

1/1

Valve setting and measurement
of
the power of a 10 H.P. simple
Engine.

Ed W. Webster '96.

Contents.

Economy requires the use of the Indicator
What the Indicator shows.

Construction of Indicator.

How it works.

Types and methods of attachment.

Engine used in these tests.

Tests made.

Name of parts of Diagram.

Record of first series.

Record of second series.

Computing Horse-power.

Conclusion.

The economic use of steam is of first importance to every user of the steam engine. It makes considerable difference in the profit and loss account if a plant is consuming a half or two thirds more coal than it should, because of an incorrect setting of the valves or of some defect in the design of the engine.

The direct investigation of the action of the steam in the cylinder is practically impossible because of the construction of the engine. The use of the steam engine indicator, however, when properly handled, gives a diagram showing the exact state of affairs. From this diagram can be read the pressures for every part of the stroke; the action of the valves; the maximum and minimum pressures; the mean effective pressure; the amount of steam used by the engine for any given period of time; and the horse power developed under various conditions of load, boiler pressure and valve action. Leaky valves, too small or too large port openings and supply

and exhaust pipes will show their effects on the diagram.

The essential parts of the indicator consist of a cylinder and piston. The top of the piston is open to the air and the pressure of steam in the engine cylinder is communicated to the bottom. Above the piston is a spring which resists the action of the steam from below.

To the stem of the piston by means of a parallel movement is fixed a pencil arm, the point of which moves over a card placed on a drum. This drum is rotated with each revolution of the engine. The combined movement of the pencil and drum gives the diagram an indicator card.

As steam is admitted to the engine the piston moves forward under its pressure. At the same time the pencil point moves upward over the paper on the drum and the drum turns with the movement of the engine piston. As the return

stroke takes place, the pencil falls and the drum comes back to its original position. The motion of the drum must exactly correspond with that of the engine piston.

To do this the string which carries the motion to the drum must be lead from the cross-head, where it is usually attached, in a direction parallel to the piston rod.

As the stroke of the engine is usually longer than the distance through which the drum can turn, there must be introduced between the cross-head and the drum, a reducing mechanism which will give the same relative motion through a shorter space.

There are several types of Indicators in use, and numerous ways of attaching them. In these tests a Crosby Indicator and a Victor reducing wheel were used.

a one half inch round post eleven inches high being screwed into the cross-head, carried the string parallel

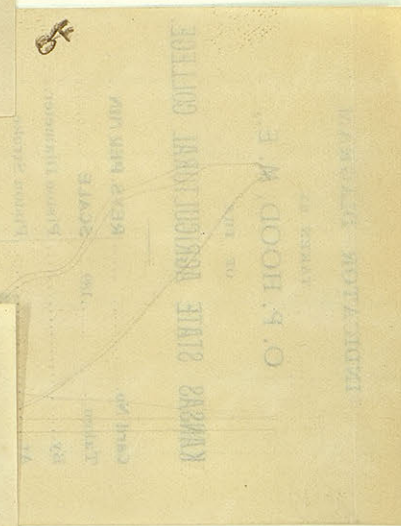
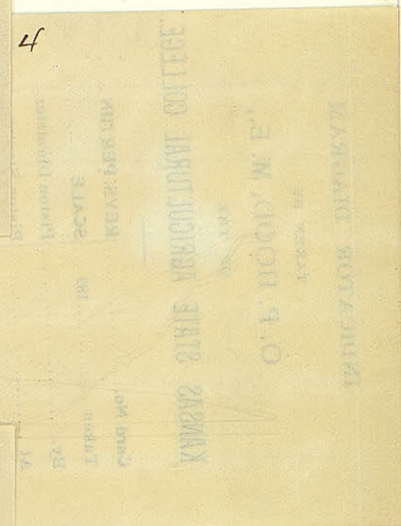
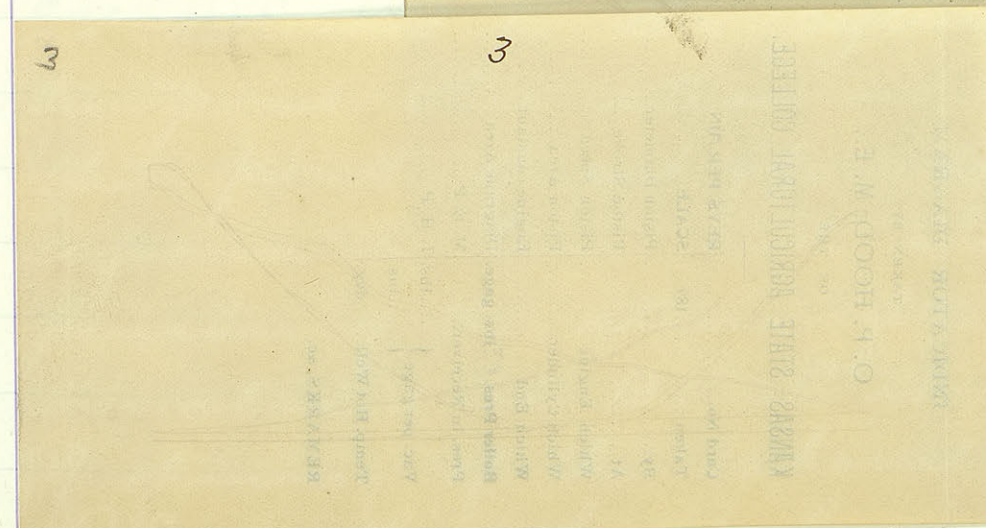
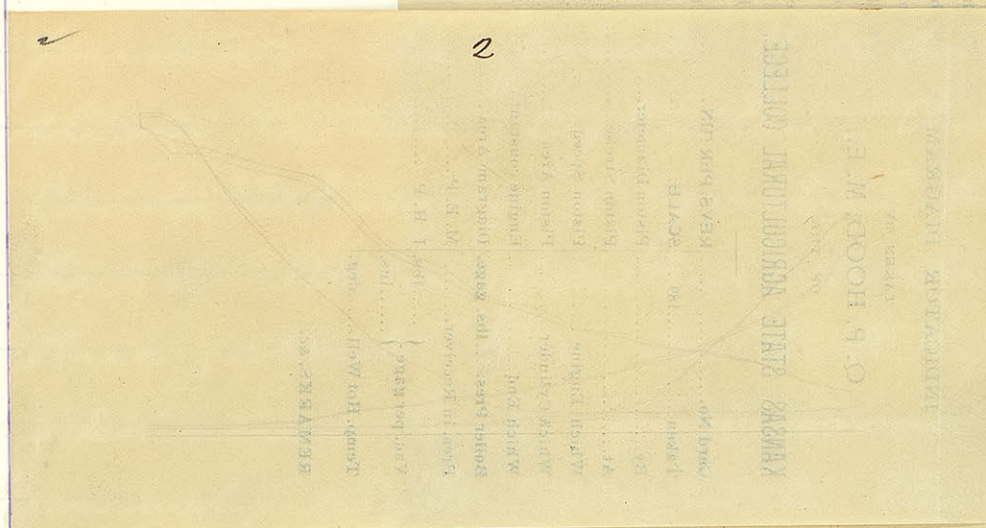
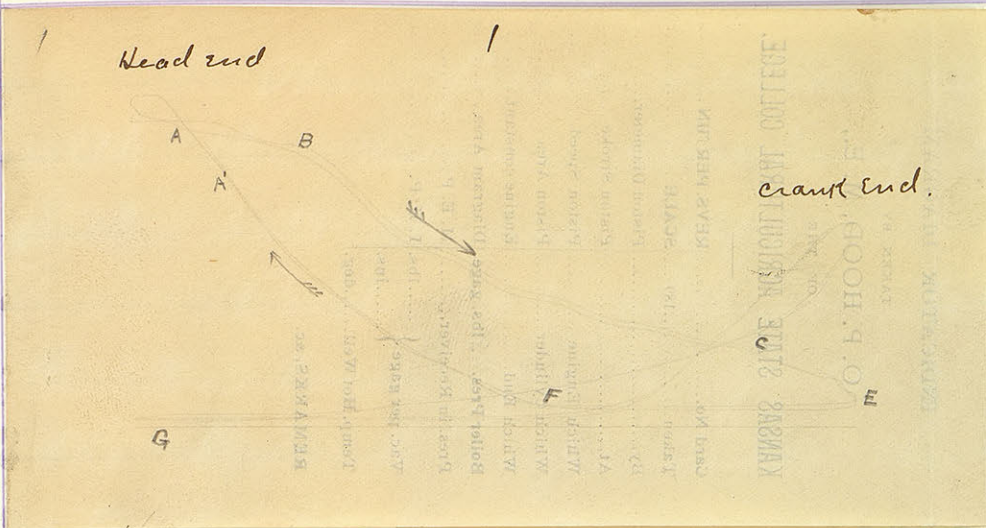
to the piston rod direct to the reducing wheel. This is fixed to the Indicator by means of an arm and screw. The Indicator was fastened to the engine cylinder by pipes from either end connected by a straight way cock to which the ring of the Indicator is screwed.

The engine used in these experiments was a 10 H.P. automatic cut off Atlas. Steam was taken from the same pipe that supplied a 5.0 H.P. engine and the exhaust opened into the exhaust pipe from that engine. Both engines were running during the tests which accounts for some of the irregularities in the cards.

Two series of tests were made, one to ascertain the value and reliability of the Indicator for setting the valve movement and the to compare the horse power developed under different loads, the boiler pressure remaining as nearly as possible the same.

The first series was made with the engine running empty and with belt throws off.

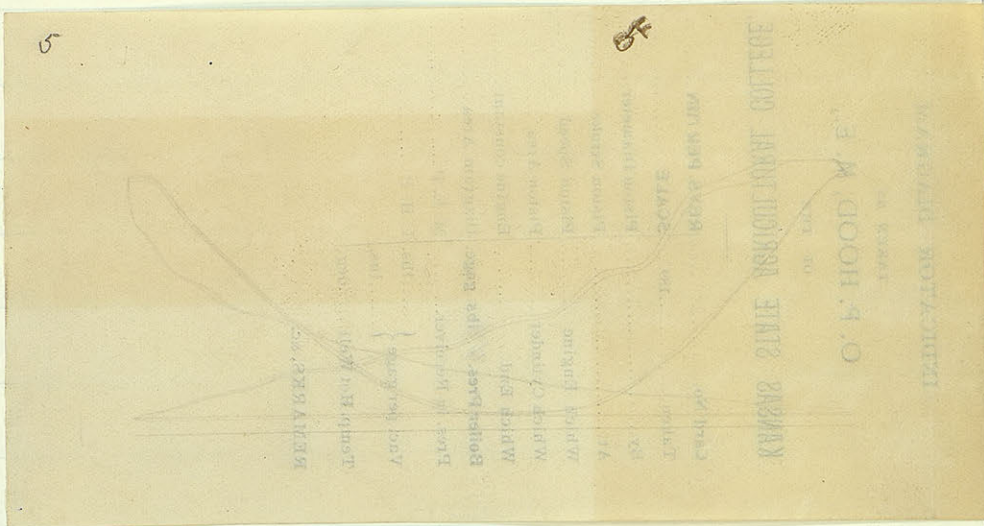
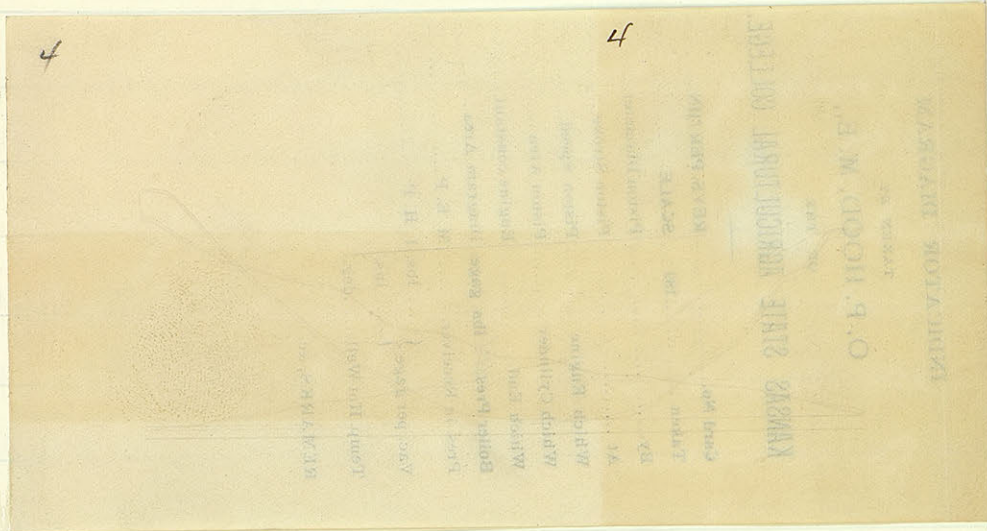
Card No 1 will be taken to name the various parts of the diagram. The line $\mathcal{B}$ represents the line of atmospheric pressure and is drawn with out steam being admitted to the Indicator. A in this card represents the point of admission of steam to the cylinder, though in cards showing a greater power it will be a little farther down on the line, about A' . and A, A' will be the admission line and would be at nearly right angles to the atmospheric line. AB is the steam line and measures the length of time steam is admitted to the cylinder B , being the point where steam is cut off, or the point of cut off. $B.C.$ is the expansion line and shows the expansion of the steam after the valve is closed at B . C is the point of opening of the exhaust valve. $C.E.$ is the exhaust line showing



Pres. in Receiver.....lbs. I. H. P.
Vac. per gage.....ins.
Temp. Hot Well.....deg.
REMARKS, &c.

Which End.....Diagram Area.
Boiler Pres. 48 lbs. gage. M. E. P.
Pres. in Receiver.....lbs. I. H. P.
Vac. per gage.....ins.
Temp. Hot Well.....deg.
REMARKS, &c.

Pres. in Receiver.....lbs. I. H. P.
Vac. per gage.....ins.
Temp. Hot Well.....deg.
REMARKS, &c.



the expulsion of steam from the cylinder. E is the point where the piston begins its return stroke.

E.F. is the counter pressure line or the distance through which the piston travels before the exhaust valve closes. FA is the compression line showing the compression of what steam there is left in the cylinder after the exhaust valve closes.

Before the cards of this series were taken the nuts of the valve-stem were given two complete turns to the right so as to draw the valve one fifth of an inch off center.

Card No 1 was then taken. It shows that the head end of the cylinder did all the work in running the engine while the crank end did nothing whatever, showing plainly that the valve was too far to one side admitting too much steam to the head end while the crank end got none. The nut was turned back one tenth of an inch on one turn. and Card No 2 taken

Practically no change was made in the admission of steam. Again the nut was given a half turn back and Card No 3 taken. This shows a change in the state of affairs.

The diagram for the head end is noticeably smaller while that of the crank end is larger. They are much more evenly balanced than before but yet not enough to give both sides of the pistons the same work to do. Another half turn was made placing the nut where it was before being moved and Card No 4 taken.

In this it will be seen that as far as the eye can detect both sides are about equal, showing that the engine is working under the best circumstances it can as far as valve setting is concerned.

Still another turn was given and Card No 5 taken which is nearly the reverse of No 1 and 2, showing that the crank end is doing the work and the head end is useless.

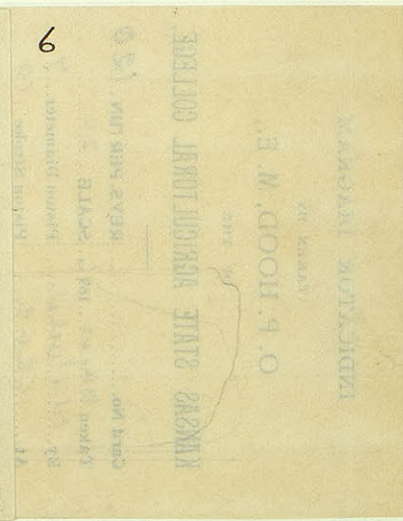
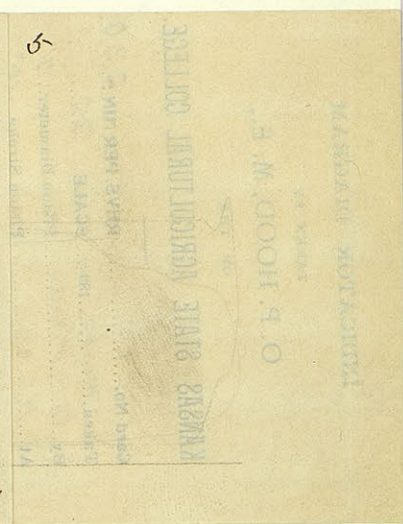
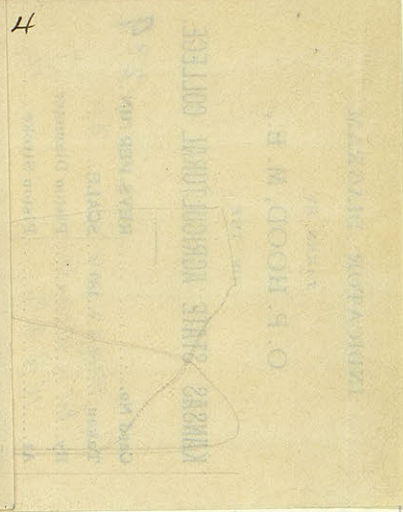
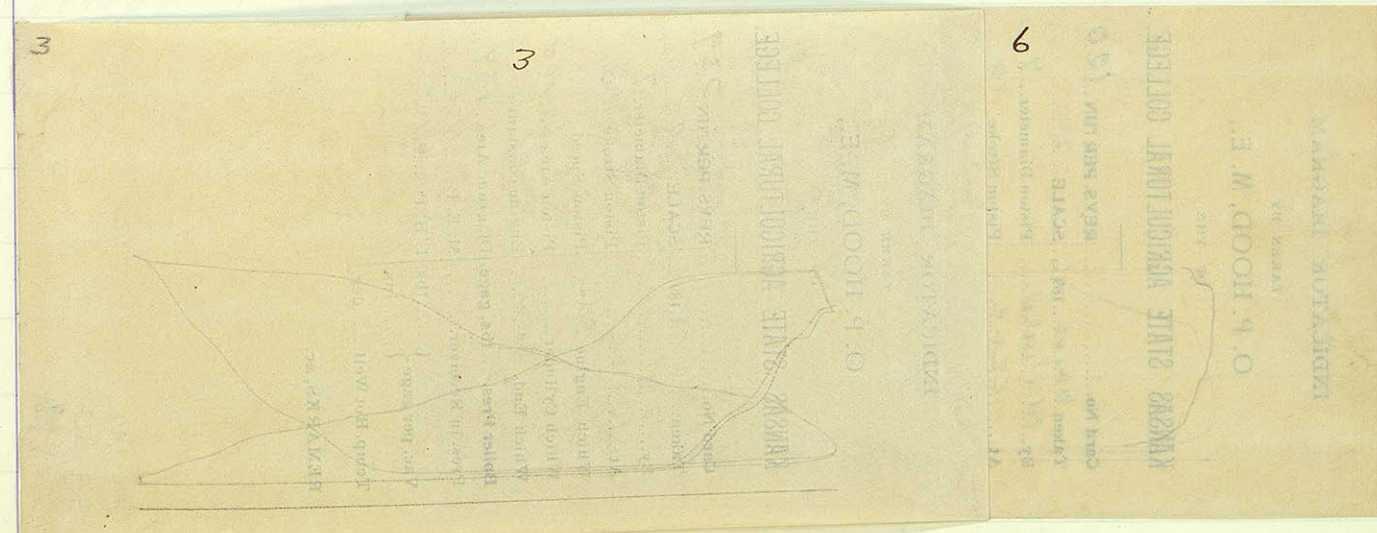
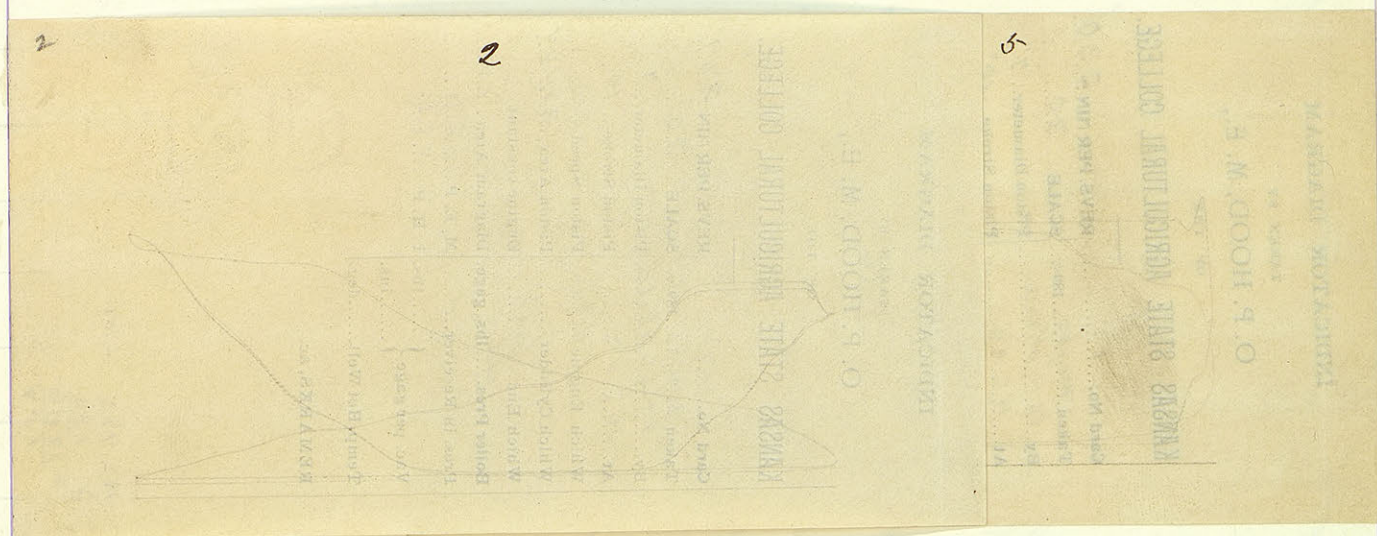
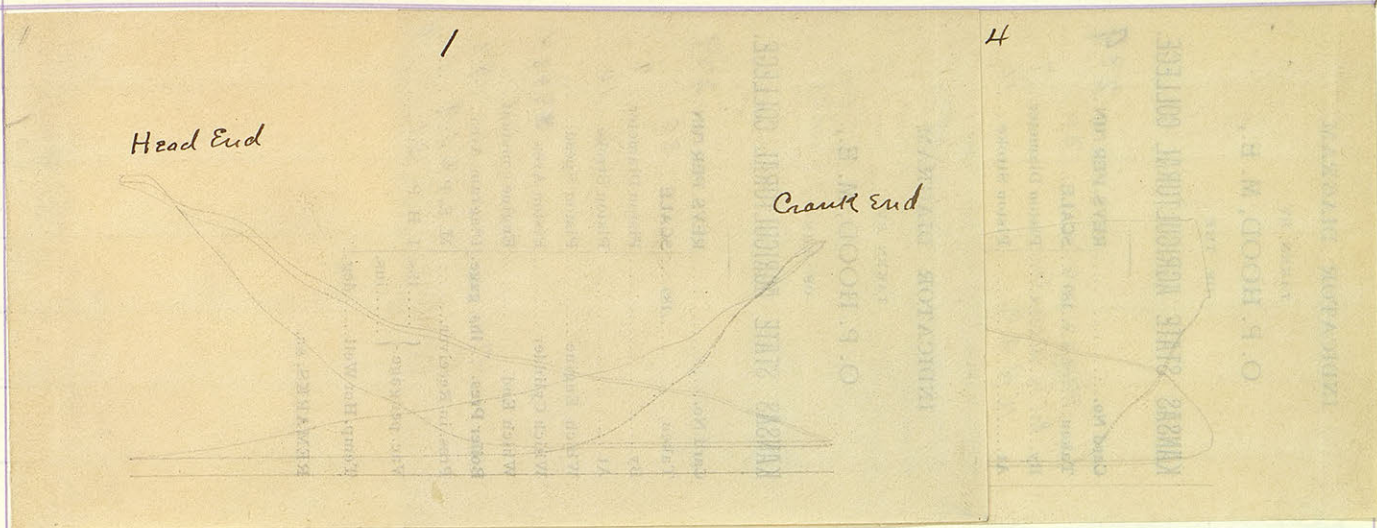
A loop will be noticed on

the head^{end} diagrams of all the series and also the point of closing the exhaust valve for this card comes earlier in the stroke than in the other cases. no matter how the valve is set. This is probably due to a faulty construction of the parts as the position of the valve will not change it.

In No's 1, 2 and 3 it can be seen that for the end doing no work, no steam being admitted through the ports, steam does get in somewhere and causes the expansion line to rise above the compression line. This is in all probability due to steam getting by the piston.

For accurate setting Card No 4 should be measured by the planimeter and the valve shifted until both sides would show an exactly equal amount of effective work.

Since No II was taken to show the actions of the engine under different loads. The belt was



Temp. Hot Well.....deg.

REMARKS, &c.

H = 197
C = 172
2/369

Temp. Hot Well.....deg.

REMARKS, &c.

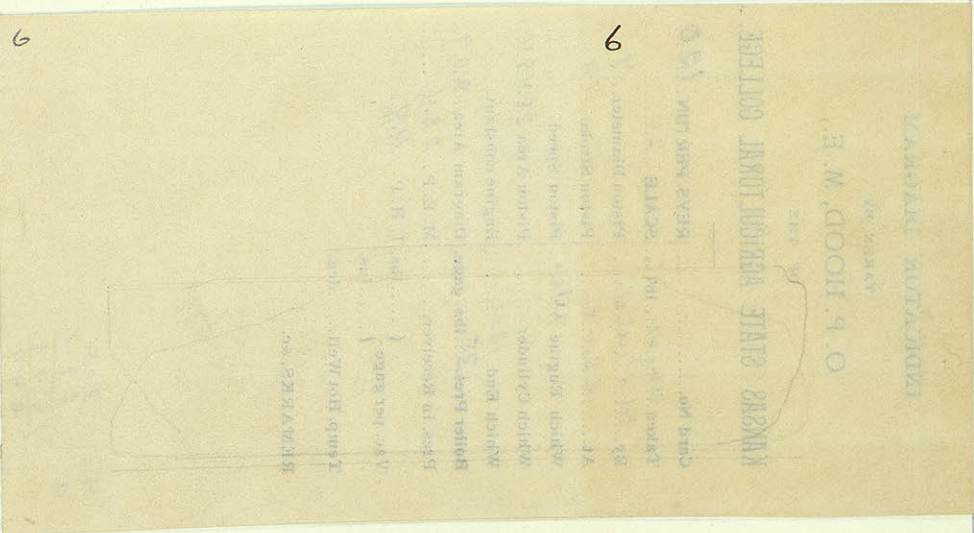
H = 173 - .01
C = 133
2/326

Temp. Hot Well.....deg.

REMARKS, &c.

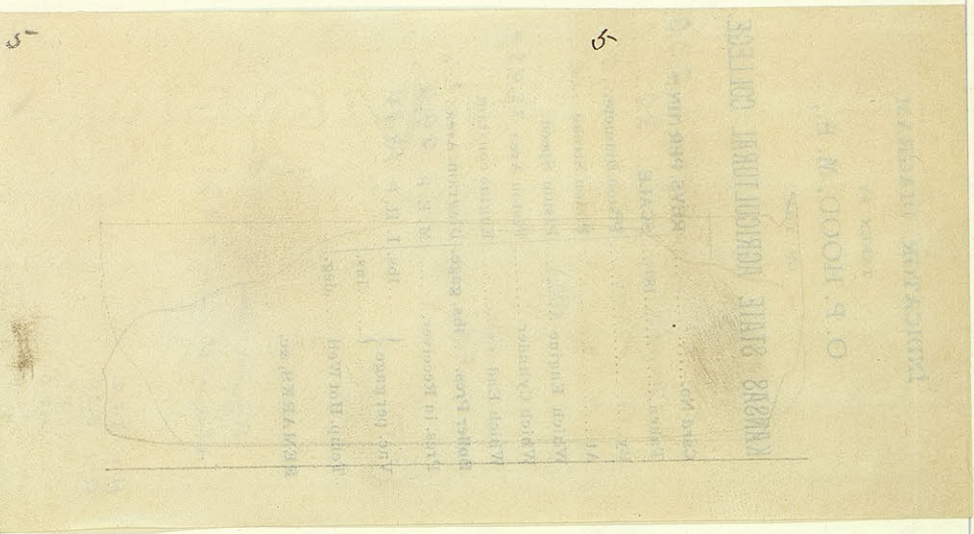
H = 107 - .014
C = 115

6



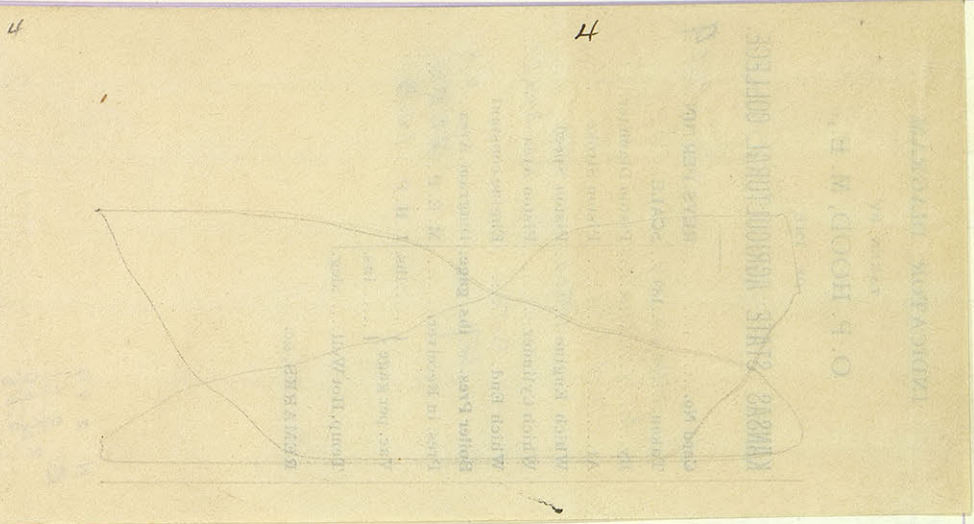
6

5



5

4



4

thrown off as in the previous series and a brake applied to the flywheel of the engine in such a way that it could be stopped by consuming all its power in friction on the wheel.

The areas of these cards were carefully measured by the planimeter the horse power then being calculated by the formula $\frac{P.L.A.M.}{33000} = H.P.$ which means to multiply together the Mean effective pressure, the length of stroke in feet, the area of the piston and the number of strokes per minute and divide by 33000 which gives the horse power. To get the mean effective pressure the area of the diagram is divided by the exact length in inches which gives the mean height in inches. Every inch in height of the diagram means so many pounds per square inch pressure. The resistance to the steams in the indicator piston is given by means of a spring these springs are made of different stiffness and carefully tested and

numbered, the number being the pounds pressure that will move the pencil point one inch against the resistance of the spring.

A No 30 spring was used in these tests which means that for every inch in height on the card 30 pounds pressure was exerted by the steam. Now by multiplying the mean height of the diagram by 30 it gives the mean average pressure or effective pressure, in pounds per square inch as used in the formula. L in this case is $1\frac{1}{2}$ ft. the stroke of the engine being 10 inches. $A = 38484$ sq. in. and N in all but No 5 and 6 is 478 strokes per minute or twice the number of revolutions.

33000 is the number of foot pounds per minute of work required to equal one horse power.

Card No 1 with no load on. Boiler pressure equals 47 lbs. This does not enter into consideration in computing the H.P. but is useful

in comparing the amount of work done under different pressures. It will be given in all the cards for this series but no further notice will be taken of it in comparing cards. Revolutions per minute equal 239 making $M = 478$. scale of spring 30. piston area 38,484 sq. in. Average area of diagram .83 sq. in. .83 divided by 2.69 the length of the card gives .223 as the average height of the diagram. This multiplied by 30 gives 6.69 = P . Substituting these values in the formula it gives

$$\frac{6.69 \times \frac{1}{2} \times 38,484 \times 478}{33,000} = 3.1 = \text{horse power}$$

It will be noticed that the head end is larger than the crank end diagram showing that the valve is not quite in the center. The same condition holds for all the cards of this series. The space between the atmospheric line and the line of counter pressure is caused partly from back pressure in the displacement of its own steam and partly from back pressure

of the other engine. Variations in the width of this space are due to the amount of steam used by the other engine.

Card No 2 was taken with a slight pressure on the break. Boiler pressure 44 lbs. Area of diagram 1.53 sq. in. giving a mean average pressure of 12.6 lbs. and 5.85 H.P. The loop in the crank end diagram has entirely disappeared and has become much smaller in the head end diagram. In Card No 3 the loop has entirely disappeared from both diagrams showing that when loaded the defects of the engine are not so apparent as in the first series. In this card $A = 1.84$ sq in. Boiler pressure 40 mean effective pressure 15. H.P. = 6.95

Card No 4 shows the best results for the engine. $A = 2.8$ boiler pressure 47, mean effective pressure 22.5 H.P. 10.3 or the power for which the engine was designed. In this card are shown the same defects

of design in the engine parts. The head end card shows a longer steam line while there is no admission line as in the crank end. This is due to the same thing that caused the loop in the first series.

Card No 5 shows an overloaded condition. But 230 revolutions were made when there should have been 239. $A = 3.69$ showing a much larger consumption of steam. The effective pressure is 29.4 while the W. P. is but 13.1 an actual loss in power when taken in connection with the amount of steam used. Boiler pressure is 43.

No 6 shows the most interesting features in an overloaded engine. The number of revolutions were pulled down to 120 per minute and while the area of the diagram is one tenth of an inch larger than No 4 and the mean pressure is $9/10$ of a pound greater the W. P. is but 4.9 showing an enormous

loss in the use under such conditions. Boiler pressure 35 lbs.

Many more interesting things can be learned from the use of the Indicator but these two tests show the principal uses and will suffice to indicate the necessity of an Indicator on the engine if it is to be run intelligently and economically.

Ed H. Webster '96.