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THE COMPOUND WINDING-ENGINE AT LUMPSEY MINE.

BY M. R. KIRBY.

Old Plant.—Some time ago it was decided to renew the power-plant at the Lumpsey mine, with a view to reducing the coal-bill. The old plant, consisting of six egg-ended boilers, supplied steam, at a pressure of 40 pounds per square inch, to non-condensing engines, driving the winding, hauling, pumping and ventilating machinery, and the dynamo used in connection with the electric drills.

New Plant.—The old plant was replaced by three Lancashire boilers, 8½ feet in diameter and 30 feet long, fitted with a Green economizer, and working at a pressure of 150 pounds per square inch, supplying steam to the winding-engine (which was converted into a cross-compound) and to a set of four steam-generators of 200 horsepower, with compound double-acting high-speed engines, and compound-wound dynamos, supplying continuous current at 240 volts to motors driving the rest of the machinery. The whole of the exhaust-steam from these engines is condensed in a barometric jet-condenser, having steam-driven air and circulating pumps. The arrangement of the new plant, which was in a large measure determined by the configuration of the ground, is shown in Fig. 1 (Plate XII.).

Winding-engine.—The winding-engine was originally a doublehorizontal engine, having two cylinders, 42 inches in diameter by 6 feet stroke, with Cornish valves; and a conical drum, from 17 to 21 feet in diameter, on the crank-shaft. It was built in 1881, and, after having run for over 20 years, was practically unworn. This engine was converted into a crosscompound by replacing one of the original cylinders with a high-pressure cylinder, 24 inches in diameter with Corliss valves. and putting in a receiver having a capacity equal to twice that of the low-pressure cylinder. Two throttle-valves were fitted, one between the main steam-pipe and the high-pressure cylinder, and one between the receiver and the low-pressure cylinder, both being worked by one handle. A reducing valve, $1\frac{1}{2}$ inches in diameter, was provided, on the main steam-pipe, to maintain the receiver-pressure during long stands. The effect of this arrangement is to make the engine handle in exactly the same manner as a double engine, and also to keep the high-pressure cylinder and receiver hot between winds. The general arrangement of the engine is shown in Figs. 2 and 3 (Plate XII.).

The winding-engine with condensing plant was completed in 1903, before the generator-engines were ready, and the opportunity was taken to make steam-consumption trials under ordinary working conditions. The results of three of these trials are given in Table I.

The steam-consumption appears, to the writer, to be exceedingly low, especially when the indicator-diagrams shewn in Figs. 4, 5, 6 and 7 (Plate XIII.) are considered. It will be seen from these that there is no expansion in the cylinders, and that there is considerable back-pressure in the low-pressure cylinder, the inlet to which is throttled.

Little advantage was gained by using the condenser, but it must be remembered that this was designed to condense the steam from the generator-engines, as well as from the windingengine, and, during the test, it was working at a very great disadvantage.

The results of trials of two double-horizontal winding-engines are also given in Table I., and indicator-diagrams taken from them are shewn in Figs. 8, 9, 10, 11, 12, 13, 14 and 15 (Plate XIII.).

Description of Winding-engines.—The Lumpsey windingengine has horizontal cross-compound condensing cylinders, 24 and 42 inches in diameter by 6 feet stroke. The high-pressure cylinder is fitted with Corliss valves; the low-pressure cylinder with Cornish valves; and both with Allan straight-link reversing-gear. The conical drum, 17 to 20 feet in diameter, is fixed on the crank-shaft.

The Park winding-engine has two horizontal non-condensing

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cylinders, both 32 inches in diameter by 5 feet stroke. The balanced slide-valves are fitted with Stephenson reversing-gear. The drum, 9 feet in diameter, is fixed on the crank-shaft. This engine was in poor order when tested.

Name of mine	Lumpsey.			Park.	Skelton.
Depth of shaft feet	590	590	590	400	125
Date of test 1904	March 11	March 25	April 12	_	
Duration of test	0.10	0.00	0 10	0.45	0.00
nours. min.	0 10	8 30	8 40	9 40	8 30
square inch nounds	130	130	125	43	45
Vacuum inches	25	26	none	none	none
Condenser	working	working	standing	none	none
Economizer	standing	working	standing	none	none
Temperature of water			Ŭ		
entering hot well				l a	1
degs. Fahr.	-	60	—	—	— ,
Temperature of not well		00			
Temperature of feed	_	92	_		_
water to boilers					
degs. Fahr.	_	210		40	100
Stone raised tons	1,774	1,685	1,742	1,639	454*
Winds with stone No.	567	528	553	530	315+
Winds with men, etc. No.				72	34
Coals used pounds	8,176	7,280	9,968	10,549	550
Ashes and clinkers from	c.			1 855	
Steam used do	50 840	80 459	61 041	70 154	4 158
Time of wind with stone	00,010	04,400	01,041	10,100	1,100
seconds	27	26	27	27	11
Indicated work of engine			-		
horsepower	1,557		-	935	68 -6
Actual horsepower-hours	1 104 0				
performed	1,184.0	1,125.0	1,162.0	741.7	53.0
bomenomen hown					
norsohower-nont	50.20	55.50	53.00	108-07	77.70
Coal used per actual			00.04	100 07	
horsepower-hour	1				
pounds	6-90	6.47	8.20	14.20	10-28
Water evaporated per					
pound of coal pounds	7.30	8.20	6.20	7.20	7.20
Asn and clinker in coal				16.4	
Time running in shaft	-	-	-	10.0	-
with stone per cent.	52.0	45-0	48-0	40.7	9.4
Mechanical efficiency do.	76-0			79-2	78-0
Steam per indicated horse.			2 1996 - 1995		
power-hour pounds	88.4	42-2	40.3	85.6	60-6
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TABLE I.-RESULTS OF TESTS OF WINDING-ENGINES.

* Comprizing 364 tons 17 cwts. of stone raised, 1251 feet, from the shaft-bottom; and 89 tons 8 cwts. raised, 17 feet, from the horse-hole. † 242 winds from the pit-bottom and 73 winds from the horse-hole.

The Skelton winding-engine has two horizontal non-condensing cylinders, 15¹/₂ and 15[§]/₅ inches in diameter respectively by 3 feet stroke. The slide-valves are fitted with Stephenson reversing-gear, run in three-quarter gear. The drum, 8 feet in diameter, is geared as 2.46 to 1 to the crank-shaft.

Method of Testing.—The feed-water was measured, in the case of the Lumpsey winding-engine, by means of a counter on the feed-pump, the capacity of which was frequently checked by a measuring tank; and, in the other cases, the water was measured in tanks.

The steam-consumptions given are the total feed-water, and include the steam used for all other purposes, together with condensation and leakage. The developed power of the engines is expressed in actual horsepower-hours and is found by the formula: $-(W \times D) \div (33,000 \times 60)$; in which W is the total weight raised in pounds; and, D, the depth of the shaft in feet.

The coal used was of about the same quality in all cases, and contained 12 to 16 per cent. of ash and clinkers. It was weighed on accurate scales.

All the tests were made under ordinary working conditions.

Conclusion.—In conclusion, the writer would say that, in his opinion, a properly designed winding-engine, on the same principle as that at the Lumpsey mine, would not use more than 35 pounds of steam per actual horsepower-hour, when running non-condensing. Further, that a very low figure indeed would be obtained by using a three-cylinder triple-expansion condensing engine, with three cranks at angles of 120 degrees, a fixed cut-off, and direct-driven air and circulating pumps.

Mr. JOHN MCLAREN (Leeds) wrote that some years ago he had the honour to submit a paper to the members on "The Economical Use of Steam in Colliery-engines."* He was glad that other engineers were turning their attention to this important subject, as he believed that it would be greatly to the advantage of the coal-trade generally if more of these tests were made, and the results discussed with a view to increased economy in the use of steam, which is synonymous with economy of fuel. Judging by what one saw and heard in the neighbourhood of

* Trans. Inst. M. E., 1891, vol. ii., page 344.

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coal-mines, in the clouds of steam exhausted into the atmosphere with a noise audible at a distance of several miles, one might be pardoned for assuming that economy of coal in the operations aboveground and belowground was not of the slightest consequence.

The paper written by Mr. Kirby was valuable, inasmuch as it threw some light on a rather obscure branch of practical engineering; and, though he could not agree with the writer that the results were at all satisfactory, he thought that his figures were important as calling attention to the huge waste which goes on with ordinary engines such as are in use at the Lumpsey mine, not to speak of the extravagance of indifferent and wasteful engines like that at the Park mine, where the enormous steam-consumption of 85.6 pounds per indicated horsepower was noted. When the majority of the well-made engines used for marine and industrial purposes required from 11 to 13 pounds of steam per indicated horsepower, it seemed extraordinary that a consumption of 38 to 42 pounds per indicated horsepower in a colliery winding-engine should be tolerated; while, with regard to the Park engine, he had no doubt that the fuel wasted there would have been sufficient to purchase a new well-made and economical winding-engine about every second year.

He (Mr. McLaren) proposed to confine his remarks to the Lumpsey engine, and he thought it was regrettable that no record was kept of the steam used for "other purposes." It was not fair to debit the winding-engine with an unknown quantity of steam which might have been required for auxiliary plant; but he assumed that the quantity was inconsiderable, or the writer would have made some attempt to apportion the relative amounts of steam absorbed by the winding-engine and that used for "other purposes." It was unnecessary to state that all enginetests, to be of any value, must be strictly accurate, and the engine must be depited with everything which fairly belonged to it; but, in this case, steam to an unknown amount had been used for "other purposes," and charged to the winding-ongine. The absence of steam-traps, by which the condensation in the long range of steam-pipes and the large receiver might have been ascertained and recorded, was rather unfortunate; because, if this had been deducted, it would probably have made an appreciable difference in the steam-result.

The indicator-diagrams were interesting, but they did not at all account for the enormous steam-consumption, and, moreover, they would have been much more valuable had they been taken simultaneously with four indicators, one at each end of each cylinder, with one and the same load, rather than at different times with different and varying loads, and they afforded no means of forming an opinion or making a comparison.

It appeared late in the day to advocate the use of condensing engines for nearly all the steam-plant about a colliery, particularly for the winding-engines, as the immense volumes of steam exhausted into the atmosphere constituted just the sort of waste which exasperates an engineer. It was a valuable residual which could be very simply utilized by means of the condenser.

There was an incomprehensible feature in the data given in Table I. The actual horsepower-hours did not vary much in the three tests (1,184, 1,125 and 1,162), equal to about 5 per cent. of extreme variation. The total steam used and the steam used per indicated horsepower varied in a somewhat similar ratio, but the coal-consumption varied enormously (8,176, 7,280 and 9,968 pounds), equal to nearly 40 per cent. of extreme variation. The last figure, as applied to coal only, would have been explained by the absence of the condenser, which was not working on this particular test, if the water used had risen in the same proportion as the fuel: but, in this case, the steam-consumption per indicated horsepower was an exact average of the three trials, whereas the coal-consumption was 17.6 per cent. above the average.

He (Mr. McLaren) was inclined to think that there must be some error in Mr. Kirby's figures with regard to the coal and steam used in the third non-condensing test, as it was contrary not only to reason, but to experience, that the steam-consumption per indicated horsepower should be practically the same when working on the atmosphere, as when working condensing with a vacuum of 25 to 26 inches of mercury, as in the first two tests. Apart from this, however, the writer's figures showed that (unless his experience was unique) there was still room for enormous improvements in the steam-plants in use about collieries, and he (Mr. McLaren) suggested that wherever possible similar tests should be made elsewhere, and the data

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carefully recorded, and laid before the members for their information.

Mr. S. L. THACKER (Walsall) wrote that the value of Mr. Kirby's paper would have been considerably enhanced had the data been supplemented by details of the masses to be set in motion in addition to the net load, the maximum velocity during the wind, with the periods of acceleration, full speed and retardation. In the absence of this information, it was not possible to calculate the kinetic energy in the moving masses and the formula (W × D) might give the total work per wind or it might give a quantity considerably less.

As he (Mr. Thacker) had endeavoured to shew in his paper,^{*} unless the cut-off of the steam to the engine was manipulated with great care, so that the kinetic energy was exactly utilized to complete the wind during the period of retardation, without the application of the brake or of back-pressure in the cylinders, it was entirely fallacious to regard the work of raising the unbalanced load as being the actual effective work of the windingengine. The same mistake had been repeated in almost all the tests of winding-engines recorded in the *Transactions*, and they were entirely inconclusive in regard to the relative merits of the engines themselves.

The figures given in Table I. were of course the results of tests, not of the engines themselves, but of the complete windingplants, and only in that sense could any comparison be made. Nothing could better illustrate the force of his contention than the figures for the mechanical efficiency, giving a higher efficiency for the Park engine in poor condition than for the Lumpsey improved compound engine. This was probably due partly to the higher ratio of the net load to the total mass in the case of the Park engine, and partly to the larger and heavier drum of the Lumpsey engine.

It was interesting to note that the highest steam-consumption of the three tests of the compound engine was obtained when the percentage of the time of actual winding was lowest, shewing that condensation in the steam-pipes, etc., was a material factor: for the same reason, it was not conclusive that no advantage

* "The Dynamics of the Winding-engine," Trans. Inst. M. E., 1903, vol. xxvi., page 445.

was obtained by using the condenser. In the case of an intermittently running engine it hardly seemed fair to debit the steam-consumption with the whole condensation while standing, and it had occurred to him (Mr. Thacker) whether a meter might not be used to measure the cubic feet of steam passing in the steam-pipe, but the difficulty was to compensate for the relative wetness or dryness of the steam.

He (Mr. Thacker) would like Mr. Kirby to explain why in the case of the Lumpsey engine, the lowest coal-consumption was obtained with the highest steam-consumption, and the highest coal-consumption with the mean steam-consumption. The time and labour expended in carrying out these tests must have been considerable and he hoped that Mr. Kirby would furnish the supplemental data he had suggested, when it might be found that the compound engine would give even still better comparative results.

Mr. B. WOODWORTH (Longton, Staffordshire) wrote that the Lumpsey winding-engine had been provided for an extremely short run, probably between 10 and 11 revolutions only per wind. He could appreciate the arrangement for cross-compounding the engine, the large receiver-provision being a necessity, but he was surprised that the steam-admission had not been reduced to at least 85 per cent. of the full stroke, as the engine would have been quite as easy to work, and the efficiency would have been as good or even slightly better, combined with considerable economy. The times of running in Table I., would be the running time in the shaft from start to stop: probably the time under steam would be over 10 seconds less, and the actual time under steam would probably be about 30 per cent. only of the full working time. The mechanical efficiency was very high for this class of work, and it appeared possible that some error had crept in on this head.

The valve-arrangements of the Park winding-engine were evidently a little better than in the case of the Lumpsey engine, and the run was considerably longer, but there was a reaction from the exhaust of the opposite cylinder shewn on the whole of the diagrams.

The Skelton engine had a very fair distribution and utilization of the steam, the exhaust and compression would suit a

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good speed of working, and the major portion of the saving over the Park engine was due to the better utilization of the steam in the cylinders, leaving the balance to the debit of the bad conditions under which the Park engine was working.

The loads all round were very lightly proportioned, the starting loads being only about 16 to 18 pounds per square inch on the average on the original cylinders, and consequently there was ample power-margin all round; but, to get the stated mechanical efficiency, the engine would need extremely careful handling with a total absence of loss by brake or reversing action, and even then it would in his (Mr. Woodworth's) opinion be hardly possible to obtain it.

Mr. M. DEACON (Chesterfield) wrote that Mr. Kirby's concluding remarks with regard to a suggested steam-consumption of 35 pounds per actual horsepower-hour, when running noncondensing, with an engine similar to the Lumpsey engine, was hardly compatible with the tests recorded in the paper, which indicated 50 pounds and upwards with a vacuum of 26 inches; and he (Mr. Deacon) did not think that under ordinary conditions of winding, in which considerable condensation must take place in the cylinders when the engines were standing, that such a low consumption could be reached. He had non-condensing winding-engines working under favourable conditions, that was, with very short intervals between the winds, in which the steam-consumption did not materially exceed 50 pounds per indicated horsepower-hour, and he doubted, very much, whether this could be materially reduced, under ordinary conditions, when winding from moderate depths. A well-designed engine winding from great depths, with high-pressure steam, and tripgear, would no doubt produce better results, probably as low as 40 pounds, but he did not think that this result could be attained with so moderate a depth as that of the Lumpsey shaft.

Comparing the Lumpsey with the Skelton engine, there appeared to be a saving in the former of about 20 pounds per indicated horsepower-hour, but the comparison was not made on parallel lines, since the proportion of stoppages to the time of winding must of necessity be greater in the Skelton engine, owing to the lesser depth of the shaft. Probably under precisely similar conditions, there would not be more than 10 pounds difference in the steam-consumption of the two engines.

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It would be interesting if Mr. Kirby would indicate, in money, the economy per annum that he had obtained in fuel-consumption at the Lumpsey engine, and compare this with the interest on the capital and the depreciation on the additional cost of a compound condensing-engine, as contrasted with a highpressure engine.

Mr. T. C. FUTERS (Broomhill) thought that Mr. Kirby's paper was a valuable one, inasmuch as it afforded reliable information concerning the actual steam-consumption in a winding-engine. Ordinarily, it was a difficult matter to obtain this information with any degree of accuracy, as usually steam was drawn from a common range of boilers, which supplied steam to other engines.

It appeared to him (Mr. Futers), however, that an opportunity had been neglected to put down a good engine; and, judging from the indicator-diagrams, the valve-gear was bad and the pipes too small. In all probability these might have been re-designed and applied at the same time as the new cylinder at a little extra cost, and with certainly very advantageous results. It was unfair, however, to credit the engine with all the saving effected in steam-consumption, as this was undoubtedly due to the higher steam-pressure; and if the old engine had been supplied with high-pressure steam, or if either the Park or Skelton engines were to be supplied with steam at 130 pounds instead of 43 or 45 pounds per square inch. the consumption would, in his opinion, be very considerably reduced, provided they could be worked with a high expansion. In all probability where compound engines were installed, and credited with a reduction of steam-consumption, the actual saving was not due so much to the engine as to the fact that the steampressure had been raised, and consequently more calorific value had been obtained from the coal. It was evident that the compound engine was not superior in mechanical efficiency to either the Park or the Skelton winding-engines, as the former was admittedly in bad order when tested.

It had always been a moot point as to whether the installation of a condensing-plant for a winding-engine was worth the capital outlay; that was, would the amount of steam saved by condensing be more than sufficient to drive the air and cir-

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culating pumps, cover the upkeep and the depreciation of the plant, and yet yield a fair interest on the capital expended? At most collieries where the fuel used was of little value, he (Mr. Futers) thought that it would not. It would be interesting to hear what was Mr. Kirby's experience with the condensingplant and the actual results of the saving effected by it, as soon as it was working to its full advantage.

Mr. C. C. LEACH (Newcastle-upon-Tyne) remarked that the indicator-diagrams were not good ones.

Prof. HENRY LOUIS (Newcastle-upon-Tyne) remarked that the mechanical efficiency of the Lumpsey compound engine was 76 per cent., while those of the Park and Skelton engines, not compounded, were 78 and 79 per cent., and the net result of compounding the Lumpsey engine seemed to be a loss of efficiency of 2 or 3 per cent.; and he (Prof. Louis) asked the writer why he recommended compounding, when that was the result of his experience.

Mr. S. F. WALKER (Bath) remarked that, in his experience, it was extremely difficult to ascertain what those who were interested were paying for a horsepower. He was not aware whether they knew themselves, but at all events they never told others. At Lumpsey mine, 3¹ tons of stone were raised in each wind of 27 seconds; and that work cost 69 pounds of coal per actual horsepower-hour. The engine was compounded, the steam was condensed, and although the engine had not the Koepe endless winding-rope, all had been done that could be done with steam, and 69 pounds of coal were expended per actual horsepower-hour. In addition, there was the cost of generating the steam, apart from the coal used, the interest on the plant, the cost of water, etc.

Mr. M. WALTON BROWN (Newcastle-upon-Tyne) remarked that the total cost per annum of producing steam per indicated horsepower-hour, where coal was used as fuel, would vary from £10 upwards.

Mr. PHILIP KIRKUP (Birtley) suggested, with regard to Mr. Kirby's conclusion, that three-cylinder triple-expansion condensing engines would be economical, but should be limited to the case of deep mines. At shallow mines, where stoppages were so frequent, it would be impracticable to use a triple-expansion engine.

Mr. JAMES S. DIXON (Bothwell) remarked that Mr. Kirby stated in his paper that "little advantage was gained by using the condenser." Fig. 1 (Plate XII.) showed the condensingplant at the Lumpsey mine condensing the steam from several engines, and the author seemed to hint a doubt as to whether that was a good method, as so little advantage was obtained from it. He asked whether there was any real reason why a central condensing-plant should not give a good vacuum on a windingengine, simultaneously with that of other engines. Mr. Kirby seemed to doubt whether it could be done.

Mr. C. C. LEACH (Newcastle-upon-Tyne) thought that it was easier for the engineman to work the engine when the condenser was off, and he was glad to leave it off. At all events, that was his (Mr. Leach's) experience.

The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. Kirby for his paper.

Mr. P. KIRKUP seconded the resolution, which was cordially adopted.

Mr. F. HIRD's paper on "The Electric Driving of Windinggears: Supplementary Note," was read as follows: ---