

ROAD TESTING  
of the

# NIAGARAS

by Richard W. Dawson



Niagara 6019 pauses in Chicago, Ill., with her train on June 25, 1950. Her headlight has been replaced with a Pyle-National twin sealed beam conversion.  
Chas. Felstead - Charles E. Winters Collection.

## MEASUREMENT AND COMPARISON OF LOCOMOTIVE POWER

In discussing two particular locomotives, the question often arises as to which is the more powerful. If the locomotives in question are both diesel - electrics, say an E7 and an F7, the question would seem to be easily answered as the horsepower rating of each locomotive is readily available and the 2000 HP E7 would obviously be more powerful than the 1500 HP F7. With steam locomotives, horsepower ratings are generally not available, but any list of specifications will provide a value for tractive force. Using this criterion, an L2d Mohawk with 73,020 lbs. starting tractive force, including 12,4000 lbs. for the booster, would be considered more powerful than an S1b Niagara with 61,570 lbs. tractive force. But these comparisons, although correct as stated, can be misleading. While the E7 does have a higher horsepower rating, the F7 has a higher starting tractive force-61,550 lbs. vs. 54,475 lbs. at 25% adhesion-and a higher continuous tractive force-40,000 lbs. at 11.5 mph. vs. 18,400 lbs. at 35 mph. Again, while the L2b has a higher starting tractive force than does the S1b, the S1b has the higher maximum indicated horsepower - 6550 at 84 mph. vs. 3800 at 48 mph.

The comparison, then, is not as obvious as it had seemed. Which is the more important measure - horsepower or tractive force? Does one compare the 6000 HP of 3 E7 units with the S1b's 6550 indicated horsepower or the 5050 drawbar horsepower? What does adhesion have to do with tractive force and why is the E7 rated at 54,475 lbs. tractive force under one condition and 18,400 lbs. under another? In an attempt to clarify these and other questions, a discussion follows of the different quantities by which locomotive power is measured and their significance in service.

TRACTIVE FORCE or TRACTIVE EFFORT is force exerted by the locomotive tending to move the locomotive and its train. Tractive force is usually defined as the force exerted by the driving wheels against the rails. The tractive force available from any locomotive is a function of speed and diminishes from a starting value as speed is increased. The value of tractive force given in steam locomotive specifications is an estimate of starting

tractive force and is calculated from the locomotive's dimensions. For two-cylinder simple locomotives, the equation is:

$$TF = \frac{kPC^2S}{D}$$

where, TF = Rated tractive force  
P = Boiler pressure  
C = Cylinder Diameter  
S = Cylinder stroke  
D = Driving wheel diameter  
k = A factor representing the ratio of the mean effective steam pressure in the cylinders to boiler pressure. k is usually set at .85 for engines with conventional cutoff.

**CYLINDER TRACTIVE EFFORT** is tractive force calculated from effective cylinder steam pressure valve derived from indicator card measurements taken during a test. Tractive effort is measured in this manner on road tests since it is virtually impossible to measure tractive effort at the rail. While cylinder tractive force and rail tractive force should ideally be the same, in reality there is frictional resistance in crossheads, crank pins, axle bearings, etc., with the result that actual rail tractive force is always somewhat lower than cylinder tractive force. In many cases, measured tractive force exceeds the rated tractive force because the mean steam pressure in the cylinders is higher than the assumed 85% of boiler pressure.

**DRAWBAR PULL** is the pulling force exerted by the locomotive on the train behind it. With steam locomotives, the pull of the tender on the train is measured rather than the pull of the locomotive on the tender. Drawbar pull is equivalent to tractive force exerted at the rail less the frictional resistance and grade resistance of the locomotive and tender, if used. Thus #6023 during the dynamometer tests developed 66,000 lbs. cylinder tractive force at 10 mph. and overcame 5,500 lbs. locomotive and tender resistance to exert 60,500 lbs. drawbar pull on the train. At 75 mph., 32,300 lbs. cylinder tractive force was developed, 7,900 lbs. of which was required to overcome locomotive and tender resistance, leaving 24,400 lbs. drawbar pull to move the train. If the train is moving at constant speed on level track, the drawbar pull will just balance the total resistance of the train. If the drawbar pull exceeds the resistance of the train, the train will accelerate at a rate of acceleration proportional to the "excess" drawbar pull. If the drawbar pull is less than the train resistance, the train will lose speed.

**POWER** is the time rate of doing work, with work defined as the exertion of force over a particular distance. Power is a derived quantity and cannot be measured directly.

**HORSEPOWER** is a unit of measure for power and is defined as 33,000 pound feet per minute, which is equivalent to 375 pound miles per hour. A locomotive exerting 37,500 lbs. rail tractive force at 20 mph. is therefore producing 2,000 horsepower at the rail.

**DRAWBAR HORSEPOWER**, also called **DYNAMOMETER HORSEPOWER** and abbreviated **DBHP**, is horsepower calculated from drawbar pull and represents the power available to move and accelerate the train. Drawbar horsepower is usually measured by a dynamometer car coupled directly behind the locomotive - behind the tender of a steam locomotive. The dynamometer measures drawbar pull, from which the horsepower can be calculated since the speed is also measured. Drawbar horsepower measured in this manner is directly comparable whether the power is produced by a steam locomotive, diesel-electric

or straight electric locomotive. However, drawbar horsepower measured on a stationary dynamometer, such as the Altoona test plant of the Pennsylvania Railroad, cannot be compared to drawbar horsepower measured in over-the-road tests. In a stationary test plant, the driving wheels turn rollers which can be adjusted to provide any desired degree of resistance and the locomotive drawbar is connected directly to the dynamometer. Since the locomotive does not actually move anywhere, no resistance is developed in the journals of the leading and trailing trucks nor would any be developed by the tender if it were attached. Resistance is generated in the driving wheel journals and in the rods and valve gear, which accounts for the difference between the indicated horsepower and the drawbar horsepower. Drawbar horsepower measured on a stationary test plant will always be higher than what would be measured in a road test of the same locomotive producing the same indicated horsepower at the same speed. Note also that the size of the tender affects the drawbar horsepower output. The power consumed in moving the additional weight of the larger tender is no longer available to move the train.



**INDICATED HORSEPOWER**, also called **CYLINDER HORSEPOWER** and abbreviated **IHP**, is based on an instantaneous measurement of steam pressure and piston travel within each cylinder by a device known as an indicator. From the indicator card, the mean effective pressure (m. e. p.) throughout the piston stroke can be determined. With cylinder and driver dimensions known, the cylinder tractive force can be calculated by  $TF = m. e. p. \times C^2 \times S / D$  and the indicated horsepower from that if the speed is known. Indicated horsepower is determined in the same manner on both road tests and stationary dynamometer tests and the results are therefore directly comparable. The difference between indicated and drawbar horsepower is the power required to move the locomotive itself. An S1b running light at 40 mph. would need about 600 IHP to maintain speed. There would, of course, be no drawbar pull and the drawbar horsepower would be zero. Since the power required to move the engine increases with speed, the maximum drawbar horsepower always occurs at a lower speed than does the maximum indicated horsepower.

**BRAKE HORSEPOWER**, or **ENGINE HORSEPOWER** and abbreviated **BHP**, is a measure of the power output of an internal combustion engine. This is the value by which diesel locomotives are generally rated and it represents the power delivered by the prime mover to the electrical generator. Drawbar horsepower is reduced from the brake horsepower value by efficiency losses in the generator and traction motors and by the power required to propel the locomotive.

**CONTINUOUS HORSEPOWER** is a rating which applies to locomotives using electric traction motors. It represents the horsepower which the locomotive in question can deliver indefinitely at a particular speed without overheating the traction motors. The overheating of the motor windings which occurs when operated at a power level above their continuous rating requires time to build up. Consequently, higher current values can be carried for a limited period of time. Since an electric locomotive has essentially unlimited power available from the central power station it can utilize the short-time power ratings of its traction motors at any speed, unless limited by adhesion. Either rail or drawbar horsepower can be stated in continuous or short-time ratings.



These engines were built with the most advanced technology possible in 1945. To save weight, aluminum was used for fabricating the cabs and running boards. Axles were made of carbon-vanadium steel, and crank pins of Timken high - dynamic steel, while main and side rods were manganese vanadium.

Niagara 6009, Class S-1b brings train No. 63, "The Water Level" into Oscawanna, N. Y. on June 23, 1946, during the peak of NYC Niagara operation.  
Howard W. Ameling Collection

**MAXIMUM CONTINUOUS TRACTIVE FORCE** is the tractive force that can be developed indefinitely without overheating the traction motors. This value is relatively constant with speed. Having essentially a constant-horsepower prime mover, diesel-electric locomotives can utilize short-time ratings when starting and at speeds up to a particular value, called the **MINIMUM CONTINUOUS SPEED**. At this speed and above, the tractive force produced by the full horsepower output of the prime mover is at or below the maximum continuous tractive force. Above this speed, there is no short-time rating available; below it, the locomotive can either sustain the maximum continuous tractive force indefinitely or sustain a higher tractive force for a limited time. Maximum continuous tractive force and minimum continuous speed are both affected by the traction motor gear ratio as well as its electrical characteristics.

**ADHESION** is the ratio of tractive force to weight on drivers and is usually expressed in per cent. The tractive force that can actually be utilized is limited to a value which will not cause the wheels to slip. Road tests over a period of time have indicated that usable tractive force is limited to about 35% adhesion at starting on dry rail and to 25% on sanded wet rail. Limiting values of adhesion decrease with higher train speed. Wheels begin to slip at

16% adhesion on wet sanded rail at 20 mph. and at 10% adhesion at 70 mph. In many cases, particularly at starting, usable tractive force is limited by adhesion rather than available horsepower or motor overheating.

Having discussed these quantities individually, it may be desirable to consider their interrelation and their significance in evaluating motive power.

A locomotive with a high starting tractive force will be able to start a heavier train than a locomotive with a lower rating. This does not mean, however, that the first locomotive will be able to move the train at any appreciable speed. As speed increases, the available tractive force is more likely to be limited by horsepower and for higher speeds, horsepower is usually the more valid basis of comparison.

Consider three locomotives—an L2d Mohawk, an S1b Niagara and a 2-unit F7 diesel locomotive. These are to be compared under three different operating conditions: drag freight up a 1.5% grade at 7 mph., medium speed freight up a 0.5% grade at 25 mph. and fast freight at 50 mph. on level track. It will be recalled that the L2d is rated at 73,020 lbs. tractive force and 3800 IHP, the S1b at 61,570 lbs. tractive force and 6550 IHP and two F7's at 123,100

lbs. starting tractive force and 3000 BHP. The three locomotives will be compared on the basis of the number of freight cars weighing 80 tons gross that each can move at the speed and grade conditions specified. At 7 mph. up the 1.5% grade, the L2d would produce about 59,000 lbs. drawbar pull, which will maintain 22 cars at 7 mph. The S1b would develop about 46,900 lbs. drawbar pull - enough for 18 cars - and the two F7's with 115,000 lbs. drawbar pull using full engine power could move 43 cars at 7 mph. But, unless the grade is very short, the F7's would soon overheat their traction motors. Since they would be operating below their minimum continuous speed of 11.5 mph., they must not exceed their continuous tractive effort of 72,000 lbs. of which would be passed on to the train as drawbar pull. At the continuous rating, they would still be able to move 27 cars, rather more than the larger L2d and S1b. At 25 mph. on the 0.5% grade, the L2d would produce 40,500 lbs. drawbar pull after the booster is disengaged - enough to move 36 cars. The S1b with 47,000 drawbar pull would move 41 cars and the F7's, now above their maximum continuous speed, would pull 29 cars with 33,000 lbs. drawbar pull. While the L2d would not pull quite as many cars as the Niagara under this condition, it is a smaller engine and might be considered more effective on that basis. Moving 50 mph. on level track, the lower horsepower rating of the F7's is now apparent; they would move 33 cars with 17,000 lbs. drawbar pull. The L2d with 22,500 lbs. would now haul 44 cars, but the S1b has shown its superiority at high speeds. It would move 72 cars with its 37,000 lbs. drawbar pull. A different locomotive could thus be considered superior in each of the three situations.

One last factor that should be considered is acceleration. As mentioned earlier under DRAWBAR PULL, a train will accelerate only if the drawbar pull exceeds that necessary to balance the train's resistance at the speed it is running. In the examples given in the previous paragraph, the locomotives could move the train sizes indicated at the particular speeds, but the time required to reach that speed would be excessive. If the S1b's 37,000 lbs. drawbar pull just balances the resistance of the 72 cars at 50 mph., the drawbar pull at 45 mph. would not be much higher than 37,000 lbs. nor the resistance of the cars much less than 37,000 lbs. The additional drawbar pull available for acceleration would only permit the train to accelerate at a very gradual rate. This undesirable condition would occur not only when starting from rest, but also when accelerating after a slowdown due to a restricting signal, negotiation of a crossover, or whatever. It should be remembered that reduction in the number and severity of slowdowns and the rapid regaining of running speed after them are more important in reducing overall running time than increasing maximum speed. In actual practice, then, each locomotive would be assigned trains smaller than those indicated so as to permit acceleration to operating speed within a reasonable time. Acceleration to operating speed and recovery of speed after a slowdown are where the short-time ratings of diesel-electric and straight electric locomotives are of great benefit. The fact that the electric locomotive has additional horsepower available throughout the entire speed range is particularly valuable in passenger service. A hypothetical steam equivalent might be a locomotive having the weight and continuous horsepower of a J3a Hudson but the power of an S1b available for acceleration.

Hasty comparisons of power ratings, then, can be misleading particularly between different types of power. As a rough approximation, starting tractive force (steam locomotives) or continuous tractive force (diesel - and straight electric) are the most important considerations for low-speed service. While drawbar pull is what actually pulls the train, it varies with grade conditions and is

generally not published for diesel - or straight electric locomotives. Horsepower is the most significant indicator of high-speed performance, but the horsepower values compared must be equivalent. The best predictor of performance would be drawbar horsepower values over the speed range of interest. A diesel's DBHP vs. speed curve will typically rise from zero to a maximum value at a speed beyond the adhesion and continuous rating limits. Beyond this speed, DBHP will decline slowly due to increasing resistance of the locomotive. A steam locomotive's DBHP curve tends to rise and fall more rapidly with its peak value at a higher speed than the peak of a comparable diesel. DBHP values, however, are often not available. The engine, or brake, horsepower of a diesel locomotive is somewhat equivalent to the indicated horsepower of a steam locomotive at the same speed. It should be kept in mind, however, that while the BHP of the diesel is essentially constant with speed above the minimum continuous speed, the IHP of the steam locomotive falls off at speeds above or below the speed of the peak IHP.

In summary, the locomotive must be evaluated in the context of the duties they are to perform. The F7 is more powerful than the E7 at 15 mph., but the E7 is more powerful at 60 mph. The L2d is more powerful than the S1b at 7 mph., but not at 30. With the many factors that must be weighed, there is usually no simple answer. This makes the choice more difficult for the Motive Power Department of a railroad, but it certainly makes our armchair retrospective evaluations more interesting.



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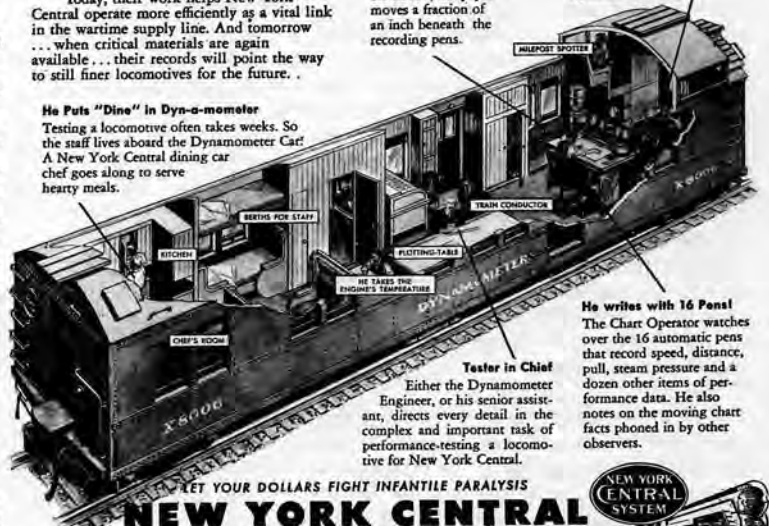


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Wartime (1944) N. Y. C. advertisement featuring dynamometer car X-8006



Niagara 6023 pauses after the August 1946 test in which she pulled 22 Pullmans. The crew seems to be taking a well earned rest atop her cab and giant PT-5 tender. Arnold Haas - NYC - Charles E. Winters Collection

#### ROAD TESTING OF THE NIAGARAS

When railroads acquire a new class of locomotive today, they are generally buying a product that has been proven through test stand evaluation and testing by the builder and, if an existing model, actual service on other railroads. Except when a proven design was being reordered, however, this was not the case in the days of steam.

While the engine and electrical components of a diesel locomotive can be developed and bench tested individually prior to combination into a complete locomotive, it is difficult to separate a steam locomotive into discrete components for individual testing. Each of the major portions of the locomotive - firebox, boiler, engine and front end - affects the performance of the others and is affected by them. Testing of the separate elements individually not only creates an artificial situation, but is difficult to accomplish. Considering that steam locomotives were almost invariably custom designed by or for individual railroads, and were consequently built in small quantities, extensive testing prior to the production of new locomotives was rare.

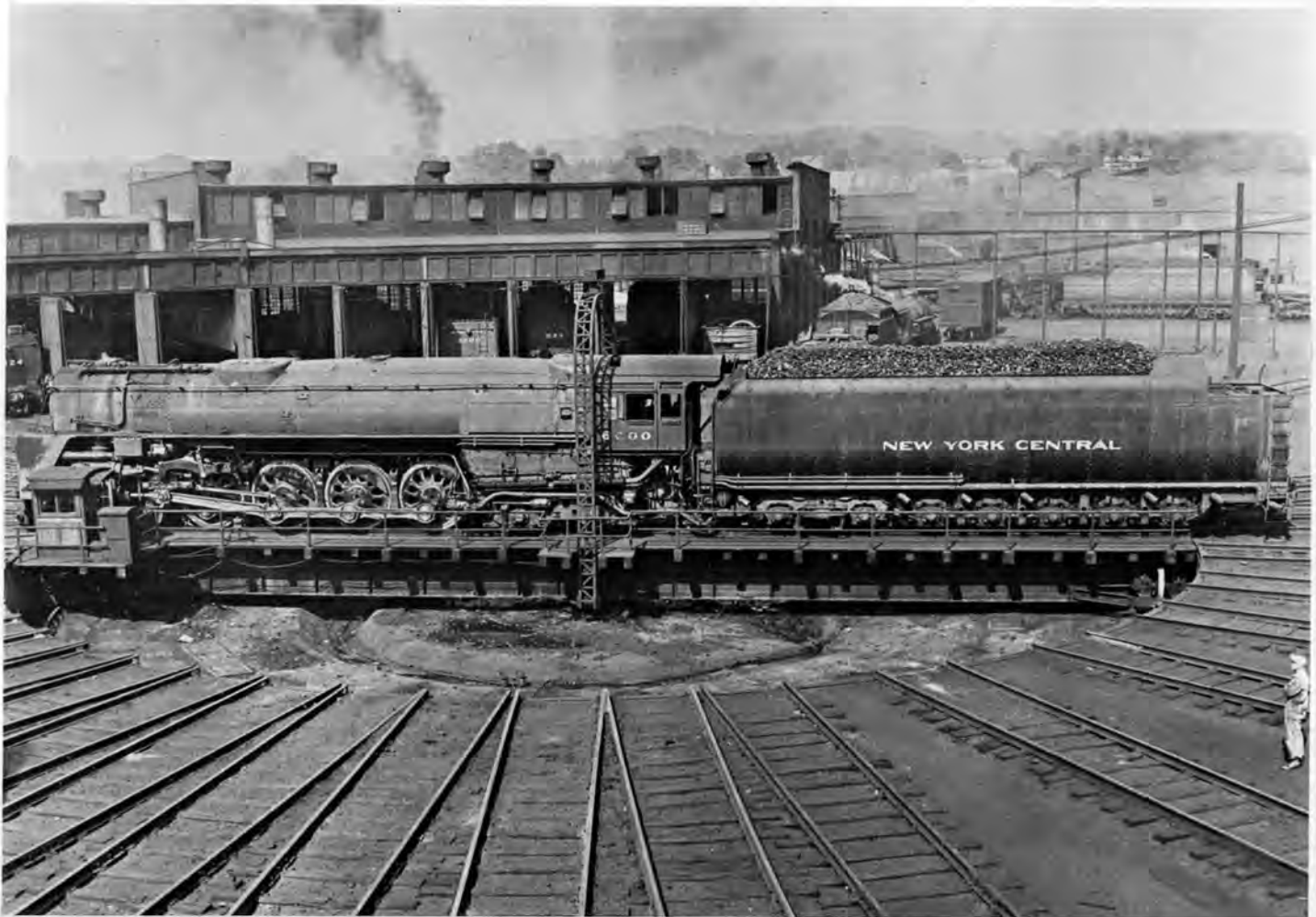
Locomotives were designed to produce desired levels of power output and coal and water efficiency at the speed range of interest by means of modifying known designs and by attempting to maintain desirable design proportions and

ratios, all the while staying within established weight and size limitations. When, actually built, the locomotives may exhibit the characteristics anticipated, they may prove disappointing or they may exceed expectations and prove unusually successful. Occasionally, locomotive designs would come along that seemed to achieve that elusive perfect balance between all its elements and would be used with minor modifications over a long period of time. The USRA 0-8-0 and light 2-8-2 come to mind as examples of balanced, long-lived designs. Yet the light 2-10-2 designed by the same USRA committee at about the same time proved disappointing. Since the actual performance of a new locomotive design could be predicted only approximately, most major railroads utilized a dynamometer car to run extensive tests soon after delivery of a representative engine so as to determine to what extent the design objectives had actually been achieved. New York Central System dynamometer car X-8006 was operated by the Test Department and saw extensive use during the development of the Central's fleet of modern power. The Niagaras, while not the last steam power, certainly represented the culmination of steam locomotive development on the System and the dynamometer runs with X-8006 behind S1b 6023 and S2a 5500 in the summers of 1946 and 1947 were clearly the high point of locomotive road testing on the New York Central. As we shall see, the Niagaras proved

to be among those locomotives whose actual performance surpassed the original design objectives. If the proof of the pudding is in the eating, the proof of a locomotive is in the running - and the S engines ran very well indeed.

The New York Central was the first railroad to utilize a four wheel trailing truck, both in freight and in passenger service (not counting the single 2-10-2 modified to 2-10-4 configuration acquired by the Santa Fe in 1919), yet it was among the last few roads to acquire the 4-8-4, a wheel arrangement that would seem ideally suited to a railroad with heavy, fast passenger trains and a considerable volume of fast freight. During the late 1920's and early 1930's, a substantial fleet of J1 Hudsons and L2 Mohawks was acquired for the heavy passenger and fast freight operations. These locomotives were performing admirably

when the reduced traffic levels of the Depression made further motive power acquisitions unnecessary for several years. The 50 J3a's of 1937 and 1938 were fully capable of handling the heaviest trains of the Fleet at the time, and so the first occasion when the Central might have been expected to seriously consider the use of 4-8-4's was the 1939-1942 period when the need arose for more fast freight power and for dual purpose power. As we know, however, L2d's 2995 and 2998 were experimentally modified for higher speeds and were sufficiently impressive when tested that 115 L3 and L4 Mohawks were acquired instead of 4-8-4's. It is the writer's opinion that a 4-8-4 with perhaps 75" drivers might have been even more effective, but it cannot be denied that the L3's and L4's performed admirably with troop trains and heavy passenger trains, to say nothing of the heavy volume of wartime freight traffic.



The original Niagara, No. 6000, Class S-1a takes a ride on the turntable at the Harmon, N. Y. roundhouse. The top half of her smoke deflectors have been temporarily removed following damage caused by a grade crossing accident. Note how the huge PT-5 tender was designed to fit on a 100' turntable. Total wheelbase of engine and tender was 97' - 2 1/2", leaving an overhang past the turntable bridge.



As freight and passenger traffic continued to expand during the war, however, the need for additional power was again experienced and it was felt that a 4-8-4 would best combine the speed of the 79" drivered J3's with the pulling power and dual service capabilities of the L4's. As the staff under Paul W. Kiefer, Chief Engineer Motive Power & Rolling Stock, started to work out the basic design of the locomotive, they were confronted with a formidable obstacle. The New York Central System, especially the eastern

portions such as the Hudson Division, had then and still has today very tight clearance restrictions, particularly with respect to height. Whereas many western and some eastern railroads were able to build their locomotives over 16'-0" in height, few New York Central Locomotives were as high as 15'-0". The J1's at 15'-1 1/8" were the highest locomotives on the System. A major requirement for the new 4-8-4's, as with any high horsepower locomotive, was ample steaming capacity at high speed which in

turn required a large boiler. The four-wheel trailing truck would permit an ample firebox, but significant increases in tube and flue heating surface as well as superheating surface were necessary if the heat generated by the larger firebox was to be effectively utilized for steam generations. Since the boiler could be lengthened from that of the Mohawks by only a limited amount, a larger diameter was necessary. Since the locomotive was being designed to accept either 75" or 79" driving wheels, only 8' - 6 3/4" or 102 3/4" was left between the 1" flanges of the 79" drivers and the 15' - 2 3/4" clearance limit that was established. Into this space, and what little could be picked up by letting the boiler curve slightly lower between the drivers, had to be packed a larger boiler - preferably 100" in diameter at the widest point -, spring rigging, allowance for vertical axle movement, boiler lagging and jacketing and steam dome. In the event, the steam dome

problem was circumvented by eliminating the dome altogether. Steam was collected instead by a series of perforations in the top surface of the dry pipe. Since the boiler tapers somewhat, it was just possible to squeeze in a very shallow sand box, turret enclosure and feedwater heater mixing chamber together with a short, stubby stack and still obtain a 100" maximum boiler diameter. The smooth, sleek profile of the Niagara was not chosen for the sake of appearance; there was simply no other way to pack so much locomotive into the restricted space available.

Compared to the outlines of other 4-8-4's, the New York Central limits for length and width and for weights were also generally more restrictive, although not as severely as was the case with height. Table 1 provides a comparison of the dimensions of the S1b Niagara with some of its notable contemporaries.

Table 1

<u>Locomotive</u>	<u>Extreme Height</u>	<u>Extreme Width</u>	<u>Total Wheelbase</u>	<u>Max. Axle Loading</u>	<u>Total Weight</u>
NYC S1b	15' - 2 3/4"	10' - 5"	97' - 2 1/2"	68,750 lbs.	471,000 lbs.
ATSF 3776	16 - 0 (1)	10 - 8	107 - 9	70,475	494,630
NP A-4	16 - 4 (1)	11 - 5 3/4	97 - 6	73,500	502,500
N&W J	16 - 0	10 - 9	95 - 4 3/4	72,000	494,000
SP GS-4	16 - 4	10 - 10	97 - 3	68,925	475,000
UP 835	16 - 2	11 - 2 1/8	98 - 5	66,623	486,340

(1) Dimension shown is based on stack extension in retracted position.



The so-called smoke lifters or deflectors were not designed to "lift smoke". They were used to neutralize the vacuum effects ahead of the locomotive cab that occurred at speed, thus insuring better visibility for the engine crew

Mighty Niagara 6010 accelerates 13 cars out of Chicago, Ill, in June 1946. The ability to make fast time over the road was appreciated by engine crews and management alike.

Harold K. Vollrath Collection



When the Central's Committee on Diesel vs. Steam Road Service Locomotives, chaired by Paul W. Kiefer, presented its report to the Research Council on July 30, 1943, the preliminary design of the proposed S1 4-8-4 had progressed far enough for estimated weights and power characteristics to be incorporated into the report for comparison with existing steam and proposed diesel and electric locomotives. At that time, it was anticipated that the S1's would have the following characteristics:

Weight on Drivers	270,000 lbs.
Total Weight	465,000 lbs.
Max. Indicated Horsepower	6000 IHP
Max. Drawbar Horsepower	4580 DBHP
Speed at which Max. DBHP is attained	62 mph.

As an indication of progress in locomotive development up to that time, the proposed S1 may be compared to previous New York Central locomotives in Table 2.

Table 2

Class	Type	First Built	Weight	Maximum Power and Speed at Which Attained	
				Indicated HP	Drawbar HP
K80	4-6-2	1904	252,500	1700 - 39	1430 - 34
K2a	4-6-2	1907	273,000	2000 - 45	1615 - 39
K3q	4-6-2	1923	295,500	2100 - 45	1720 - 39
K5b	4-6-2	1926	302,000	3200 - 54	2530 - 44
J1a	4-6-4	1927	343,000	4070 - 66	3300 - 58
J1e	4-6-4	1931	358,600	3950 - 66	3240 - 58
J3a	4-6-4	1937	360,000	4725 - 77	3770 - 60
L2d	4-8-2	1929	363,400	3800 - 48	3330 - 39
L2d Conv.	4-8-2	1939	385,100	4200 - 50	3640 - 43
L3a	4-8-2	1940	388,500	5260 - 72	4120 - 58
L4a	4-8-2	1942	397,300	5400 - 76	4290 - 62
S1 Prop.	4-8-4	-	465,000	6000 - ?	4580 - 62
S1b	4-8-4	1945	471,000	6550 - 84	5050 - 62



The first of the fleet, Niagara 6000 class S-1a is shown here rolling a milk train near Cold Spring, N. Y. in April, 1945, only a month after she was built at Alco's Schenectady Works. Note that 6000 is still equipped with the 75" drivers which gave her a slightly "top heavy" look that was remedied later when 79" drivers were applied.

Arnold Haas - Charles E. Winters Collection

When approval was received to proceed with construction, one prototype locomotive was ordered from American Locomotive Company and the basic design developed by Kiefer's staff was executed in detail by the Alco engineering department. The first Niagara - after all, the Water Level Route couldn't just call them "Northerns" - was delivered during March of 1945 as Number 6000 (6000 IHP), Class S1a. It was equipped with 25" diameter by 32"

stroke cylinders. A boiler set at 275 psi. but designed for 290 psi. and 75" drivers, although the frame was designed to accept 79" wheels as well. It is not known to the writer whether it was originally intended to run comparative tests with both driver sizes on the 6000 so as to choose the optimum size for the production engines. In any event, the 25 S1b locomotives, 6001-6025, were delivered between October, 1945 and January, 1946 without the tests



having been run. The S1b's came, not with 75" drivers, but with the Central's traditional driving wheel diameter for high speed passenger service ever since the K2-79". The cylinders were increased to 25 1/2" diameter so as to maintain approximately the same tractive force. Piston stroke and steam pressure remained unchanged at 32" and 275 psi., respectively. Since the locomotives are so well known, only a brief description of their features will be given. In addition to the high capacity boiler mentioned previously, the S1's were equipped with roller bearings on all axles, lateral motion driving axle boxes, aluminum cab body and running boards for weight reduction, smoke lifters to prevent impairment of the crew's vision by drifting smoke, light weight roller bearing - equipped main and side rods and Class PT-5 pedestal tenders. The PT tanks, in addition to improving the tender weight to capacity ratio and lowering the center of gravity, also permitted the carriage of sufficient coal to run from Collinwood to Harmon

or Chicago while keeping the total wheelbase short enough to fit onto 100 ft. turntables. The water scooping apparatus had also been modified to greatly improve venting and overflow characteristics so that water could be picked up from track pans at 80 mph. Finally, test applications of the Franklin oscillating - cam type of poppet valve gear on other railroads, particularly to Pennsylvania Railroad K4s Pacific no. 5399, had seemed sufficiently promising that one Niagara was ordered with this type of valve gear. S2a no. 5500 was delivered in June, 1946, with the same boiler and front end, the same cylinders and running gear; differing only in the valve gear used. June, 1946 was also the month when road tests began on S1b no. 6023. These tests continued through the summer and into November of 1946. Comparable tests were run with the 5500 during June through November of 1947 so as to determine the improvement actually provided by the poppet valves. As tested, the two locomotives had the following dimensions:

Locomotive Number	6023	5500
Class	S1b	S2a
Date Built	January, 1946	June, 1946
Cylinder Diameter	25 1/2"	25 1/2"
Piston Stroke	32"	32"
Driving Wheel Diameter	79"	79"
Steam Pressure	275 psi.	275 psi.
Rated Tractive Force	61, 570 lbs.	61, 570 lbs.
Engine Weight, Total	471,000 lbs.	485,000 lbs.
" " , on Drivers	275,000 lbs.	275,000 lbs.
" " , Engine Truck	91,400 lbs.	102,000 lbs.
" " , Trailing Truck	104,600 lbs.	108,000 lbs.
Tender Weight, Loaded	420,000 lbs.	407,400 lbs.
" " , Empty	178,000 lbs.	179,400 lbs.
Tender Capacity, Water	18,000 gals.	16,000 gals.
" " , Coal	46 tons	47 tons
Overall Length, Engine & Tender	115' - 5 9/16"	115' - 5 9/16"
" " , Engine alone	63' - 5 7/8"	63' - 5 7/8"
Total Wheelbase, Engine & Tender	97' - 2 1/2"	97' - 2 1/2"
" " , Engine alone	48' - 5"	48' - 5"
Rigid Wheelbase of Engine	20' - 6"	20' - 6"
Grate Area	101 sq. ft.	101 sq. ft.
Firebox Volume	560 cu. ft.	560 cu. ft.
Combustion Chamber Volume	196 cu. ft.	196 cu. ft.
Combustion Chamber Length	81 1/4"	81 1/4"
No. & Diameter of Flues	177 @ 4"	177 @ 4"
No. & Diameter of Tubes	55 @ 2 1/4"	55 @ 2 1/4"
Length over Tube Sheets	19' - 11 1/4"	19' - 11 1/4"
Type Superheater	"E"	"E"
Heating Surface, Firebox (fireside)	503 sq. ft.	503 sq. ft.
" " , Tubes & Flues (waterside)	4320 sq. ft.	4320 sq. ft.
" " , Total	4823 sq. ft.	4823 sq. ft.
" " , Superheater (fireside)	2605 sq. ft.	2605 sq. ft.
Valve Gear	Baker	Franklin - Oscillating Cam
Valve Type	Piston	Poppet
Valve Diameter	14"	3 Exhaust @ 6" 2 Intake @ 6 1/2"

The 6023 began its dynamometer test program in June, 1946 under the jurisdiction of the Office - Engineer of Tests at West Albany, New York. The Engineer of Tests, Walter Collins, and the Ass't. Engineer of Tests, Malcom Riegel, were responsible for road testing of locomotives, both trial runs of new classes and evaluation of proposed modifications, the stationary test plant at Selkirk where locomotive boilers and front ends were tested independently of the engine portion and a variety of other duties as well. The Selkirk test plant was one of the few installations in this country where smokebox drafting arrangements and other boiler appurtenances could be tested under controlled conditions. While the stationary test plant was very valuable for a variety of boiler testing, it was considered preferable when a complete locomotive was to be tested to run actual road tests because of the greater

fidelity to actual service conditions. The actual road tests were supervised by the Dynamometer Engineer, Ted Fredriks, and the Ass't Dynamometer Engineer, Ken Relyea.

During a road test, dynamometer car X-8006 would be coupled immediately behind the tender and a train of the desired weight coupled behind the dynamometer car. When testing for power output, the dynamometer car crew would record drawbar pull, speed, acceleration and other data while other men on board the locomotive, some in the cab and others in temporary shelters erected on the pilot beam and the left running board, recorded steam pressures and temperatures, kept track of coal and water consumption and took indicator readings while the locomotive was operating at the desired conditions. In addition to

Overleaf - Niagara 6008 has train No. 3 well in hand at Farnham, N. Y. in October, 1950.  
Photo by H. L. Vail, Jr.





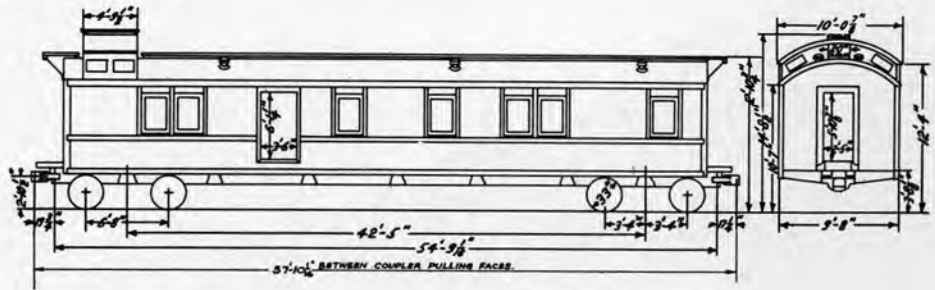
testing for power capacity and for ability to accelerate trains of given size, road tests also served to determine the most efficient cutoff settings for the valve gear.

Dynamometer car X-8006 was built specifically for the purpose at West Albany Shop in 1923 as NYC Lot 943 and was equipped with dynamometer equipment manufactured by the Burr Company. A dynamometer is nothing more than a means of measuring force accurately. The coupler at the leading end of the car, instead of being attached through a conventional yoke arrangement to a friction draft gear, was connected by means of special vertical and horizontal yokes to a large vertical lever. The upper end of the lever was located between two large diameter cylinders directly in front of and behind it and the lever was directly connected to the pistons. Depending on whether the coupler was being pulled out or pushed in, the pistons were moved forward or back by the lever. The pistons in turn built up hydraulic pressure within a liquid mixture which actuated movable pens on the recording table. Underneath the pens a 24" wide roll of paper moved continuously at a speed proportional to the speed of the train. Movement of the paper was controlled by a gear drive connected to one of the axles. The wheels on that axle, inci-

dentally, were without brake shoes so as to reduce wheel tread wear and the resulting variation in chart speed. Recording pens driven by the hydraulic pressure traced drawbar pull, either draft or buff as the case may be, onto the moving paper along with a number of other variables. The dynamometer apparatus was designed to measure up to 1,250,000 lbs. impact in buff without damage. In addition to drawbar pull, the recording machinery automatically recorded onto the paper train speed, air brake train line pressure, locomotive brake cylinder pressure due to independent brake applications and train brake cylinder pressure due to automatic brake applications. During the 1946 tests, Bill Lawson was the recording table operator. An observer in the raised cupola of the X-8006 pressed an electrical switch whenever a milepost was passed. The switch actuated a recording pen to show a notch or spike on the chart. A man at the recording table, Bob McAndrews during the 1946 tests, would write the milepost number onto the chart as well as station names. Other recording devices in the car kept track of stoker engine revolutions, feedwater temperatures at several points between tender and boiler check valve, firebox temperatures at several locations and smokebox temperatures at a number of locations.



**X-8006**



OFFICIAL DIAGRAM FOR N. Y. C. STEEL DYNAMOMETER CAR NO. X-8006



The Burr Company  
Chicago, Ill.      Chicago, Ill.

N. Y. C. Dynamometer car No. X-8006 was built in 1923 by N. Y. C.'s West Albany Shop under Lot No. 943 and was equipped with dynamometer equipment manufactured by the Burr Company. Note carbony mounted spotlight mounted near truck side-frame.

H. L. Broadbelt Collection



Interior of the X-8006 showing members of the test crew at the recording table. Man seated in cupola has push button to activate milepost indicator on chart.



Running board enclosure and instruments. Note locking link which holds valve gear at predetermined cutoff setting for entire run. Linkage driving indicator and steam line to indicator from crank end of cylinder are also visible.



Operator prepares left side indicator for testing. Note string which rotates card mounted on cylinder back and forth.



Extra firemen shovel coal into calibrated bucket as member of test crew prepares to dump coal into stoker trough when scale indicates proper weight has been loaded.

While the information was being recorded in the dynamometer car, other members of the test crew would be taking readings on board the locomotive. The test crew included not only members of the Test Department, but also Special Apprentices from West Albany Shop and "warm bodies" provided by supply companies such as Locomotive Superheater Co., Worthington, Standard Stoker and Franklin Railway Supply. In the cab of the locomotive, one man sat in the brakeman's seat and recorded steam pressure, throttle and reverser position, stoker settings, etc. For performance tests, two extra firemen shoveled coal into a 200 lb. bucket on a scale which would be tripped to drop into the stoker trough by a member of the test crew when the bucket reached the proper weight. Water consumption was controlled by watching feedwater heater operation and checked by calibrating the tender with gage glasses at each corner and taking gage readings at the start and whenever water was taken on. As shown in the illustrations, an enclosure was built up on the pilot beam to house additional men. One man in the center had an aspirator and a carboy - a large glass jug - with which samples of smokebox gasses would periodically be taken. The gas samples would later be analyzed with Orsat apparatus for chemical composition to indicate completeness of com-

bustion. For capacity and acceleration, one man would be located on either side just forward of the steam chest to take indicator readings. Briefly, the indicator is a device which plots instantaneous steam pressure in the cylinder against piston stroke. The resulting indicator diagram is used to determine indicated horsepower (IHP) and cylinder tractive force. Two of the Special Apprentices, Harold Crouch on the right side and John Sheehan on the left, took the indicator cards during the 1946 tests. A valve would admit steam from either the head end or the crank end of the cylinder when a reading was desired. Indicator plots from both ends of the cylinder were traced onto a single card. The readings were taken every five minutes, the operators being signalled by a light exactly when to take their readings. During pull - speed tests when indicator cards were taken every two minutes, two men were needed at each position. The final man on the locomotive worked in an enclosure built on the left hand running board just behind the sand box. He took calorimeter measurements for quality of the steam moisture content just prior to entry into the dry pipe. He also observed steam pressure and temperature in the dry pipe and recorded the duration each time the safety valves released or the boiler was blown down.



N. Y. C. 6023 with test train including a 4-8-2 Mohawk coupled on behind Dynamometer car X-8006. Note test crew in position behind special enclosures on pilot deck and running board and absence of smoke deflectors.  
 Arnold Haas - NYC Charles E. Winters Collection

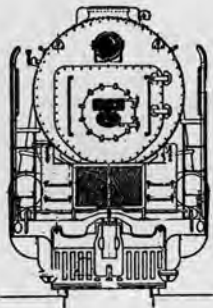
The main types of tests run were capacity, acceleration and pull - speed tests. All were run on the Mohawk Division between Rensselaer and Syracuse or a portion thereof. The Mohawk Division was chosen because of the variety of grade conditions available which were considered representative of the rest of the System. Proximity to West Albany Shop and to headquarters in New York were also useful. Capacity tests were primarily concerned with determining the maximum power output available and measuring the economy of the locomotive in terms of boiler efficiency in the generation of steam and efficiency of the cylinders in use of the steam. With an 80 mph. speed limit that was generally adhered to and a relatively flat profile, it was difficult to utilize the full power of locomotives of such high capacity when using "small" trains of only 14 to 22 cars. The capacity tests were run from Rensselaer coach yard to Tower 48 in Syracuse. Acceleration tests were run to determine the time and distance required to accelerate given train sizes up to a desired speed with the locomotive operated at full capacity throughout the run. All tests were started from the same point just east of Utica and run over track No. 2 towards Herkimer. This track is essentially flat with the maximum grade of 0.25% extending for less than 1.5 miles. At least two tests were run with each train weight to confirm the results. Pull - speed tests were run to determine the proper settings for the valve pilot. The Locomotive Valve Pilot was a combination speed recorder, back pressure gage and cutoff gage. After the optimum cutoff setting for

each speed has been determined by test for a particular type of locomotive, a cam and linkage would result in the equivalent speed being shown by a needle on the dial of the speed recorder for each valve gear cutoff setting. As the speed of the locomotive changed, the engineman would adjust his reverser to keep the speed needle and cutoff needle superimposed on the dial, thereby obtaining the most efficient cutoff for each speed. To obtain the data needed to establish the proper cam contour, a series of test runs would be made. throughout each run, the valve gear would be fixed at a particular cutoff setting by a locking link. This link can be seen in the illustration of the instrumentation on the left side of the engine. The power output and cylinder efficiency throughout the speed range would be obtained for each cutoff setting. When the curves for all the cutoff settings were superimposed onto one graph as in Figure 3, the most efficient setting for each speed could be chosen. When running pull-speed tests, the test train would start west from Rensselaer and make a series of short runs, changing the valve gear cutoff between runs, and would finally get into Syracuse, most likely late in the day. Since it would be difficult to accelerate the train at low speeds when running with short cutoffs, a second locomotive was coupled behind the dynamometer car to help accelerate the train up to speed. Because it was behind the dynamometer car, the second engine did not influence the drawbar pull readings of the test locomotive and, in effect, neutralized part of the train's rolling resistance.

All the tests were run on the 6023 during 1946 as Dynamometer Test No. 46-53 and on the 5500 during 1947 as Dynamometer Test No. 47-53. After a full series of tests had been run with the 6023 as built, the 79" drivers were removed and the 75" drivers from the 6000 were installed in their place. The cylinders were not bushed down from 25 1/2" to the 25" diameter of the 6000 so the rated tractive force increased from 61,570 lbs. to 64,850 lbs. A series of capacity tests were run to obtain a comparison of power output at higher speeds when equipped with 75" drivers versus 79". The power output at lower speeds would of course be greater with 75" drivers since no other dimensions were modified. The test report covering Tests 46-53 and 47-53 dated July 3, 1948 makes no

mention of efficiency or acceleration tests having been run with 75" drivers. In addition to the road tests run with the 6023 and 5500, S1a no. 6000 underwent a series of stationary boiler performance tests as the Selkirk test plant starting in 1945.

The actual results of the tests are notable, not only for the very high power outputs attained, but also for the high speeds at which the maximum power levels occurred and the high level of efficiency. The curves for indicated and drawbar horsepower and for drawbar pull and cylinder tractive force are shown for the 6023 with 79" and 75" drivers and the 5500 in Figures 1 and 2. The maximum horsepower outputs are tabulated below.



Locomotive	Driver Diameter	Maximum Power and Speed at which Attained.	
		Indicated HP	Drawbar HP
6023	75"	6600 @ 78	5100 @ 58
6023	79"	6550 @ 84	5050 @ 62
5500	79"	6620 @ 90	5000 @ 65

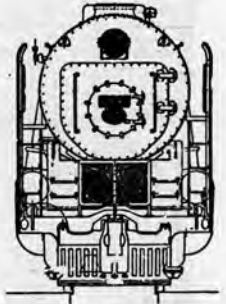


FIGURE NO. 1

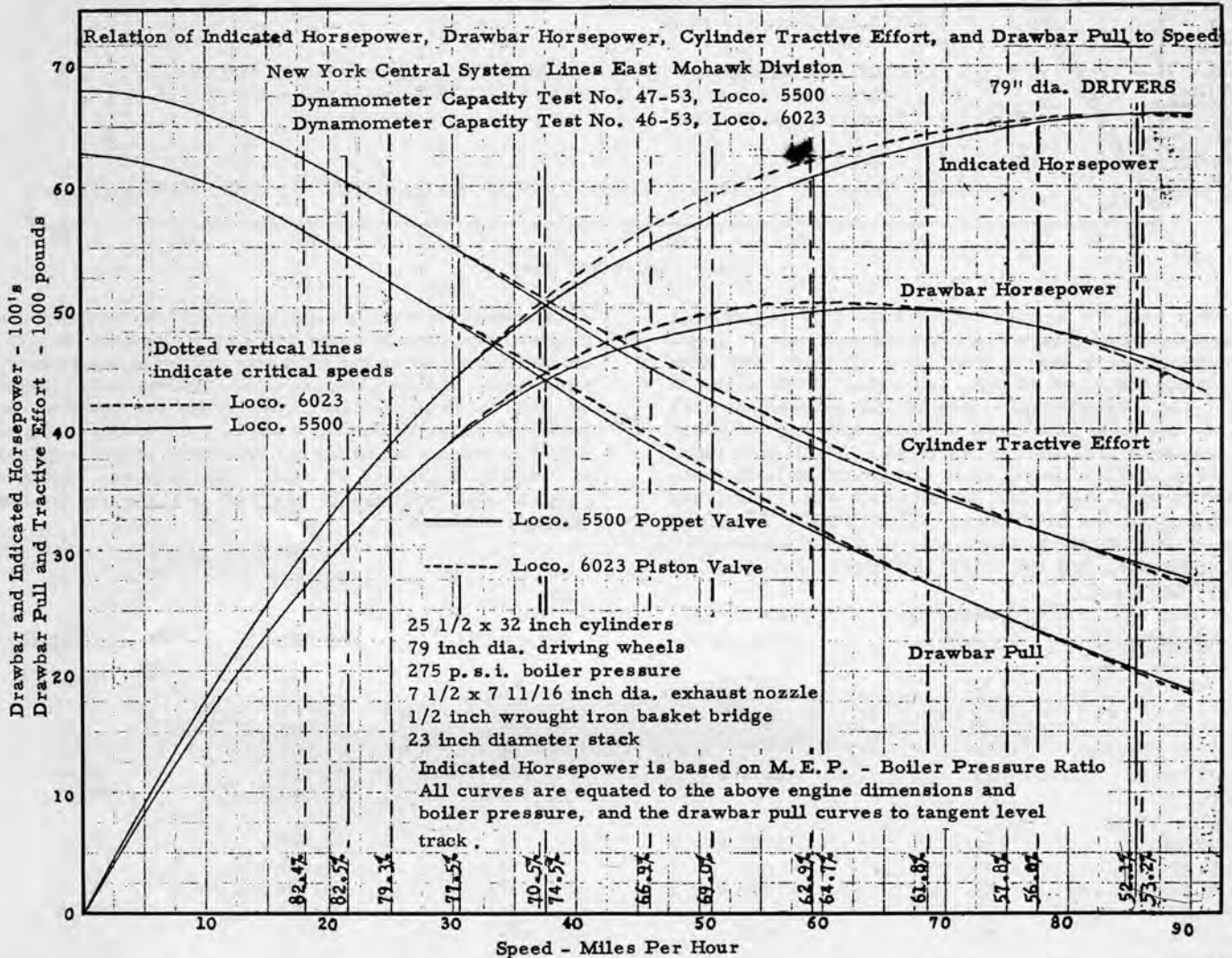
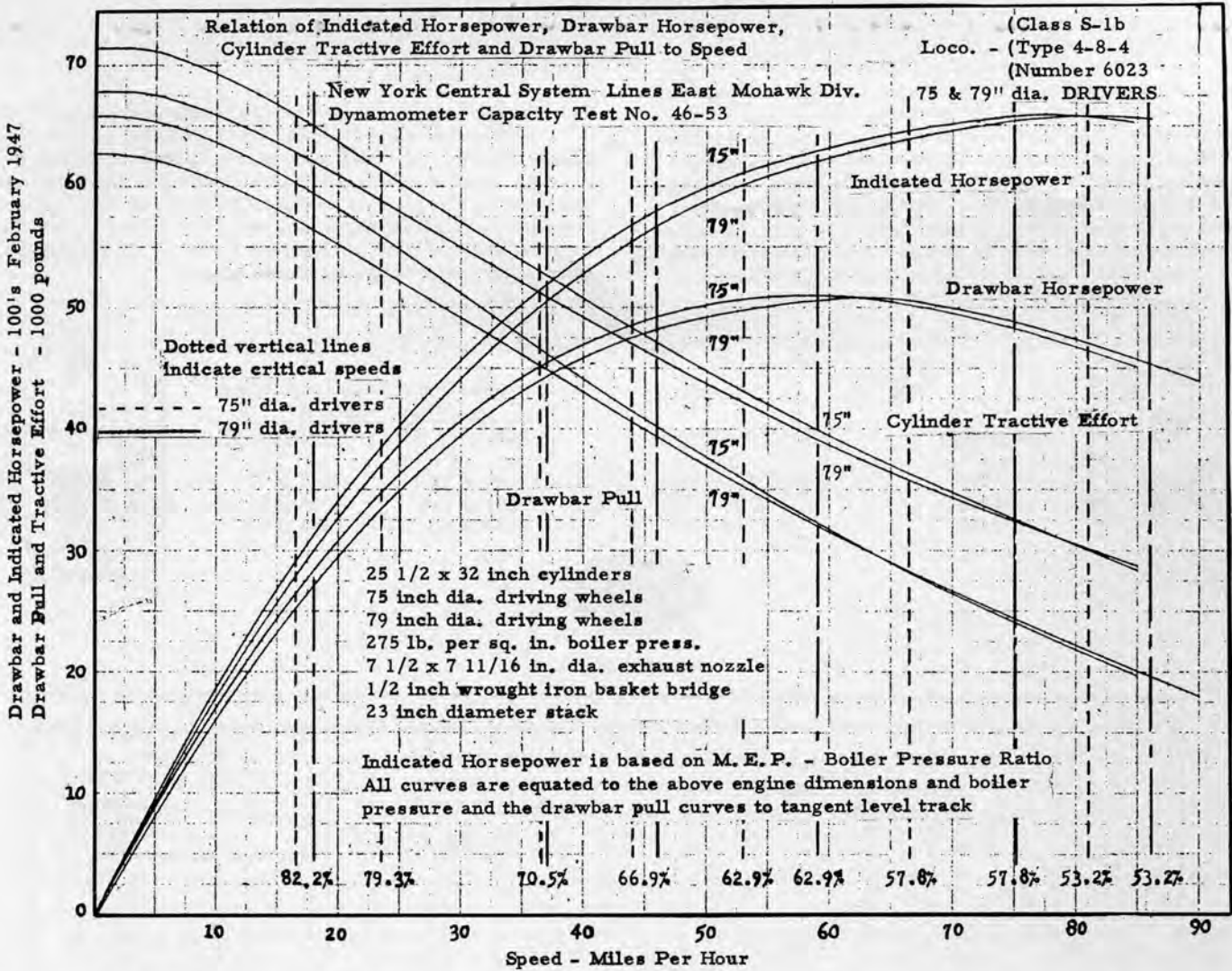


FIGURE NO. 2



The 6023 with 79" drivers exceeded the 5500 in indicated horsepower at all speeds from 32 to 82 mph, and in drawbar horsepower at speeds from 30 to 70 mph. The 5500 had higher IHP above 83 mph, and higher DBHP above 75 mph. The maximum difference in IHP between the 6023 and the 5500 was 180 HP at 52 mph, favoring the 6023. The maximum difference in DBHP was 100 HP at 47 mph. The 6023 with 75" drivers had higher IHP up to 81 mph, DBHP up to 62 mph. IHP was higher with 79" drivers above 81 mph, and DBHP higher above 63 mph. The maximum difference due to driver size on the 6023 were 1401 IHP at 44 mph, and 100 DBHP at 42 mph., both favoring the 75" drivers.

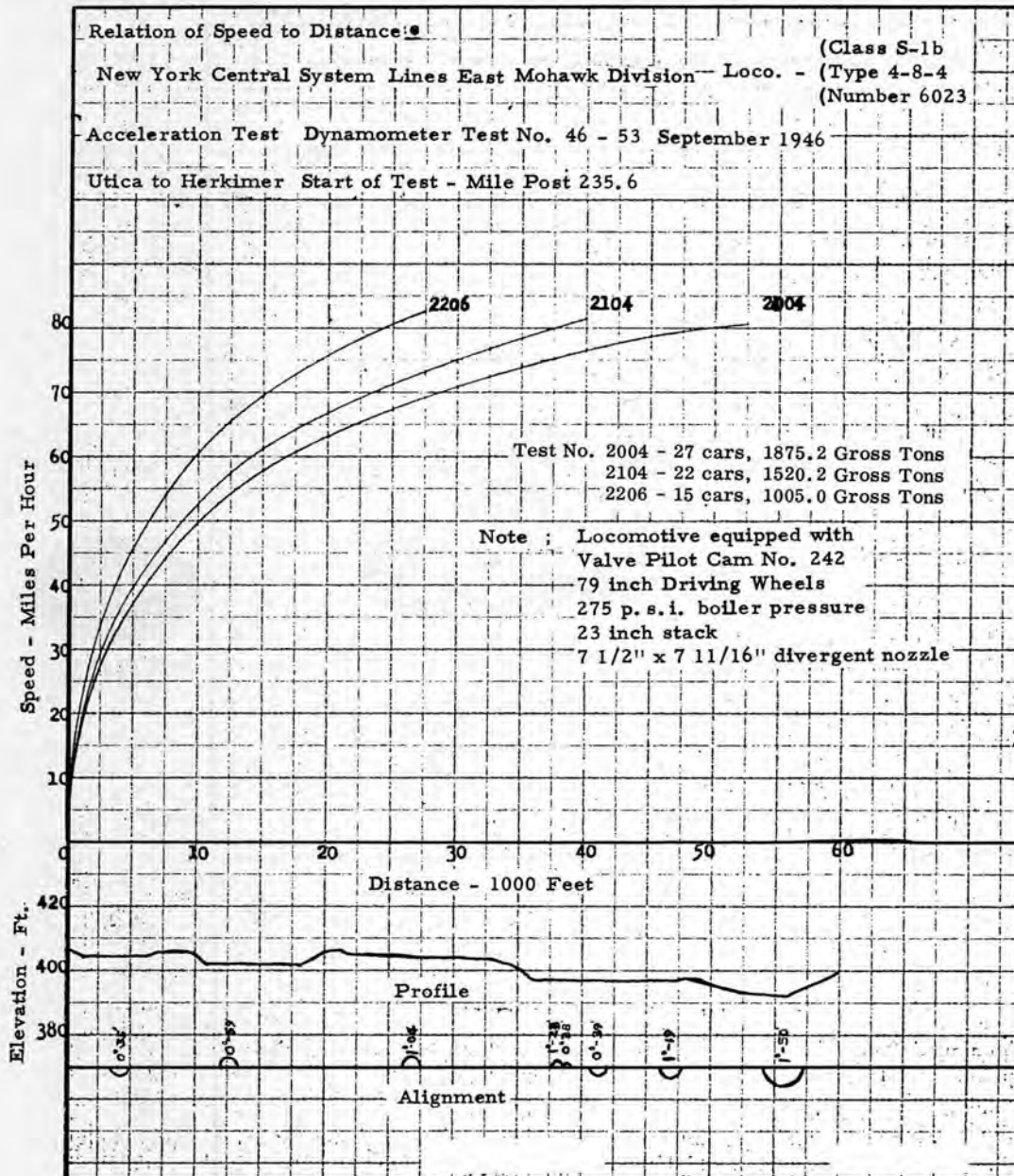
Acceleration tests were not run with 75" drivers, but the greater capacity at lower speeds of the 6023 with 79" drivers compared to the 5500 was evident in the acceleration runs. The performance of no. 6023 exceeded that of no. 5500 with all trains. The results for distance vs. speed are shown in Figures 4 and 5. A summary is presented in Table 3 below for the time and distance required to reach 75 mph, and 80 mph. The 5500 was unable to reach 80 mph, with the 27 car train within the limited distance available.

Table 3

Loco.	Number Cars	Train Weight Gross Tons	Speed, mph.	Distance, ft.	Time, min.
6023	15	1005.0	75	19,400	5.02
"	"	"	80	24,200	5.75
"	22	1520.2	75	30,000	7.46
"	"	"	80	37,600	8.63
"	27	1875.2	75	37,200	9.00
"	"	"	80	49,700	10.71
5500	14	1000.0	75	21,000	5.20
"	"	"	80	26,300	5.96
"	21	1485.0	75	30,900	7.96
"	"	"	80	38,400	9.10
"	22	1560.0	75	34,500	8.57
"	"	"	80	47,000	9.97
"	27	1915.0	75	45,000	10.50



FIGURE NO. 3



Item	Table 4	Rate at which Measured	Locomotive	
			6023	5500
Steam per IHP, including auxiliaries,		4000 IHP	17.0	16.6
" " " , excluding		"	15.8	15.4
" " DBHP, including		2500 DBHP	28.9	27.2
" " " , excluding		"	26.7	25.4
Dry Coal / IHP, including		4000 IHP	2.29	2.05
" " " , excluding		"	2.10	1.92
" "DBHP, including		2500 DBHP	3.95	3.42
" " " , excluding		"	3.63	3.18
Thermal Efficiency, incl.		2500 DBHP	4.77	5.51
Exhaust Pressure, psi.		52,500 lbs. steam through nozzle per hr.	10.0	7.8
Steam Temp. at Superheater Header, °F		9000 lbs. coal (as fired) /hr.	676	689
Equivalent Evaporation, lbs. per hr.		"	88,900	94,300
Boiler Efficiency, %		90 lbs. dry coal fired /hr. /sq. ft. grate area	54.7	57.3
Combustion Efficiency %		"	82.2	85.7
Efficiency of Heat Absorbtion, %		"	80.1	82.0

It is interesting to note that, although the 5500 had greater power available at the highest speeds, this was overshadowed by the greater DBHP of the 6023 at speeds from 30 to 70 mph. The 5500's poppet valves certainly showed no great advan-

tage in terms of power or train acceleration, but the comparison for efficiency was another story. By virtually every measure, the 5500 used less coal and less steam to perform a given amount of work. A variety of these results are presented in Table 4.

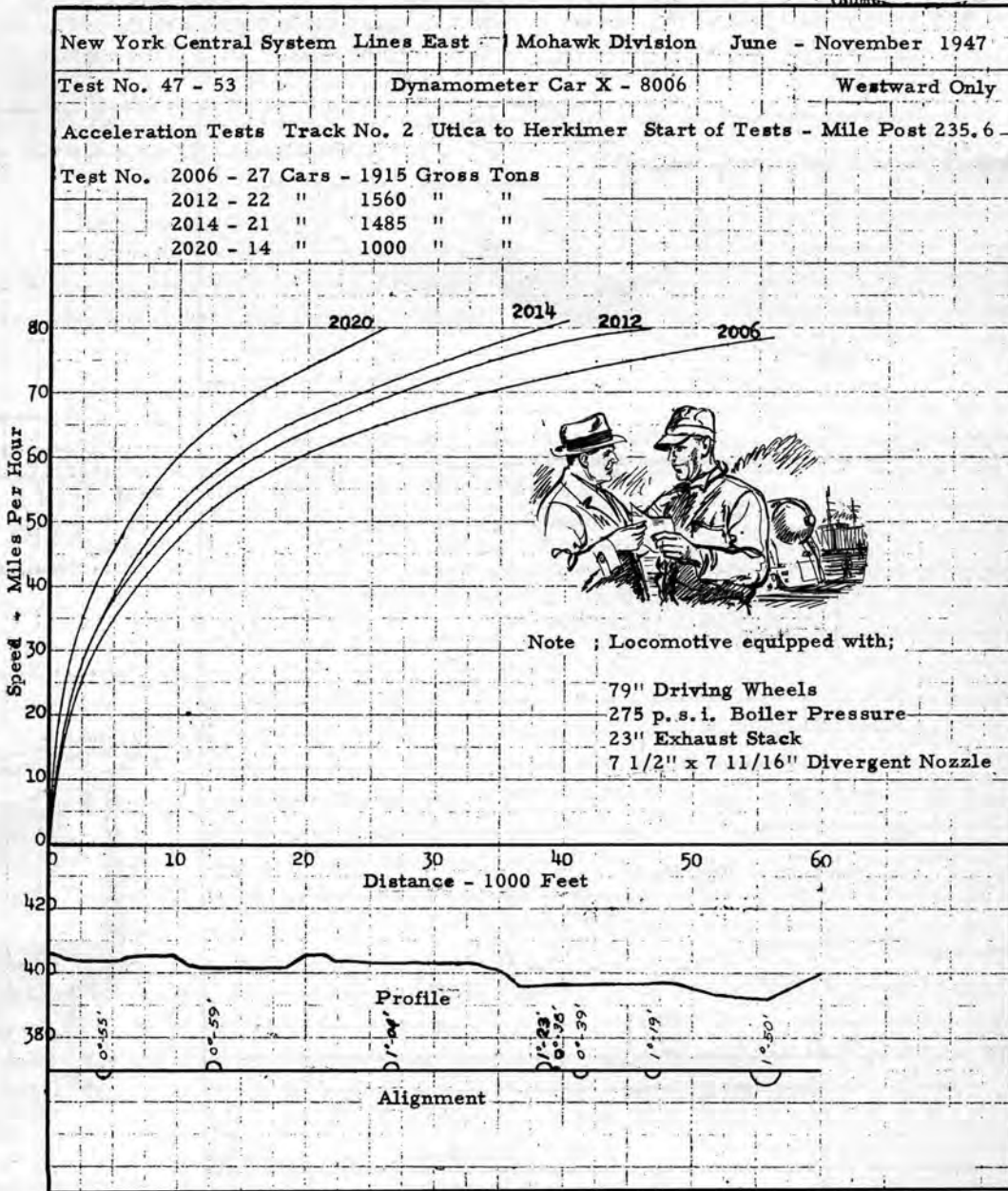


FIGURE NO. 4

As previously mentioned, stationary boiler tests were run with the 6000 on the Selkirk Test Plant. During these tests, constant rates of firing and evaporation were maintained for periods of about one hour, whereas five minute observations were used during the road tests. During road operation, the coal rates tended to be heavier, especially during periods of acceleration. Consequently, the efficiencies tended to be lower than those measured on the 6000 during stationary testing. For that reason, results of the Selkirk tests with the 6000 will not be presented.

The maximum thermal efficiency obtained with the 5500 was 5.86% and the minimum 4.93%. The range of thermal efficiencies for the 6023 over the tests was 4.94% to 4.22%. The combined boiler efficiency of the 5500 average 2.5 to 4% above that of the 6023. Since the boilers of the two locomotives were identical and the coal used was from the same source, it was assumed in the report of the Test Department that the firing rates during capacity or

near-capacity operation were higher for the 6023 than for the 5500. It is known that as a locomotive approaches the limit of its evaporative capacity, increases in the firing rate produce less than a proportional increase in evaporation. As will be recalled, the 6023 developed greater power output at speeds between 30 and 70 mph. Boiler demand is greatest in this speed range and by increasing firing rates to take advantage of the additional power, coal rates and thermal efficiency would be adversely affected. The minimum steam rate per IHP including auxiliaries - 16.9 lbs. per hour for the 6023 and 16.5 for the 5500-occurred at about 3750 IHP. The steam rate increased slightly with output until at 4900 IHP, it became 17.7 lbs. per hr. for the 6023 and 16.9 for the 5500. The steam rate per DBHP decreased from 35.9 lbs. per hr. for the 6023 and 32.3 lbs. per hr. for the 5500 at 1550 DBHP to 28.0 lbs. per hr. and 25.6 lbs. per hr., respectively, at 3100 DBHP. The curves for steam rates based on IHP and DBHP excluding auxiliaries showed the same relationship between

the two locomotives, but with a decrease of from 1 to 3 lbs. per hr. because of the auxiliaries' steam consumption. While machine efficiencies had not been thoroughly studied by the time the 1948 report was issued, the greater difference in DBHP steam rate than for IHP steam rate would indicate a greater machine efficiency for the 5500 than the 6023. Dry coal per IHP hour including aux-

iliaries varied from 2.20 lbs. at 3200 IHP to 2.44 lbs. at 4850 IHP for the 6023. The coal rate varied from 2.0 lbs. to 2.19 lbs. at the same outputs with the 5500. Dry coal per DBHP hour varied from 4.54 lbs. at 1550 DBHP to 3.92 lbs. at 3100 DBHP with the 6023. The comparable rates for the 5500 were 3.87 lbs. and 3.38 lbs. respectively.

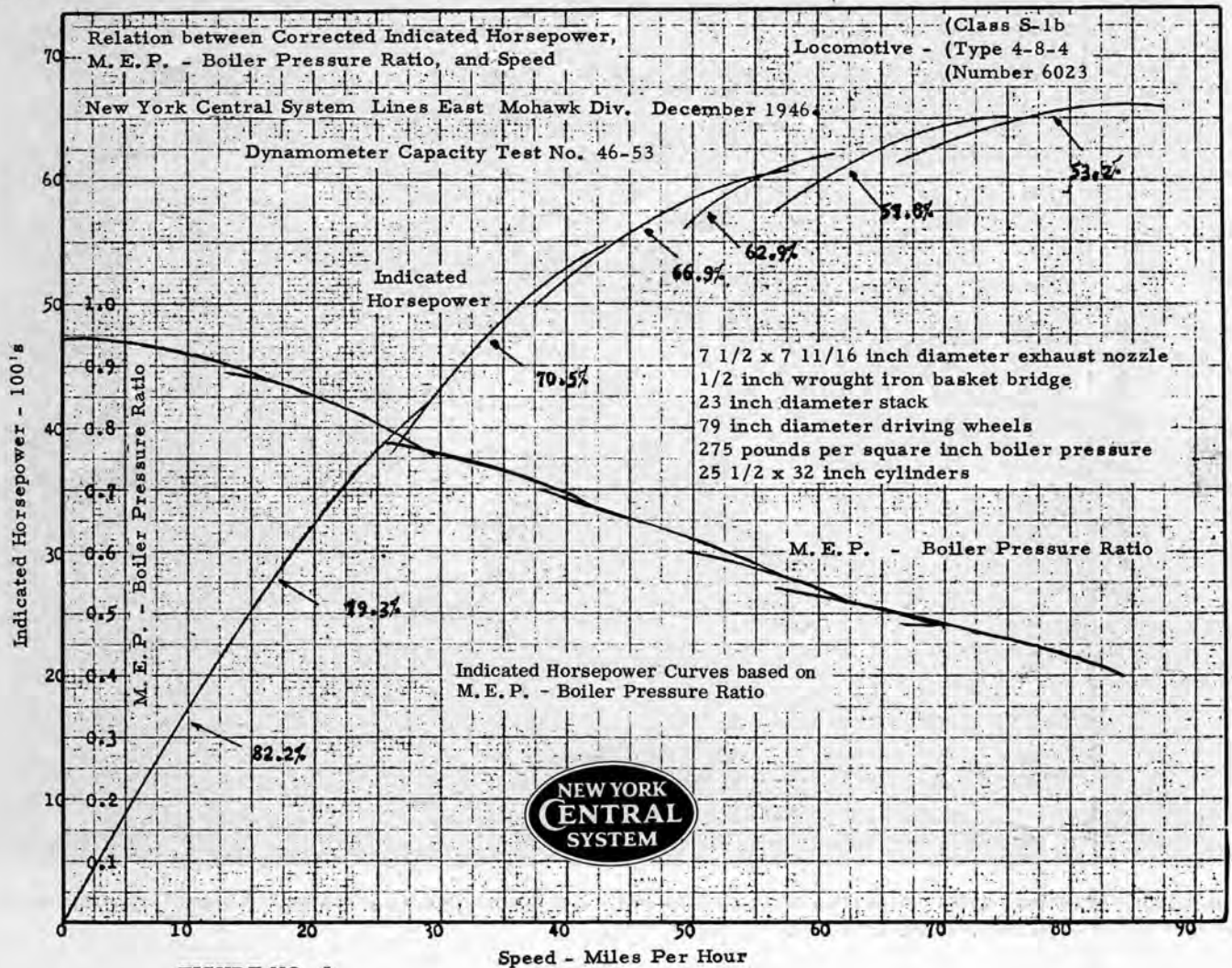
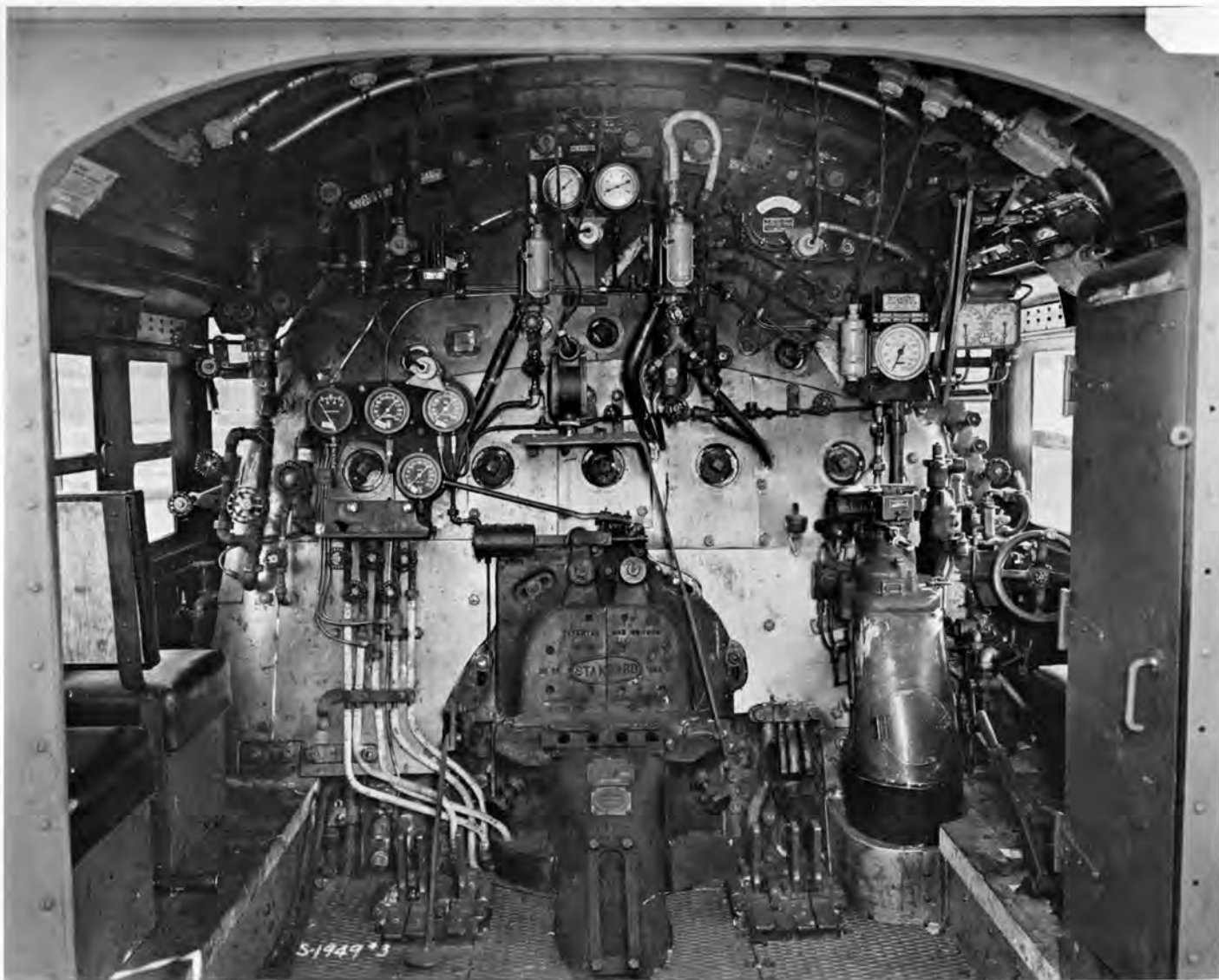


FIGURE NO. 5

In reviewing the results of the tests, there are two main questions to be answered. First, how did the S1b production engines compare with other locomotives, including notable designs on other railroads? Secondly, did S2a no. 5500 provide the benefits expected of the poppet valve system? Considering the first question, the S1's certainly rate as one of the great steam locomotive designs of all time. Their remarkable power output from the small outline and their very high utilization in service were exemplary. When the S1b performance of 6550 IHP and 5050 DBHP is compared to the 3800 - 4100 IHP range and 3200-3400 DBHP range of the J1's and L2's, the advancement within a relatively short time is dramatic. It is also interesting to note that of the locomotives in Table 1, all of which exceeded the S1b in weight and in height by a least 9", to the writer's knowledge none had a greater power output except the N&W Class J with 5100 DBHP at 40 mph. It will be remembered that the S1b, when tested with 75" drivers, also produced 5100 DBHP, but at 58 mph. rather than 40. The S1's IHP at this speed would certainly have been above that of the J at 40. The J's were more powerful in the lower speed range but the S1's had the greater output at high speeds.

The availability and utilization attained by the Niagaras were certainly without peer. During the first few years of operation, the entire fleet of 27 locomotives averaged an availability of 75.9% and 65% utilization. The entire fleet averaged over 16,000 miles per month per locomotive from 1945 to 1948. On selected runs, such as Trains 51 and 58 or 50 and 57, where the schedules permitted one to 1 1/2 hour engine turns at each end, well over 20,000 miles per month was achieved. The 6024 averaged 20,636 miles per month in eleven consecutive months in 1946 and 1947. Six engines averaged 26,200 miles per month in October and November of 1946. The Niagaras averaged 190,000 miles between classified repairs, with the peak being 232,000. As examples of what other railroads were able to achieve, The Union Pacific 820 and 835 Class 4-8-4's averaged 12,500 miles per month during their first year, the Santa Fe's 4-8-4's averaged 13,000 to 14,000 miles per month and the Norfolk & Western J's 11,400 miles per month over three years. As an indication of the difficulty entailed in attaining this level of utilization, 26,200 miles per month is 61% of perfect utilization on a train averaging 60 mph. start to stop, i. e. no allowance whatsoever for inspection, maintenance or servicing; just averaging 60 mph. day in and day out.



Backhead view of Niagara 6001. Although a large modern steam locomotive, the Niagaras were designed for efficient operation with well laid out controls and gauges for the engine crew.

The Niagaras, in addition to their power and efficiency, provided solid mechanical reliability and freedom from road failures. Only a few modifications were found to be necessary over their lifetime. Rather soon after construction, a number of flexible staybolts at the combustion chamber and crown sheet proved defective and had to be replaced. All the locomotives were brought into Beach Grove Shop where tooling was set up to drill out the faulty bolts and install new ones. The location of the bell behind the pilot and the generator on a low bracket between the fourth driver and the trailing truck on the right side proved troublesome because of the dirt and debris that collected. Consequently, both were relocated, the bell underneath the right hand running board between the mechanical lubricator and the valve gear frame and the generator under the left hand running board at the third driver. It was found that the rubber sandwich device in the axle pedestals of the PT-5 tenders did not provide the intended centering effect. The tenders did have a tendency to derail when backing up on very tight curves. Probably the most significant change was replacement of the original nickel steel boilers with new carbon steel boilers. In common with a number of other railroads, the New York Central utilized nickel steel for the boilers of its most

modern power so as to save weight, which was made possible by the higher tensile strength of the nickel steel. Also in common with the other railroads, however, it was found that the boilers were susceptible to embrittlement after being in service for several years. Consequently, a program was instituted through which some, but not all, of the Niagaras' original boilers were replaced with conventional carbon steel boilers. The truest picture of the S1's maintenance history, however, was not the modifications found necessary but the high service mileage that they generated. This could not have been achieved if the locomotives spent much time in shops and enginehouses. The S1's were unqualified successes. They exceeded their design objectives by a considerable margin, were good riding engines and were popular with their crews, the Operating Department and the Mechanical Department alike.

The second question to be answered by the road tests was to determine the extent to which the 5500 achieved the increased performance promised by its poppet valve steam distribution system. The performance demonstrated by the locomotive is clear; the reason for it is less certain. Briefly stated, the S2a developed slightly less power than did the conventional S1b, but it performed its work with

considerably greater economy. It had been anticipated that the ability of the poppet valves to open and close more quickly and to time the admission and exhaust events independently would provide greater economy, particularly at high speeds. With the piston valve opening and closing each valve port over 6 times per second at 90 mph., starting and stopping the steam flow precisely was difficult. It was also anticipated that the same advantage of precise action would enable the S2a to achieve a higher power output. Why this did not occur is now in the realm of conjecture. Some have alleged that the 5500 was simply not fed as much coal as was the 6023, and that, had the 5500's firing rate matched that of the 6023, its lower steam and coal rates would have led to a higher power output. The Test Depart-

ment's July 3, 1948 report simply states that "locomotive 6023 has a greater power output than locomotive 5500 at speeds between 30 and 70 mph. . . . To take advantage of this slight increase in horsepower during periods of acceleration, the firing rates were increased considerably. . . ." No reason is suggested as to why the 6023 had the greater output for most of the speed range. Since the purpose of the test was to determine the maximum capabilities of each engine and to provide a comparison between the two, it seems unlikely that one locomotive would be fired at its maximum rate and the other at a lesser rate. The difference was observed both in the capacity tests and in the acceleration tests. Unless there is evidence to the contrary, it would appear that the answer lay within the 5500.



A great experiment that was born too late. No. 5500, Class S-2 displays an unusual location for a "Niagara" air pump, a relocation that was necessitated by the front mounted Franklin poppet valve gear.

During the 1930's and 1940's, it became apparent that for high speed operation at high power outputs, it was necessary to provide great cross sectional area in all the pipes and passageways through which the steam moved, from dry pipe to exhaust nozzle. Failure to do so forced the steam to move through the constricted passageway at greater speed, hence with greater flow resistance and pressure loss. The S2a had the same dry pipe, superheater header, tubes and throttle as did the S1b's. Obviously, no difference in steam flow resistance occurred there. The steam pipes leading from the throttle casing to the poppet valves were different for the 5500, but had adequate cross section. Many feel, however, that Franklin's passageways from the inlet and exhaust valves to the cylinder were unduly restricted. If so, this would explain the seemingly contradictory results of the tests. The steam simply could not get into or out of the cylinders fast enough to develop comparable power. Yet the precise action of the poppet valves would obtain the maximum power from the steam that did make it through the passageways. In service, the 5500 was a relatively successful engine, although less so than the S1's. When everything was working correctly, the 5500 was an excellent performer and easy to fire. The poppet valves, however, did have their

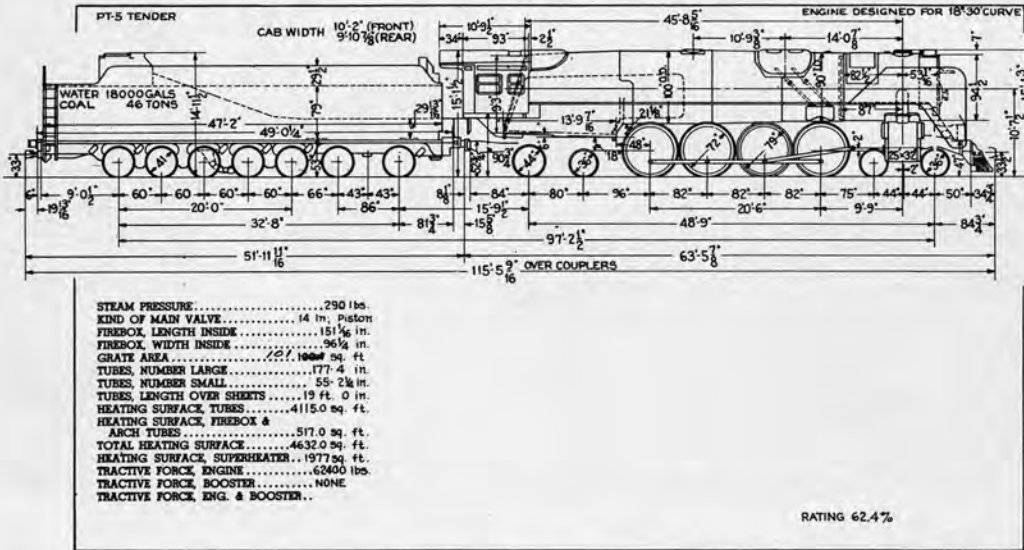
teething problems. When it first went into service, it was necessary to replace the bronze bushings between the main crank pins and the main rod roller bearings every two days. T. R. Fredriks of the Test Department determined from an analysis of the 5500's indicator diagram that closure of the exhaust was occurring too late in the piston stroke for an adequate cushion of steam to build up in the clearance volume of the cylinder. This in turn led to high inertia forces on the piston and main rod as the piston rapidly changed direction. When the valve setting was revised, the premature bushing failures ended. Access to the gearbox controlling the valves was also much less convenient than with the outside mounted Walschaerts or Baker gear. Finally, the 5500 stripped its rods at least three times during its lifetime, usually after descending the grade near Silver Creek, N.Y. at high speed. There is little doubt that the above problems could have been resolved with time as the bushing problem had been. The 5500, however, was an orphan and maintenance forces were not always familiar with its eccentricities. Most importantly, it became apparent soon after the 5500's introduction that steam locomotives of any sort had a very limited future. There was little incentive to resolve the problems.

Rather than repair its latest transgression, the 5500 was retired in 1951. The S1's held on for a few more years but all were retired in 1955 and 1956 and all were dismantled. This remarkably successful design proved not to be a long-lived one. The 6000 HP diesel whose road performance it could easily match proved unbeatable in terms of overall economy. All that remain of the Niagaras today are a few artifacts such as number plates, builder's plates and the like. Of much greater value than these, however, are the memories retained by those who knew the Niagaras when they ruled the Water Level Route. We shall not see their equal again.

I am indebted to several Society members for their generous assistance in providing information and illustrations

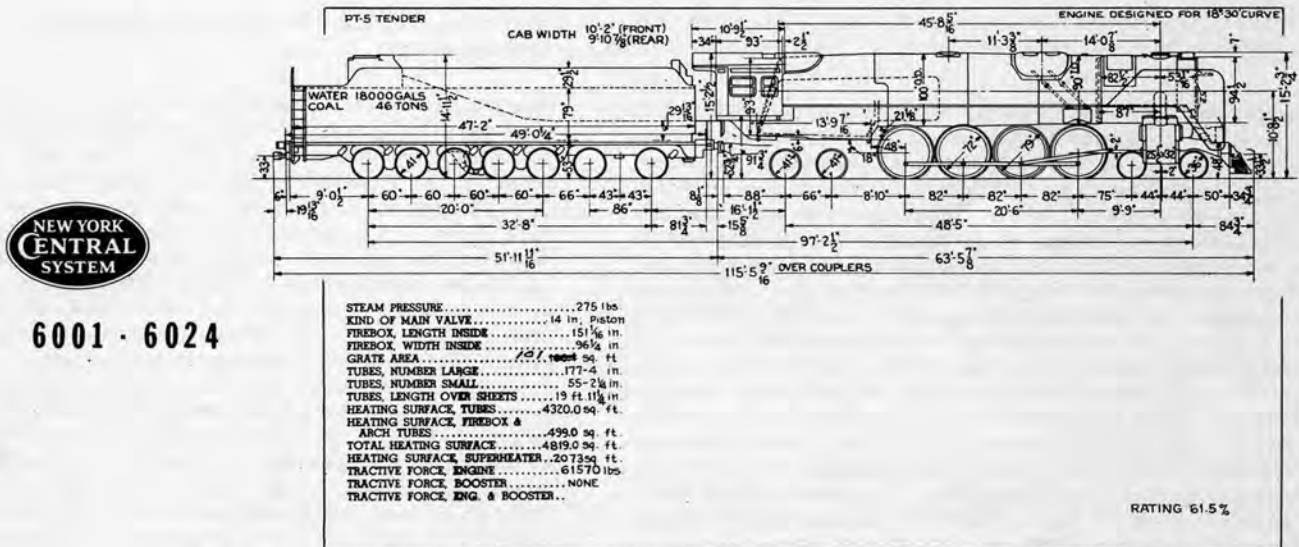
for these articles, including H. L. Vail, C. M. Smith and R. B. Street. I am particularly grateful to H. C. Crouch, one of the indicator operators during the 1946 tests, who provided information on the instrumentation and testing procedures used.

These articles are dedicated to the memory of the late T. R. Fredriks, Dynamometer Engineer at the time of the tests run with 6023 and 5500. It was my privilege to work under Ted for eight months at the beginning of my railroad career and the close of his. Ted was always willing to give some of his time to a young man with a lot of questions - especially when the questions concerned his Niagaras.



S-1a 6000

N. Y. C. 4-8-4 NIAGARA - CLASS S-1a ENGINE NO. 6000 (after conversion to 79" drivers)



N. Y. C. 4-8-4 NIAGARA - CLASS S-1b ENGINES 6001 - 6024 (note minor differences from S-1a)

BUY MORE  
WAR BONDS



**NEW YORK CENTRAL**  
THE WATER LEVEL ROUTE



N. Y. C. Niagara 6011 thunders over the Pennsylvania R.R. crossing at "XC" tower in Erie, Pa. with train #90 on a crisp September morning, presenting a portrait of typical N. Y. C. Niagara operation. Photo by Paul W. Prescott



When new, Central's Hudsons got much more public relations exposure than the Niagaras did. One exception was this publicity stunt that was staged in the summer of 1946 to promote the easy rolling qualities of 6001's roller bearings. There are five glamour girls in the photo - including 6001. Arnold Haas - NYC - Charles E. Winters Collection

18000 GALS.

46 TONS

6008

S-1980 \*5  
N.Y.C.



**Errata to “Road Testing of the Niagaras” by Richard W. Dawson  
in *Central Headlight* of the New York Central System Historical Society,  
Vol. V, No. III (August, 1975)**

<u>Page</u>	<u>Paragraph</u>	<u>Column</u>	<u>Line</u>	<u>Correction</u>
5	1	Left	11	“...including 12,400 <del>0</del> lbs. for.....”
6	2	Left	2	“...from <u>the</u> effective cylinder steam pressure valve values.”
8	1	Left	14	“ <u>80,000</u> lbs., 72,000 of which....”
8	3	Left	2	leading, particularly between....”
11	1	Left	6	“...generations. Since the....”
12	1	Right	1	“...cylinders. <del>A</del> a boiler set at....”
17	1	Right	1	“...one man would <u>be</u> ...”
17	1	Right	20	“...quality of the steam (moisture content) just...”
18	1	Right	10	“...would be made. <del>throughout</del> <u>Throughout</u> each run...”
18	1	Right	17	“...as in Figure <del>3</del> <u>5</u> , the most...”
19	1	Right	4	“...performance tests <u>as at</u> the Selkirk test plant...”
20	1	Left	11	“...on the 6023 were <del>1404</del> <u>140</u> IHP...”
21	Table 4		2	“...excluding “ , “ “ 15.8...”
21	Table 4		3	“...including “ , “ 2500 DBHP 28.9...”
21	Table 4		4	“...excluding “ , “ “ 26.7...”
21	Table 4		5	“...including “ , “ 4000 IHP 28.9...”
21	Table 4		6	“...excluding “ , “ “ 2.10...”
21	Table 4		7	“...including “ , “ 2500 DBHP 3.95...”
21	Table 4		8	“...excluding “ , “ “ 3.63...”
21	Table 4		9	“...including “ , <u>%</u> 2500 DBHP 4.77...”
23	2	Left	15	“...and in height by a <u>at</u> least...”

Additions are underlined, deletions are struck through.