Model Railroad News

By-The-Numbers

Testing Guide 2003

by John Sipple, editor

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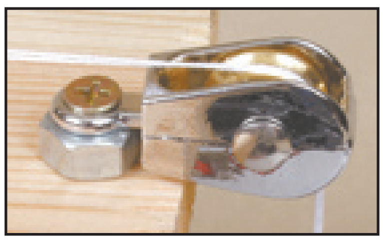
Things at Santa Fe shops sure have gotten interesting since the merger.

Introduction and Overview

By-The-Numbers testing came about in response to many letters from readers wanting car counts which a given locomotive could pull. There is no way to accurately define the rolling resistance of a "string of cars" since the cars in the string can vary considerably in both the consist and the circumstances of the track. In an effort to come up with something which would satisfy this request and still possess some scientific common sense, By-The-Numbers (BTN hereafter) was born.

BTN really consists of two testing suites, each with its own goals and equipment. Pull Testing sets out to determine the pulling power of a given locomotive. This, in itself, opens a whole can of worms since it leaves unresolved a number of significant issues. First, the test locomotive may or may not be indicative of the entire run. Second, the test information may or may not accurately translate into real world applications. We can't resolve the first of these issues, and it is up to the individual reader to make some sense out of our numbers.



The basic premise of pull testing is the classic test of horsepower, except that the element of time is left out. We measure the weight of the locomotive without the tender unless it is powered. Then we measure the weight pulled. That number, divided by the loco's weight, equals a non-integer in the range of 1>n>0 and is expressed as a percent. I have labeled this "tractive efficiency" since the resulting number is NOT tractive effort, factor of adhesion or any of the other real world measure of locomotive pulling power. I test the locomotive to the point where it slips. Some locos will produce their maximum pull just before they slip while others reach it while slipping. Using the pre-slip measure is hard to nail and often misleading. I measure the voltage and amperage of this full slip point.

The second test is actually a suite of operating performance numbers. I test the locomotive at the minimum continuous operating power setting, the scale maximum, and one or more points in between. This is a timed test over a known distance and is expressed in scale miles per hour. I also record the voltage and amperage for each speed, as well as measure the starting voltage and stall amperage.

The advent of DCC has placed further demands upon BTN. While pull testing remains the same, speed tests have changed to reflect the nature and needs of DCC operation. Again, three speeds tests are performed, but this time I use the DCC system to tell me what Step is reached before the locomotive actually starts to roll. All of these tests are performed with factory default settings and before I perform any modifications whatever.

A second test is performed at the maximum step setting which is Step 128 on a speed table with 128 steps. The third is performed at 64, representing exactly half throttle. These three tests will then tell the operator what, if any, programming changes might be necessary.

The DC stall voltage is absolutely essential on DCC-ready locomotives since the decoder's motor amperage rating MUST exceed the loco's maximum draw.

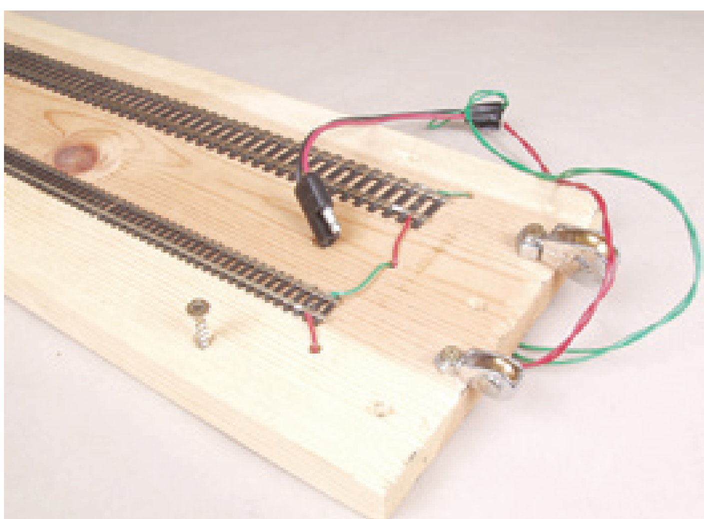
While I sometimes regret ever getting into all this testing, I am gratified to note that we no longer get letters asking for car counts. Many readers have stated that they like our testing feature and have endorsed our methodology. That doesn't make it perfect. Included in this guide is a listing of all the items you'll need in order to duplicate my madness. Mike says he'll reimburse you for the unusual items (this would not include lumber, track, or power packs.) All I can say is: Go for it!

Section 1: Tractive Efficiency Testing

I purchased this scale for about $35 in the kitchenwares section of Target. It is actually the most expensive single piece of equipment I use. It weighs in units of 1/10 of an ounce and up to a maximum weight of 4.5 pounds (80 ounces). When you turn it on, it zeros out with whatever is on the scale at that moment.

The Master Padlock weighs 12.2 ounces but when I power up the scale with it on the platen, the scale reads zero. If I lift on the string, the scale reads in negative numbers! Thus, I can have a loco pull on the string and the result will be the ounces pulled.

A few items are needed to make the test track. Shown here is the one I use, based on a humble 3 foot piece of 1 x 6 inch pine. On it I have a section of HO and N flex track. Both are wired together to one of my favorite auto trailer 2-pin plugs which I use for all of my power connections.



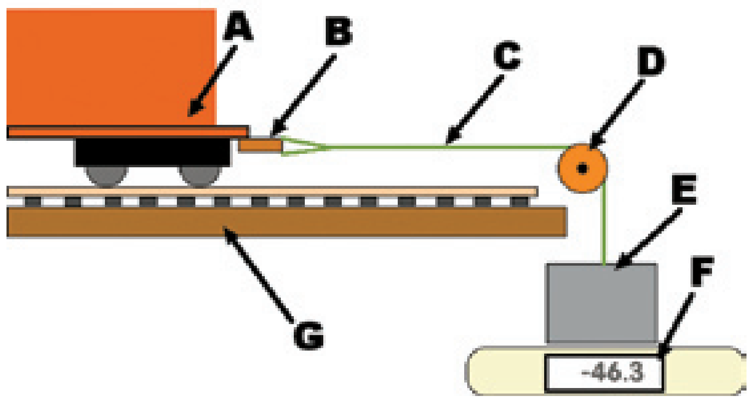
The pulleys come from Ace Hardware in several sizes; two are shown here. I space them up using ordinary steel nuts and hold them in place with drywall screws. The idea is to raise the pulley such that the string pulls neither up nor down on the coupler of the locomotive, since that might skew the tests.

I place the board so that it hangs over the table edge and the scale is positioned directly under the pulley such that the string can pass up through the pulley, over the wheel of it and to the locomotive. I use butcher's string, and the loop on the string will hook any Kadee, X2F, clone, Micro-Trains, dummy, or Rapido coupler.

In practice, I place a "meter set" in between the power pack and the track connector so that I can measure DC voltage and amperage at the same time. (See the section on the meter set for more information on it.)

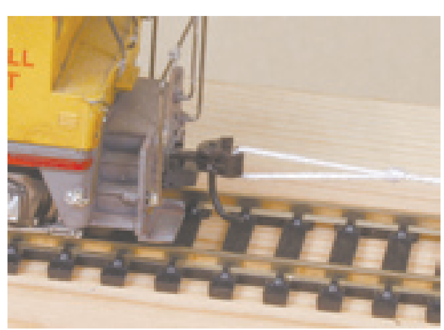
On the advice of loco makers and others, the maximum volts for each scale should be: 10 volts for N, 12 volts HO, and 18 volts for G. Most locos can handle more, but these are good for testing purposes.

The testing is pretty straight forward. It helps if the board is level, of course. Power up the track and the digital scale. Advance the throttle until the string is taut and the wheels slip. Watch the scale and meter readings. Take the loco up to the scale maximum. Record pull, voltage and amperage. I've had locos which put out more pull at less than scale maximum, for whatever reason, and so I go with that measurement.



This drawing illustrates the basic testing sequence. [A] represents the locomotive while [B] is where the string connects with the coupler. [C] is the string in the horizontal section of the pull. [D] is the pulley wheel with the top dead even with the center of the coupler. [E] is the counterweight against which the coupler pulls. [F] shows the measurement as a negative number, but we simply use the absolute value by dropping off the minus sign.

When you weigh-in the locomotive, make sure none of it is touching anything other than the platen of the scale. I don't include tenders in this weight since most tenders are only trailing weight and add nothing to the tractive effort. I do, however, use the tender during the actual pulling event, since that is usually the best way to attach the string. Also, it is a more honest measure of how the entire model will pull. It is possible to test locos pulling both directions, though I haven't seen factorable differences from such testing.



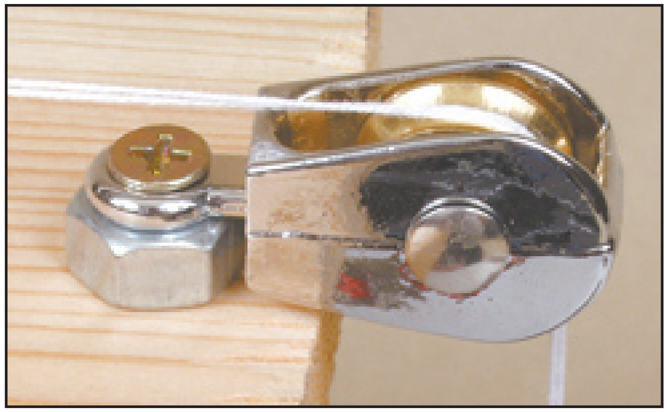
This scale has two readout scales: pounds, expressed in hundredths and ounces expressed in tenths, controlled by the right-hand button. I, of course, prefer ounces in tenths. The center button controls Tare Weight and a press of that button will set the scale to zero. Lifting the loco off would then cause the scale to read the loco's weight as a negative number. That value should be the equal absolute value to the result of simply weighing the locomotive. Use of this button is easy and productive.

If you are worried about the scale's accuracy, simply weigh one or more objects with a known weight. For example, you could use a known scale to weigh a stack of quarters or other coins. Then weigh that same stack and see if your scale checks out. This scale automatically powers down after a period of time, so the same batteries have lasted me two years so far.

The bottom shot shows the string looped onto a Kadee coupler. Note that the string is dead center on the coupler and pulling horizontally. This helps guarantee a more accurate measurement.

If you feel that the loco wheels are polishing one section of track to the exclusion of the others, possibly skewing results, first make sure the track is clean and dry. A Brite Boy helps here. Next, you can have more than one string or loop in your string. Also, you could put something flat under the scale to raise it or lower it.

The single pulley wheel [D] represents a only a single axle with very little rolling resistance and a very small part of the overall equation. It is also the same for every test. If you wish, you can give it some lubrication from time to time, but since the pulley is brass and the axle is steel, I wouldn't anticipate any factorable resistance from it.

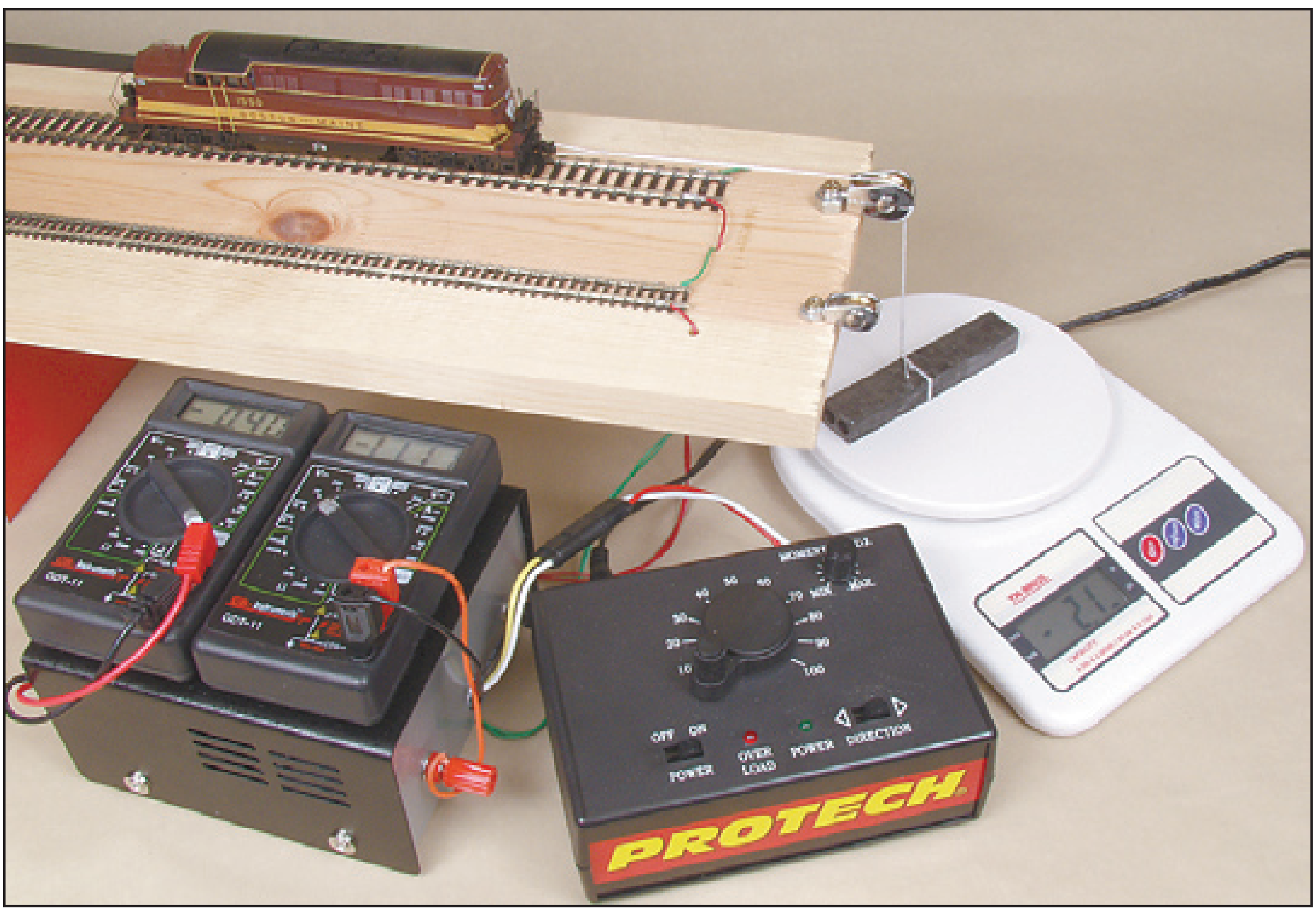


The close-up of the pulley should help you to locate something similar on your local market. This particular pulley design has a part of the pulley housing on the backside of the wheel, making threading a bit interesting. However, I haven't had any problems and only briefly considered hacksawing the offending bit of metal away.

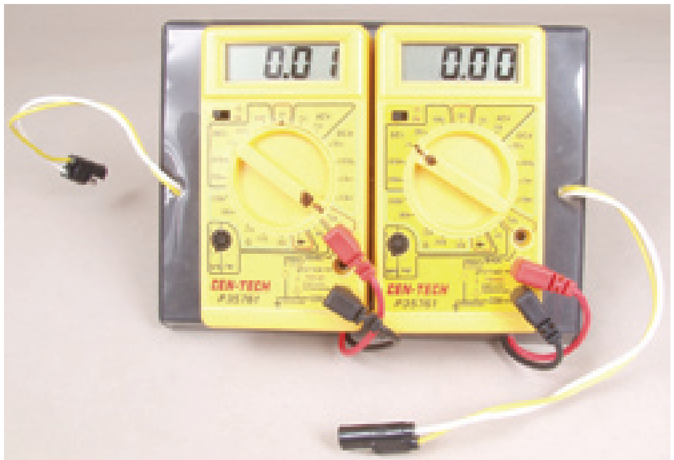
The nut is something I found in a parts can, so I can't tell you exactly what it is, and since pulley designs can vary, I'll leave that to your inventiveness. This is a long way from being rocket science, so it shouldn't be too much trouble to figure out. It is important to get the screw tightened snugly so the pulley doesn't pivot left or right during testing.

The picture below shows the whole rig set up for operation. I used a different weight when this shot was made, and the meters are rigged diffently, but that just shows the growth of the concept from then until current times.

Please notice that the string above the pulley is horizontal and a straight pull for the loco, while the string below the pulley is vertical and a straight pull for the weight. The entire operation only takes a couple of minutes to set up and the testing doesn't take much longer than that. Locomotive not included and some assembly required!



Dual Meters for DC Power Testing



For analog DC power testing, there's no substitute for this little rig. It's inexpensive and can be constructed in less than an hour. You need a pair of inexpensive digital VOMs, a DVD case, a package of Velcro, and a pair of trailer connectors. I use these two-pin plugs on all of my power connections, allowing me to change devices quickly while making good electrical connection.

I get the meters on sale at Harbor Freight for about $5 each. The DVD case is free, courtesy of AOL (LOL). A small package of self-adhesive velcro strips came from Ace Hardware, and the trailer connectors came from an auto parts place.

I place the bottom of the meters to the hinge edge of the DVD case and poke holes in the hinge edge for the meter wires to pass through. I also punch holes on either side of the meters for the trailer connectors.

You will have to cut the meter test leads, about in half and strip the socket ends. Designate one meter to be your Ammeter and the other to be the Voltmeter. The purpose of this exercise is to get both readings at the same time.

Install two Velcro strips to the back of each meter case, taking care not to pave over the battery access door. I then place the matching Velcro strips on the back of the meters, peel off the self-stick tape and press the meter onto the case where I want it to end up. If you can assemble Kato locomotives, this should be a piece of cake by comparison. You'll end up with two meters sitting side-by-side.

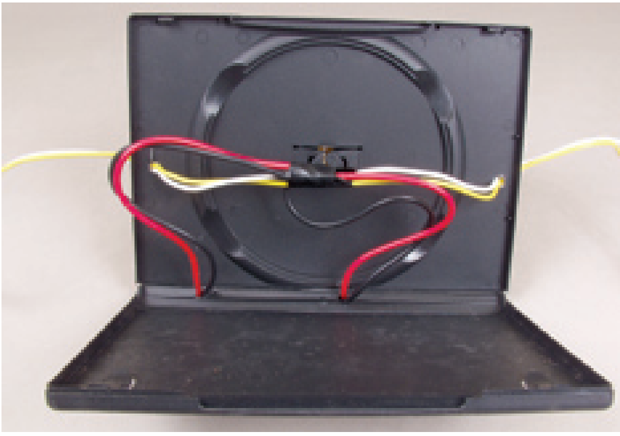
Plug the test leads into the meters. This picture shows the Ammeter on the left. The red lead is plugged into the high amperage test socket. This meter is good for short-time ratings of up to 10 amps, so I can use this on G-scale stuff. Note that the control switch is pointing to the 10 amp setting.

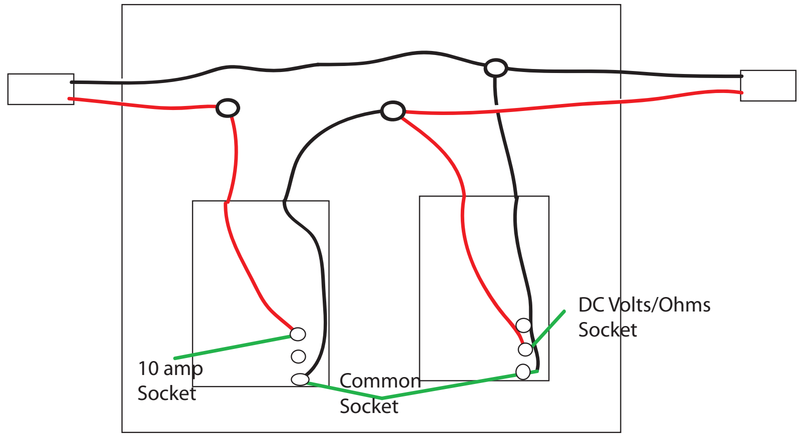
The right meter is set up as a Voltmeter with the red lead in the Volts/Ohms/Milliamps socket. The dial is set for 20 volts. You can use other scales for voltage if you wish.

Take your trailer connetors and strip the wire ends as you did with the test lead ends. You now have two pair of probe ends left over. Enjoy. Thread all of the wires through the appropriate holes and prepare to wire.

I soldered mine, since simply twisting connections can lead to spurious readings. I also covered the connections with electrical tape. The schematic and drawing on the next page should guide you through. Basically, volts are measured in parallel while amps are measured in series.

It should be noted that you don't have to use this metering solution; others are equally possible. To simultaneously read both voltage and amperage will require two meters, however. I find digitals easier to read in this type of operation.





At the bottom of the page is a schematic showing the basic truth about the wiring. The ammeter is in series on the green line while the voltmeter is measuring the voltage across the red and green.

The drawing shows how the wires are actually connected. Wire colors may vary, so be consistent. Often, the trailer connectors are green and yellow. Just pretend the green is black and the yellow is red. I like to strip all wires to be connected with about a half inch bare lead.

The common black from the voltmeter is going to join the splice of the two "black" wires from the trailer connectors. Solder and tape.

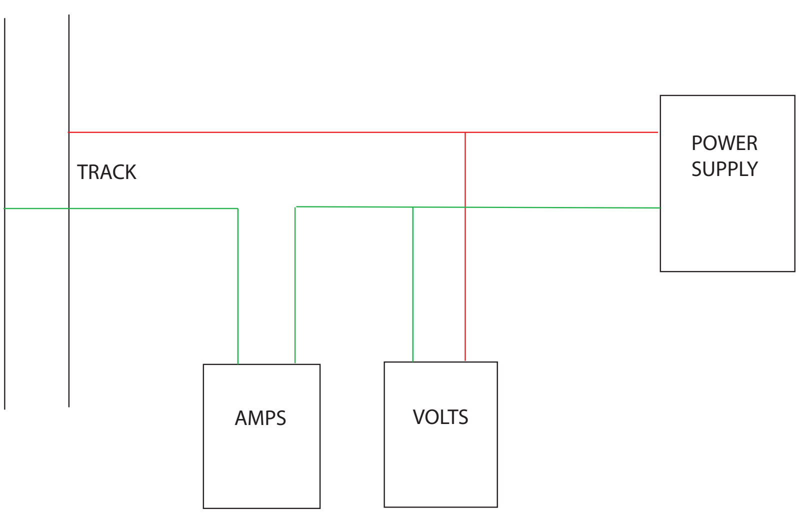
Take the "red" from one trailer connector and splice it with the red from the voltmeter and the black from the ammeter. Solder and tape.

Finally, splice the red line from the ammeter to the "red" line from the other trailer connector. Solder and tape. Double check all connections.

The photo at the top shows how all of the connections are then bundled into the center of the case. You can place a prop inside the case and cause the meters to tip up for easier reading (bottom photo.)

These are not auto-shut off meters, so remember to turn the dials to off when finished. If you forget, you can run through some 9 volt batteries. I put a black mark on the indicator point to make it easier to read.

Note: these meters can't be used with DCC since digital meters can't "see" DCC voltage and the amperage would have to be measured inside the decoder. DCC voltage can be read with an analog AC meter with varying degrees of success. This is why we test DCC using Speed Steps, since that gets away from this problem. The most important amperage reading in DCC is the DC stall amps before putting in the decoder.



Section II: Speed Testing

Speed testing involves time. There are some very sophisticated systems for measuring time, most involving optical speed gates and computers. These things are also very expensive. For our purposes, the extra accuracy just doesn't warrant the expense.

The stopwatch on this page came from a local discount retailer for around $7. It keeps time and date, as well as doing all sorts of timing things. The button on the top left starts and stops the timer. The button on the top right resets the timer.

Pick a precise point on the track (the edge of a certain tie) and a point on the loco (front edge of the pilot) to make your readings more accurate. Be consistent and it gets easier.

The methodology of timing is not hard. As with any other measurement, it requires only a consistent approach. Obviously, you'll need a locomotive and some track. A test loop is most helpful. Please keep in mind that any test under ten seconds is likely to be flawed by its shortness. Any test over three minutes probably is wasting your time.

If your loop of track only requires a locomotive at top speed to spend 7 seconds going around it once, measure it based on two laps. On the other hand, if a single loop at minimum speed is going to take over three minutes, mark off a one yard or even a one foot section and measure it there. The Bachmann N-scale 2-8-0 required over a minute to travel a single inch!

Curves apply rolling resistance to locomotives, so the widest radius possible is more desirable. Virtually no loop will be level, so the entire loop is a fair measure. If you use less than a loop, measure both ways and average. Use the meters rig to give you accurate volt and amps readings in all tests. These reading are important to modelers.

It is very important to have an accurate measure of the your track's length. If you use 22 inch radius track and run a full loop, you can use π times 44 (C=πD) to find the circular portion of the loop. Measure both straight sides and add that in for a pretty accurate measure of your track length. For example's sake, we're going to say your loop is 500 inches long.

Just as you will put all time measurements in seconds, convert all distance measurements into inches. Now, let's assume that you timed the loco around this loop at one minute and 14 seconds. We will use the following formula:

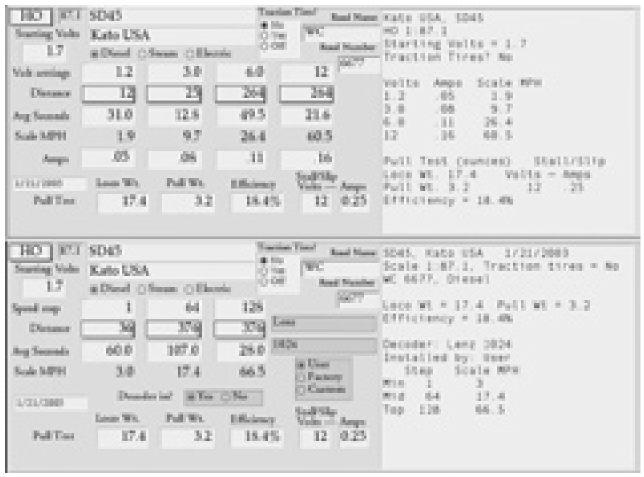
$$SMPH = [(T \times F/12)/5280] \times (3600/S)$$

SMPH is the Scale Miles Per Hour. S is the Seconds, which in this case is 60+14 seconds or 74 seconds. T is the Track length and F is the scale factor which for HO would be 87 or if you're picky, 87.1 because HO is 1:87.1. The 12 is the inches in a foot, a constant, as is the number of feet in a mile, 5,280.

For this particular loop of HO track, we can figure this number once and use it forever. It would be 500 x 87/12/5280 which equals .68553. If you used 87.1, you'd get .6873422. Big deal. Write this number down.

What portion of an hour did this test take? Take 3600 seconds in an hour and divide it by your time, in this case 74 seconds. The resulting time factor is 48.648649 or just 48.65. Write that down.

I do enough of this stuff that I give it over to a computer, but for just now-and-then testing, a good calculator is enough. Your calculated track factor will stay the same and doesn't need to be calculated every time if you write it down and keep it handy.



So now we multiply the track factor of .68553 by the time factor of 48.65 and get 33.35 scale miles per hour. If we used the 87.1 figure of .6873422, we'd get 33.44. Big deal.

Since I do this as part of my livelihood, I use a database to keep and report my results, but that really isn't necessary for the rest of the world. You can do this in a spreadsheet, but it's just as easy to do it on paper and type it into the review.

The database gathers the data on the left and reports it on the right. I copy and paste the information on the right into your review and off it goes. From this example, you can see the format.

The Kato SD45 shown on this page is actually how it appears when I turn in your manuscript. Please notice that all columns of numbers have their decimal points aligned.

I've used a monospaced font. We use Andale Mono but you can use Courier, if you wish and I'll convert it to our font. If you take the time to create a template document in Word, when it comes time to put in your results, it should all go very easily. **One thing, *please*: with the monospaced font, use spaces and not tabs.** That way, regardless of font or size, it all lines up. You just add or subtract spaces to align your table.

In the near future, with DCC results being mixed in with regular DC reports, I will probably drop off one of the DC readings. In this case, I would probably drop off the 3 volt line.

At first, all of this testing may seem to be a burden on you, but if you don't do it, then I have to. When I have to do it, there will be occasions when the turnaround time for me to do it, ship the model to you, and get your review will involve enough extra time that it would be simpler for me to just do the review and keep the product in-house.

I think that in time and with practice and feedback from me, you can learn to accomplish this quickly and with fair ease. You will find the results to be fascinating and this will add to the connection between you and the product. I am also open to altering details to make it easier.

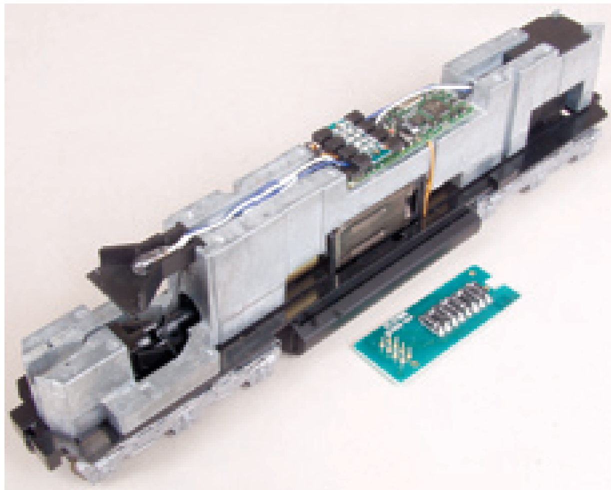
By-The-Numbers

```
Kato USA, SD45
HO 1:87.1
Starting Volts = 1.7
Traction Tires? No
Stall Amps = .78

Volts  Amps  Scale MPH
 1.2   .05     1.9
 3.0   .08     9.7
 6.0   .11    26.4
12.0   .16    60.5

Pull Test (ounces) Slipping
Loco Wt. 17.4    Volts — Amps
Pull Wt.  3.2     12    .25
Efficiency = 18.4%

Decoder: Lenz 1024
Installed by: User
     Step   Scale MPH
Min    1      3.0
Mid   64     17.4
Top  128     66.5
```

Testing DCC-equipped Locomotives

DCC is far more than a fad. It is here, and it will be the future of model railroading. In fact, if anything can reach out to the twenty-to-forty age demographic, it will be the hi-tech whizzery of DCC.

This means we have to review it, and that includes testing the performance of DCC-equipped pullers. Some things change while others don't. First, most DCC decoders allow operation under analog DC. This, in turn, means we can perform all of the standard pull testing under regular DC.



Second, if we receive a loco which is DCC-ready, we should install a decoder and test it under DCC, too. But first, we run all the DC testing as usual. Many old-timers are still buying locos but aren't going DCC. To leave them out would be a huge mistake.

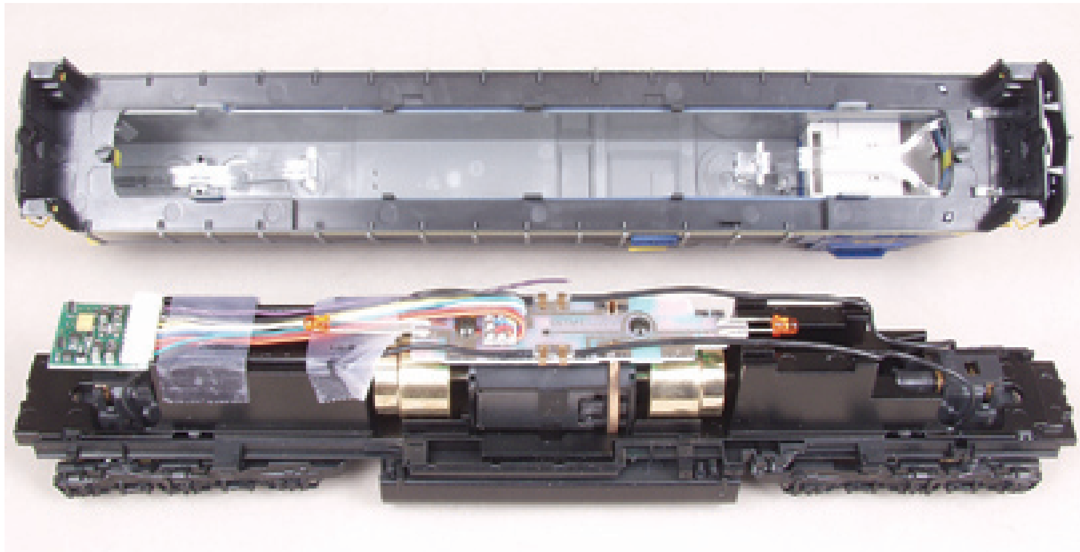
Getting decoders requires more effort. I am developing a network of decoder makers who will ship me product either in advance or on short notice. Thus, I can bring a loco into the shop and call for a decoder. It will take a few days to get it, so I do the photography, run the DC tests, and work on the review. Since I leave the DCC section to last, I then perform the DCC testing when I install the decoder, including photos of the decoder in place with the shell off. The picture on this page shows a Life-Like SD45 with a Digitrax DH163L0 decoder installed and the stock light board sitting to the side.

This also means another section in the header, this one for the decoder and its manufacturer. I know this means more work, but it also means more toys, too. Between the decoder-equipped locos from reviews and the decoders I've purchased and installed myself, I now have around a dozen. I prefer to run DCC now, and a loco without a decoder is just no fun anymore.

Because decoders can be programmed, great variations in performance can be achieved. That is not what we wish to test. Rather, we want to stick to our "Out-Of-The-Box" model. What is the product like before someone starts messing with it? To do that, we need to test the locomotive without changing any programming.

Most decoders support 128-Step Speed Tables, so we want to know three things: [1] what speed step starts the locomotive and how fast does it go? [2] how fast does the loco go at speed step 128. [3] how fast does it go at speed step 64. From this basic information, we can then make numerous changes. It isn't our job to make those changes for the review, but to show the basic performance characteristics. If a loco doesn't start until it reaches speed step 12, it's going to need to have its Start Volt CV02 tweaked. If its slow speed is 5 smph, that can be fixed in other ways, usually by adjusting the Back EMF.

If step 128 is too fast, Top Volt CV05 will need to be adjusted downward. If the top speed isn't fast enough, there may be little which can be done for that. The half throttle reading gives us an image of the throttle curve. Adjusting Start and Top volt may temper that some. The bottom line remains that we wish to illustrate the Out-Of-The-Box nature of the loco-decoder team; it is up to the individual owner to tailor the locomotive to a particular set of needs.



It is inevitable that an active DCC modeler will want to make changes to improve the operation of a locomotive. Go ahead but don't include those results in the BTN report. Instead, wax eloquent in the text (using 50 words or less — oops, the editor got out).

On the right, we have the Kato SD70MAC and a real puzzle. In straight DC testing, its 12 volt top speed was only 32 smph. When running without a decoder on DCC track under address 00, it cranked up around 45 smph. However, with the Lenz 1035 in it, the Step 128 speed was 67 smph. Go figure.

Frankly, if I took this thing home, spent four hours gluing on all the little parts and then found out my regular transformer at 14 volts would only give me forty-some-odd smph, I'd be ticked off. However, under DCC, this critter's a real winner. So it goes.

The installation of a decoder may find you having to solve problems. In this case, the wires from the decoder would have interfered with the rear light pipe if I hadn't taped them under the LED. The Lenz decoder doesn't have a shrink shroud and nothing should be taped to it or otherwise interfere with its cooling, so I hung it over the back. Looks goofy but it works fine.

As it turned out, I didn't have to modify a single CV to get superlative performance slow, medium, or fast. Would I have gotten different results with a different decoder? I don't want to know badly enough to take the loco's shell off and change out the decoder. There is a JST plug, so almost any JST decoder will fit without having to mess with my fancy wiring, but it just isn't important to me. (A JST plug is the in-line miniature nine-pin used to connect the decoder to its harness.)

This leads to another point which dearly needs to be made: only one decoder per loco review. If the ABC company is cooperative and gets you a decoder while the XYZ company doesn't, then ABC gets the nod ... and the publicity. As such things go, a decoder at manufacturer's cost is a pretty cheap investment in publicity.

What if the loco comes with the decoder installed? So far as I'm concerned, you do the pull testing under DC and skip the rest of the DC suite. The Trix Big Boy 4015 was a case in point. The stats were what I would expect and the loco performed very well. Reporting on sound systems is yet another can of worms, but that's another whole book.

Get to know which CVs are NMRA basics and which are manufacturers' optionals. More are the latter than the former. If your system has the capability, always read an address before changing it. Check the default state you find with that stated in the manual. The discrepencies are few but interesting.

Finally, let's stay in touch about this DCC thing. This is one area where we already have a considerable competitive advantage and are actually drawing away from the rest of the field. Virtually no one else is doing bundled reviews and connecting the dots. Let's maintain our lead; that's one way to be sure we get the best toys quickest.

Parts and Supplies for BTN Testing

Reimbursible Parts

1 Digital weight scale Up to $50

1 or 2 pulleys Up to $5 each

1 Stopwatch Up to $10

3 or more pair trailer connectors Up to $3 each

2 Digital VOM 10 amp Up to $10 each

Total Up to $100 reimbursement

If you cannot find an item or locate it at a reasonable price, contact us and we'll see what we can do. Otherwise, it would be best for you to locate items in your marketplace such that you can obtain local service and resupply as needed.

If you personally want a higher quality scale or better quality meters, that's your decision and you are expected to pay the difference.

For reimbursement, send Karen your non-returnable and labeled receipts and allow 30 days for processing.

Supply Yourself

Lumber and fundamental hardware.

Flex track

Test loop or layout

Power Supply/transformer

Soldering equipment

Electrical tape, paper, pencils

Calculator

Computer/Software

String and weight

Wire and other electrical stuff

Various tools

Batteries, fuses, medical supplies

Vickie & her USA Trains GP38-2

For some, locomotive testing remains relatively pointless. In the middle of all the numbers and prototypical accuracy, we must always remember that many of our readers see trains the way Vickie does. She sees the bright Warbonnet colors, and they fill her with joy. She doesn't care that Santa Fe never painted a GP38-2 in Superfleet. She isn't concerned that the unit cannot pull as much as Aristo's SD45. She represents the wide-eyed wonder of many MRN readers, and we cannot forget to write for them, too.