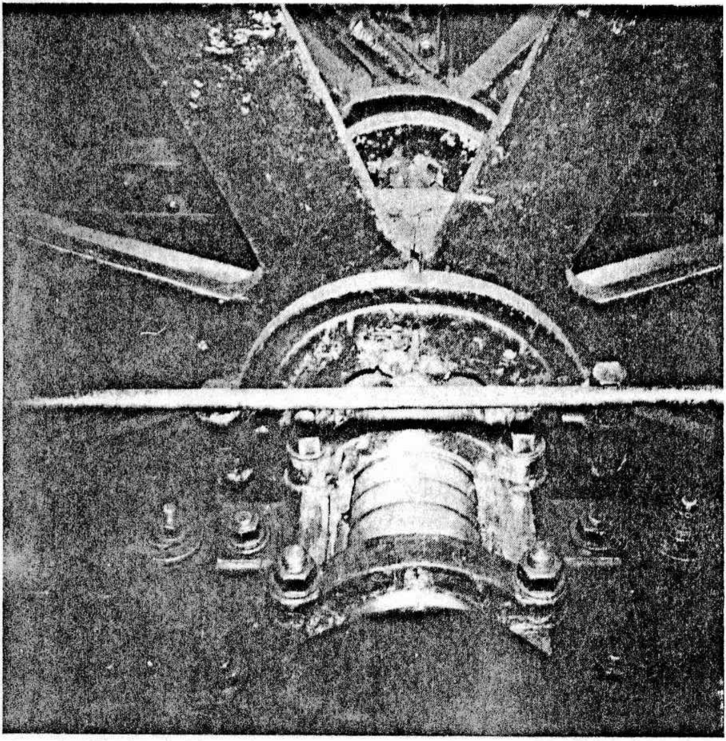


FIG. 4.

Arrangement of a bearing and the flywheel hub on the Isabella Winding Engine.

The dimensions of this hole are slightly larger than the dimensions of the drumshaft and the flywheel is fastened to the drumshaft with staked wedges in a similar manner to the crank. The rim of the flywheel is used as the braking path and the flywheel spokes also act as one set of spokes for the rope drum, The rope drum has two further sets of spokes, each set containing eight spokes. The centre set of spokes are made of cast iron, they are square in section and are bolted into a metal hub. This hub is built up out of two iron castings and the halves are held together by wrought iron straps and two large bolts,. The centre hub is fastened to the drumshaft by staked wedges and is built up in the manner described to increase the rigidity of the hub. This is necessary since the hoop stress produced by the winding ropes will tend to deflect the cylindrical surface of the drum a greater amount at the centre of the drum than at the edges. The outer set of spokes are made of cast iron, they are T shape in section and the spoke set is cast in two halves, the dividing line in this case being along the centre of two diametrally opposed spokes. The hub halves are fastened together in the same manner as the flywheel hub and are wedged in position on the drumshaft. The cylindrical surface of the rope drum is constructed from oak staves which are bolted to three cast iron rims, which are in turn bolted to the three sets of spokes.

The design of the flywheel and rope drum is quite sound and by casting the spokes and rims in sections the internal stresses set up on cooling will be a great deal lower than if one piece castings had been employed. The method of fastening the hubs onto the drumshaft by staked wedges obviates any great need for accuracy as the hubs can quite easily be centred by adjustment, of the wedges.

The free end of the drumshaft passes through the wall of the engine house and has wedged onto it a cast iron drum which has a heavy balance chain wound on it, see *fig.* 5. The length of this chain is always a quarter of the winding depth and is so arranged that at the commencement of a winding sequence it exerts a positive torque on the drumshaft and assists the engine in accelerating the loaded cage. As the winding sequence proceeds the balance chain unwinds from its drum and when the cages are at the same height in the shaft it is completely unwound. The chain then starts to wind back on the drum in the opposite

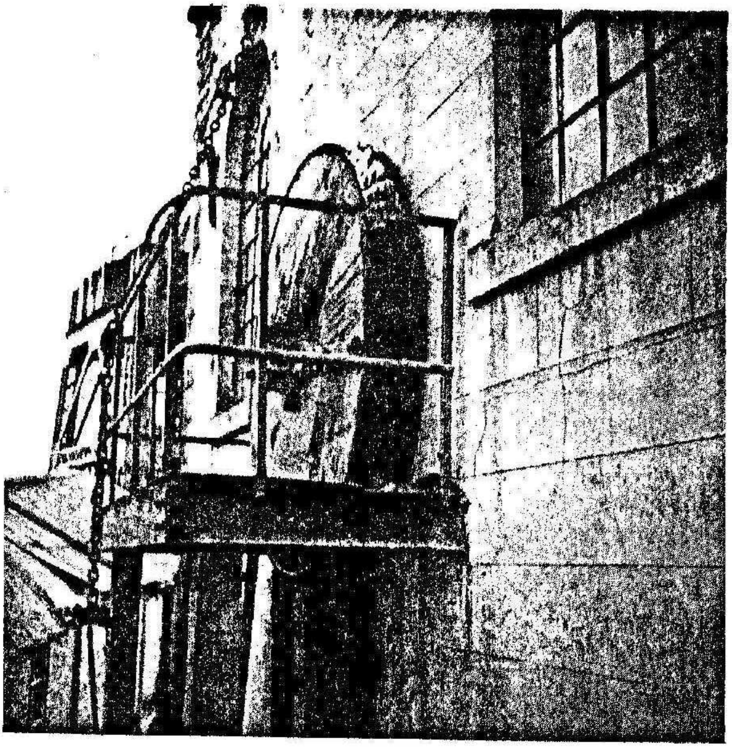


FIG. 5.
Arrangement of the drum and balance chain on the Isabella Winding Engine.

direction and exerts a negative torque on the drumshaft and assists the engine in braking as the loaded cage approaches the top of the shaft. Since the direction of rotation of the flywheel is reversed in the next winding sequence the chain is thus in a position to assist the engine at the commencement of the next wind. If the engine is run without this balance chain the engineer has difficulty in controlling the speed of the engine and on stopping the engine, it usually pulls up with a savage jerk.

The steam for the engine comes from a bank of boilers which usually work at pressure of 80 to 100 lbs/sq.in. gauge. The steam is then reduced through a valve to a pressure of 30 lbs./sq.in. gauge and the amount of steam which actually passes to the engine when it is running is further controlled by a throttle valve.

Admission and exhaust of the steam to the engine is controlled by four mushroom mitre valves, two inlet and two exhaust. The arrangement of the steam pipes, porting and the respective valves is shown diagrammatically in *fig*. 6. The mushroom mitre valves in use are similar in design to the double beat valves that were used extensively in Cornish pumping engines, (4). They were invented by Johnathan Hornblower about 1800, to over-

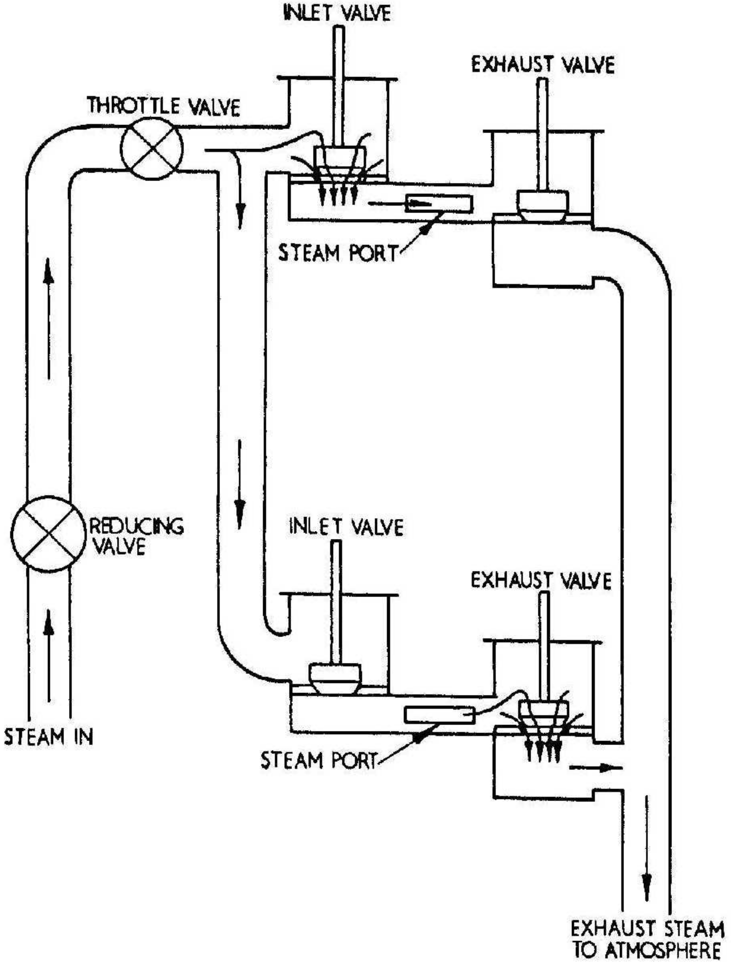


FIG. 6.
Diagram showing arrangement of Valves and Steam Ports.

come the large force required, even with low steam pressures, to lift an ordinary flat top mitre valve from its seat. In the double beat valve the effective area over which the steam pressure acts is comparatively small and the force required to lift the valve from its seat is considerably reduced. The valves are cast out of gunmetal and the only portions machined are the valve seats and the fitting for the valve seats which are pressed into position in the valve chests. The valve chests for the top and bottom of the cylinder are one piece castings in iron and are excellent examples of early 19th century foundry work. The various steam pipes connecting the two valve chests are also iron castings.

The valves are operated by a system of push rods and tappets and the valve timing is controlled by the two bobbins fastened to the plug rod. The plug rod method of valve timing was developed by Henry Beighton in 1718 (5) who made several mechanical improvements to the early Newcomen engines. The arrangement of the Isabella winding engine valve gear, is shown diagrammatically in *fig.* 7.

When the valves are closed each camshaft is locked in position by means of a catch that engages with the rocker arm. This rocker arm is free to rotate on a pin and is tensioned by having a plumb bob fastened to its lower end. Each camshaft operates its respective valves by means of two small levers which are connected to the push rods. The top camshaft opens the top inlet and bottom exhaust valves by rotating clockwise and closes them by rotating anticlockwise. The bottom camshaft opens the bottom inlet and top exhaust valves by rotating anticlockwise and closes them by rotating clockwise. The angle turned through by each camshaft is approximately 70° giving a valve lift of 2ins. On automatic valve operation the turning moment required to rotate the respective camshaft in opening a set of valves is obtained by having a heavy weight attached to a lever which is securely fastened to the far end of the camshaft. The turning moment required to close each set of valves is obtained from the bobbins on the plug rod which engage with the levers fastened to the camshafts. The lever on the top camshaft is pressed down and the lever on the bottom camshaft is pulled up. Opening and closing of the valves can also be controlled manually by the use of two handlevers.

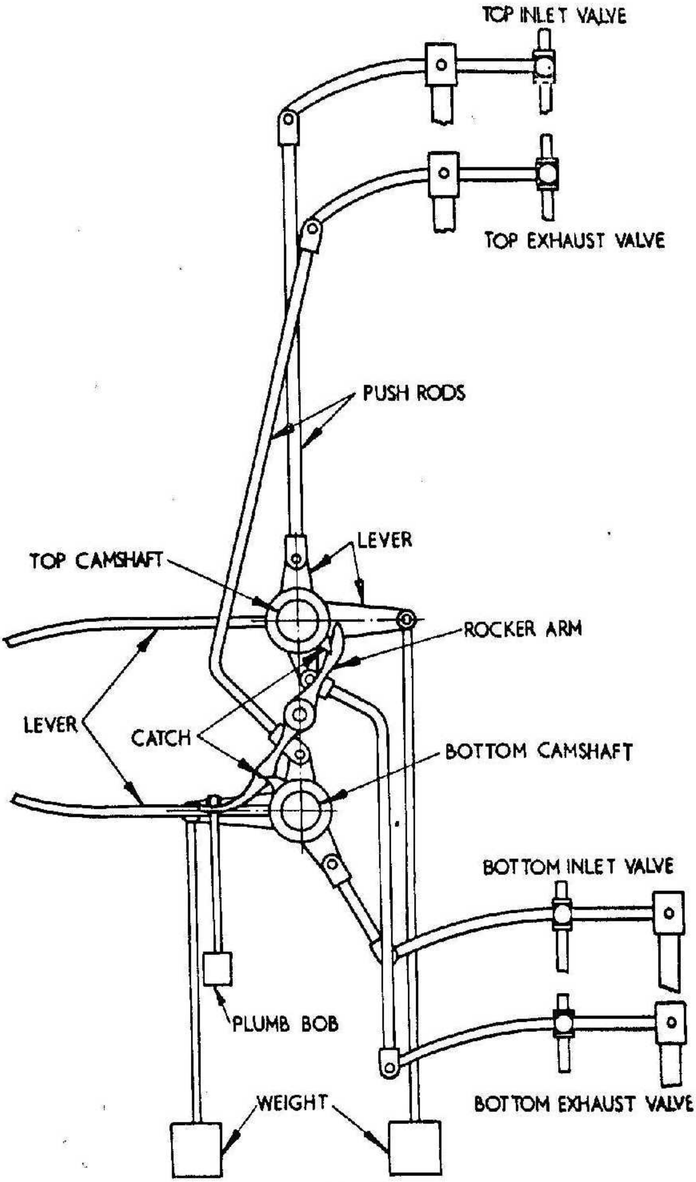


FIG. 7.
Diagram of Valve Gear.

The timing of each set of valves is dependent, one on the other and in automatic operation the rocker arm is so arranged that one set of valves is shut before the other set is open. Apart from the bearing brasses and cast iron weights the whole of the valve gear is manufactured from wrought iron.

Operation of the Engine

Assume that a winding sequence is to be started and that a cage with loaded tubs is at the bottom of the shaft and a cage with empty tubs is at bank. Also assume that both sets of valves are closed, that the position of the crank and conn. rod is as shown, see *fig.* 8 and that the rope drum has to rotate as indicated in *fig.* 8. Thus the top inlet and bottom exhaust valves must be opened first and the following sequence of operations is followed.

(a) The engineman lifts the handlever fastened to the bottom camshaft and by its use rotates the bottom camshaft clockwise, see *fig.* 7. The catch on the bottom camshaft presses against the rocker arm rotating it clockwise by an amount sufficient to release the catch of the top camshaft.

(b) As soon as the catch of the top camshaft is released then the camshaft rotates clockwise due to the turning moment of the weight acting at the end of the lever attached to the camshaft. The top inlet and bottom exhaust valves open, steam enters the top of the cylinder and the piston commences to move down.

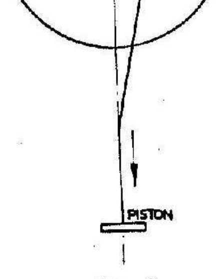


FIG. 8.

(c) Near the end of the piston stroke the top bobbin on the plug rod presses down the lever of the top camshaft and closes the top inlet and bottom exhaust valves.

(d) As the top camshaft rotates anti-clockwise in closing the valves the catch presses on the lip of the rocker arm and the rocker arm rotates clockwise sufficiently to release the catch of the bottom camshaft.

(e) The bottom camshaft now rotates anti-clockwise and opens the bottom inlet and top exhaust valves. Steam enters the bottom of the cylinder and the piston moves up.

(f) Near the end of the piston stroke the bottom bobbin on the plug rod pulls up the lever of the bottom camshaft and closes the bottom inlet and top exhaust valves.

(g) As the catch of the bottom camshaft passes over the lip on the rocker arm it rotates the rocker arm clockwise and the catch on the top camshaft is released.

(h) The top camshaft rotates clockwise and opens the top inlet and bottom exhaust valves, steam enters the top of the cylinder and the piston commences to move down the cylinder again and the above sequence is repeated "ad lib".

A slide indicator informs the engineman of the position of the cages in the shaft, and when the engine is to be stopped the engineman simply takes hold of the handlevers and prevents the valves from opening when once they have closed, at the same time the brake is applied.

Referring to *fig.* 8, if the rope drum was required to rotate in the opposite direction to that indicated then the bottom inlet and top exhaust valves would be opened first.

When the tubs are being changed the cage has to be raised or lowered a relatively small distance and in this case the enginemane controls the whole movements of the valves by hand and just allows sufficient steam to enter the cylinder in order to move the piston the required amount. This operation presents no difficulty since the engine is extremely flexible in operation and the tubs of the three deck cages can be changed in 30 seconds.

No speed governor is fitted to the engine as the time for the winding cycle does not warrant the use of one but an Exhall overwinder and speed trip is fitted as a safety precaution. The brake for the engine has two Ferodo brake bands and is steam operated. This brake is very powerful, and if required, will hold the engine against the full admission of the steam pressure.

Maintenance

The Isabella winding engine has proved to be very reliable in operation and general maintenance is of a simple nature. An oil pump is fitted and is intended to lubricate the valves and piston by injecting oil into the supply stream. This oil pump is in the form of a pressure itensifier and is operated by a tapping into the engine induction pipe. When the pump is functioning correctly it is filled regularly with oil but at the present time (February 1956) it is out of order and the piston and cylinder are lubricated by pouring oil through the small stop cock near the top of the cylinder. The various bearings and working parts of the engine mechanism are greased regularly and the packings in the valve chest stuffing boxes and cylinder cover stuffing box are renewed at regular intervals, usually at the end of three months. Occasionally the wedges holding the crank, flywheel and rope drum in position work loose and have to be tightened. The Exhall overwinder and the safety device on the steam brake are tested once a week to ensure their correct functioning. As the winding ropes become stretched adjustment is made for their increase in length by nailing oak saddles on the circumference of the rope drum. One saddle has the effect of shortening the length of the winding rope by 1 in. and this adjustment is usually made every fortnight. When the circumference of the rope drum has been fully lagged with these adjusting saddles the rope is removed and recapped and the saddles are also removed from the drum so that a new cycle of adjustment can proceed.

Alterations and Repairs

The most important alteration to the engine was the removal of the condenser, which considerably reduced the thermal efficiency of the engine. Unfortunately no information is available as to the date when the condenser was removed.

In 1936 the cylinder base was found to be badly fractured and a new one was made and fitted in 1937. Unfortunately while the work was being carried out the chain slings holding up the piston snapped and the piston, piston rod and cylinder were badly damaged and consequently had to be replaced.

In 1942 the Exhall overwinder was fitted.

In 1946 a steam operated brake engine was fitted replacing the original lever operated brake.

In 1948 a broken eye bolt on the bottom brake had to be replaced.

In 1949 new wedges were fitted to the flywheel and the engine was noticed to run much smoother. Also in 1949 the cast iron crank fractured across the web due to a blowhole in the casting and a new wrought iron crank was fitted.

In 1950 a broken brake strap was replaced and in 1954 new wedges were fitted to the rope drum.

The engine house has had to receive attention at one time and another, the alterations usually consisting of strengthening the existing structure by means of iron girders.

Performance of the Isabella Winding Engine

It was not possible to carry out a series of controlled tests on the engine and the performance values quoted are estimates of the probable values which would be obtained under specified conditions.

Performance Values

The following values are based on a constant speed of 30 r.p.m. except where otherwise stated. The values quoted are overall values for the engine and winding head gear.

Brake Horse Power= 152·8
(Mean Brake Horse Power considering complete winding cycle = 68·8)

Indicated Horse Power = 201

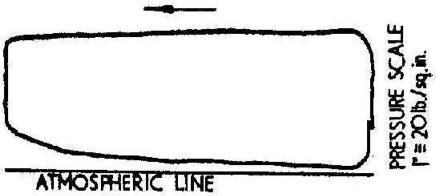
Mechanical Efficiency = 76%

Brake Thermal Efficiency = 1·81%

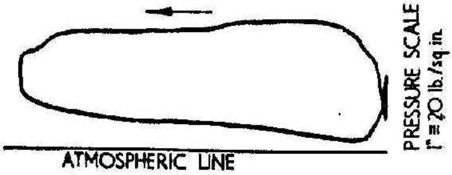
Indicated Thermal Efficiency = 2·38%

Rankine Efficiency = 7%

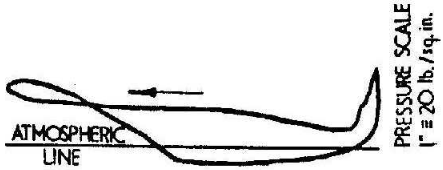
Steam Consumption = 18,450 lbs. per hour.



(a) Diagram taken at commencement of wind.
Automatic valve operation.
Mean effective pressure = 18·5 lbs./sq. in..



(b) Diagram taken at maximum speed of 30 r.p.m..
Automatic valve operation.
Mean effective pressure = 15·5 lbs/sq.in..



(c) Diagram taken at end of wind.
Hand controlled valve operation.
Mean effective pressure = 4·9 lbs./sq.in.

Fig. 9.

Indicator diagrams taken on the topside of the piston.

Indicator Diagrams (6)

Due to the inaccessibility of the bottom of the cylinder, diagrams were only taken on the top side of the piston. The indicator diagrams obtained are shown in *fig.* 9 and as well as giving the mean effective pressures they also give valuable information on the manner in which the valves work.

Fig. 9 (a), shows the indicator diagram taken when the engine was just commencing the wind and working on automatic valve operation. Wire drawing through the throttle valve and inlet valve has reduced the supply steam pressure from 30 lbs/sq. in. gauge, to 22·5 lbs/sq.in. gauge, but since the piston was moving relatively slowly, the admission pressure was maintained more or less constant to the point of cut off, with consequently high starting torque. The extent of the rounding off at the corners of the diagram indicates very well the crisp action of the valves in opening and closing.

Fig. 9 (b), shows the indicator diagram taken when the engine was running at maximum speed on automatic valve operation. The wire drawing effect has been increased and the steam pressure of admission has been reduced to 20 lbs/sq.in. The point of cut off is well defined and is estimated at 90% of the stroke. The small loop in the diagram was caused by extemely late admission and can be explained in the following manner. During compression the steam was heated up because work was being done on it. The steam became hotter than the cylinder and gave up some of its heat by partly condensing. As the admission did not occur promptly the condensation caused a drop in pressure and hence the loop. This defect could be remedied by resetting the valve timing either by increasing the diameter of the bobbins on the plug rod or by altering the position of the flat levers on the camshaft.

Fig. 9 (c) is an interesting diagram indicating conditions in the cylinder while the engine was being braked and in this case the engineman was controlling the valves by hand. The major portion of the work was being done by the flywheel giving up some of its kinetic energy with a consequent reduction in speed. Thus, depending on the experience of the engineman, the engine can be braked very smoothly and consequently less stress is imposed on the engine components.

Component	Material	Nature of Maximum Stress	Value of Stress (7) lbs/sq.in.	Ultimate Strength lbs/sq.in.	Safety Factor
Piston Rod	Mild Steel	Tensile Compressive	4370 4430	56,000 56,000	13 $12^1/_2$
Piston Rod Cotter Pin	Mild Steel	Shear	7280	42,000	6
Cylinder	Cast Iron	Hoop Tensile	470	16,000	34
Cylinder Cover Bolts	Mild Steel	Tensile	2830	56,000	20
Cylinder Base Studs	Mild Steel	Tensile	3000	56,000	$18^1/_2$
Cross Head Pins	Wrought Iron	Shear	1430	40,000	28
Drumshaft	Wrought Iron	Shear	7940	40,000	50
Crank Pin	Wrought Iron	Shear	2850	40,000	14
Crank	Wrought Iron	Tensile (due to bending)	5220	48,000	9
Foundation Bolts	Wrought Iron	Tensile	6830	48,000	7

Connecting Rod Safety Factor = 7 at load of 35,800 lbs.
Maximum pressure in drumshaft bearings = 143 lbs/ins.
Maximum Fluctuation of energy = 45,000 ft.lbs.
(See crank effort diagram, *fig.* 21).
Coefficient of speed fluctuation = 5·5%.
Speed fluctuation at 30 r.p.m. = 9 + $^3/_4$ r.p.m.
Maximum speed of flywheel = 30 r.p.m.
Maximum safe speed of flywheel = 62 r.p.m. (7).

Conclusion

In concluding this report on the Isabella winding engine two important questions require answering they are :-

(a) Why has the engine lasted so long ?

(b) Why hasn't the engine been replaced by a more efficient engine ?

In considering the first question it must be remembered that the Isabella engine has now been in use for 130 years, indeed a remarkable performance. This long term of service without serious breakdown, is due almost entirely to the exceptional strength of the engine components. Reference to the stress values and safety factors quoted in the "Design Analysis" clearly indicate the strength of the engine componenets (they also seem to indicate that these components were designed on a basis of practical knowledge rather than theoretical knowledge). Regular maintenance has also helped to keep the engine running and the present day (February 1956) sound mechanical condition is good proof of the maintenance carried out.

The answer to the second question is a little more complex and involves consideration of what is required of the winding engine and the economics of operation. Apart from its extremely low brake thermal efficiency, then mechanically, the Isabella engine is eminently suitable for use as a winding engine. It has a good starting torque and is very flexible and simple to operate. The only major mechanical disadvantage compared with a modern electric winder is the maximum speed of the cages in the shaft i.e. 17 m.p.h. as compared with 40 m.p.h. This is an important consideration on large depths of wind. The low thermal efficiency means that with continuous operation the Isabella engine consumes a great deal of coal and it is interesting to estimate the saving in coal that would have been made if a more efficient steam engine had been installed, for example the Weighton Steam Engine now installed in the Heat Engines Laboratory, Department of Mechanical Engineering, King's College.

This engine was built in 1894 and has a brake thermal efficiency of 15% at 100 B.H.P. (8) and if it is assumed that it had been installed at Elemore Colliery in 1894 then over a period of 62 years there would have been a nett saving in coal consumption of 50,500 tons. Even with the use of poor grade coal this represents quite an appreciable saving in costs and the Weighton Engine would certainly have justified the expense of its installation. However, a factor that has so far been ignored is the amount of use the engine would have received. Until 1944 the Isabella winding engine was only used for winding men in and out of the pit and consequently stood idle a great proportion of the working day. Under these conditions the saving in coal by use of the Weighton engine is difficult to estimate but it is reasonable to assume that in this case the Weighton engine would not have justified its expense of installation.

Since 1944 the Isabella engine has been used to wind coal as well as men, out of the pit and due to its lack of speed and low efficiency the question of replacement has become one of major importance. Consequently an electric winder is now being installed at Elemore Colliery as a replacement for the Isabella winding engine and will be put into operation in June, 1956, thereby ending 130 years of faithful and reliable service supplied by the Isabella winding engine.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to the following, for their assistance in the preparation of this report on the Isabella Winding Engine.

Professor A. F. Burstall	Head of the Mechanical Engineering Department, King's College, Newcastle upon Tyne.
Mr. W. L. Tulip	Area Chief Engineer, No. 2 Area, Durham Division, N.C.B.
Mr. Middleditch	Group Engineer, No. 2 Area, Durham Division, N.C.B.
Mr. Lawson	General Manager of the Lambton Engine Works.
Mr. Coxon	Colliery Engineer, Elemore Colliery.

Members of the N.C.B. Drawing Office, Philadelphia, Durham Division.

The Fitters and Enginemen, Elemore Colliery.

The Staff of the Mechanical Engineering Department, King's College, Newcastle upon Tyne.

Mr. Smith, a fellow student who gave assistance in taking the indicator diagrams.

REFERENCES

1.	Wood, L.	*Transactions of the North of England Institute of Mining Engineers. Vol.* 30. *Page* 164. 1880.	
2.	Crowther, P.	*Crowther's Specification A.D.* 1800 *Feb.* 28*th. Patent No.* 2378.	
3.	Spooner, H. J.	*Machine Design, Construction and Drawing.*	Longmans Green & Co., Ltd. 1927.
4.	Dalby, W. E.	*Valves and Valve Gear, Page* 9.	Edward Arnold, London. 1906.
5.	Tredgold, T.	*The Steam Engine. Vol.* 1. *Page* 12.	
6.	Lyle, O.	*The Efficient Use of Steam. Sections* 261-264.	H.M.S.O. London 1947.
7.	Oberg, E. & Jones, F. D.	*Machinery's Handbook.* 12*th Edition.*	The Industrial Press. New York 1944
8.	Watson, H.	*B.Sc. Hons. Thesis.*	Durham Univ. 1950.
9.	Morley, A.	*Strength of Materials.*	Longmans Green & Co., Ltd. 1954.