NOMINAL HORSE-POWER

BY

LIEUTENANT-COMMANDER R. J. TOMLIN, R.D., R.N.R., C.ENG., M.I.MECH.E.

During the last decade of the 18th Century and the early years of the 19th Century the calculation of power output from reciprocating steam engines developed along two lines of thought. The first, an approximation, later to be called Nominal Horse-Power and the second method, the accepted true horse-power, now known as Indicated Horse-Power. These notes cover the now discarded first method, Nominal Horse Power.

As a result of his endeavours to produce a yardstick of the power developed by his steam engines James Watt produced a systematic method of determining a ratio of power equivalent or horse-power. This was derived from an estimate of the work done by a mill horse walking round a twenty-four-foot circle at a speed of two and a half turns per minute and exerting a pull of one hundred and eighty pounds. Using three instead of the true value of pi he arrived at a figure of 32,400 ft lb per minute. Although this was a rough approximation it remained unconnected and a year later in 1783 it was rounded off to 33,000 ft lb per minute, the now universally accepted equivalent of one horse-power. During the late 18th Century and largely through Watt's influence, the output of steam engines were first rated at so many horses and then later their horse-power equivalent.

Piston speed and Mean Effective Pressure form the basis of horse-power calculations. By experiment Watt arrived at the expression $128 \times \sqrt[3]{\text{Stroke}}$ for the piston speed of his engines and 7lb per sq in. for the mean effective pressure. At the same time he was working on an instrument to determine the MEP in a working engine. Using only the piston diameter and stroke Watt calculated the horse-power equivalent of his engines using the following equation:

$$(1) \qquad \text{NHP} = \frac{\text{Piston Area (Sq in.)} \times 7 \times 128 \sqrt[3]{\text{Stroke}}}{33{,}000}$$

This equation gave a close approximation to the values of indicated horse power obtained in practice. However, during the early part of the 19th Century there was a steady increase in piston speeds although there was no significant change in boiler pressures. To allow for the change in operating conditions the Admiralty modified the original formula and the true piston speed was introduced into the equation. The modified equation then read:

$$(2) \qquad \text{NHP} = \frac{\text{Piston Area (Sq in.)} \times 7 \times \text{Piston Speed (fpm)}}{33{,}000}$$

The accuracy in determining mean effective pressure increased with the improvements of the engine indicator during the years 1825–30 and the calculation of IHP had become well established. However, the use of NHP continued into the early years of this century. The reason for this is not clear but it would appear that the long usage of NHP, which gave a good indication of the size of an engine, was useful in determining costs of construction, insurance rates and staffing numbers for engine and boiler rooms. About this time it was well understood that NHP had ceased to have any practical value as a method of determining the power developed by reciprocating steam engines and the foregoing equations were abandoned for the simple ratio, IHP/6.

Equation (2) and the ratio IHP/6 give similar values of NHP but these are lower than the values of NHP quoted for steam driven warships built during the 1860's. At first it would appear that Equation (2) was further modified. However, using this equation with MEP as the unknown factor, values of MEP higher than 7 lb/sq in. are obtained. Bearing in mind the well established principles involved in calculating MEP, it is safe to assume that with increasing boiler pressures the arbitary values of MEP were also increased to between 10–11 lb/sq in.

Other equations for the calculation of NHP have appeared in print and an analysis of these reveals that there was no further development in the calculation of NHP beyond the formulation of Equation (2). Of the equations that have come to notice two were quoted by Rear-Admiral J. G. Liversidge:

Simple Condensing Engines

(3) $$\text{NHP} = \frac{D^2 \times N}{30}$$ Where D = Cylinder diameter in inches
N = Number of cylinders.

Compound Condensing Engines

(4) $$\text{NHP} = \frac{(D^2 \times N) + (d^2 \times n)}{30}$$ Where D = LP Cyl. Dia. in inches
d = HP Cyl. Dia. in inches
N = Number of LP cylinders
n = Number of HP cylinders

The final variation of Equation (2) is the most interesting. This is quoted by John Scott Russell in his monumental book on naval architecture in which he referred to this as the Admiralty Equation:

(5) $$\text{NHP} = \frac{D^2V}{6000}$$ Where D = Cylinder Dia. in inches
V = Piston speed in fpm.

Scott Russell attempted to provide a scientific basis for the calculation of NHP and compared the values of Equation (5) with his own basic values of piston speed and swept volume of the cylinder. His method was based upon the following statement of principle:

'That an engine of one nominal horse-power is one in which the swept volume is equal to the cubic capacity of one gallon and operating with a piston speed of 180 fpm.'

Using a piston diameter of 5·4157 inches, a stroke of one foot and a piston speed of 176·875 strokes per minute, Scott Russell arrived at a product which approximated to 180 gallons per minute. However, instead of this product he chose to multiply square inches by feet by strokes per minute, thus arriving at the following:

Area of piston (sq in.) × Stroke (ft) × Strokes per min.

Or, 23 × 1 × 176·875 = 4,600

As he developed his theory he rounded off these figures and produced the following:

30 round inches × 180 fpm = 5,400

He then compared the product 5,400 with the divisor of the Admiralty Equation and concluded that the value 6,000 was obtained by multiplying

30 round inches (sq in.) × 200 strokes per min. = 6,000.

In assuming this he appears to have not known or chosen to ignore that the Admiralty Equation was derived from Equation (2) where,

$$\text{NHP} = \frac{\pi \times D^2 \times 7 \times v}{4 \times 33{,}000} = \frac{D^2v}{1} \times \frac{\pi \times 7}{4 \times 33{,}000}$$

$$\text{NHP} = \frac{D^2v}{1} \times \frac{1}{6{,}000}$$

During the period when both NHP and IHP were in regular use it was not uncommon to quote a figure by which the NHP of an untried engine could be multiplied to give an anticipated IHP.

Again, Scott Russell set out to determine a similar ratio by calculation. In this case it was between what he called 'Real Horse-Power' and NHP. In essence he estimated that a cubic foot of water evaporated into steam at atmospheric pressure in one hour would occupy a one foot square column 1,698 feet high. That is, 62·5 lb of water will produce 62·5 × 27·18 (cu ft of steam per lb at atm. press.) = 1,698. (Scott Russell's figures). Then without qualification

Ship	Year of Launch	Engine Type	Engine Builder	Boiler Pressure	Piston Diameter	Effective Piston Area (Sq In.)	Stroke (Ft)	Trials r.p.m.	Trials Piston Speed (f.p.m.)	Trials I.H.P.	Quoted N.H.P.	Calculated N.H.P.			
												Equ. (1)	Equ. (2)	Equ. (2) Increased M.E.P.	I.H.P./6
Warrior	1860	Trunk	Penn	20	112″ Trunk 41″	8520	4	55	440	5507	1250	367	865	1240	918
Royal Oak	1862	Horizontal Direct Acting	Maudslay	20	82″	5281	4	60	480	3000	800	228	538	770	500
Zealous	1864	Return Connecting Rod	Maudslay	20	82″	5281	4	60	480	3450	800	228	538	770	575
Prince Albert	1864	Horizontal Direct Acting	Humphrys & Tennant	24	72″	4071	3	61	366	2121	500	159	311	530	358
Repulse	1868	Trunk	Penn	20	89 Trunk *32″	5417	4	59	472	3350	800	233	552	790	455

* Determined by ratio.

he worked out the work done by the steam on the superimposed atmosphere in occupying the above volume. Thus, 144 × 14·7 × 1,698 = 3,594,647 ft lb per hour or 59,894 ft lb/min, which he called one real horse-power. Finally dividing this by 33,000 he arrived at a ratio of 1·815 real horse-power to one nominal horse power.

A limited study of the results of Scott Russell's calculations reveals that he was given to rounding off dimensions and taking short cuts in his calculations. The foregoing is a typical example of his sometimes questionable presentation of technical matters to those without his academic background.

Sources of Information

(1) Science Museum. (Mr. M. P. Sayer, Dept. of Marine Engineering.)
(2) *Engine Room Practice.* Rear-Admiral J. G. Liversidge. (Charles Griffin & Co., Ltd.)
(3) *James Watt.* H. W. Dickinson. (David & Charles: Newton Abbot)
(4) *The Modern System of Naval Architecture.* John Scott Russell.
(5) *British Battleships.* Oscar Parkes (Seeley, Service).

TALKING POINTS

1. Material failures (only) occur when the stress exceeds the strength.
2. All failures are mechanical. Material (only) fails mechanically.
3. No two things are exactly the same.
4. Environments are continuously changing.
5. Everything fails sooner or later.
6. Time is issued at a constant rate (virtually constant rate).
7. Each (person) gets the same ration of Time (to fill as best he may).
8. The time to hurry is before the start.
9. Every action affects, and is affected by, every other action.
10. Everything affects, and is affected by, every other thing.
11. This is a probablistic world where the Laws of Probability are as binding as any other natural revealed law.
12. The world has been made to a pattern. We are trying to discover what the pattern is—and how to twist or use it to our (material) advantage.
13. Man is made in God's image. Man is a naked ape.
14. Everything is paid for by somebody somewhere sometime.
15. Nothing can be got for nothing. Everything costs something.
16. Mortals need information before decisions can be made by them.
17. Unless people are formally trained it is unfair to expect them to be good at doing things.
18. Formal education tended to peter out at 20 or 25 years of age. Nowadays training until 60 or 65 is more sensible. Education and work and leisure are needed all the time in some measure.
19. Everything is simple—when you know how.
20. Believe that it is beyond your capabilities—and you are in the best position to prove yourself right.