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NOMINAL HORSE POWER OF ENGINES.

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It is obviously very convenient, not to say absolutely necessary, to be able, given the principal dimensions of a steam or other prime-mover, to state the probable rate at which it will work under normal conditions. The power thus calculated, is, or ought to be, known as the Nominal Horse Power; but this term has been much abused in the past, chiefly because the actual powers of engines of given dimensions have vastly increased owing to increased pressures and piston speeds while the method of calculating Nominal Horse-Power remained the same, or irrational contracted rules had been adopted which ignored important factors. Except for marine engines, the term Nominal Horse-Power may be said to be obsolete, and although still used in reference to these, no one can just say how its value is determined, or what it means when found. Even for marine engines, the term is not used by Engineers, except under compulsion; the Shipping Laws of the State and the Empire recognize the term, although they fail to define it; and so, when it is "de facto" dead, it drags out a legal existence in the pages of the Statute book, and the awards of Wages Boards.

The reference in the Acts of Parliament to the term is found in the provisions as to certificated marine engineers; a foreign-going steamship of 100 Nominal Horse-Power or over must have a first-class certificated engineer in charge of its machinery, and so on. This provision occurs both in the Imperial Law (the Merchant Shipping Act), and in the State Navigation Act. The regulations made under these Acts require service at sea with engines of a stated minimum Nominal Horse-Power, to qualify engineers for certificates; but neither the Acts nor the regulations give any hint of what a Nominal Horse-Power is. All British ships have to be registered under the Merchant Shipping Act, which applies, of course, to Australian ships as well as to English ones; and in the Register certain particulars, prescribed, not by the Act, but by the Board of Trade, which administers it, have to be entered; one of which, for steamships, is the Nominal Horse-Power, and another the Indicated Horse-Power, thus making a distinction. This requirement of nominal power in the Register is clearly a matter of regulation, and could be dropped or altered by the Board of Trade at any time; only the expression has crept into the clause of the Act relating to engineers' certificates, and its value as stated in the Register is the only thing we have to go by.

The great Insurance Registries have found it necessary to fix some standard measure of power or size of engines by which to regulate Surveyors' fees; the British Corporation go by the capacity of the low-pressure cylinder in reciprocating engines, and by that of the low-pressure annulus in steam-turbines, but it does not mention nor try to define a Nominal Horse-Power. Lloyds' Registry, however, fixes its fees by Nominal Horse-Power, and gives rules for determining it for reciprocating engines, which are definite enough in form; only the power found by them has no proportion to the Actual or Indicated Horse-Power. Lloyds' Register is the admitted authoritative record of steamships, and their technical data, and as in the great majority of cases it gives the Nominal Horse-Power of steamers as calculated by Lloyds' rules, we could not do better, if we are content to retain this fictitious value of horse-power, than to adopt Lloyds' rules and have them recognised by the Shipping Acts, just as Lloyds' rules for freeboard are sanctioned and adopted by the Government. For many steamers, however, the engine-power stated in Lloyds' book is not N.H.P. by Lloyds' rules, but R.H.P. or the horse power given in the ship's register, which seems to follow no rule at all. Lloyds' takes data from both engine and boiler, making the N.H.P. of engine proportional to square of low-pressure cylinder diameter and to square root of the piston stroke. The N.H.P. of a steamship is approximately the mean of the engine and boiler power, calculated separately. When no data for the boiler are available, the rule for engine power is N.H.P. $= \frac{D^2\sqrt{S}}{100}$ for triple and quadruple engines; for compound engines, divisor is 120, and for simple engines, 130. D is the low-pressure cylinder diameter, and S the stroke, both in inches. For boilers, the heating surface in square feet H is the criterion, and $\frac{H}{15}$ the N.H.P. with natural, $\frac{H}{12}$ that with forced draft. The complete rule applicable to any surface condensing engine, is,— for natural draft;—

$$N.H.P. = \frac{P + C}{K}\left(\frac{D^2\sqrt{S}}{100} + \frac{H}{15}\right)$$

the 15 in the last term being 12 with forced draft. Here P is the boiler pressure in lbs. per sq. inch, and C. and K constants, C being 340 or 590 accordingly as P is below or above 160 lbs., and K, 1000 or 1500 according to the same circumstance. It will be noticed that $\frac{P+C}{K}$ equals $\frac{1}{2}$ when P is 160, with either pair of constants. Thus we take the mean of the engine and boiler power as the combined power with 160 lbs. pressure; rather less than the mean for lower pressures, and rather more for higher ones; thus the factor for 210 lbs. is .533.

This rule has been in use for many years; in Lloyds rules for 1889 it appears with $\frac{1}{2}$ in the formula instead of $\frac{P + C}{K}$ and may be older than that date, but it has an appearance of complication that has prevented engineers in general getting familiar with it. Previously to its introduction there cannot be said to have been any rule, but there was a great variety of practice, every engine-builder was supposed to have a rule of his own, nearly all taking piston area only into account, but differing in the number of circular inches area allowed per Nominal Horse-Power. Of course, rules founded on piston area only, neglect the other factors of horse-power, pressure and piston speed per minute, and so are of really no value for their supposed purpose. The power thus found was thought to be some guide to commercial men, some index to the weight or size of an engine, but this certainly is doubtful.

The sum of the squares of the diameters of the cylinders in inches, divided by from 30 to 33, according to district, gave the N.H.P.; for triple or quadruple engines, divisor was often reduced to 22. The sum of the cylinder diameter squares in inches divided by 30 = N.H.P. (that is, 30 circular inches of piston area per one N.H.P.) is known as the Board of Trade rule, but he is not aware of the Board of Trade having ever recommended it or authorised it, though no doubt it has tacitly accepted its use for Registration purposes. Our New South Wales Marine Board published in 1886 a rule to this effect, which seems to have been copied from a Board of Trade circular "for calculating the N.H.P. of compound engines, to be inserted by Surveyors in their declarations and also in the certificate of Survey." As there is no requirement for inserting it in declarations or certificates of ordinary periodical surveys, it appears to refer to the declaration made when first registering a new steamer. The rule is for ordinary condensing engines, $\frac{D^2N}{30}$ = N.H.P. where D = diameter of cylinder in inches, and N = number of cylinders; for compound engines, $\frac{D^2N + d^2n}{30}$ = N.H.P. where D is diameter in inches of low-pressure cylinder, N number of low-pressure cylinders, d diameter in inches of high-pressure cylinder, and n number of high-pressure cylinders. The rules were repeated in subsequent editions in 1892 and 1897, with misprints in both, but as it was a dead letter no one seems to have noticed them; in the 1897 edition of the rules, which superseded all former editions but is now also obsolete, the formulae were given as $\frac{D \times N}{30}$ and $\frac{(D^2 \times N)+(d^2 \times 2)}{30}$.

No such rule appears in the Board of Trade's instructions to Surveyors; the only reference to the matter in the Board's rules for examination of engineers occurs in the edition of last year's date, which says—"the Nominal Horse-Power as given in the vessel's Certificate of Registry may in all cases be accepted by the Examiner," irrespective apparently of how it has been determined.

These sum of the squares rules, whether rational or not, have at least the merit of simplicity, but might be simplified still further to produce the same result. With compound, triple, and quadruple expansion engines, the sums of the squares of the cylinder diameters have nearly fixed ratios, for each class of engine, to the square of the low-pressure cylinder diameter; and by dividing the latter by a suitable constant for each class of engine, we may get the same result as by the sum of the squares rule. Thus in a modern compound engine Σd^2, the sum of the squares of both diameters, is not far from 1.25 D^2, the square of the low-pressure diameter, and dividing the latter by 24 gives about the same result as dividing the sum by 30. So in triple expansion engines Σd^2, seldom varies much from 1.5 D^2, and the latter divided by 20 is the same as the former divided by 30. Also for quadruple engines Σd^2 is always about 1.85 D^2, so we may use the latter divided by 16 with very little error. Hence Lloyds' is quite justified in taking the low-pressure cylinder area as a measure of the power. Taking the squares of each cylinder diameter is a mere superfluity, now-a-days at least, when cylinder proportions have got standardised.

In Seaton and Rownthwaite's pocket book we find mention of a rule current on the North-East coast, which introduces the cube root of the stroke in inches into the formula, as follows:—

$$N.H.P. = \frac{\Sigma d^2 \sqrt[3]{S}}{92}$$

This is certainly an improvement on rules that only note the diameters, but yet does not give anything like the real horse power. If the stroke is 27 inches, divisor will be 92/3 or 30.6, if stroke is 64 inches divisor will be 92/4 or 23. This makes allowance for the probable greater piston speed of longer strokes, but ignores pressure. The North-East Coast Institute of Engineers attacked the problem long ago, and published in 1890 a rational formula for the "Estimated Indicated Horse Power" to be expected in a loaded steamship under normal conditions, or the every-day full power as distinguished from a trial-trip spurt. This is what Nominal Horse Power ought to mean. Their rule is—

$$E.I.H.P. = \frac{(D^2 \sqrt[3]{S} + 3H) \sqrt[3]{P}}{100}$$

This is reasonable and gives useful results, but it is complicated by mixing up engine and boiler data. H here stands for heating surface in square feet, P for boiler pressure in lbs., and D and S for L.P. diameter and stroke, in inches. The rule may be taken thus—Engine Power = $\frac{D^2 \sqrt[3]{SP}}{50}$ and boiler power = $\frac{3H \sqrt[3]{P}}{50}$ while combined power is half the sum of the two. This gives a fair value of actual power, and is far better than any of the other rules mentioned, but might be improved on yet.

About 20 years ago, in June 1892, a conference was held in our Association's rooms in Sydney, of representative engineers to try to formulate some rule in the vexed question of N.H.P.. Unfortunately it was abortive. Lloyds' rule seems never to have been mentioned, and the representatives of the sea-going engineers seemed only concerned to fix a divisor for the sum of the squares, as if that was the way to determine real power. Three more rational proposals were made by some of our members; the minutes of the select committee appointed to consider the ideas brought forward, say—"Although agreeing that the adoption of any of the three rules (the 'crank-shaft' rule finding most favour) would be a decided improvement on the old one of expressing N.H.P. in terms of cylinder area divided by a constant, yet it was unanimously resolved that it was simply impossible to frame any rule that would give anything like general satisfaction, and the opinion was freely expressed that this method of expressing N.H.P. should be expunged."

The crank-shaft rule referred to involved such a fallacy that it is difficult to believe the minutes that it found most favour with the Committee. It was N.H.P. $= A\sqrt[3]{D}$, A being sectional area of crank-shaft in square inches, and D its diameter in inches. It might be written N.H.P. $= \sqrt[3]{D^7} \times .7854$. But D was not to be taken as the actual shaft diameter, but as that calculated by the Board of Trade rule for shafts in passenger steamships, where the data are cylinder diameters, length of crank, absolute steam pressure, and the angles the cranks are set at; so that the rule is far from simple. The fallacy is that the engine power is proportional to the strength of the shaft, the stress in the latter being thus considered to be the mean torque or turning moment, whereas the stress the shaft has to be designed for is the maximum torque or turning moment which is no measure of the horse power. This varying stress is allowed for in the Board of Trade rule, by giving constants differing according to the crank angles. Thus a heavier shaft is demanded with a tandem engine, two cylinders over one crank, than would be needed with the same two cylinders and pressures over two cranks at right angles, but no one would expect more power from the tandem engine.

Of the other two suggested rules, one was E.H.P. $= \frac{PD^2}{C}$, P being boiler pressure in lbs., D low pressure diameter in inches, and C a constant for each class of engine, 336 for compound, 420 for triple, and 480 for quadruple engines; E.H.P. being estimated horse-power to be expected in actual