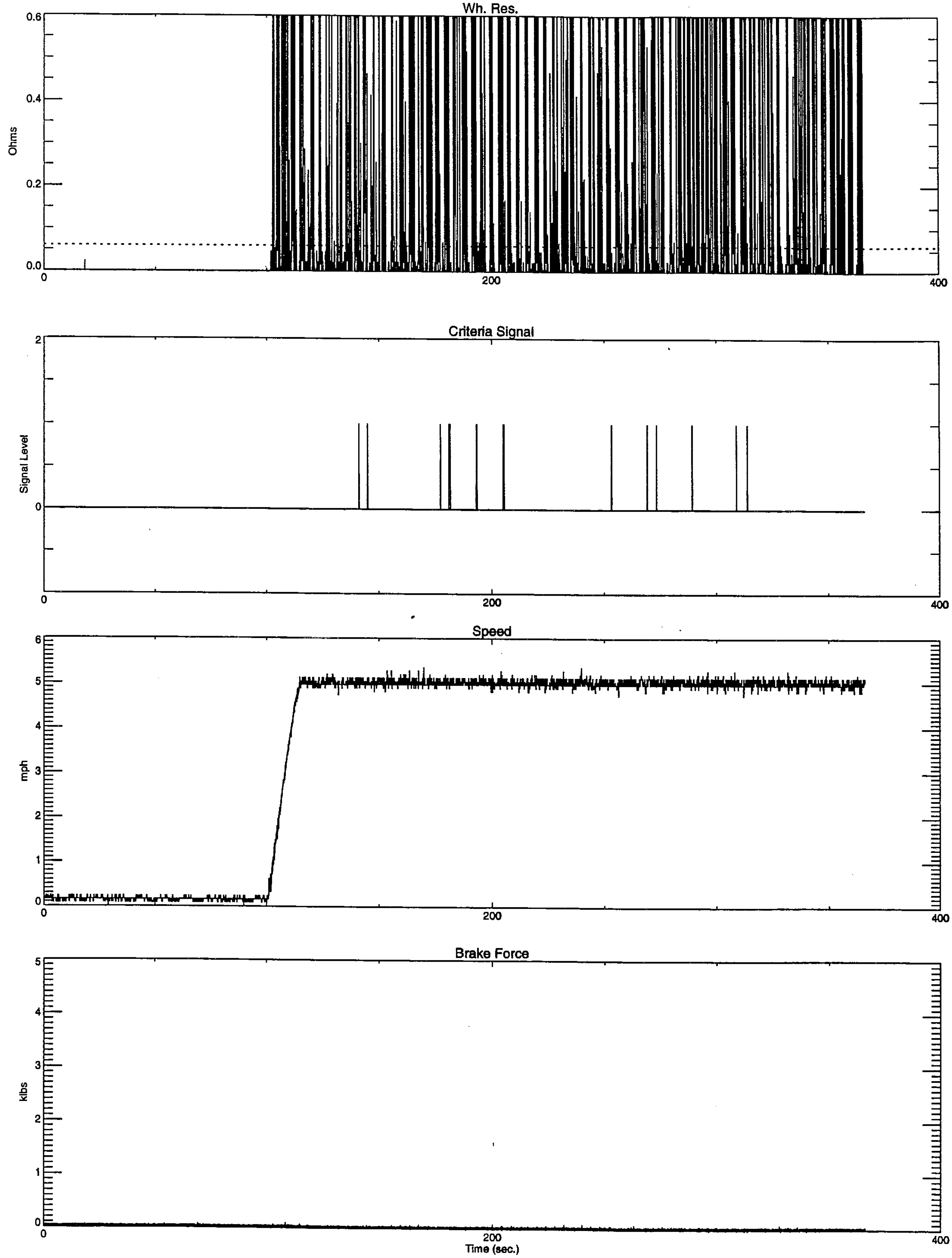
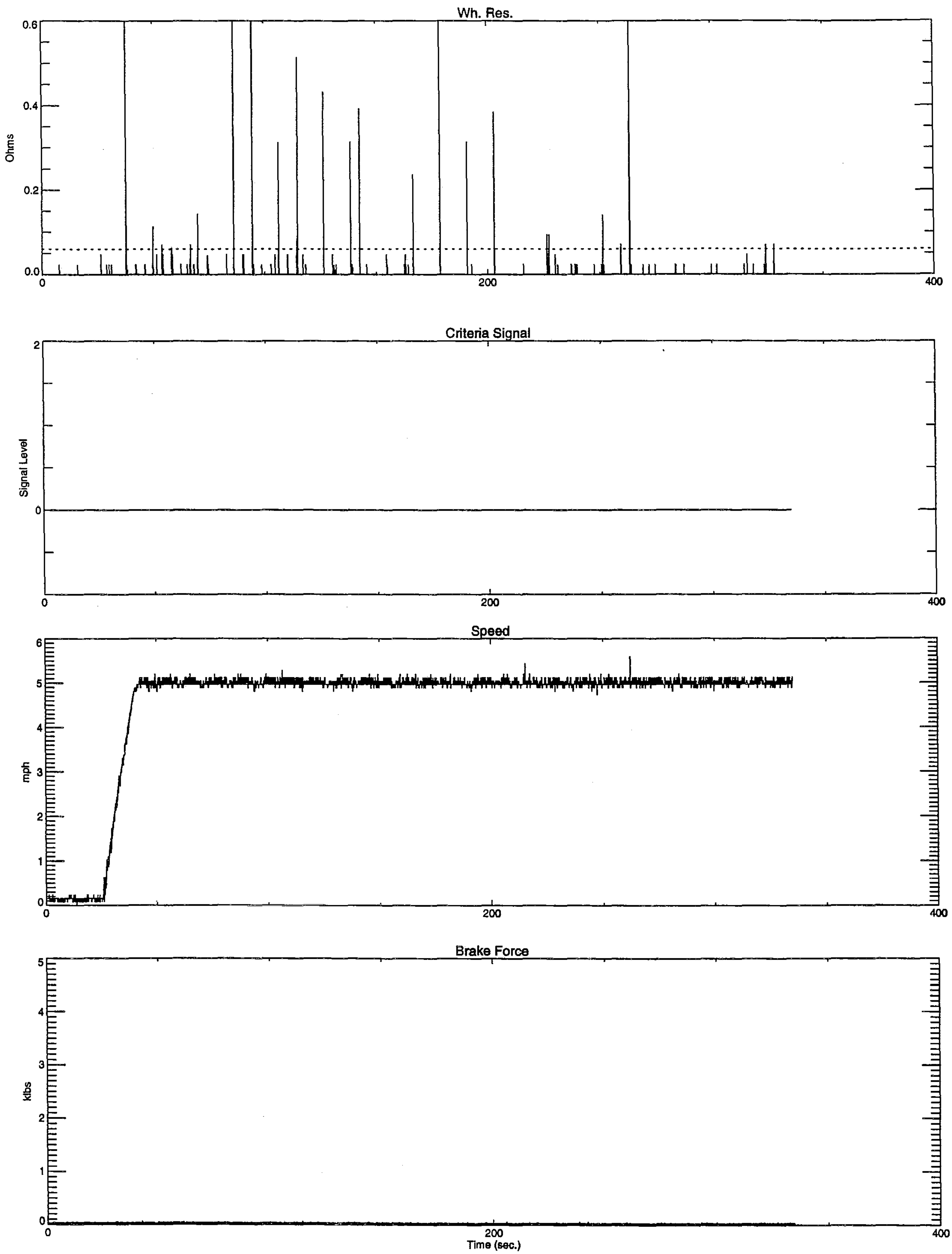
APPENDIX D

Data Runs

Run 000a - Wheel Load 6,300 lbs.

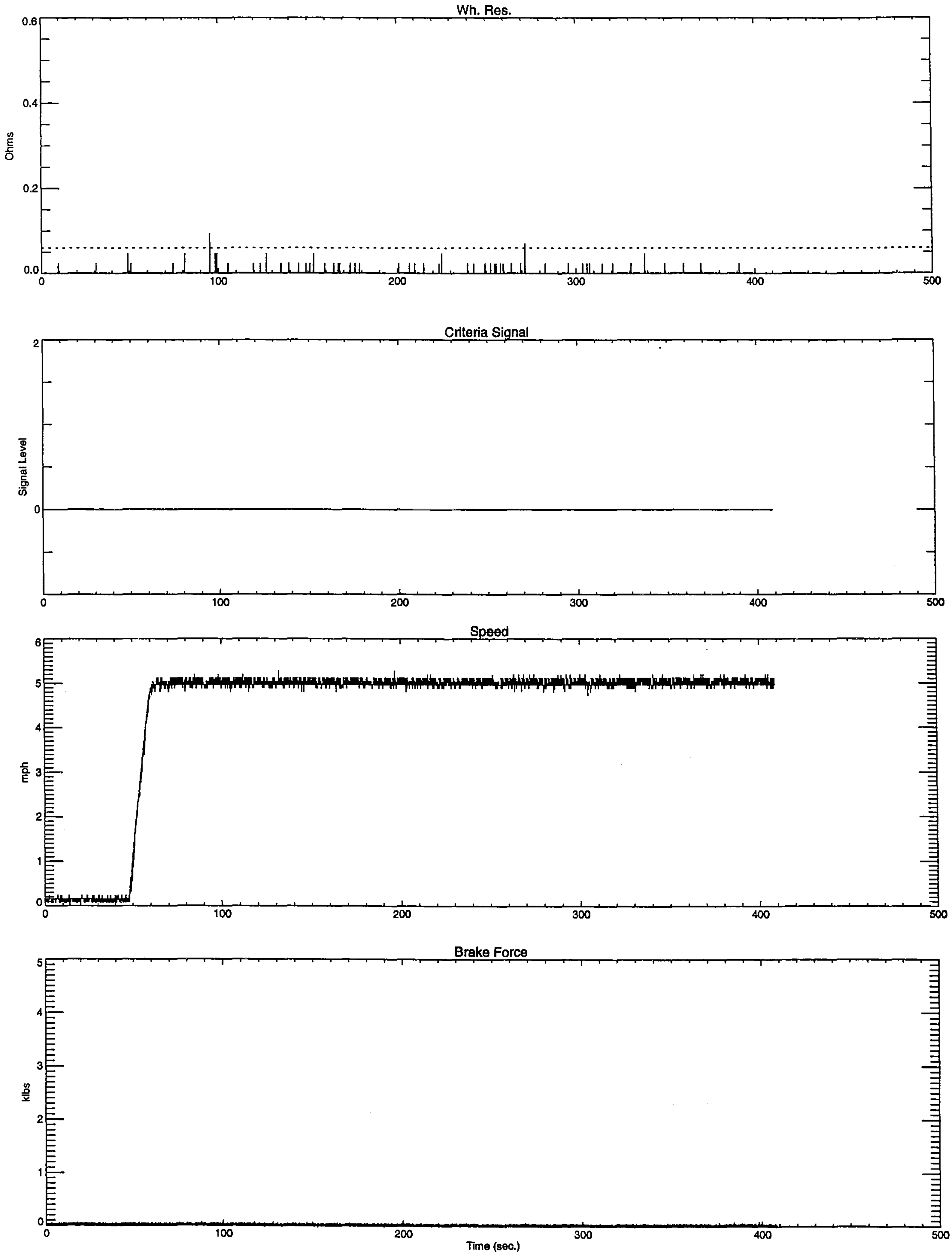


Run 003 A

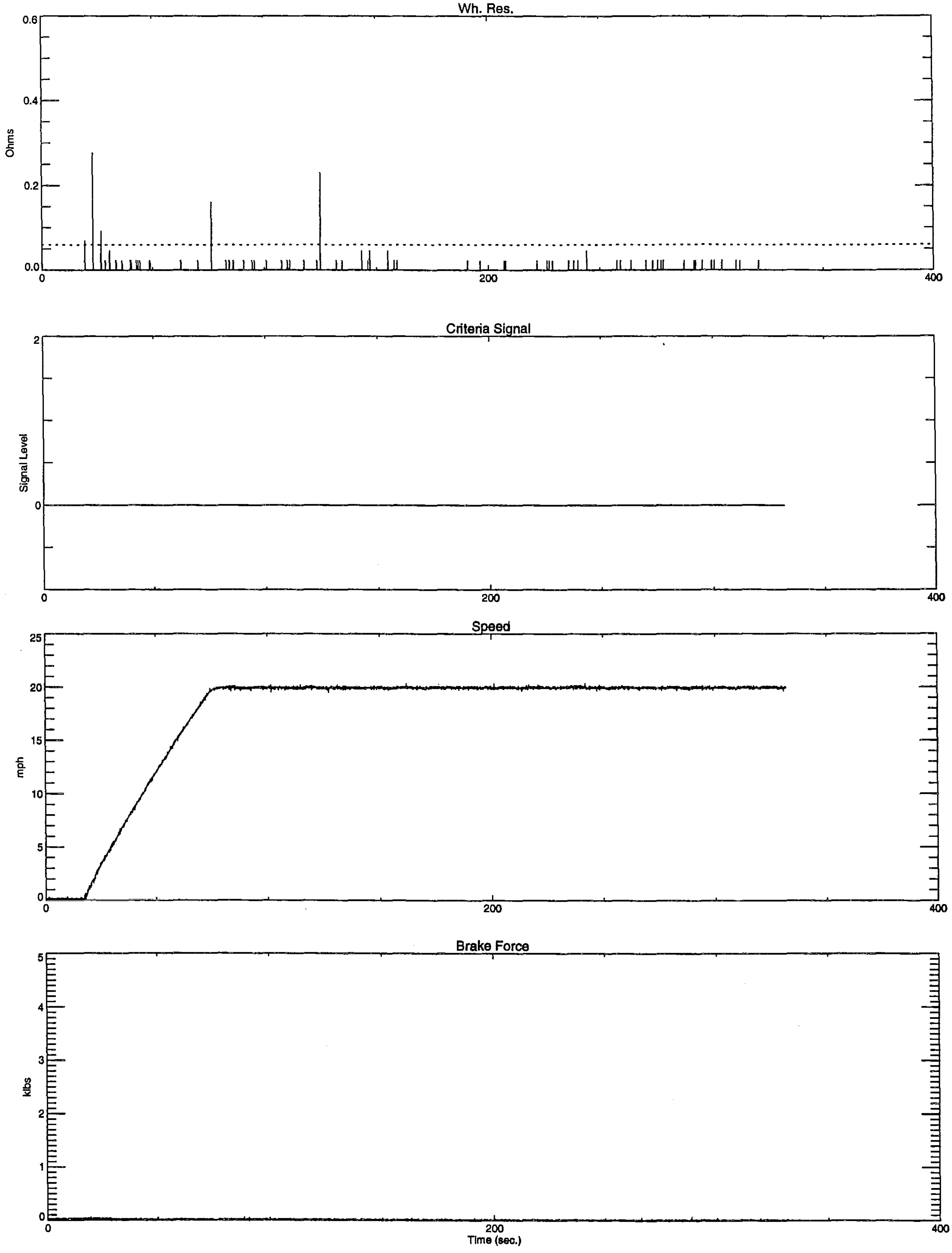


Wh. Res.
Ohms
0.6
0.4
0.2
0.0
0
200
400
Criteria Signal
Signal Level
2
0
0
200
400
Speed
mph
6
5
4
3
2
1
0
0
200
400
Brake Force
klbs
5
4
3
2
1
0
0
200
400
Time (sec.)

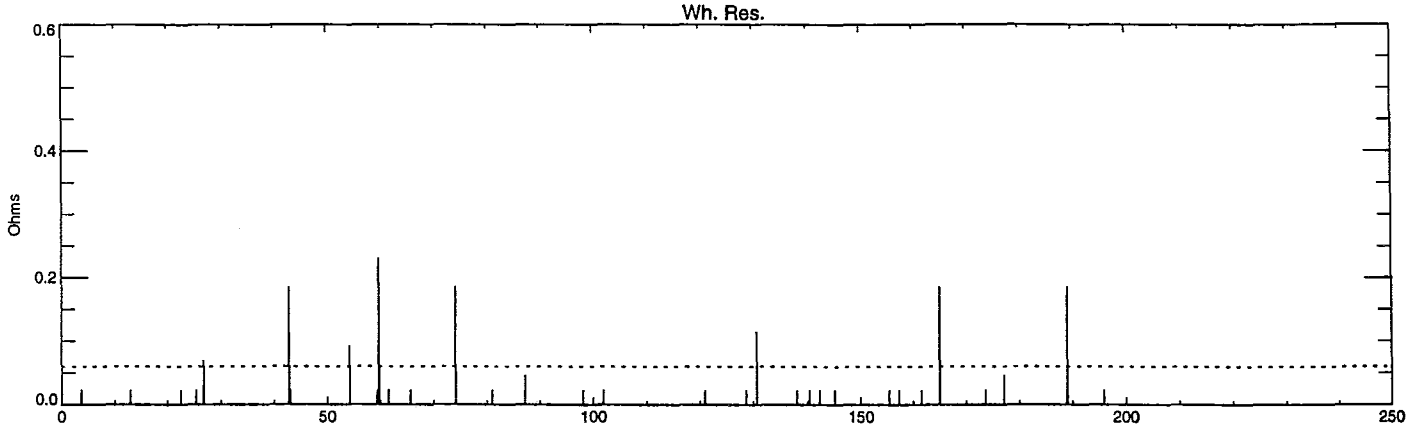
Run 004 A - 6,300 lbs.

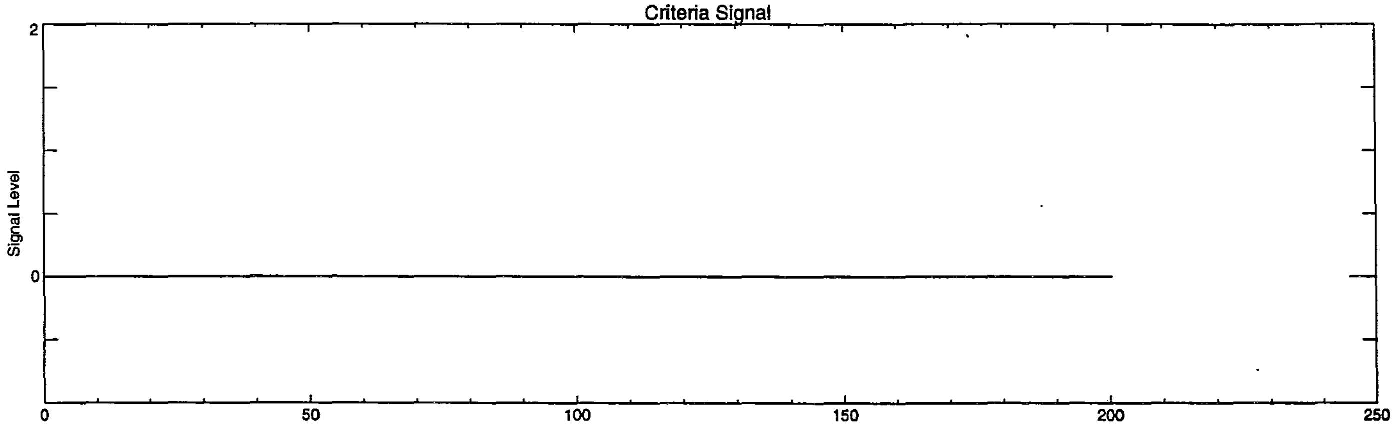


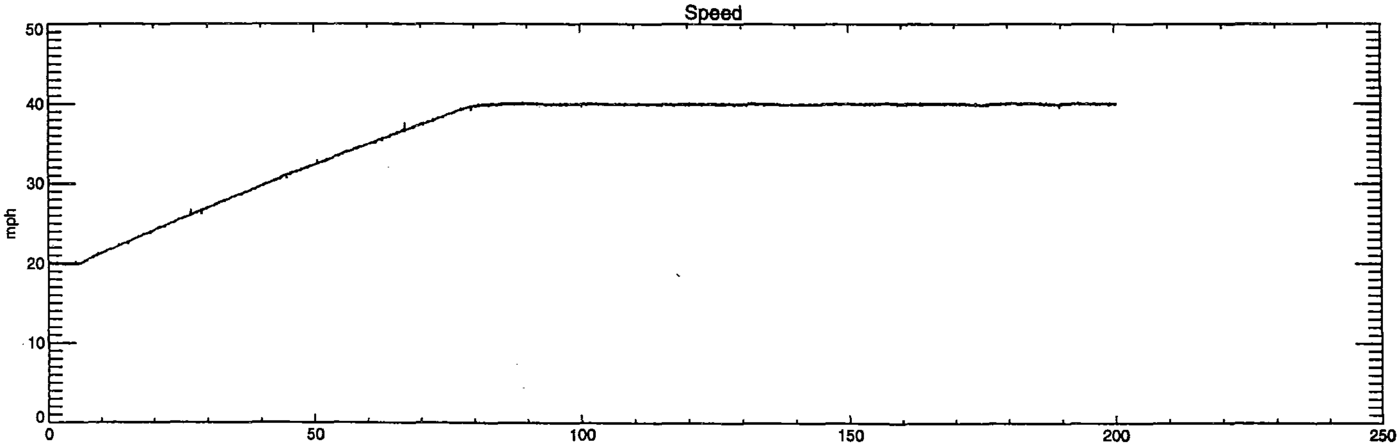
Run 005 A - Wheel Load 6,300 lbs.

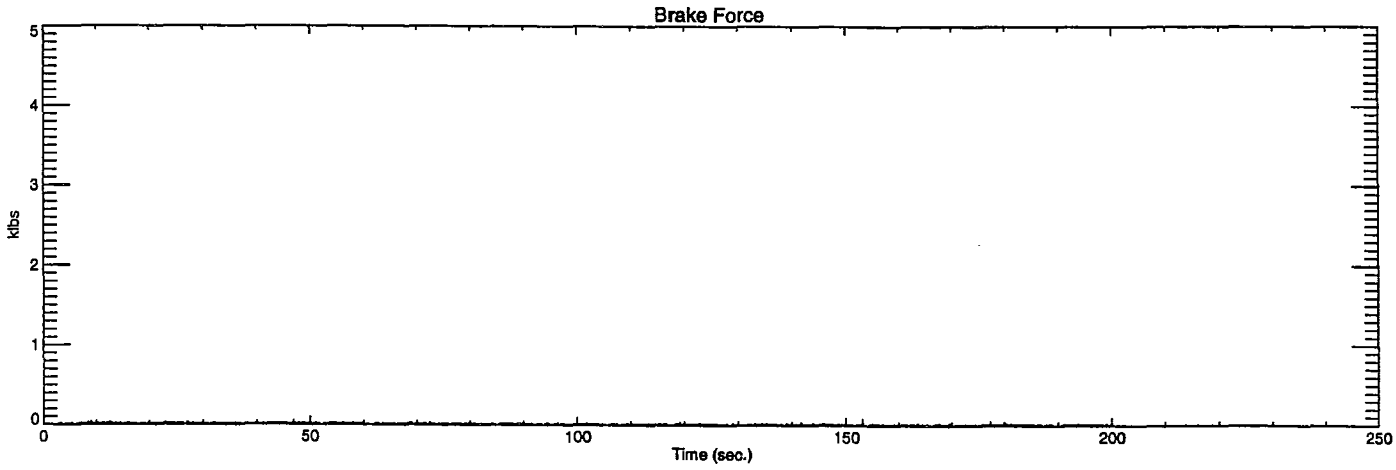


Run 006 A - Wheel Load 6,300 lbs.

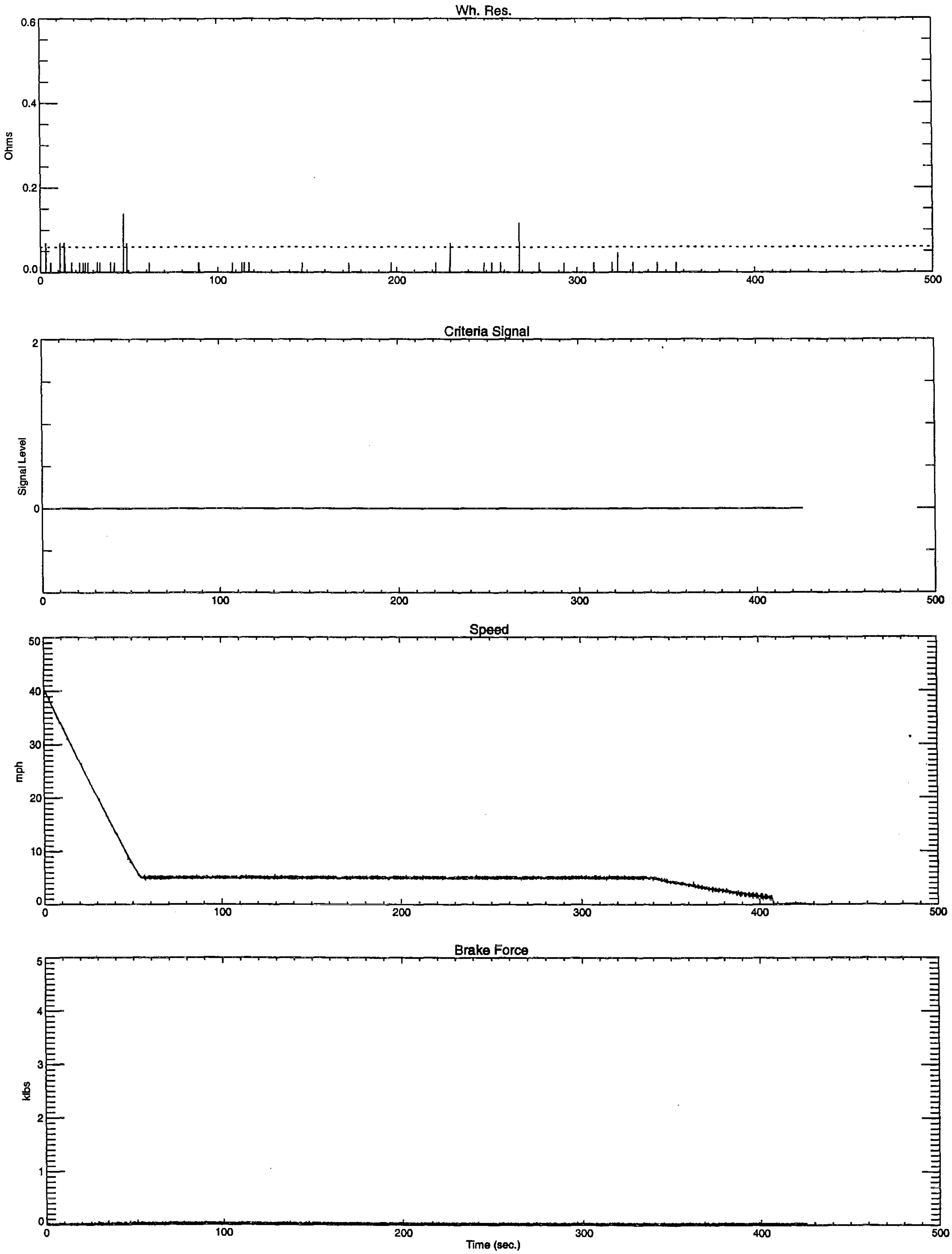




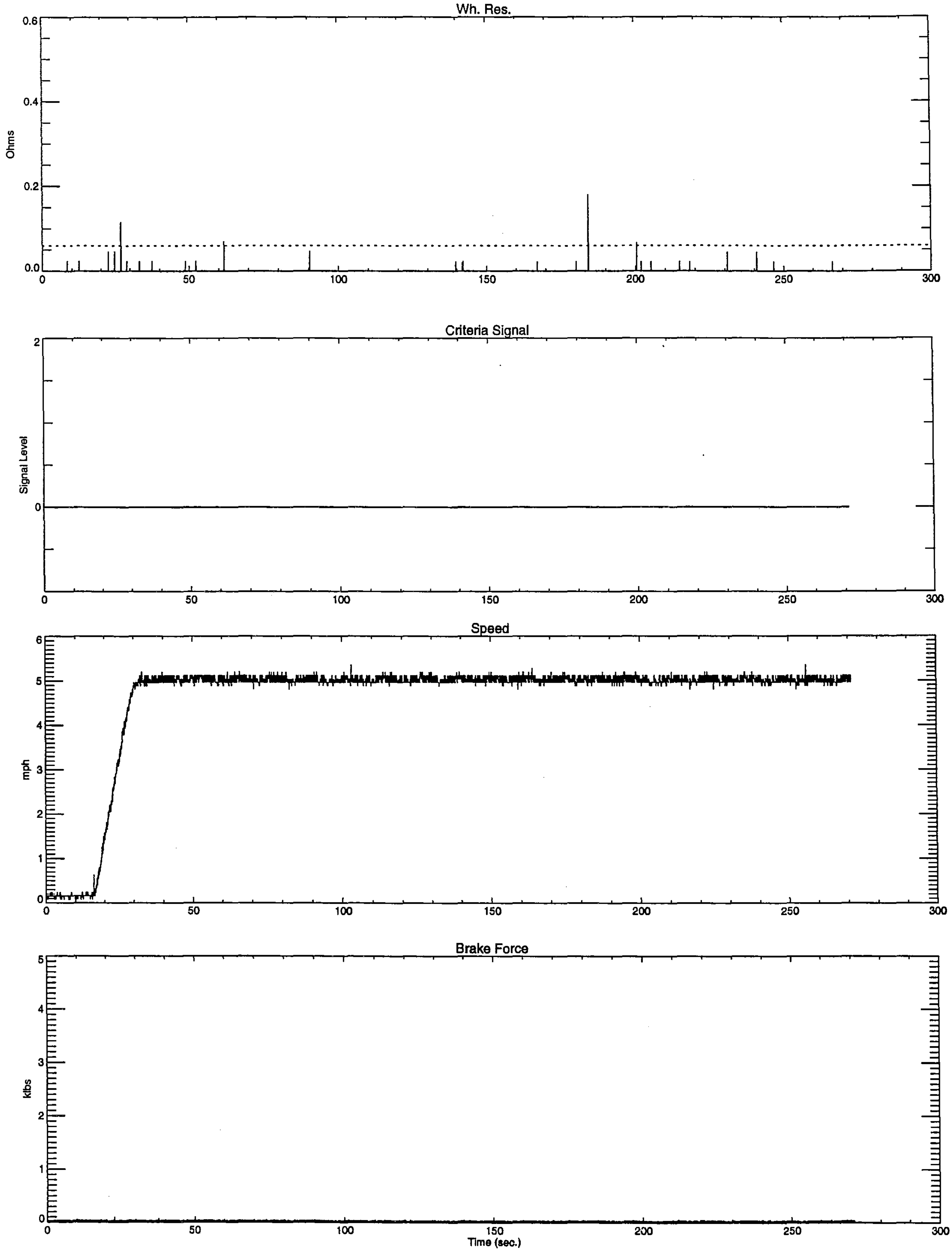




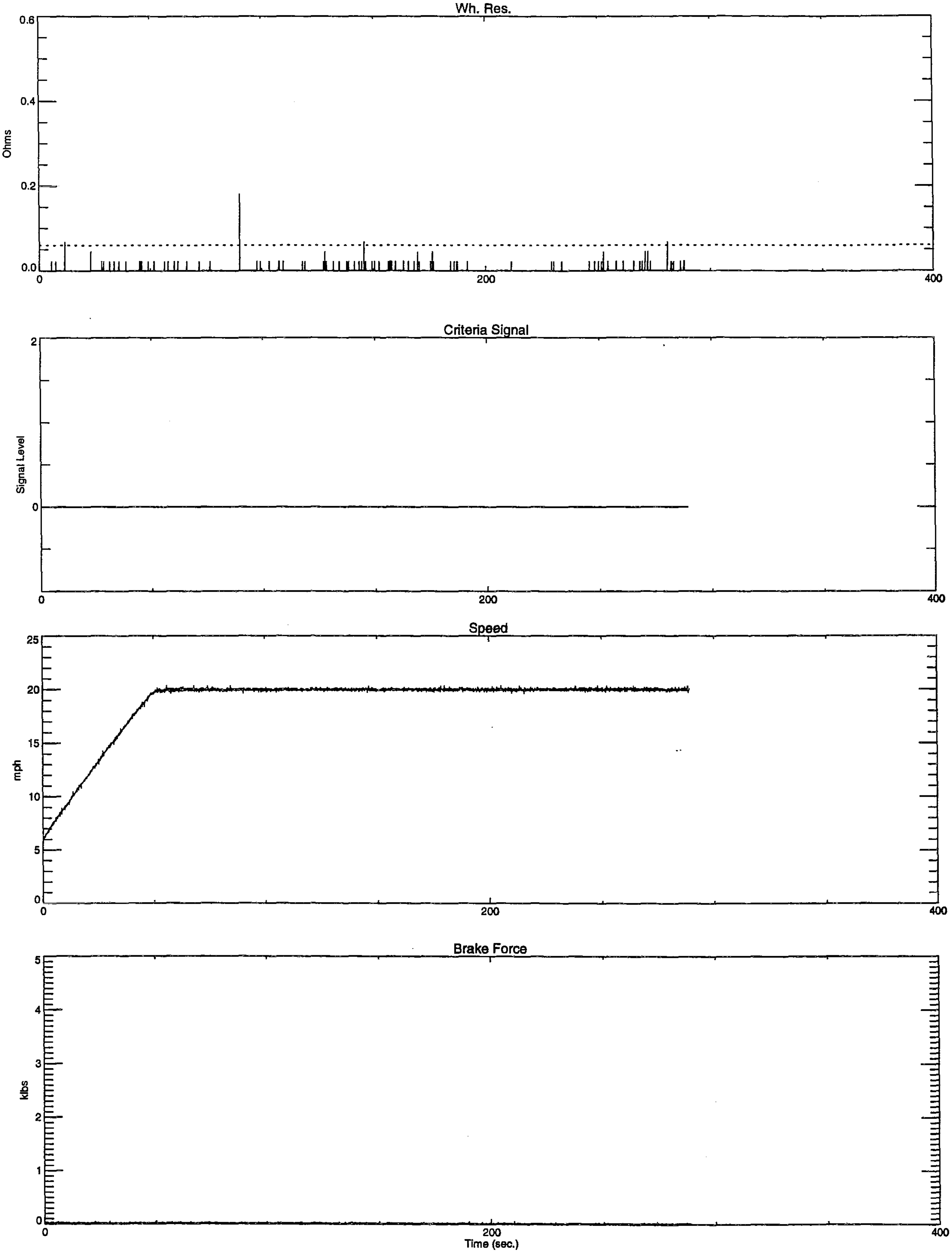
Run 007 A - Wheel Load 6,300 lbs.



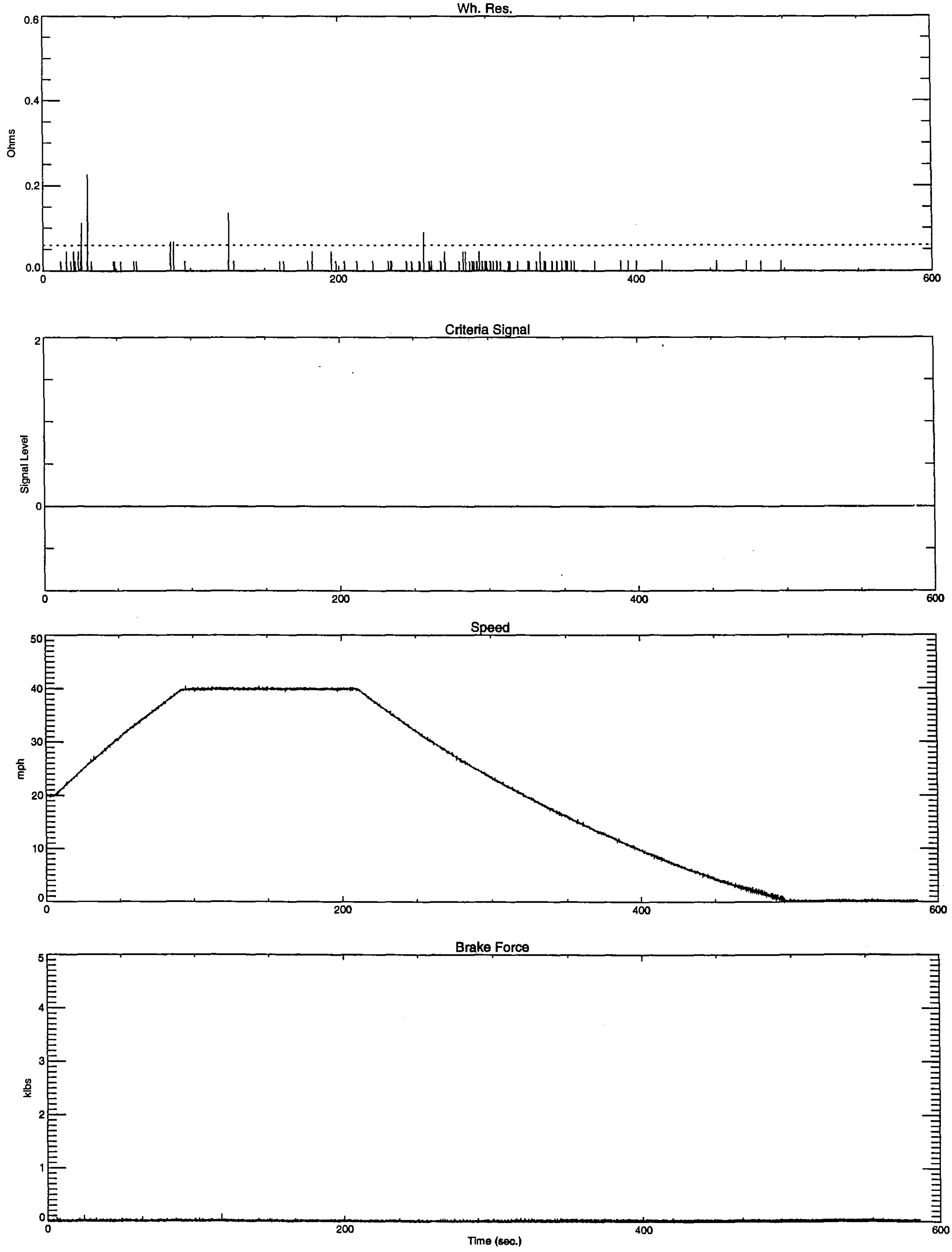
Run 008 A - Wheel Load 32,000 lbs.



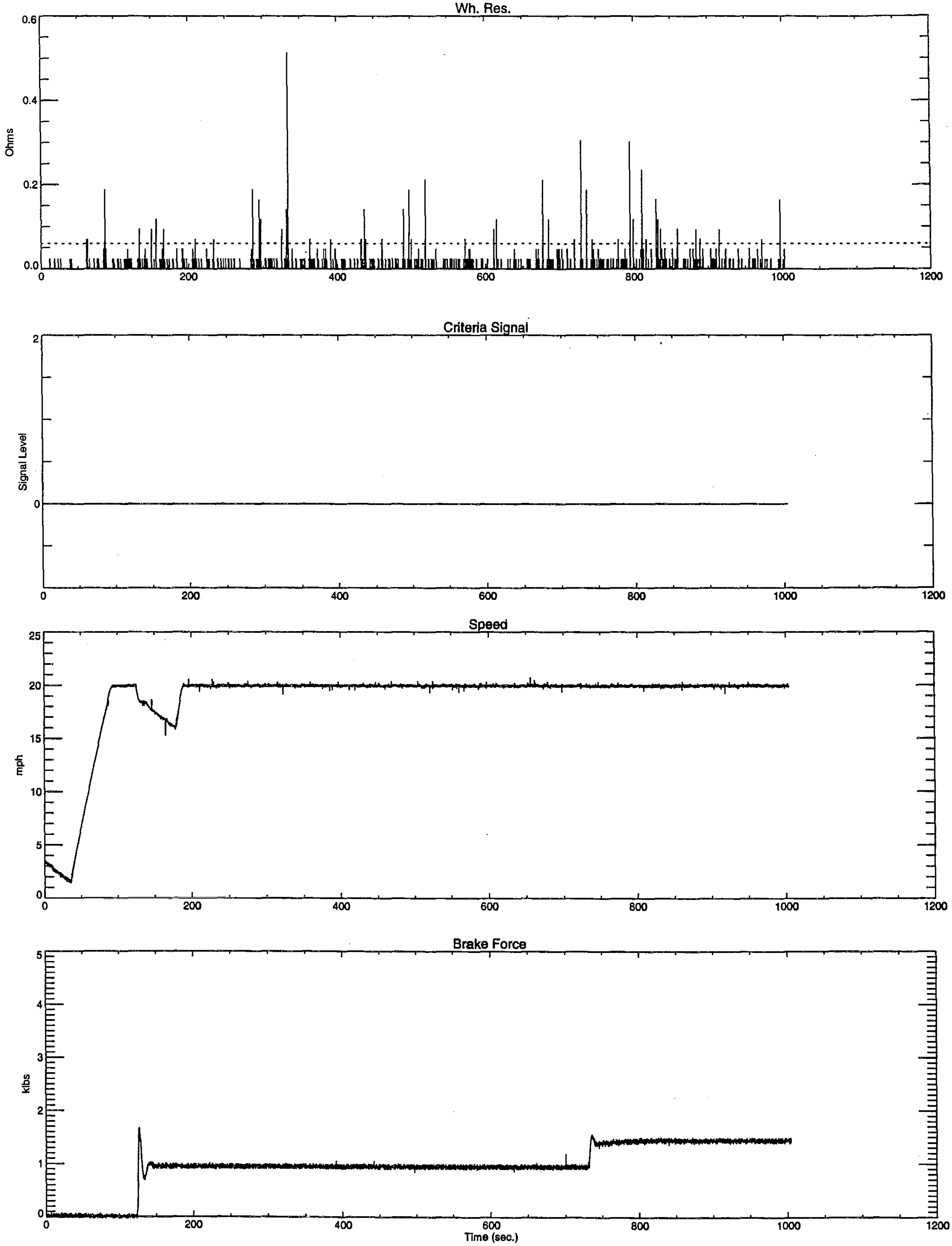
Run 009 A - Wheel Load 32,000 lbs.



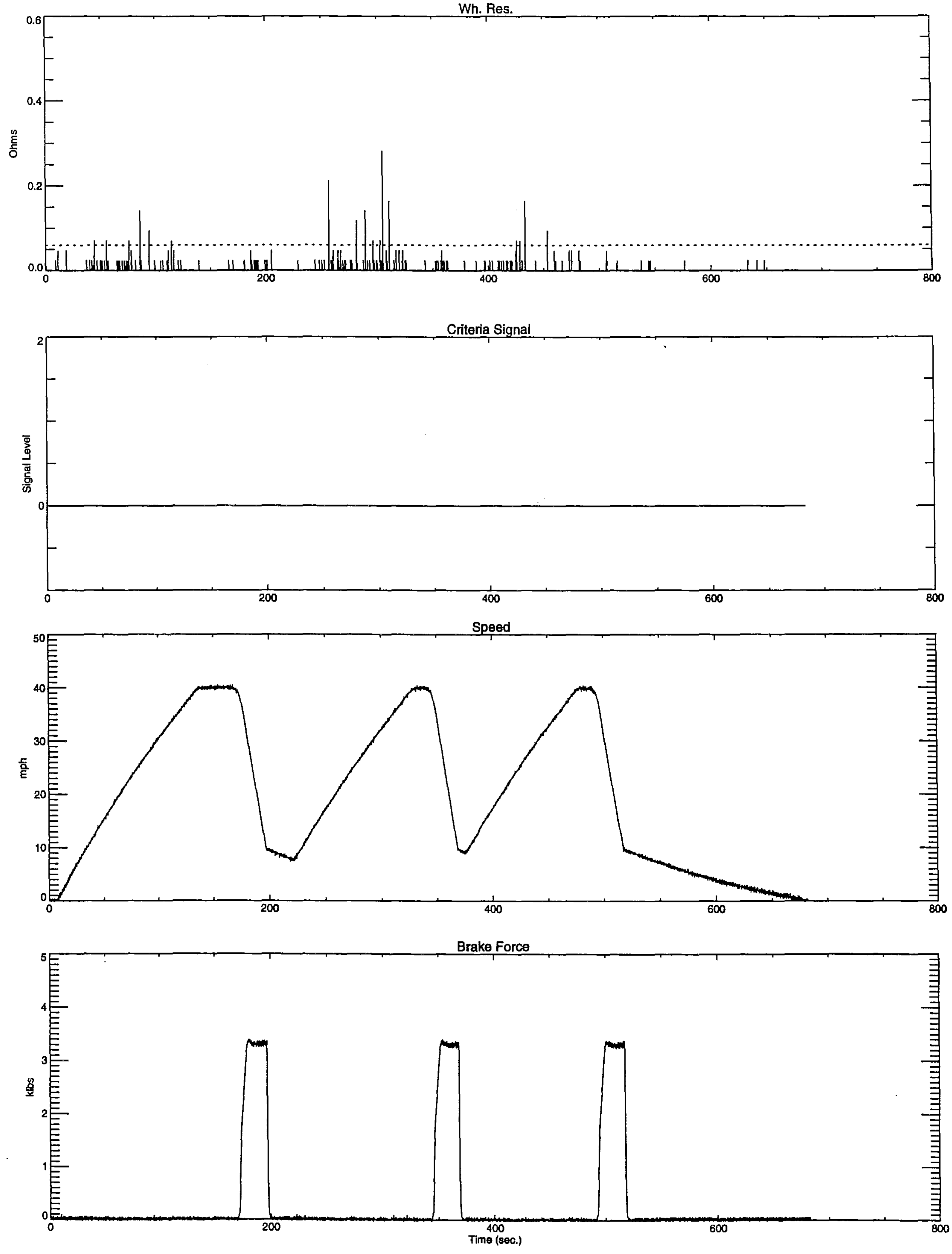
Run 010 A - Wheel Load 32,000 lbs.



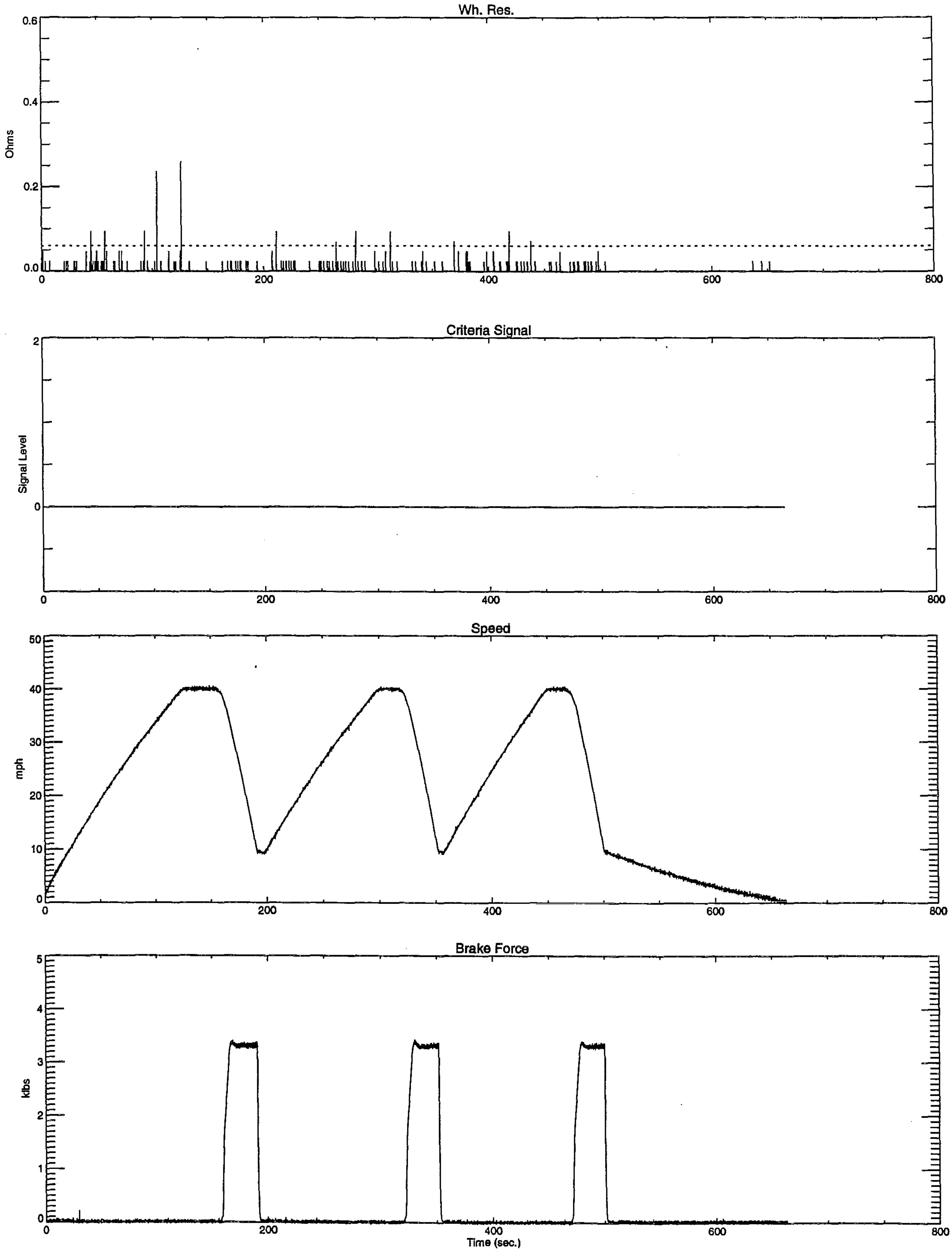
Run 011 A - Wheel Load 6,300 lbs.



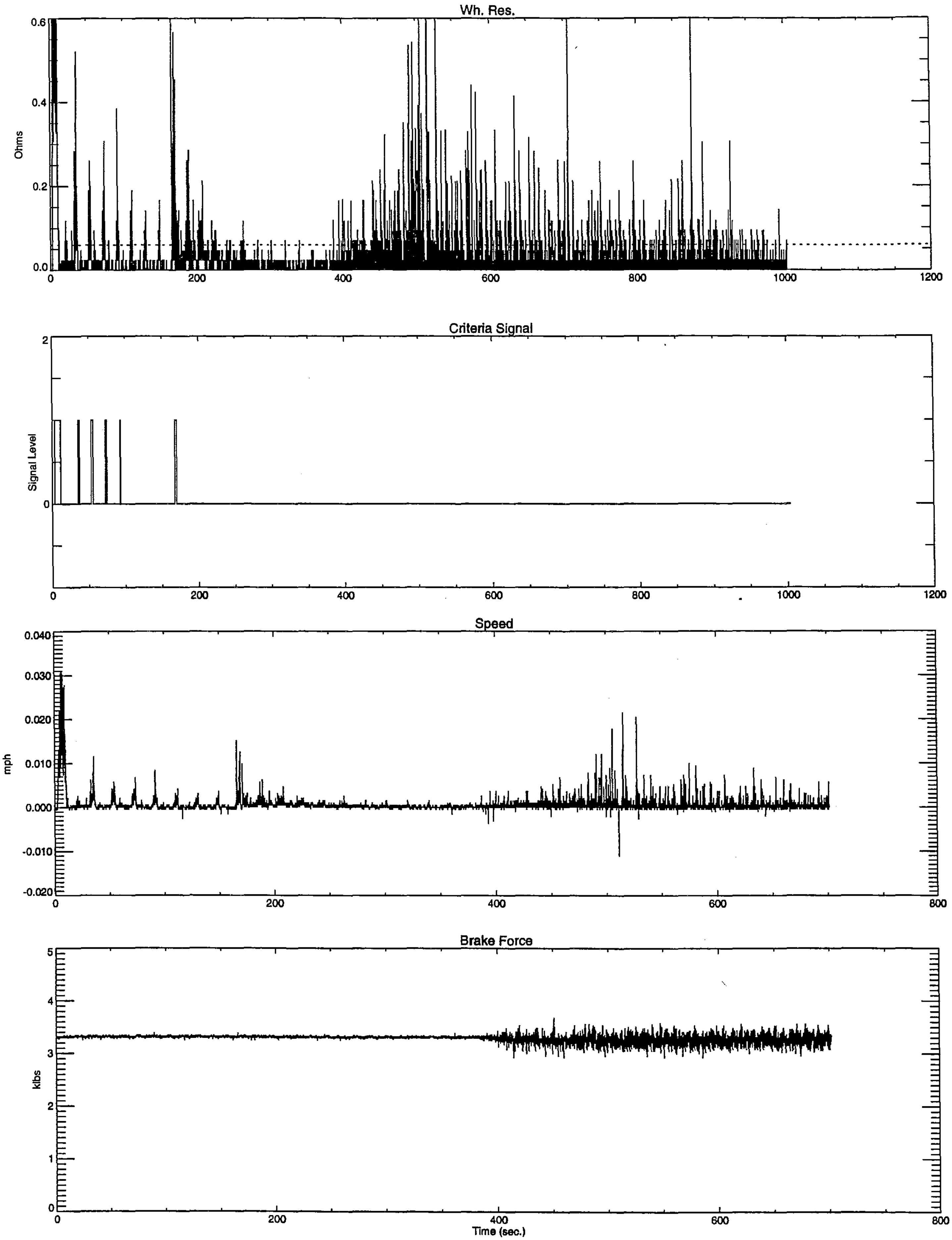
Run 013 A - Wheel Load 6,300 lbs.



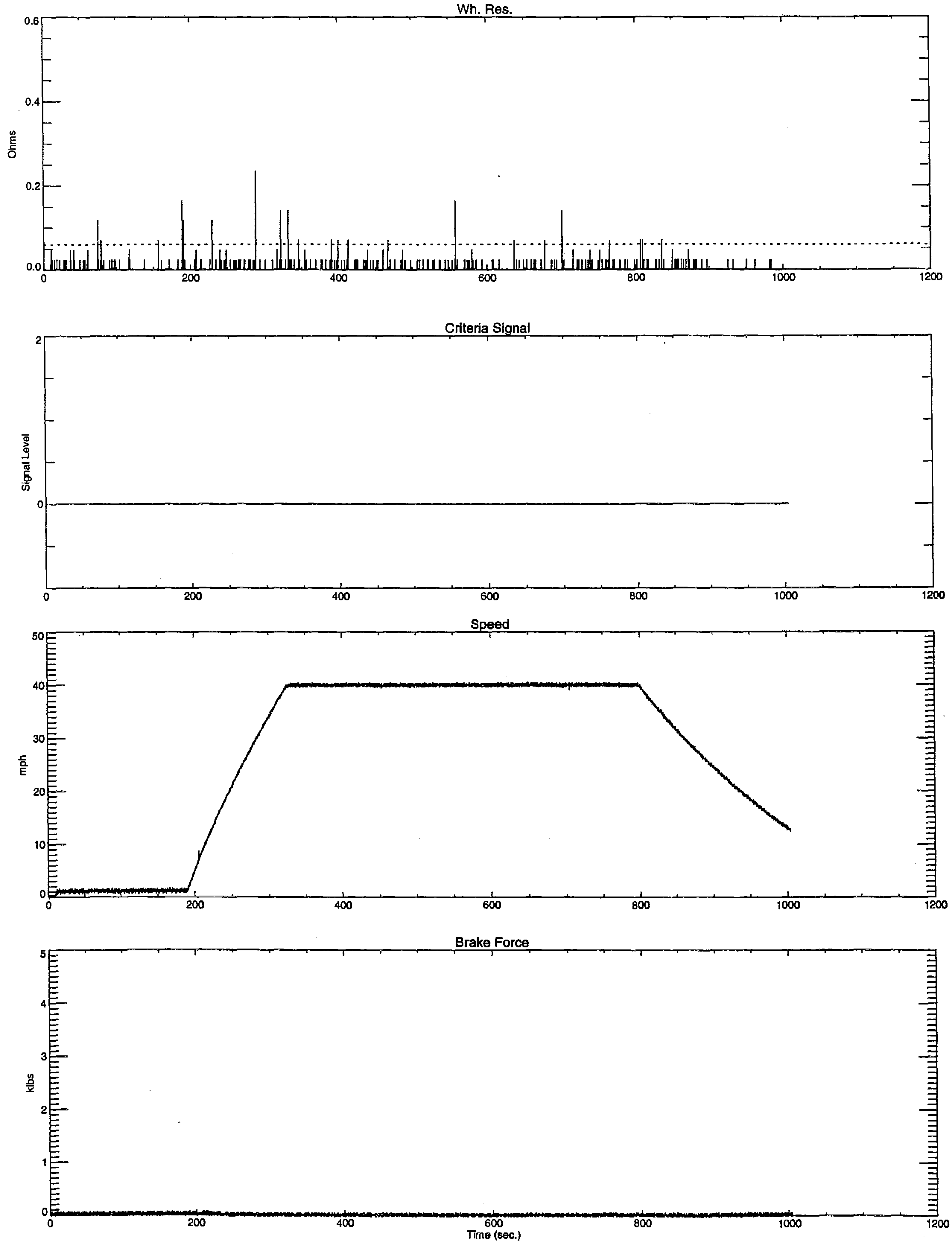
Run 014 A - Wheel Load 6,300 lbs.



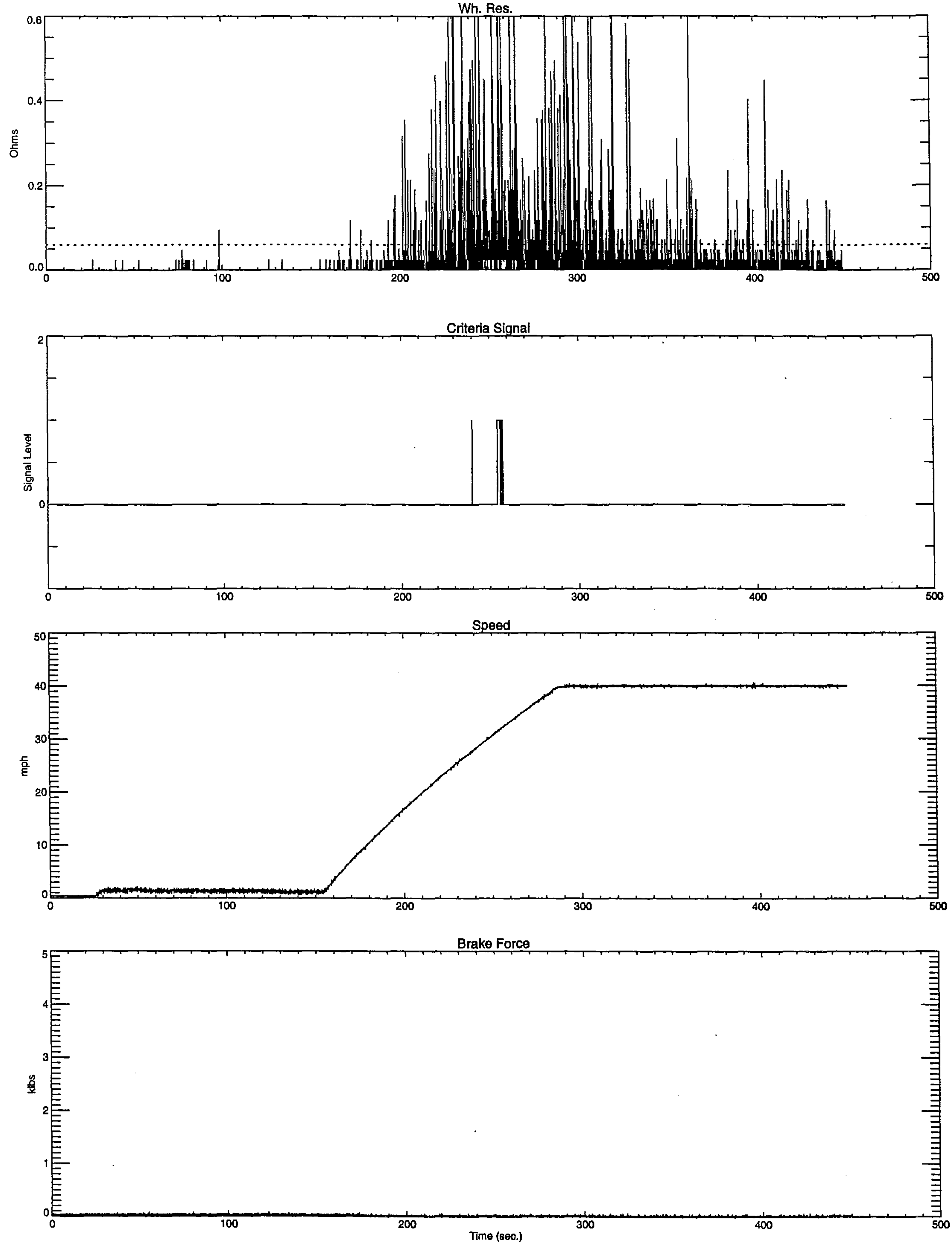
Run 015 A - Wheel Load 6,300 lbs.



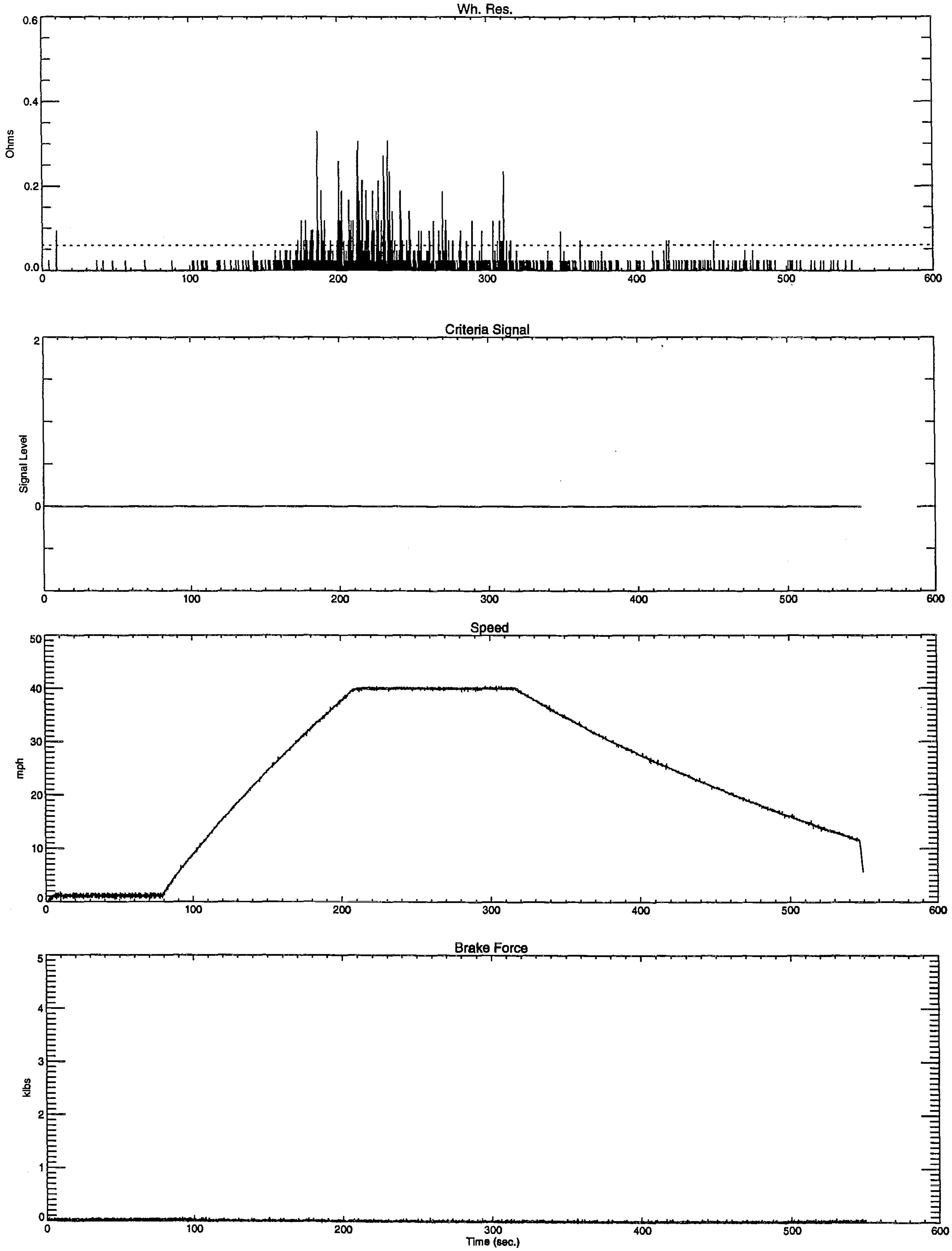
Run 016 A - Wheel Load 32,000 lbs.



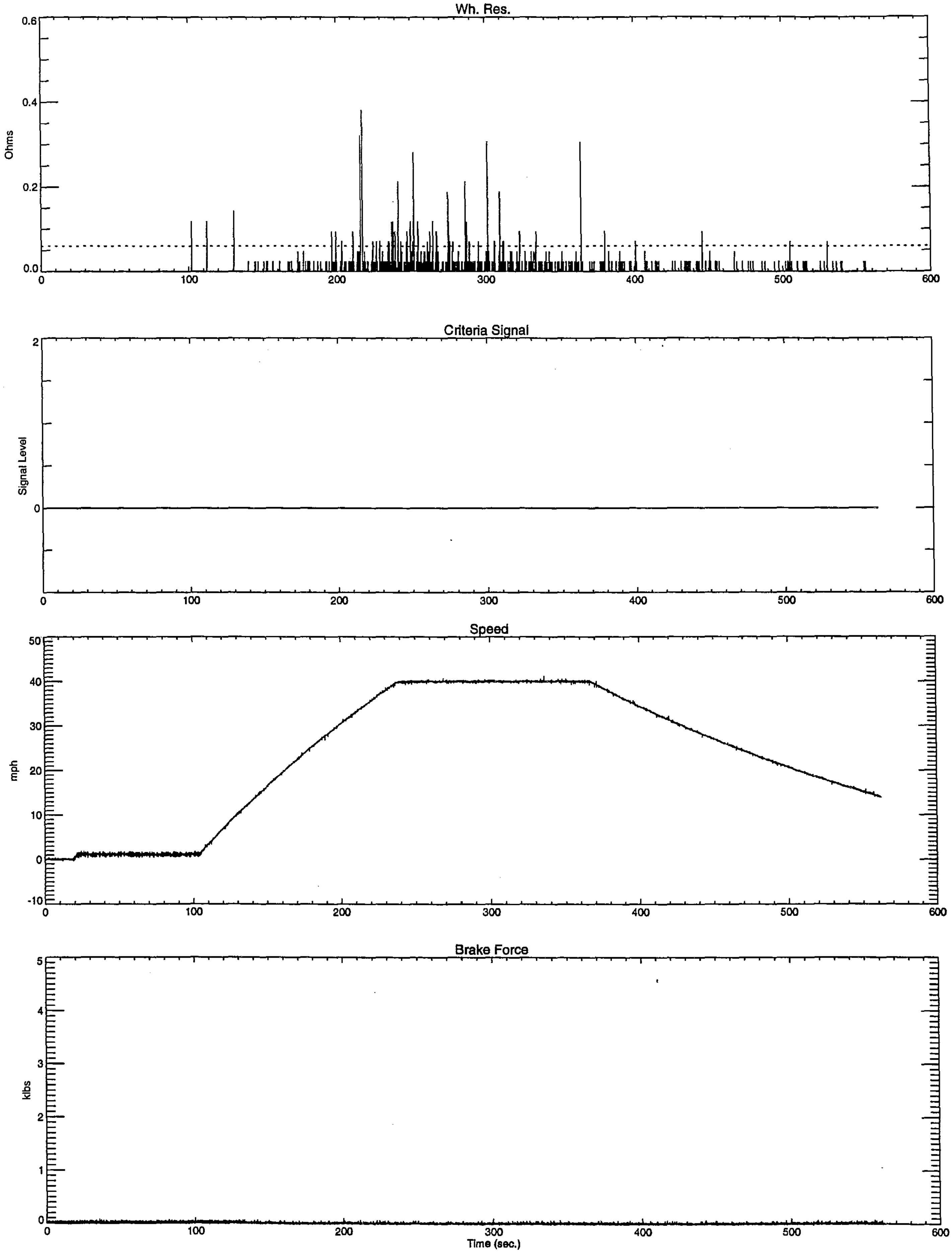
Run 017 A - Wheel Load 12,000 lbs.



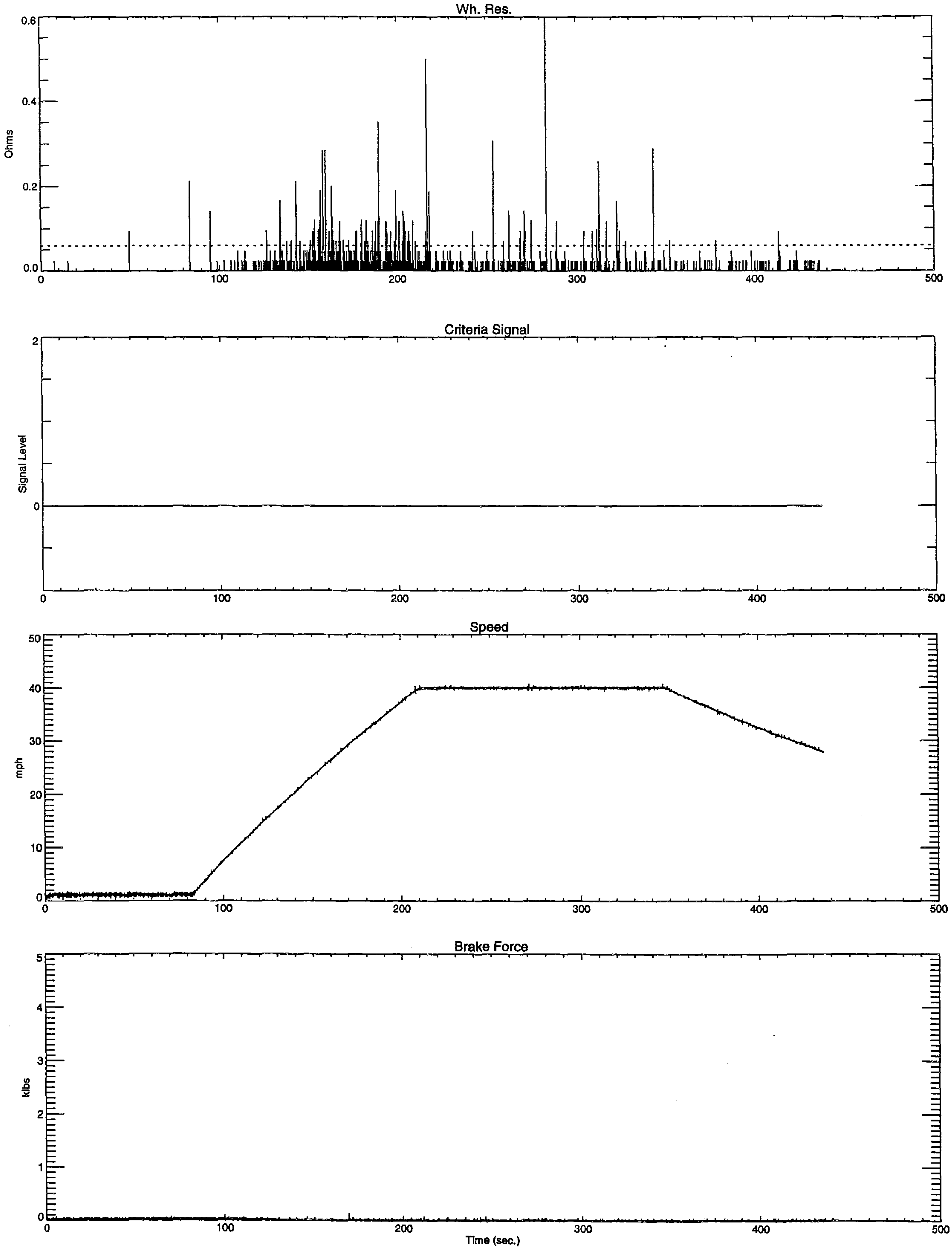
Run 018 A - Wheel Load 18,000 lbs.



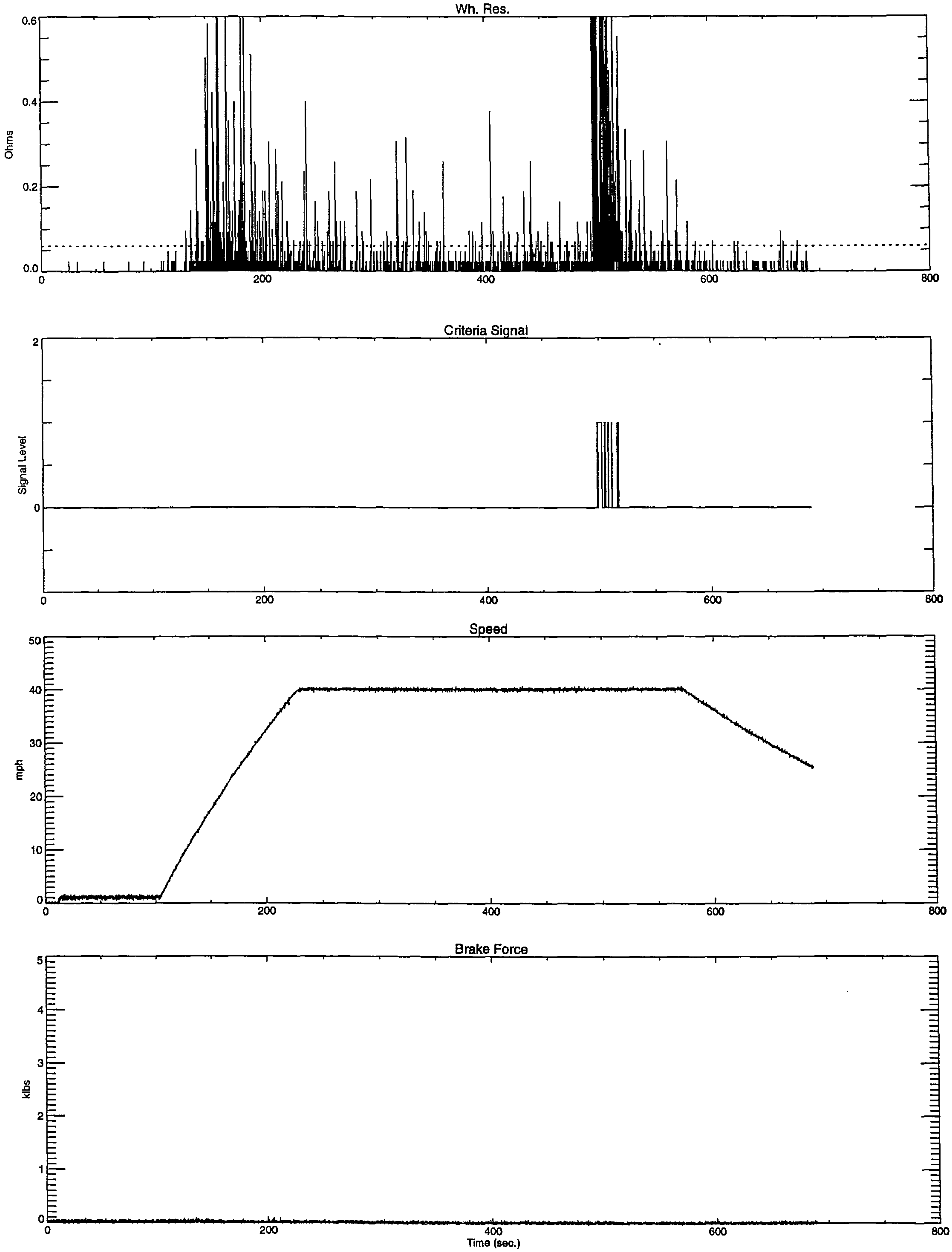
Run 019 A - Wheel Load 24,000 lbs



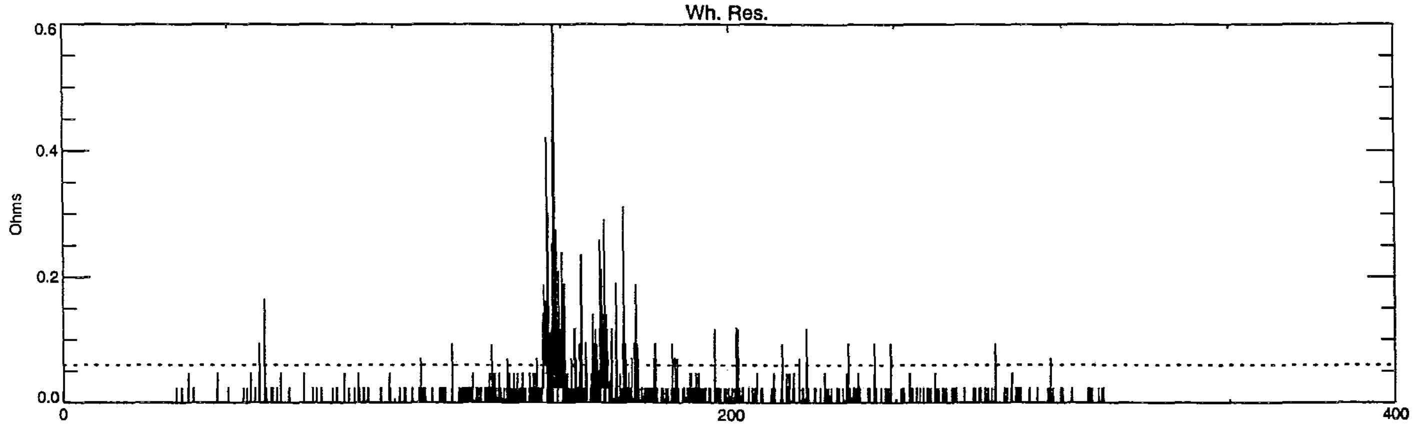
Run 020 A - Wheel Load 9,000 lbs.

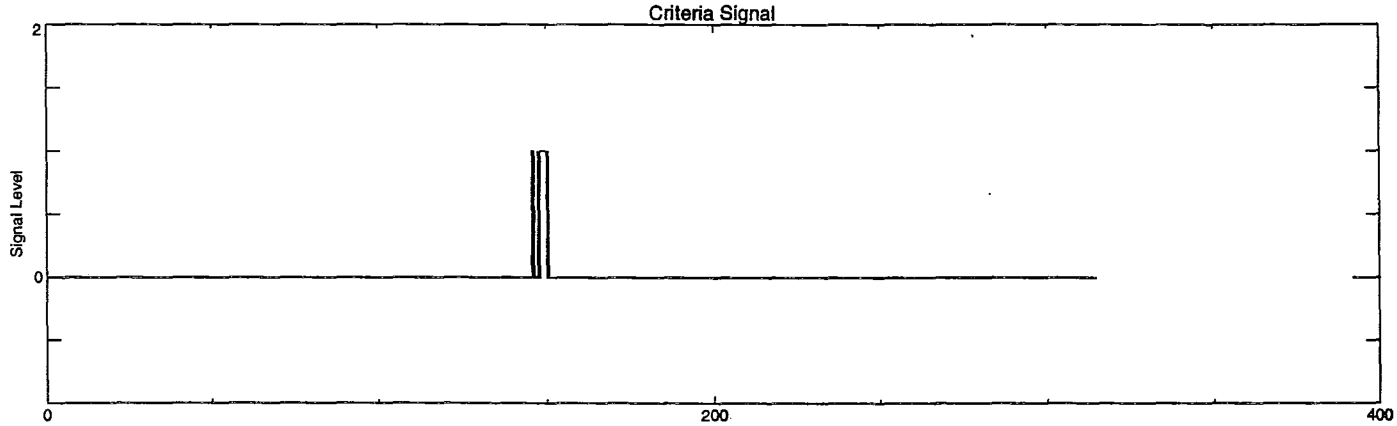


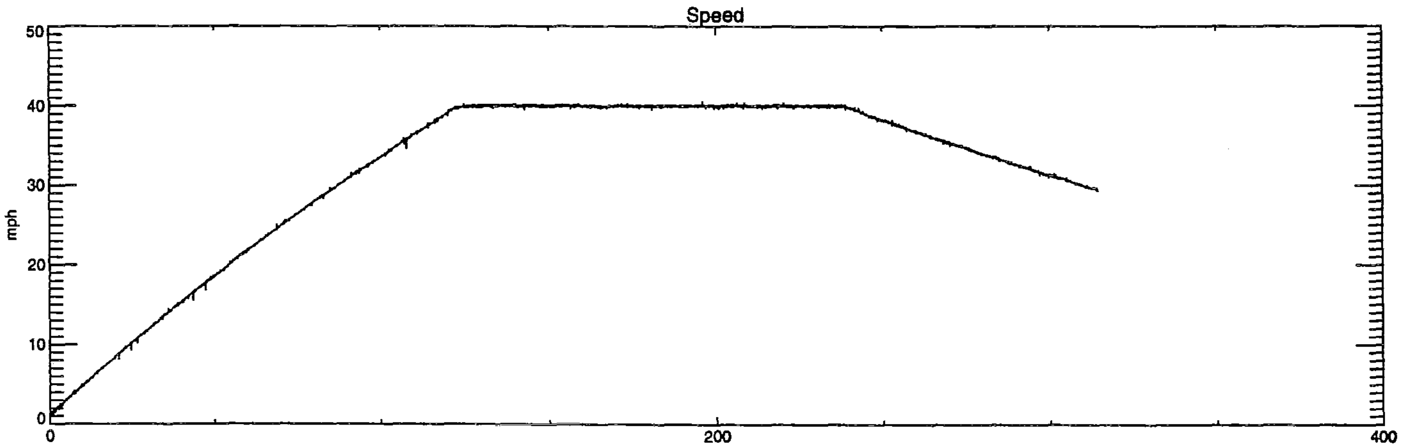
Run 021 A - Wheel Load 6,300 lbs.

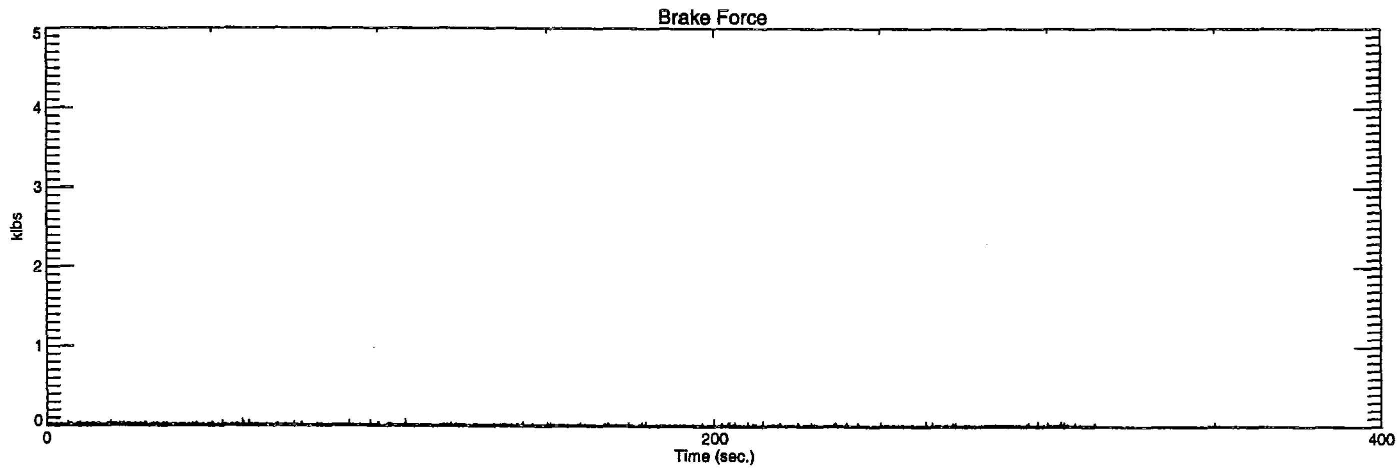


Run 022 A - Wheel Load 12,000 lbs.

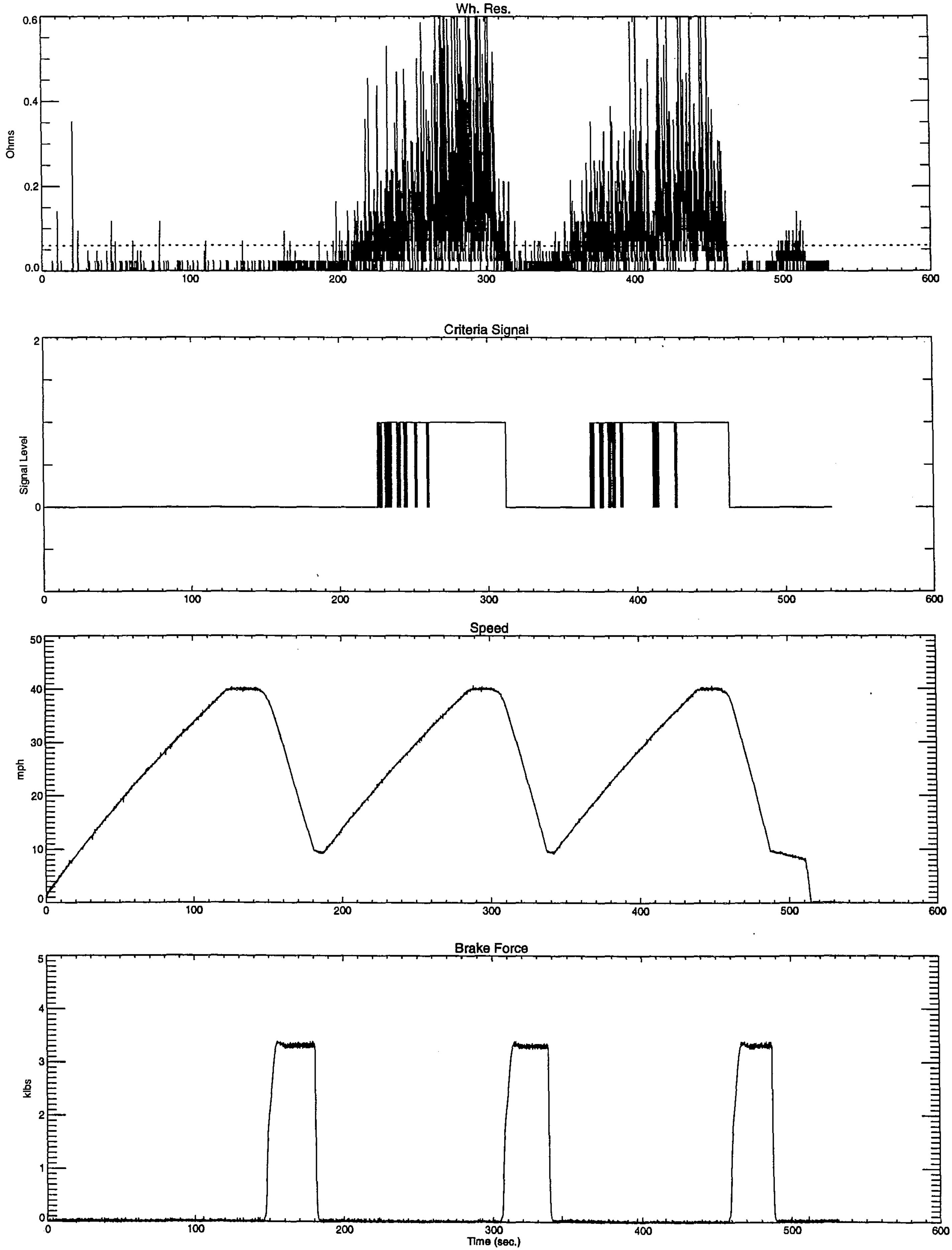




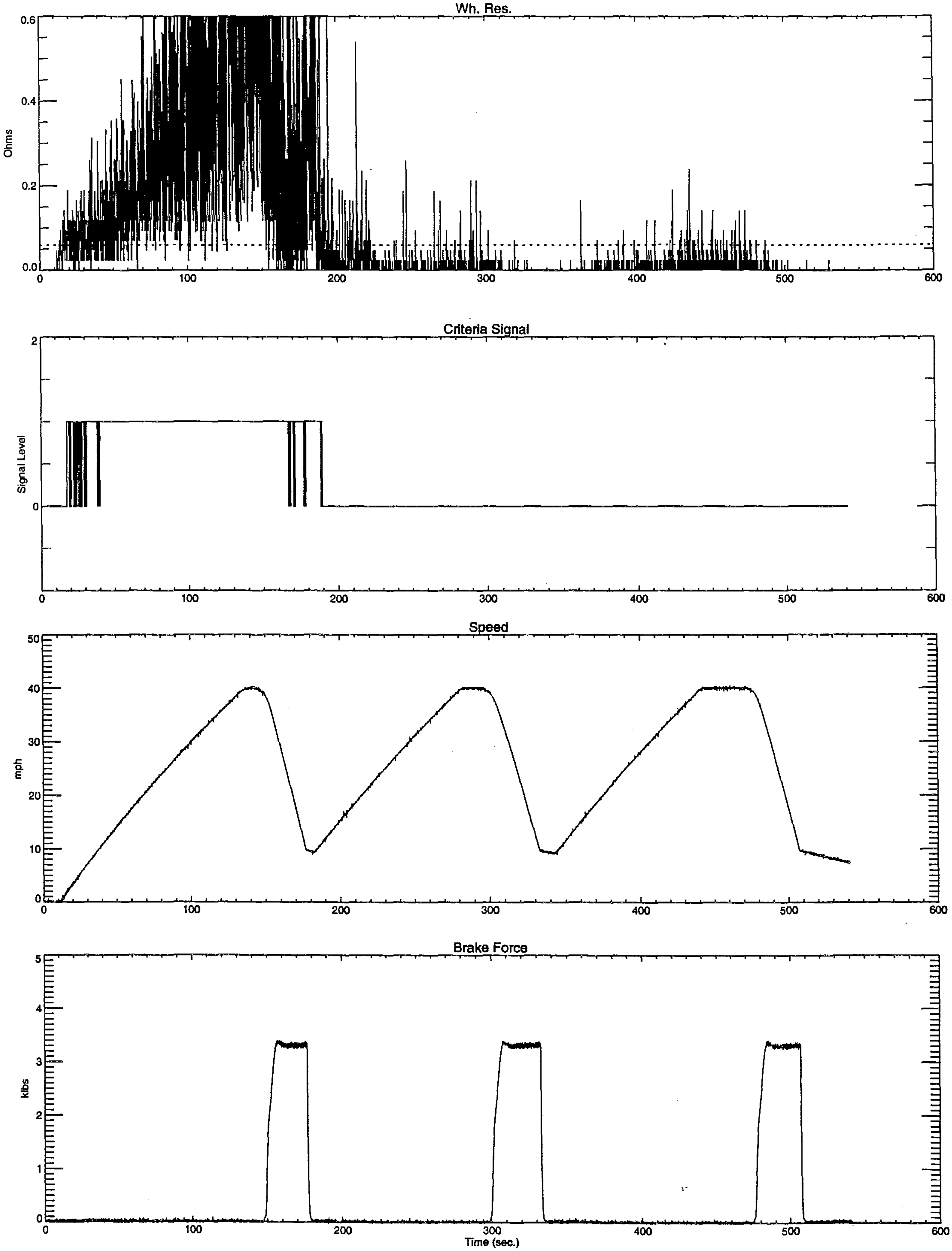




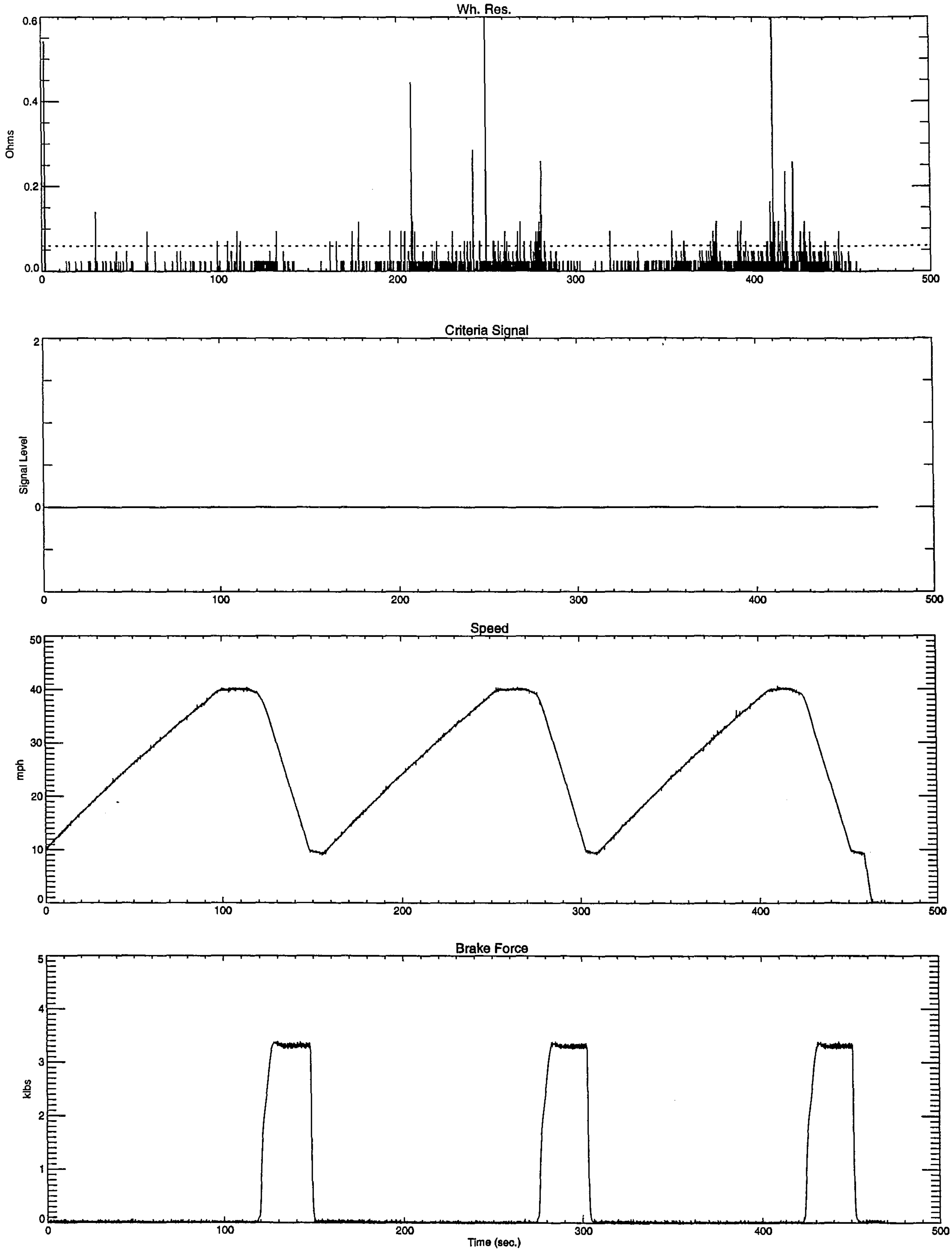
Run 023 A - Wheel Load 6,300 lbs.



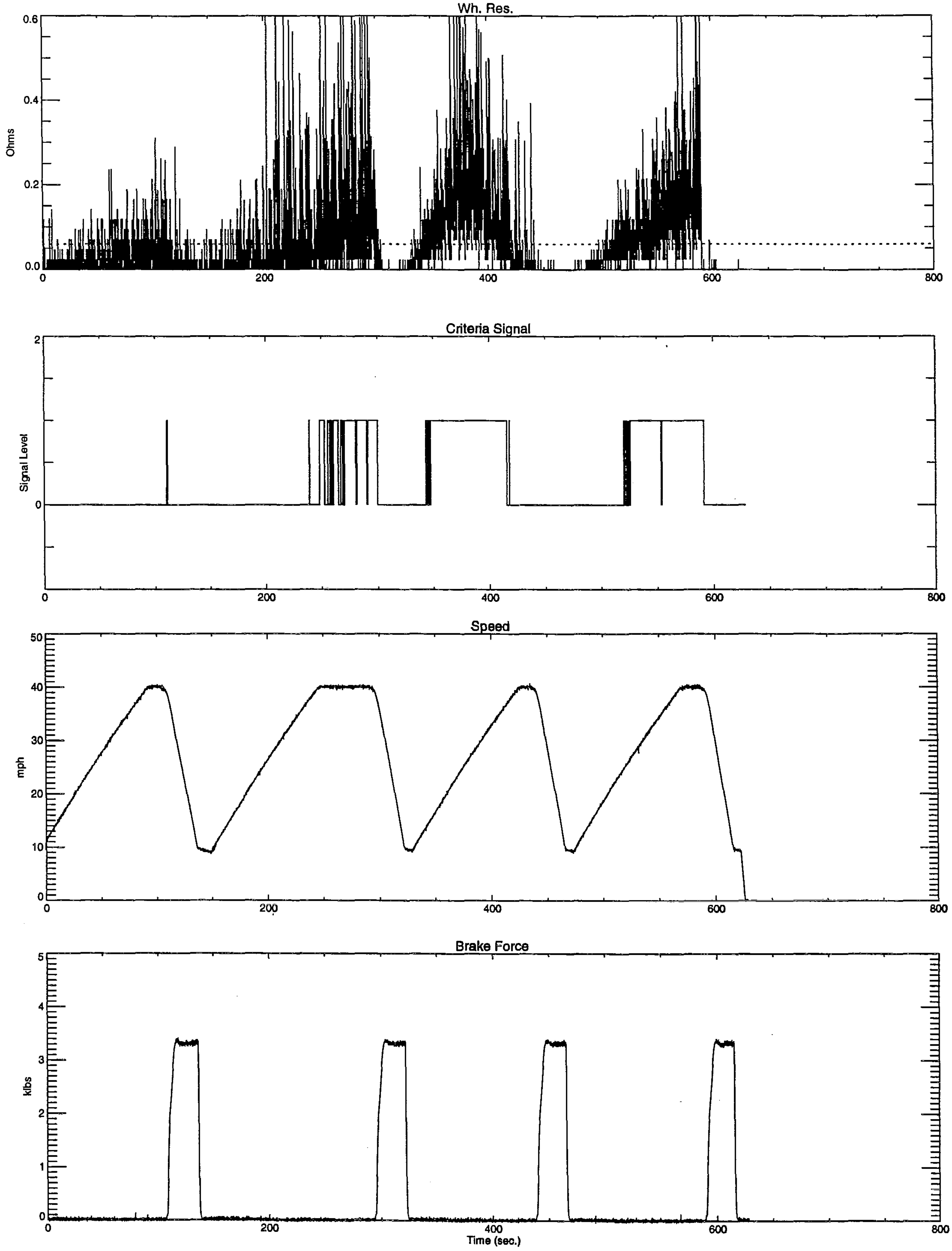
Run 024 A - Wheel Load 6,300 lbs.



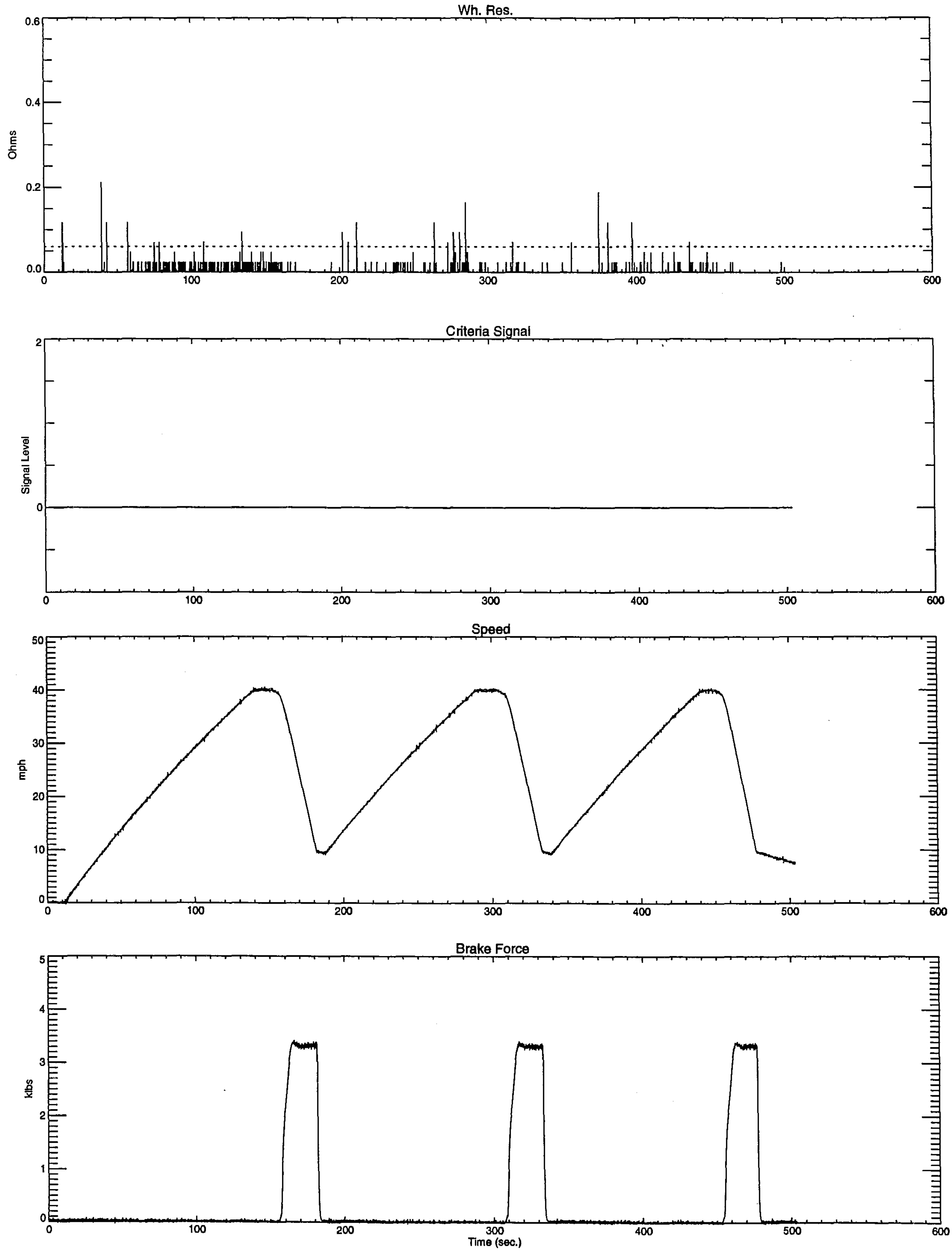
Run 025 A - Wheel Load 6,300 lbs.



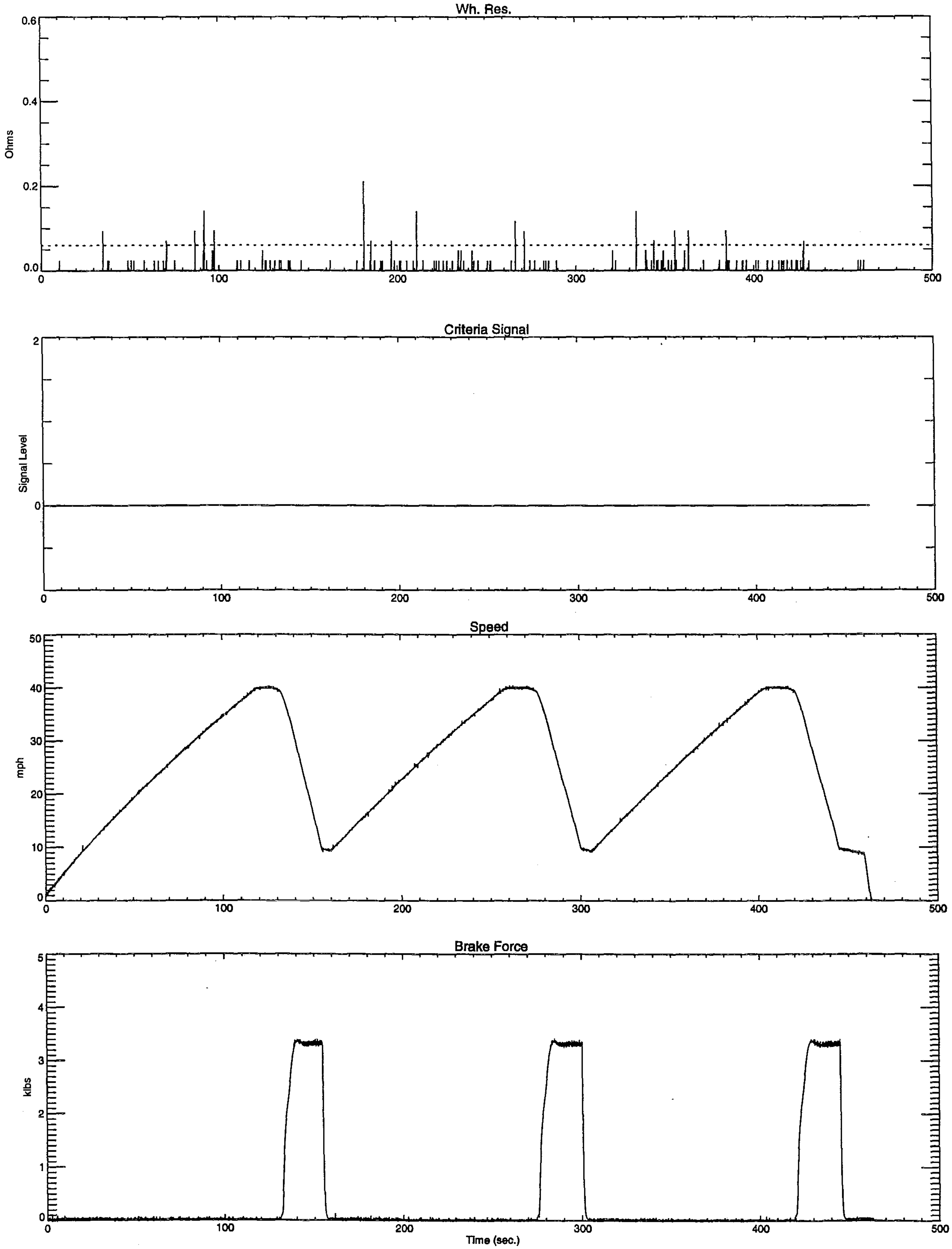
Run 026 A - Wheel Load 6,300 lbs.



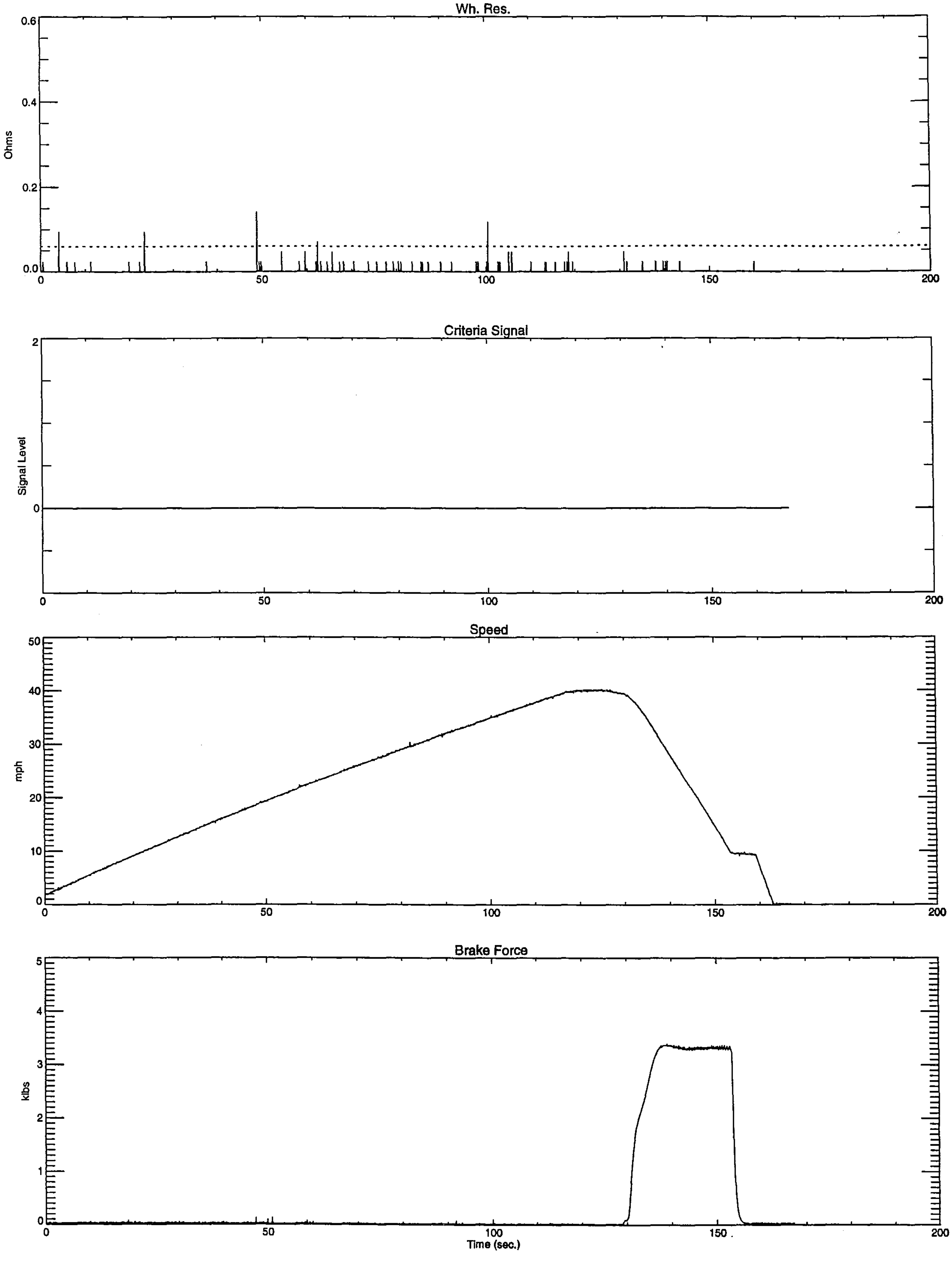
Run 027 A - Wheel Load 18,000 lbs.



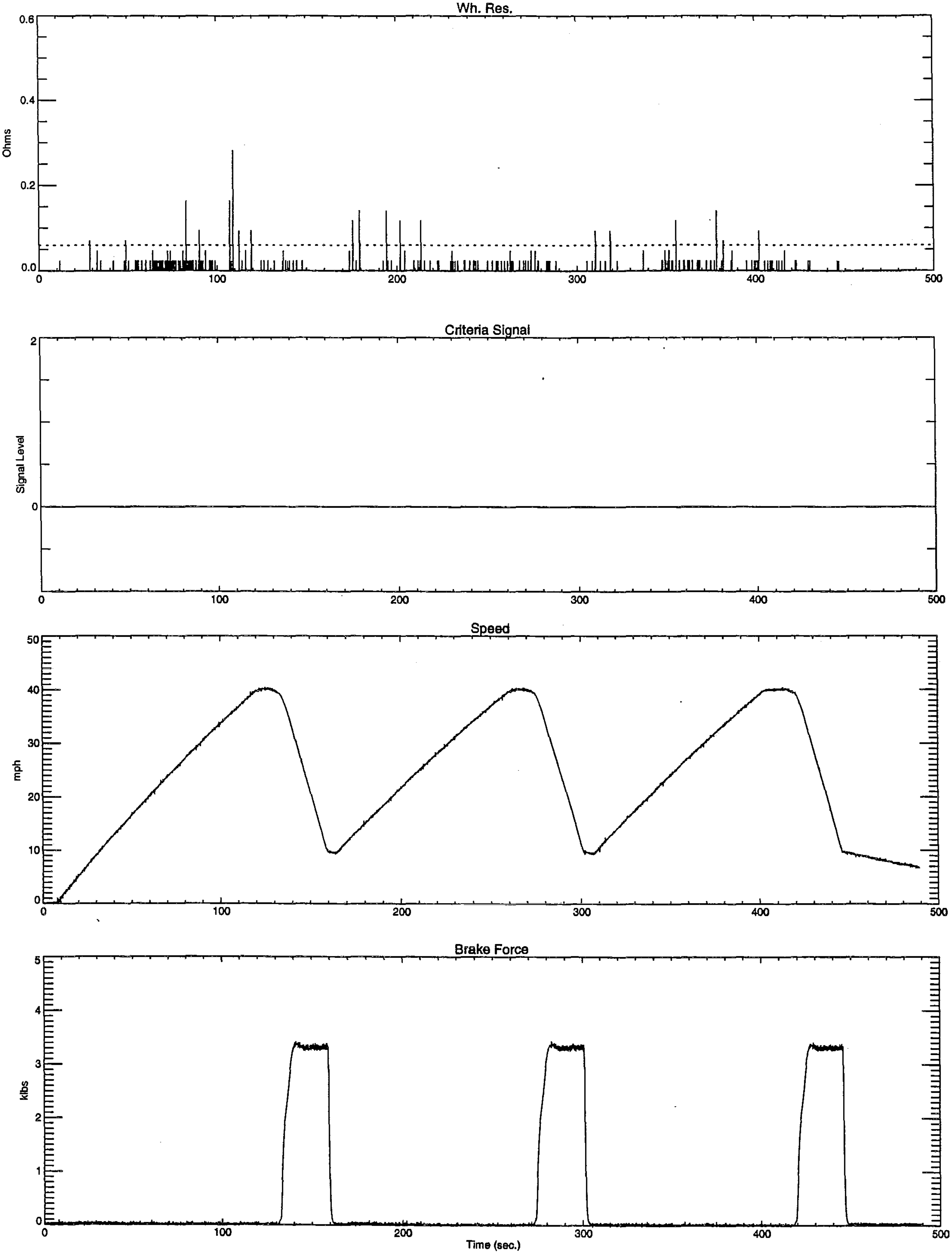
Run 028 A - Wheel Load 9,000 lbs.



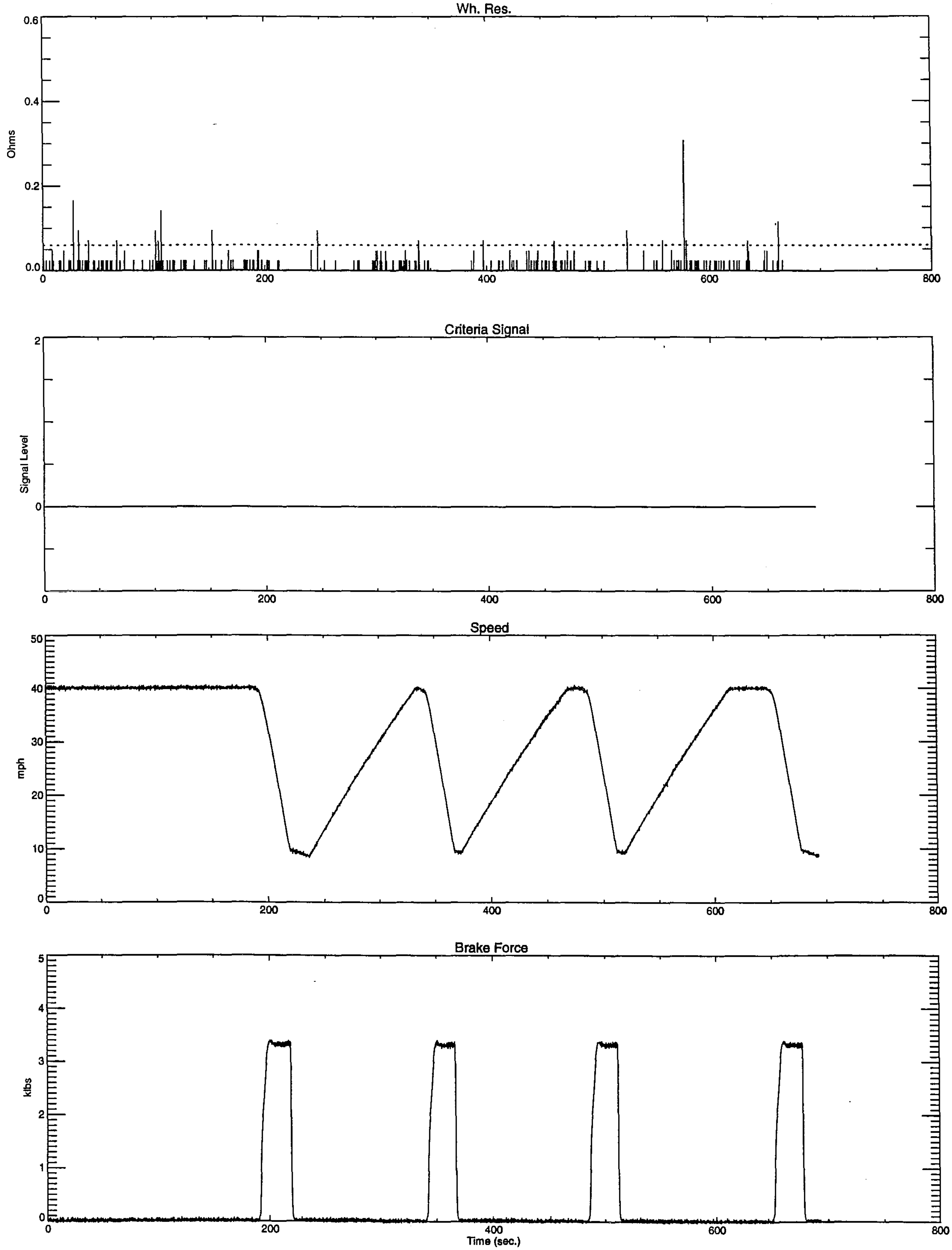
Run 029 A - Wheel Load 6,300 lbs.



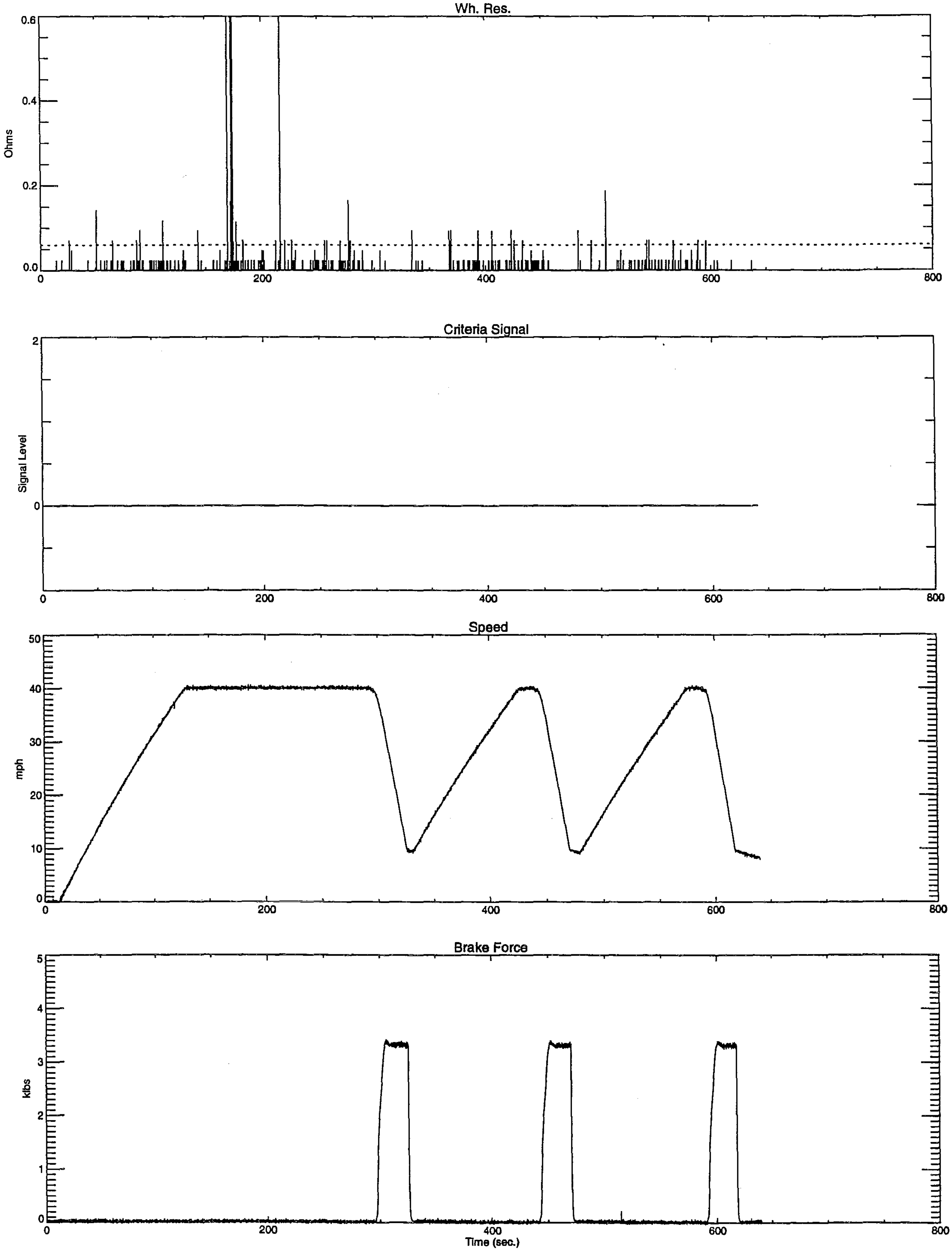
Run 030 A - Wheel Load 6,300 lbs.



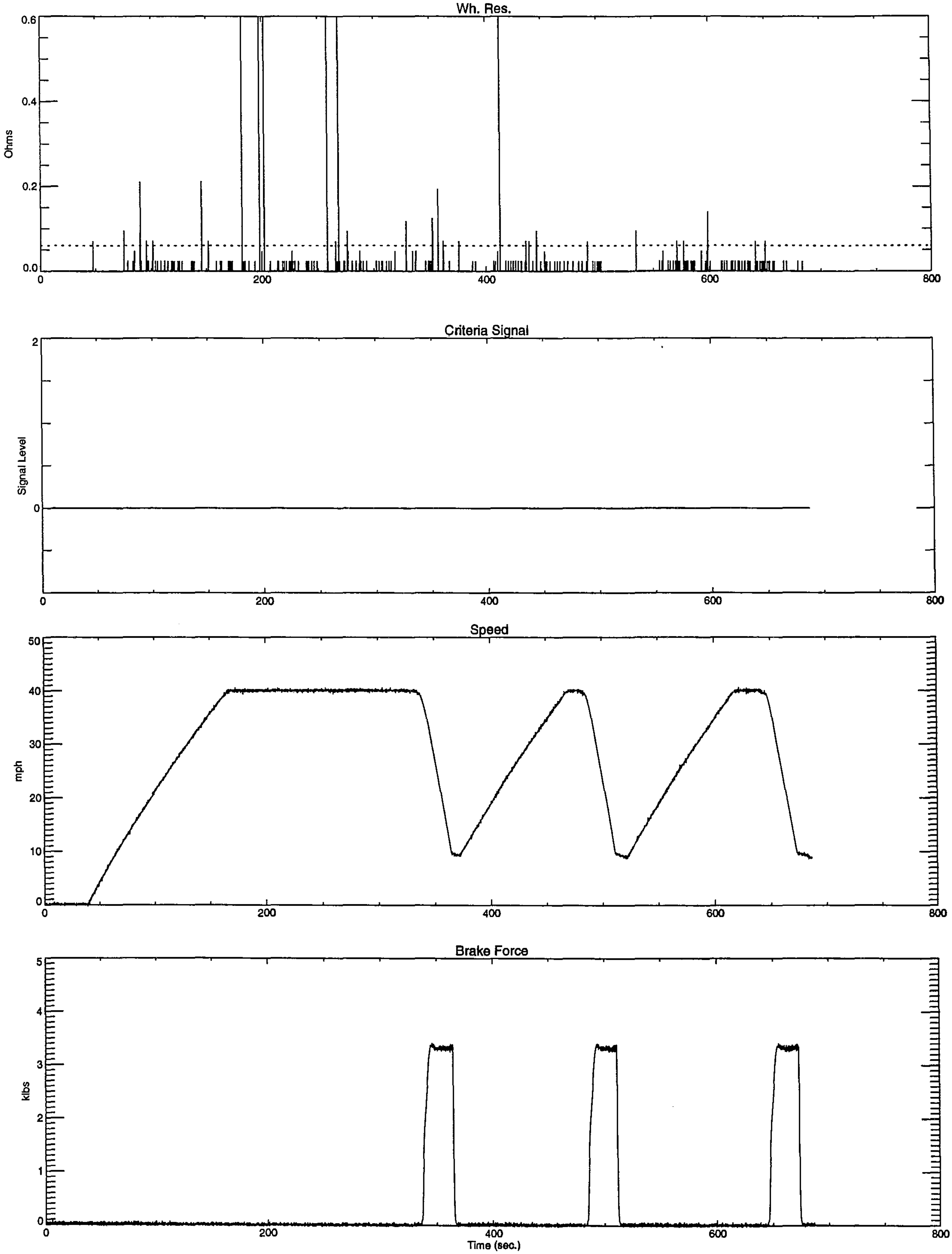
Run 032 A - Wheel Load 6,300 lbs.



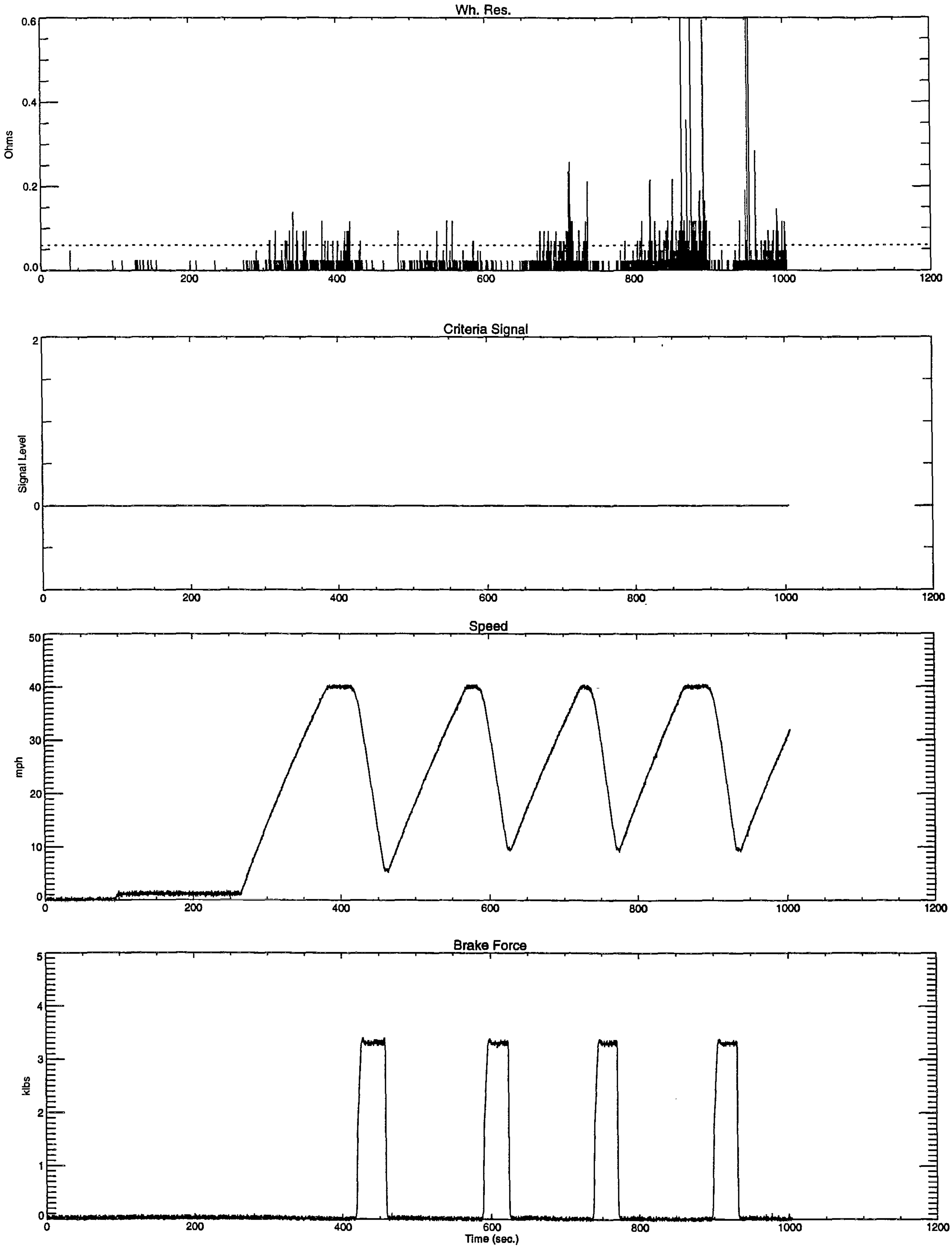
Run 033 A - Wheel Load 6,300 lbs.



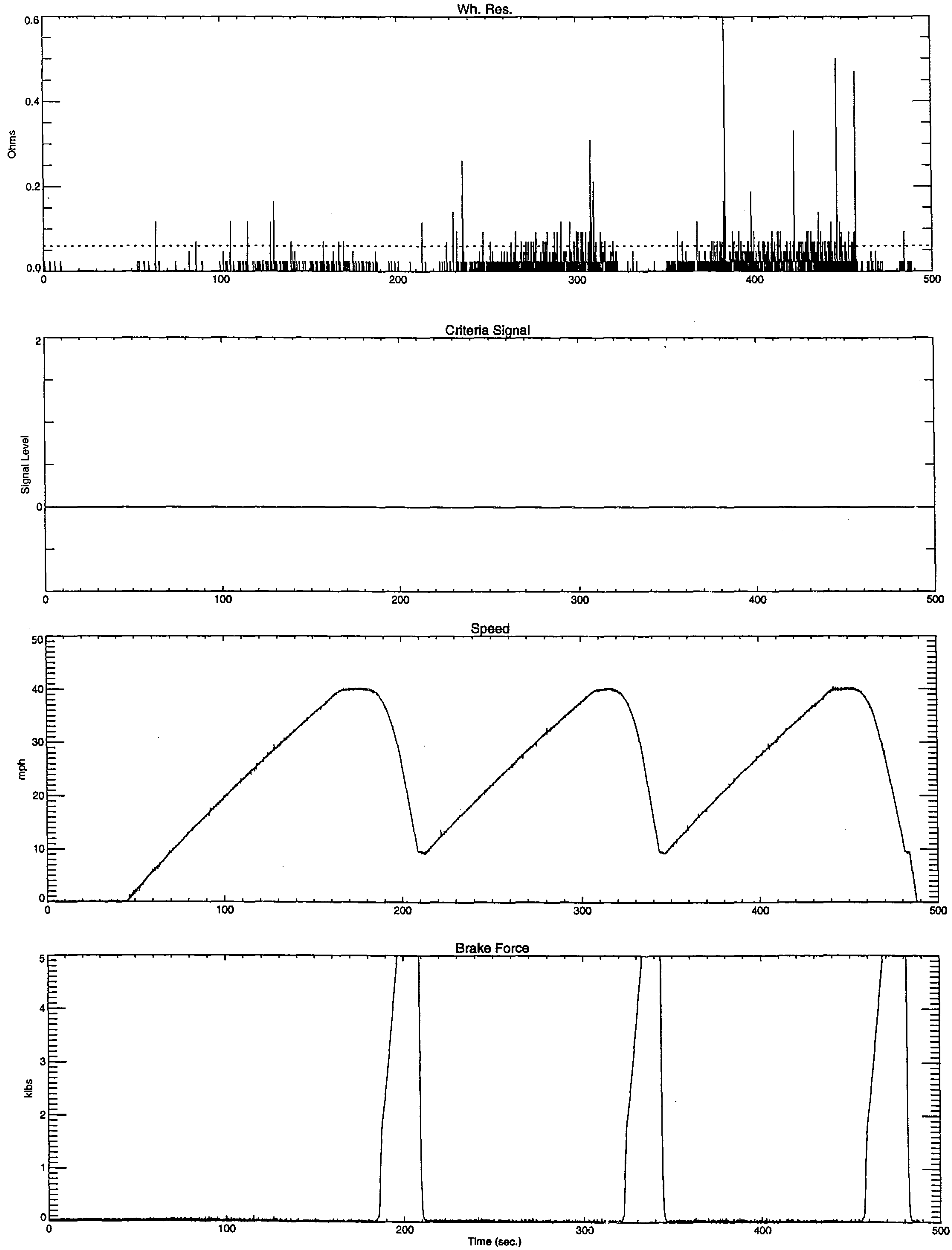
Run 034 A - Wheel Load 6,300 lbs.



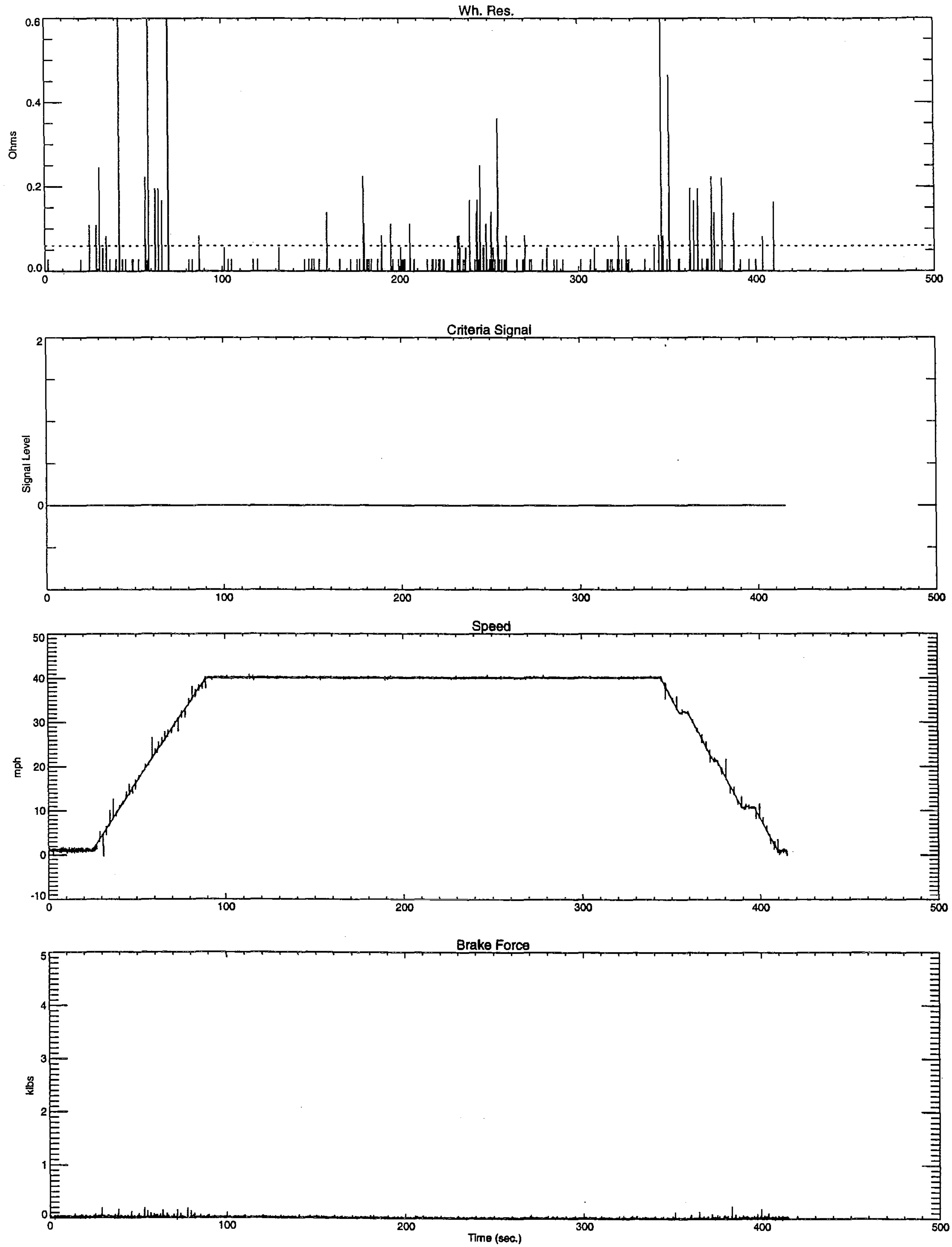
Run 036 A - Wheel Load 6,300 lbs.



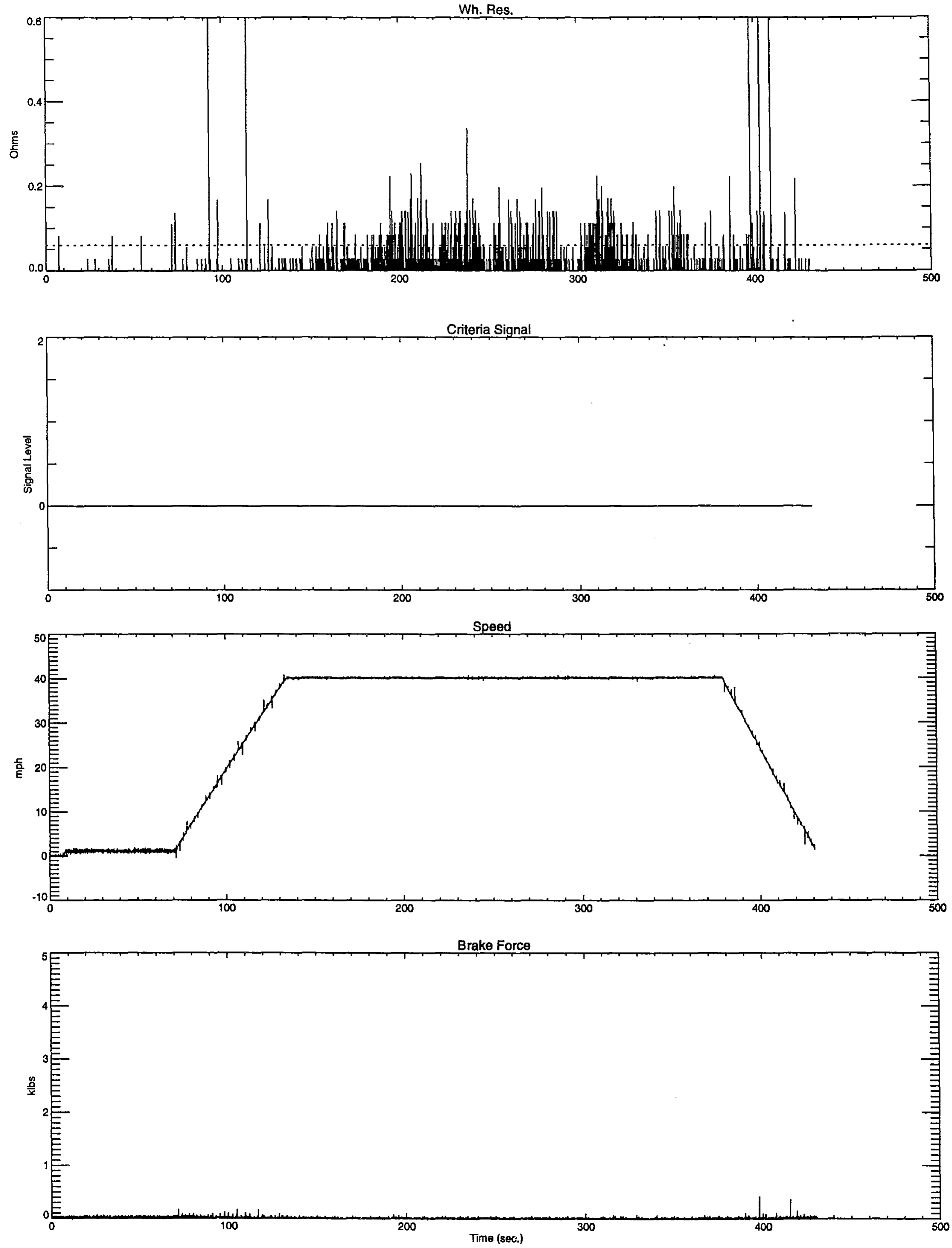
Run 038 A - Wheel Load 6,300 lbs.



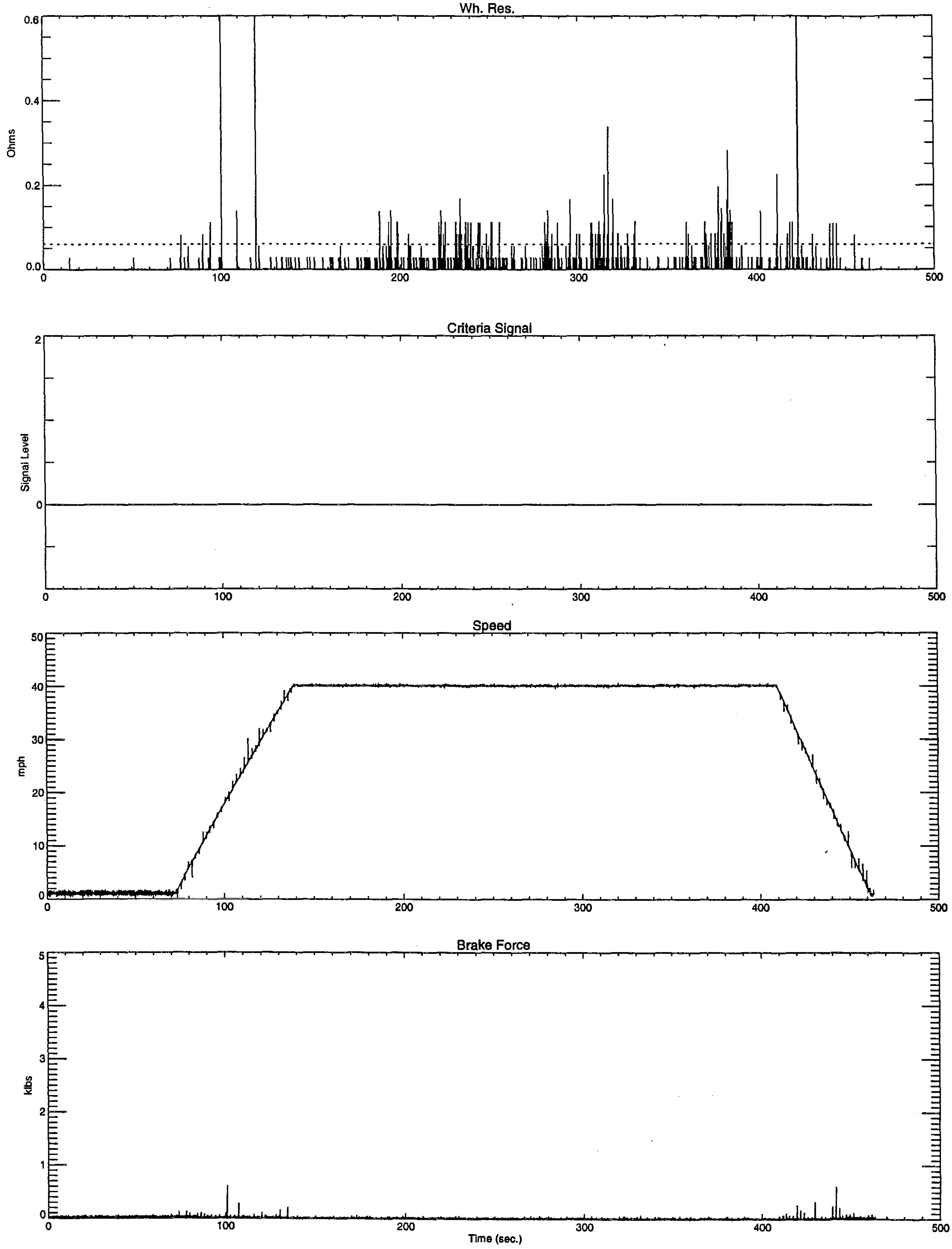
Run 003 B - Wheel Load 6,300 lbs.



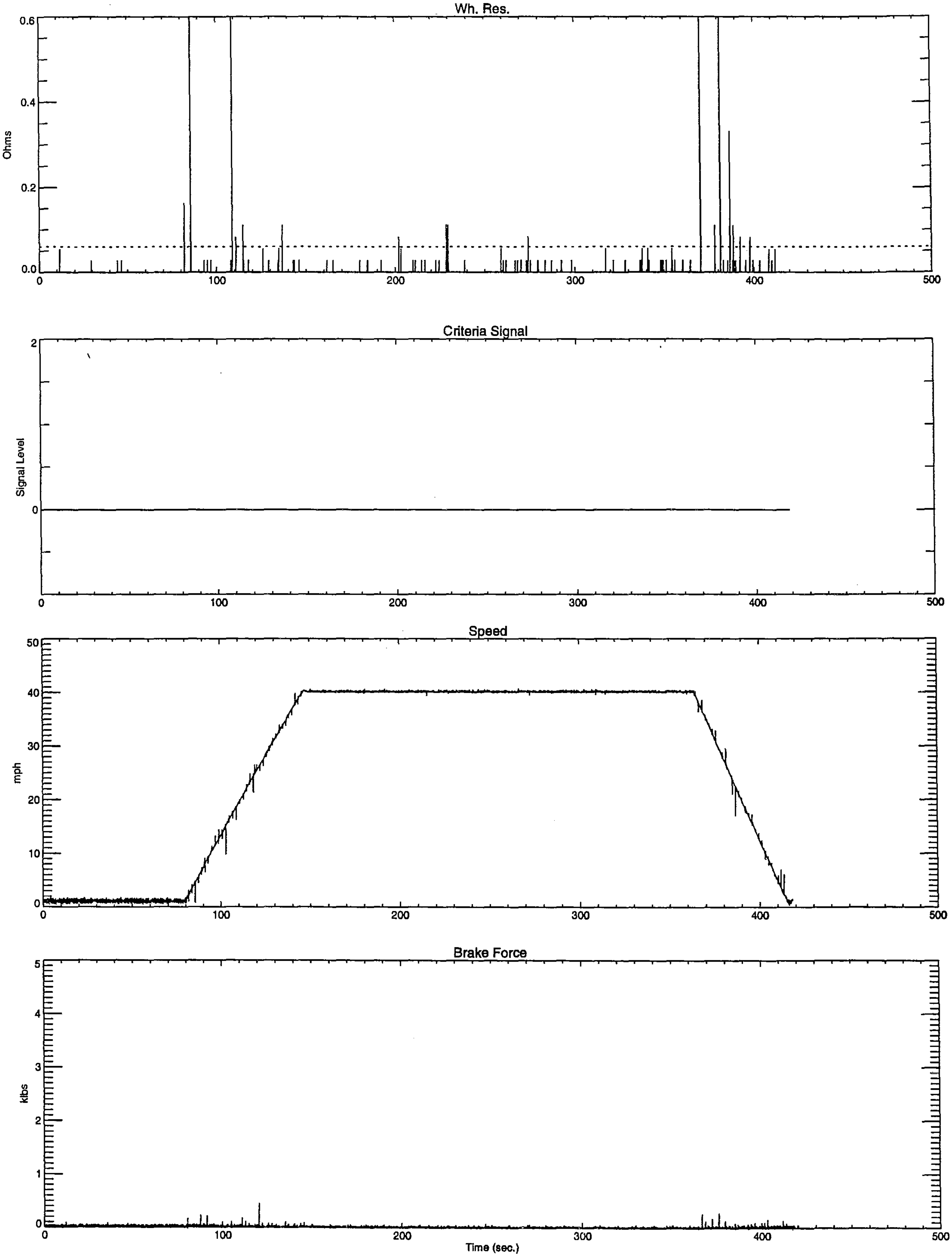
Run 004 B - Wheel Load 6,300 lbs.



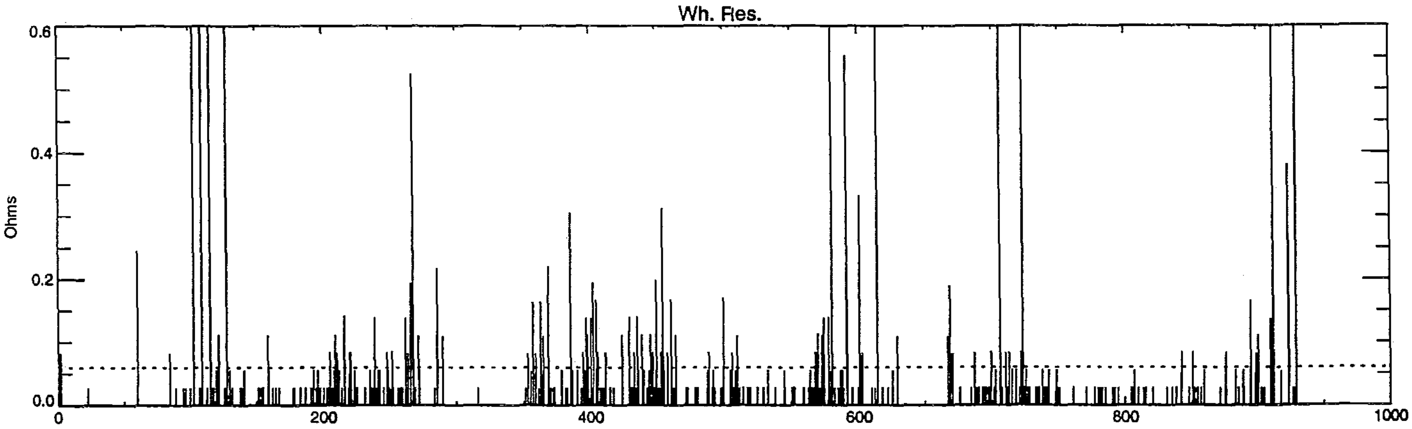
Run 006 B - Wheel Load 6,300 lbs.

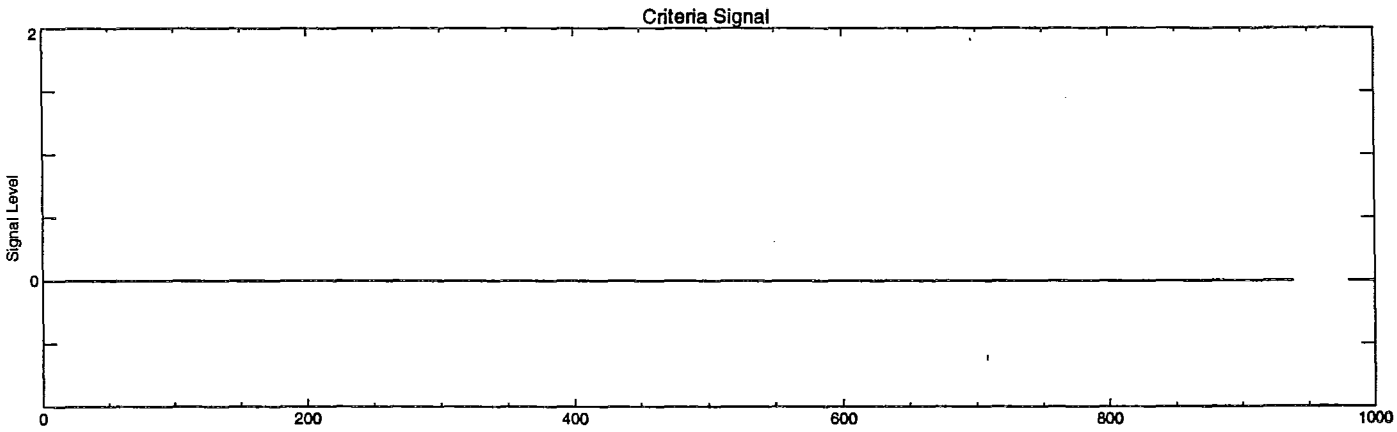


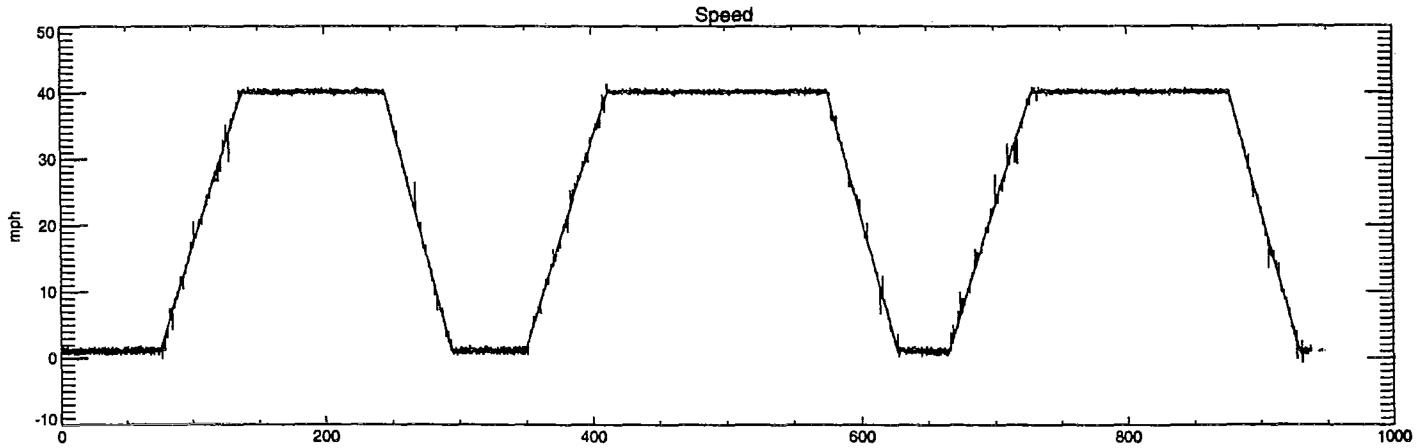
Run 007 B - Wheel Load 6,300 lbs

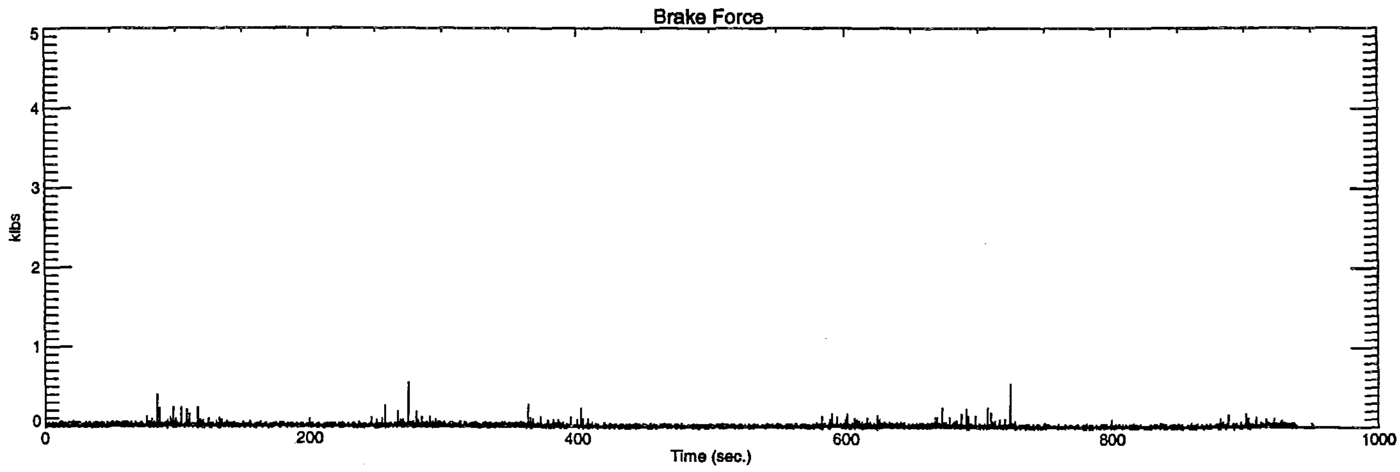


Run 008 B - Wheel Load 6,300 lbs.

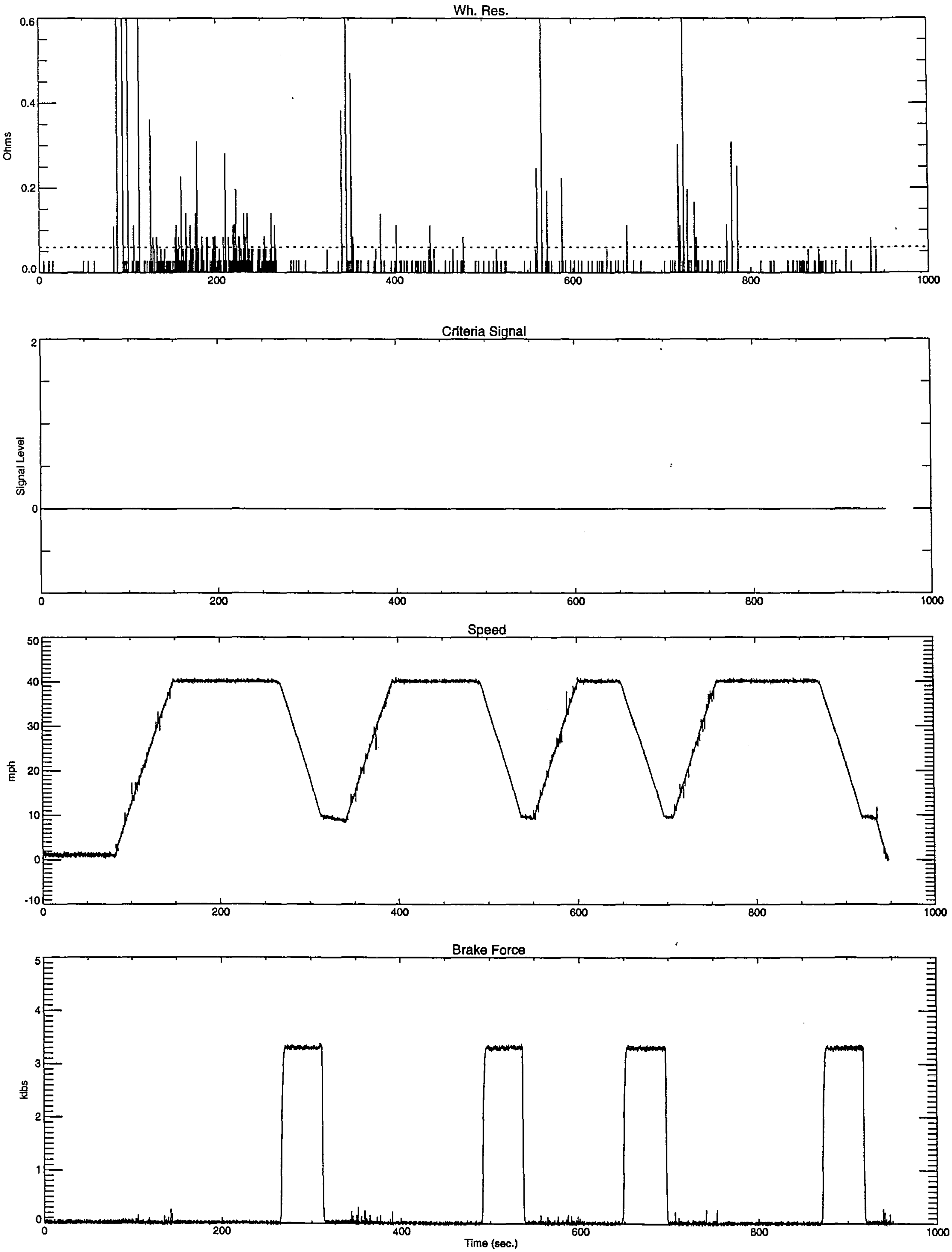




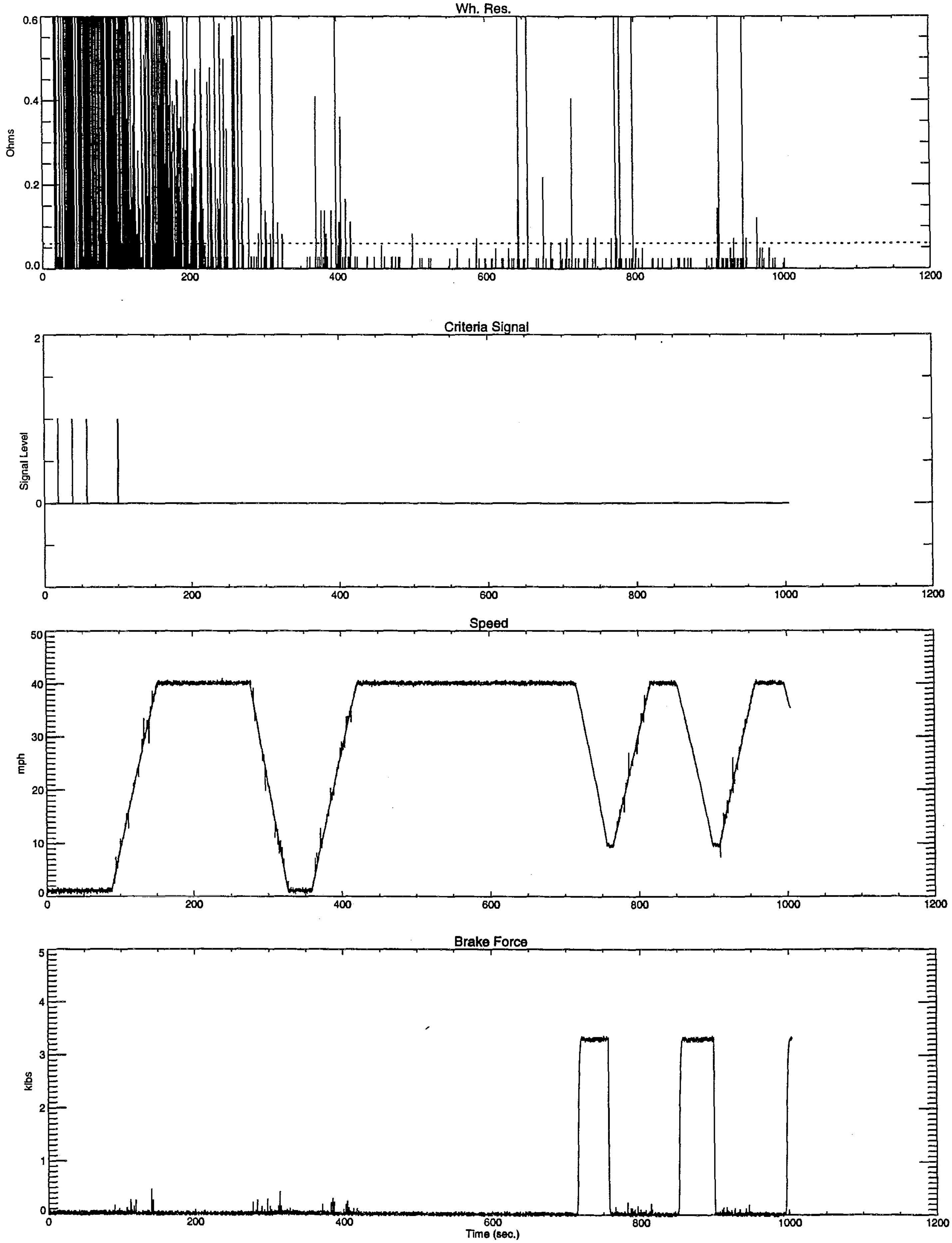




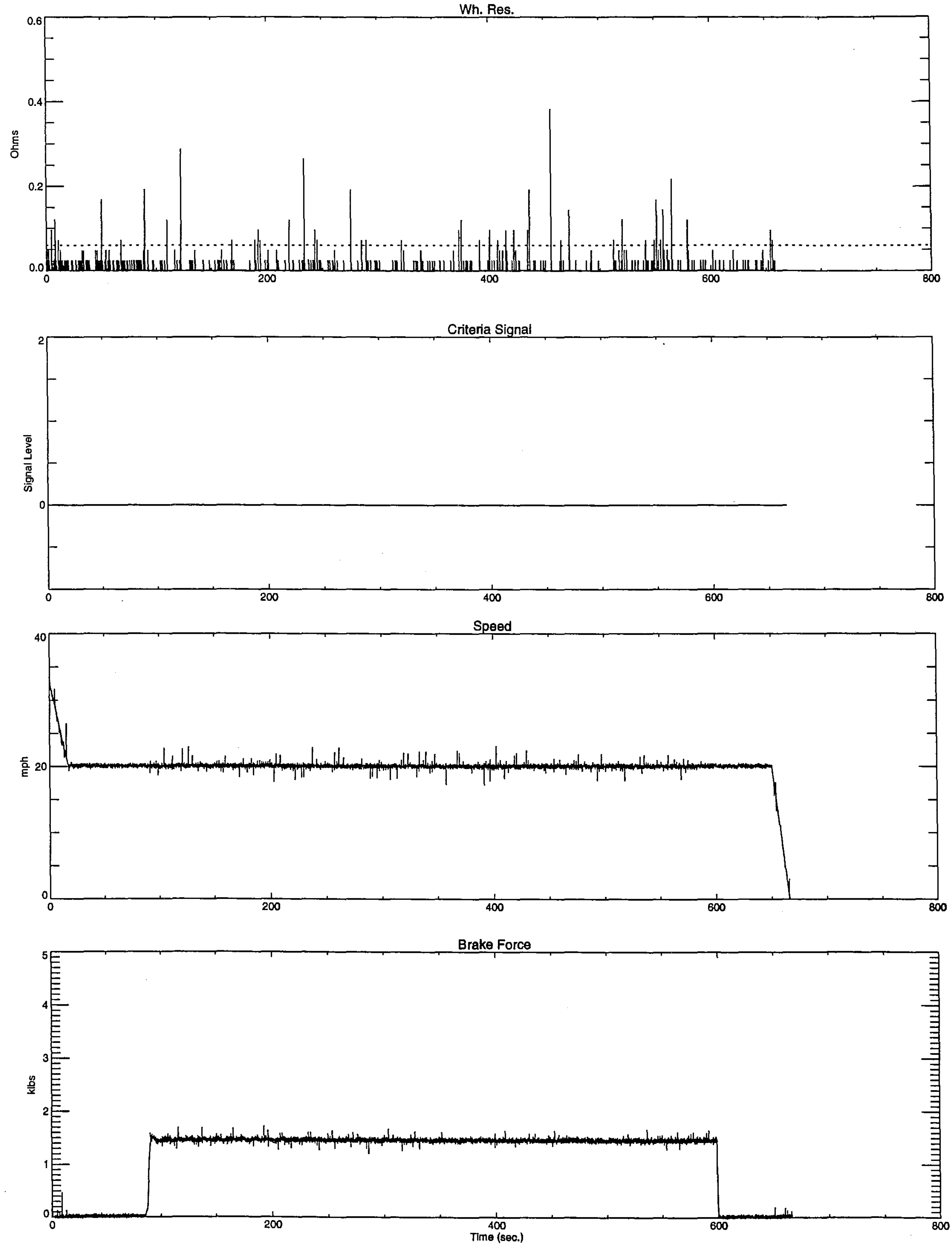
Run 009 B - Wheel Load 6,300 lbs.



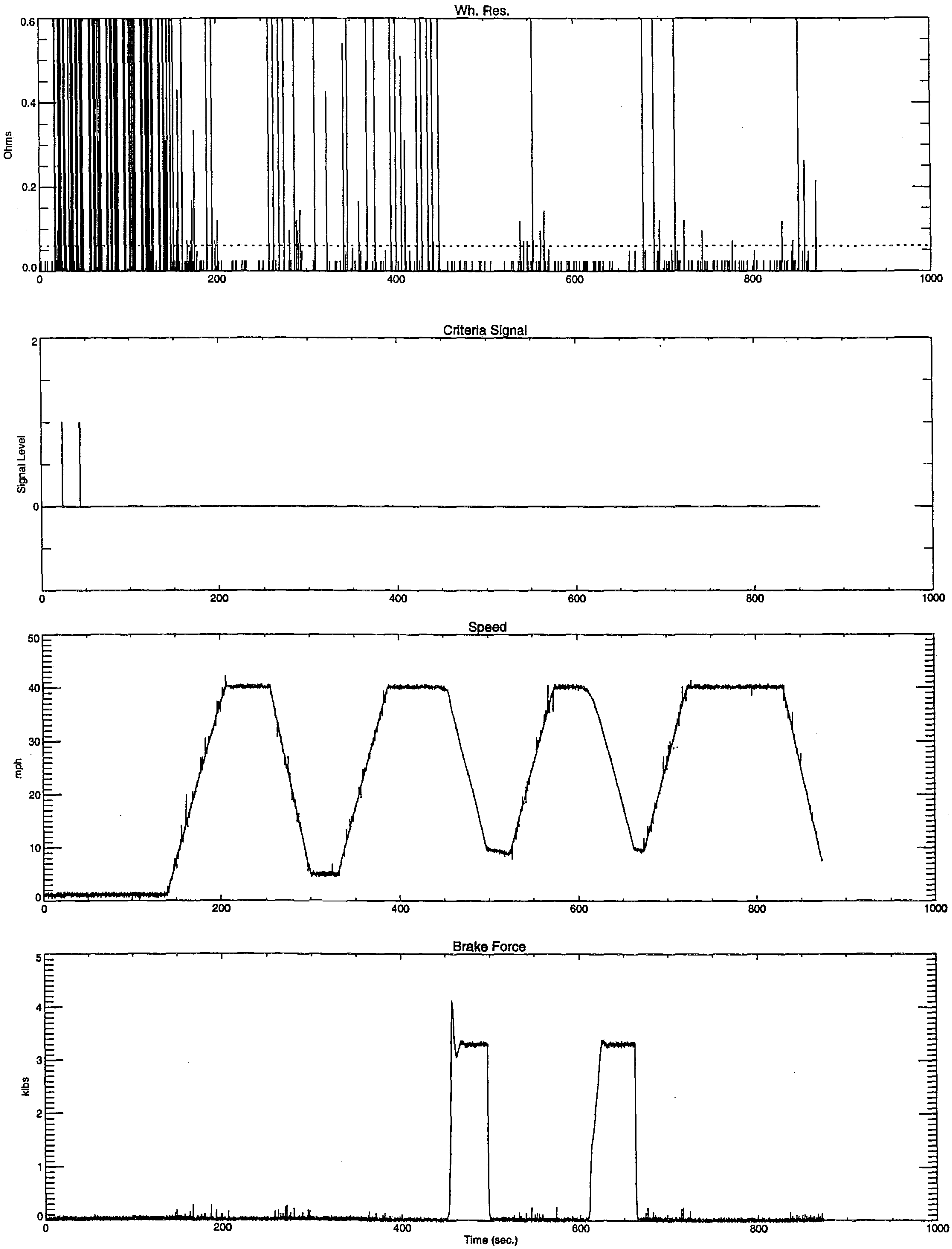
Run 010 B - Wheel Load 6,300 lbs.



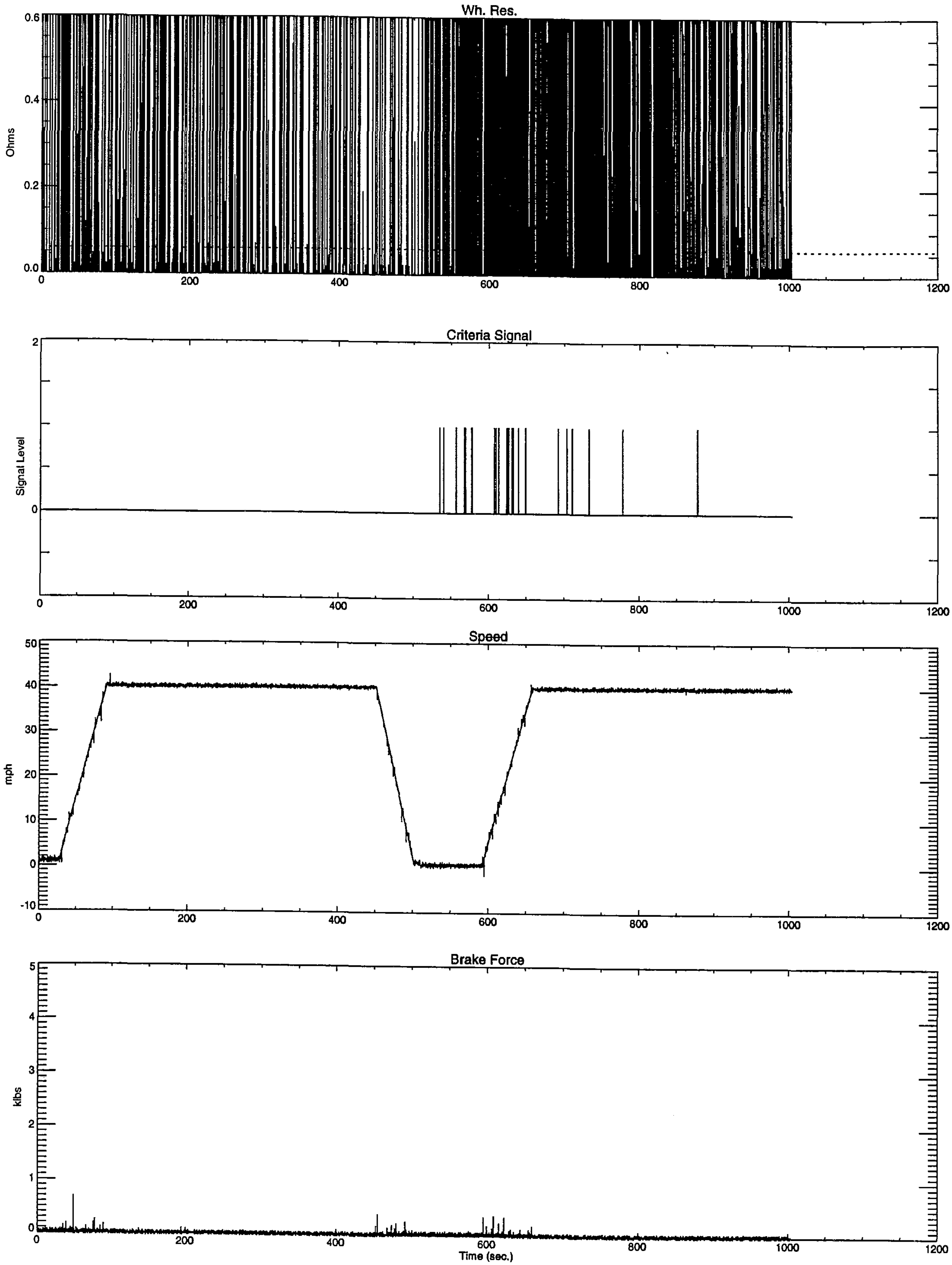
Run 011 B - Wheel Load 6,300 lbs.



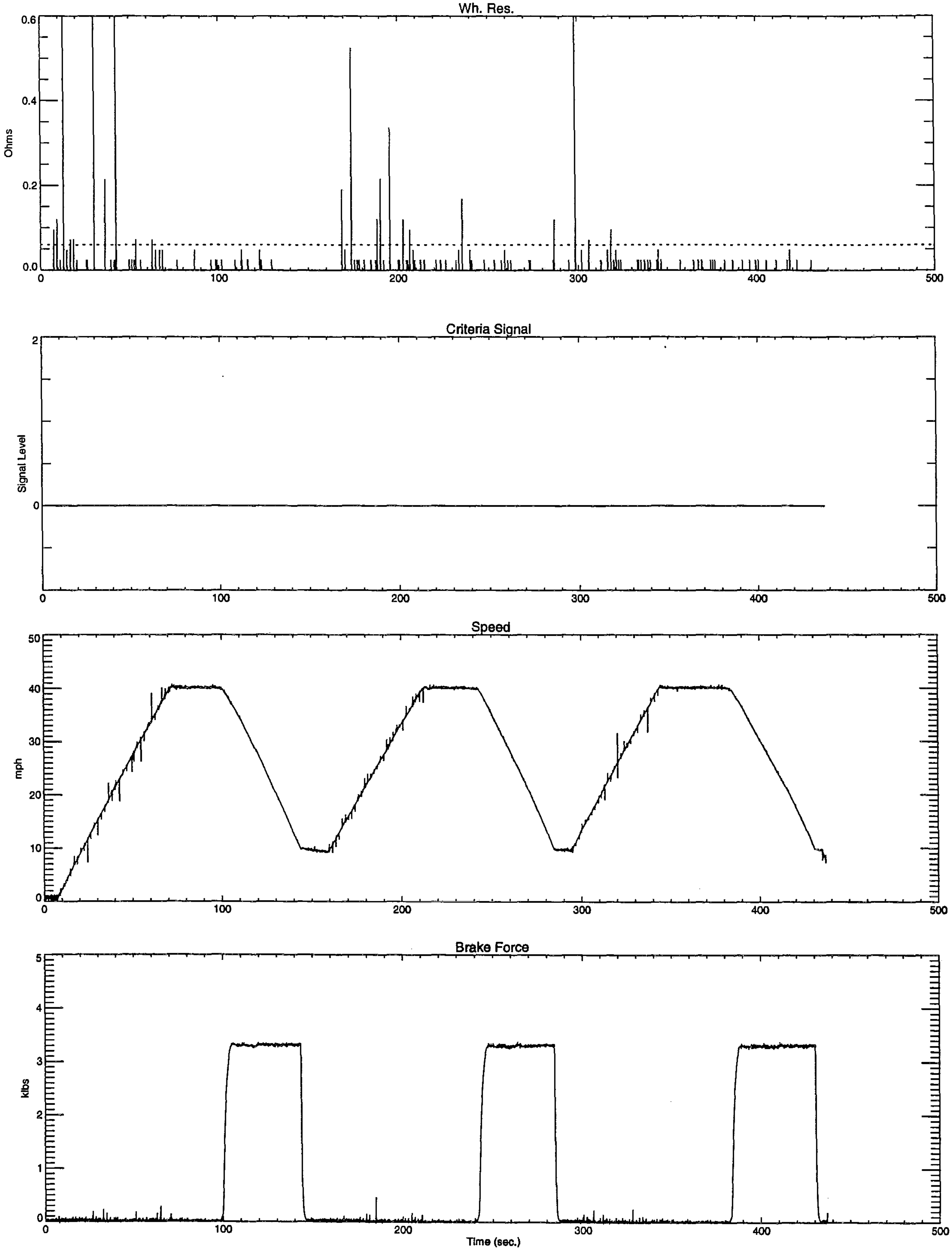
Run 012 B - Wheel Load 6,300 lbs.



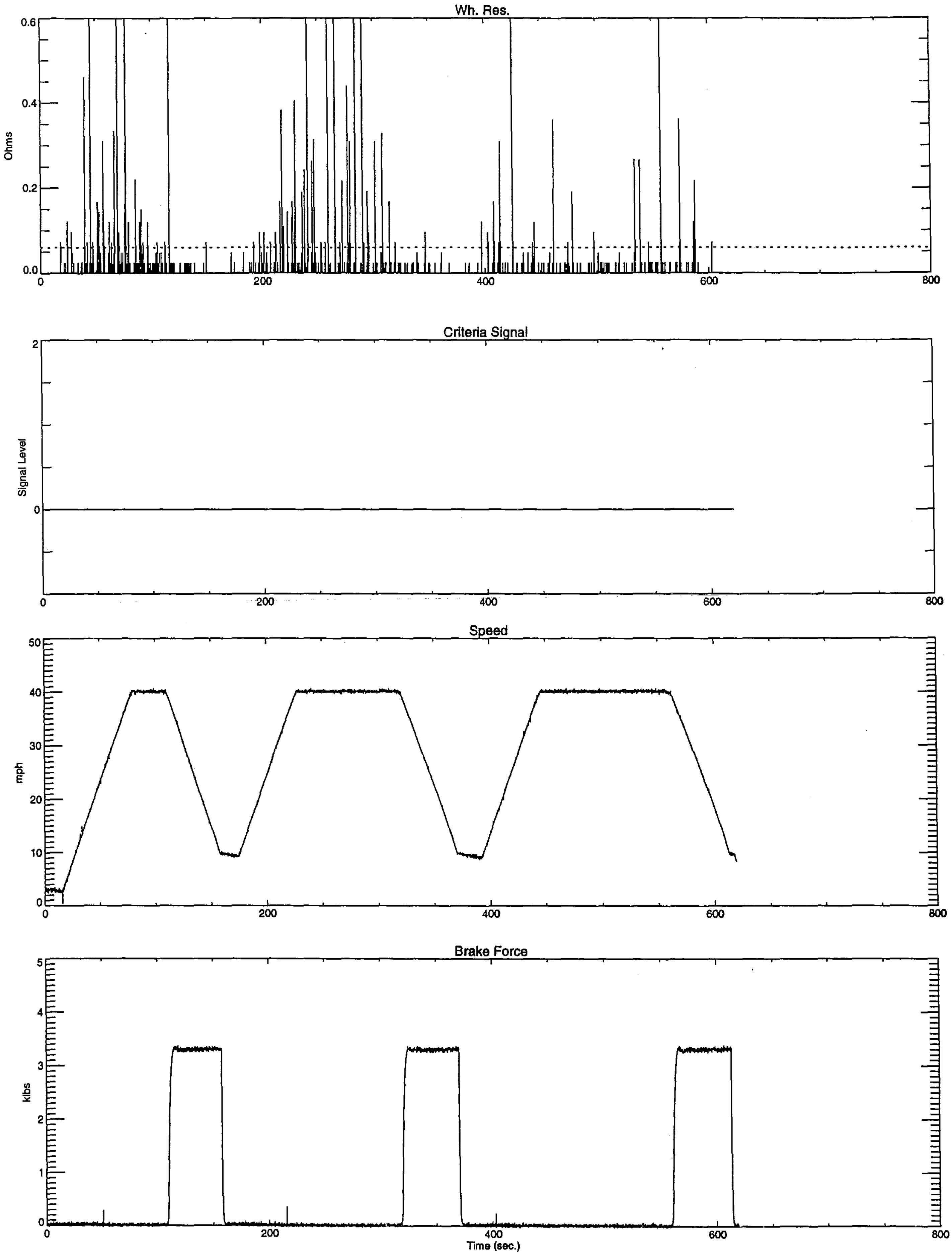
Run 013 B - Wheel Load 6,300 lbs.

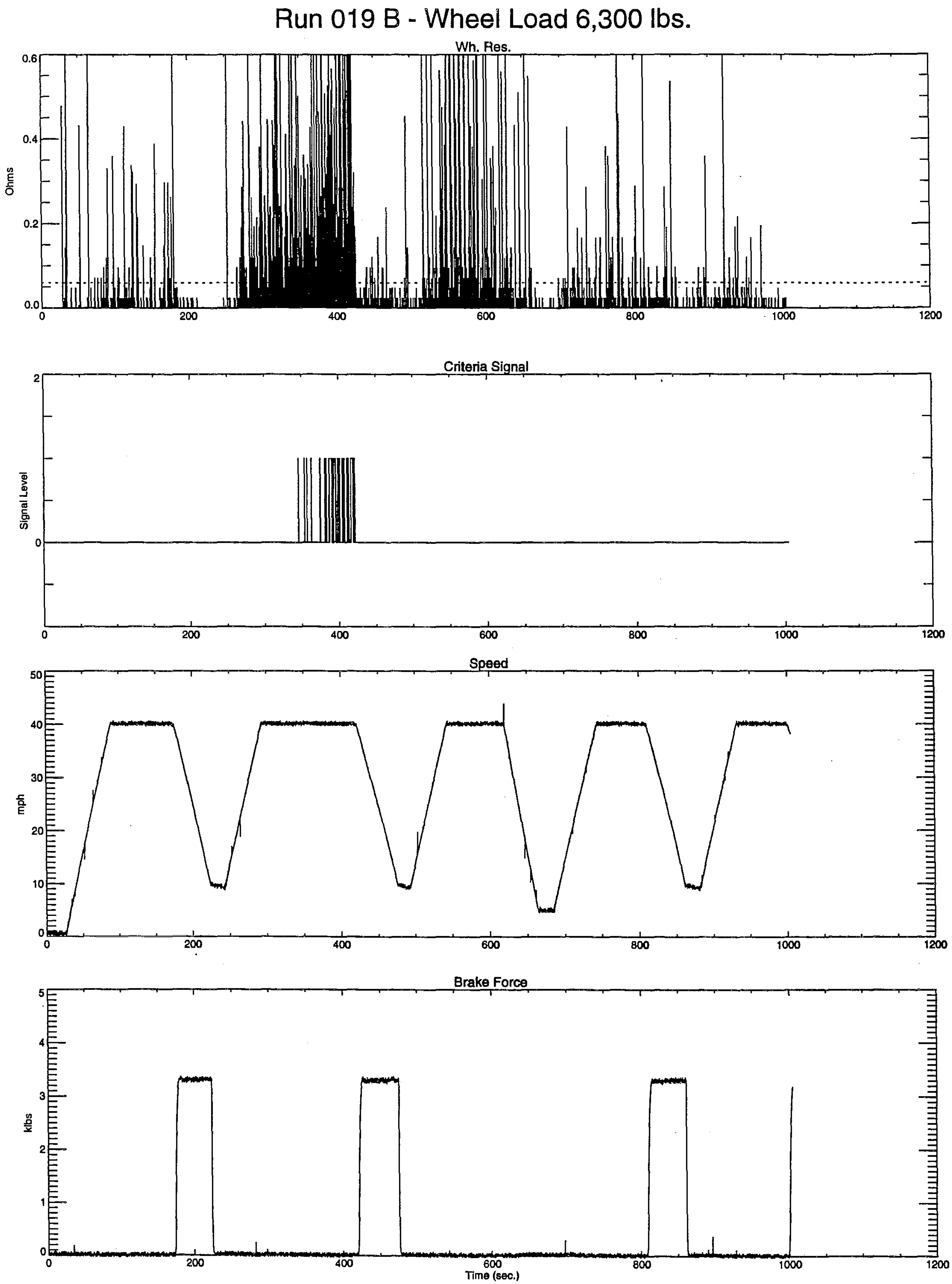


Run 015 B - Wheel Load 6,300 lbs.

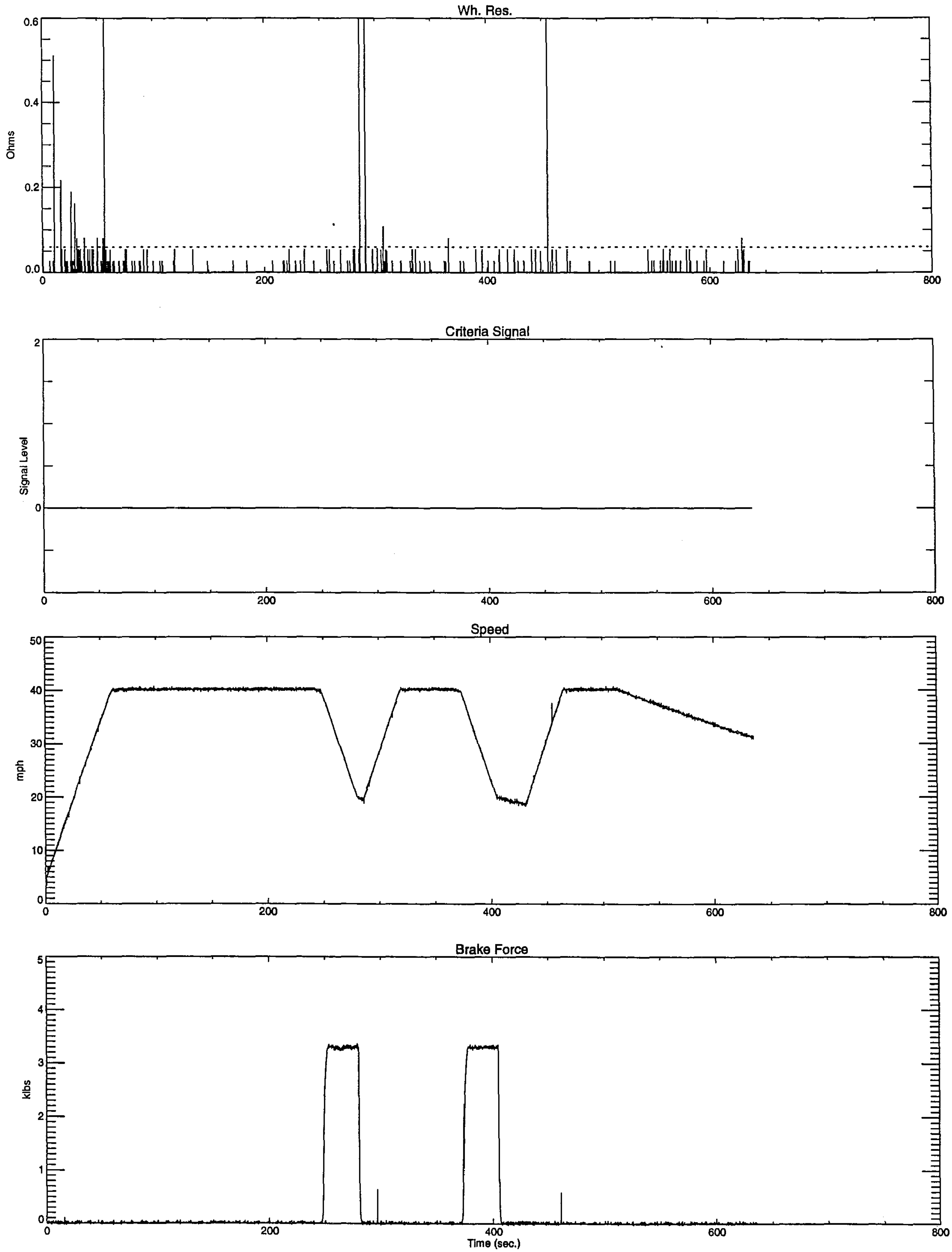


Run 017 B - Wheel Load 6,300 lbs.

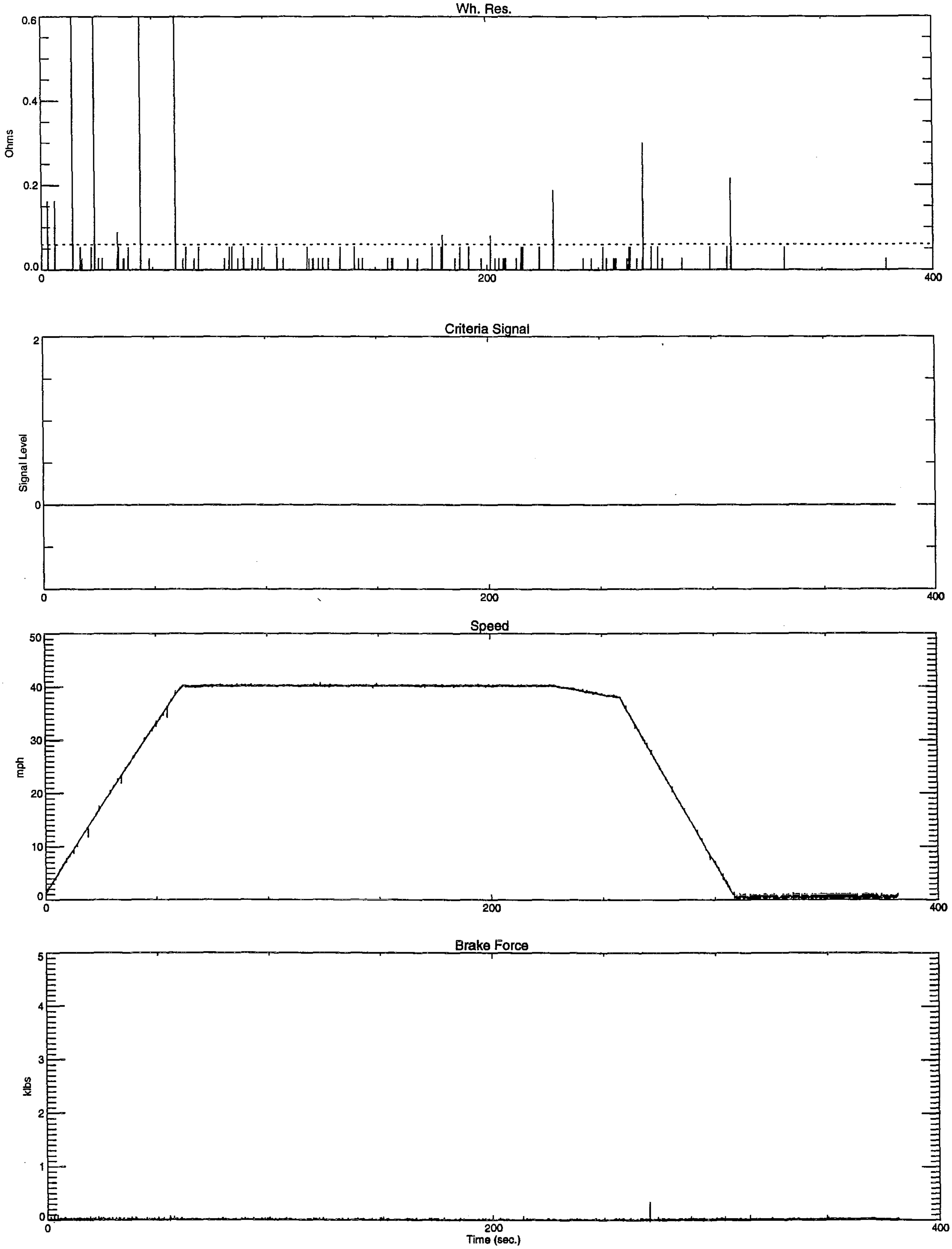



Run 019 B - Wheel Load 6,300 lbs.
Wh. Res.
Ohms
0.0
0.2
0.4
0.6
Criteria Signal
Signal Level
0
2
Speed
mph
0
10
20
30
40
50
Brake Force
klbs
0
1
2
3
4
5
0
200
400
600
800
1000
1200
Time (sec.)

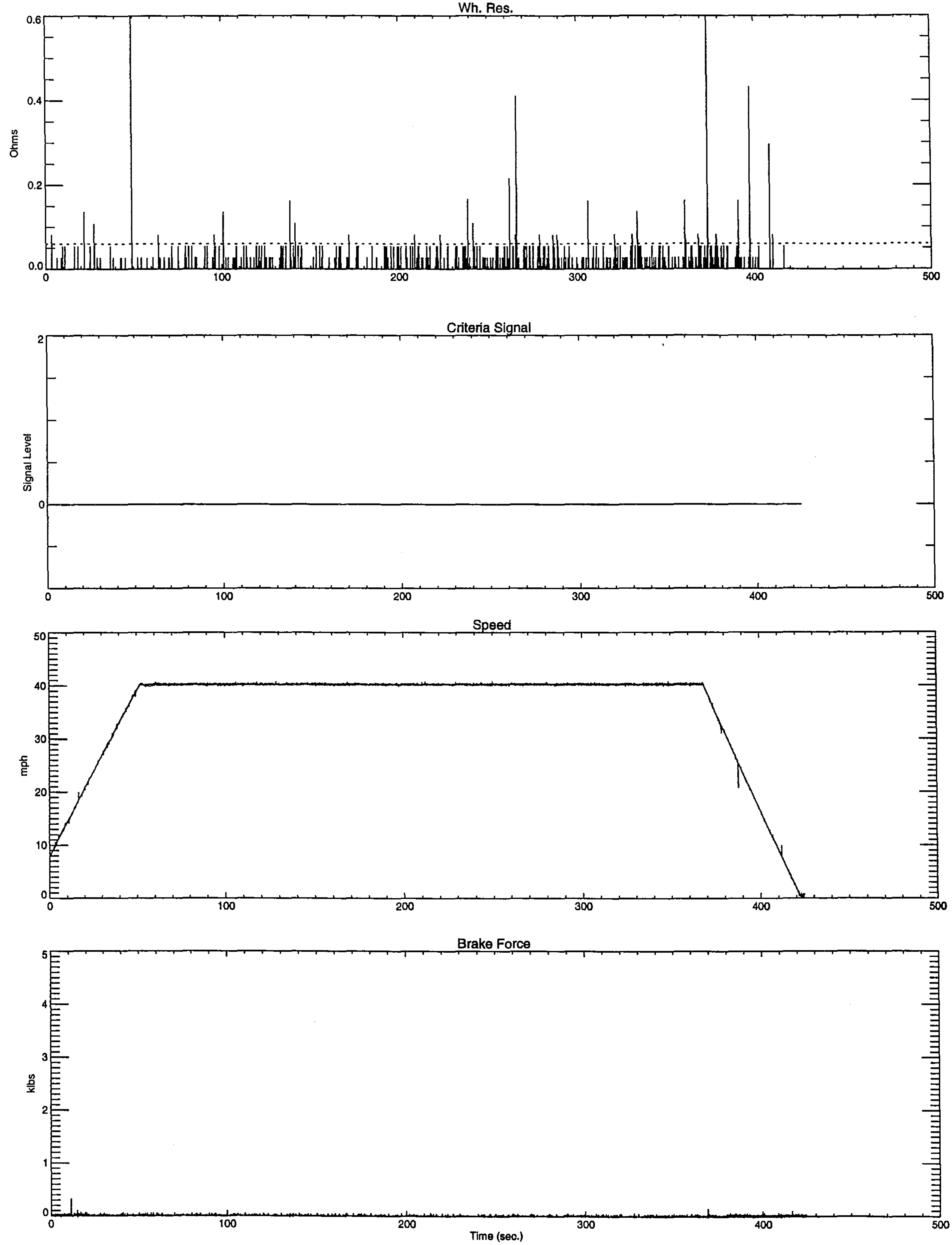
Run 013 C - Wheel Load 6,300 lbs.



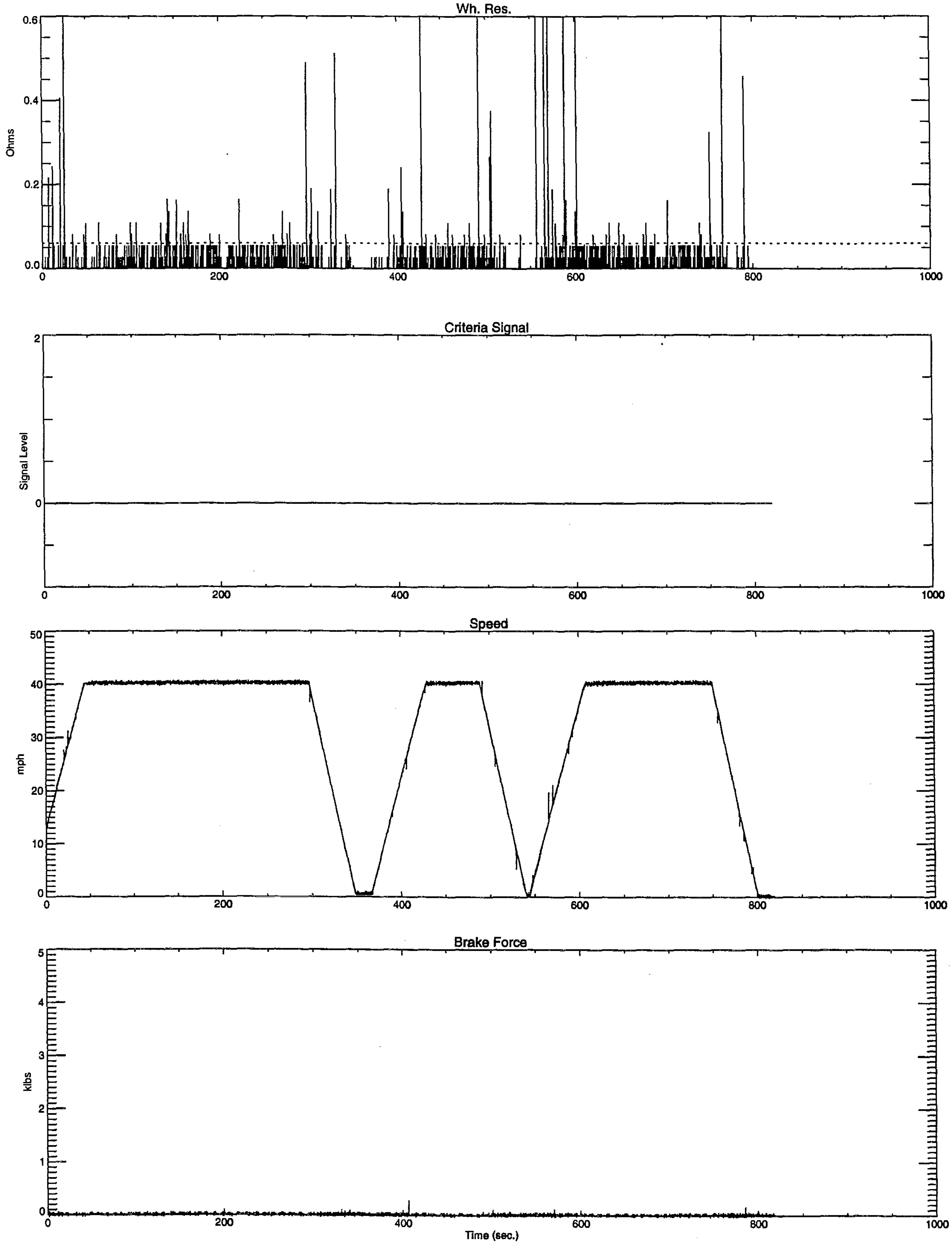
Run 014 C - Wheel Load 6,300 lbs.



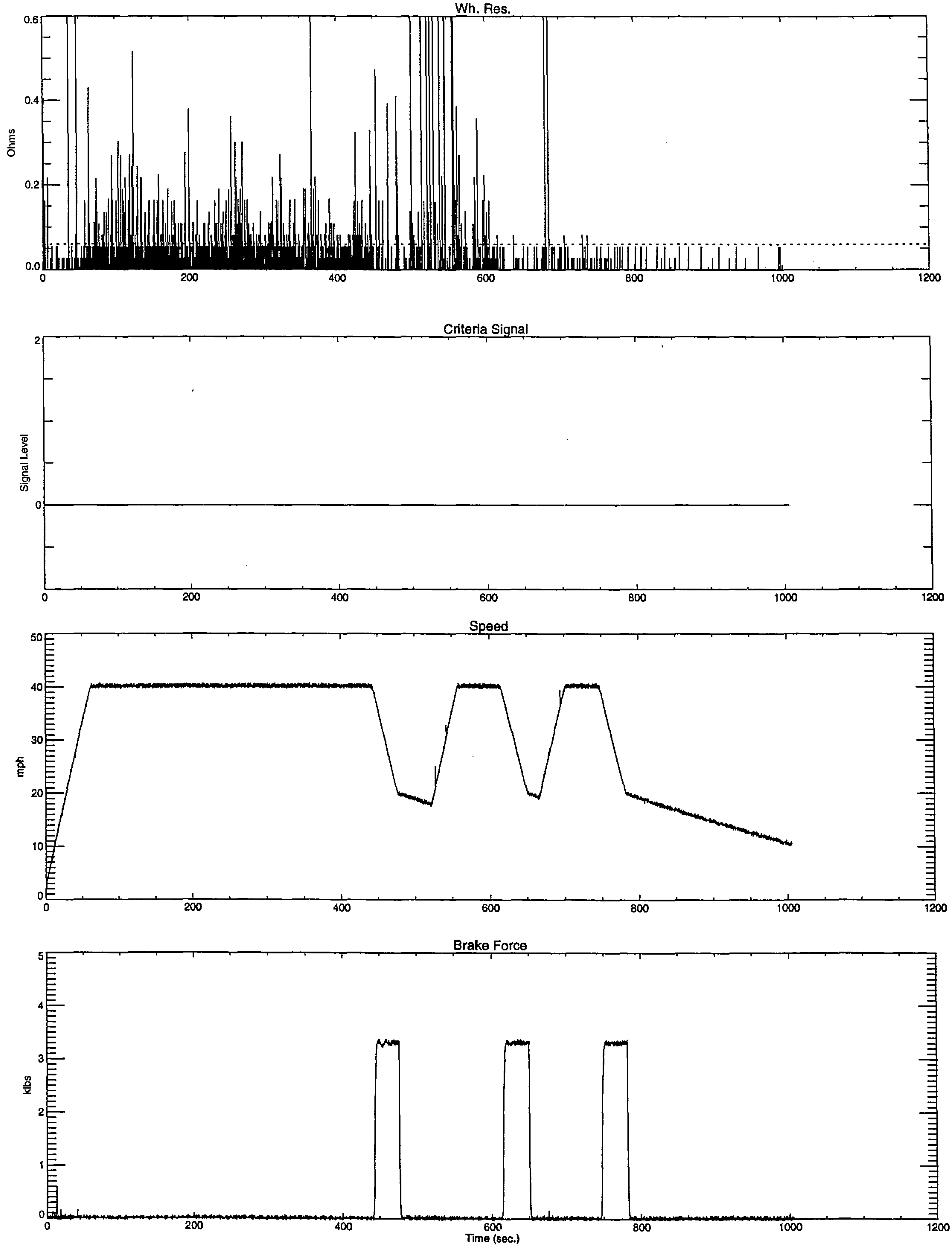
Run 015 C - Wheel Load 6,300 lbs.



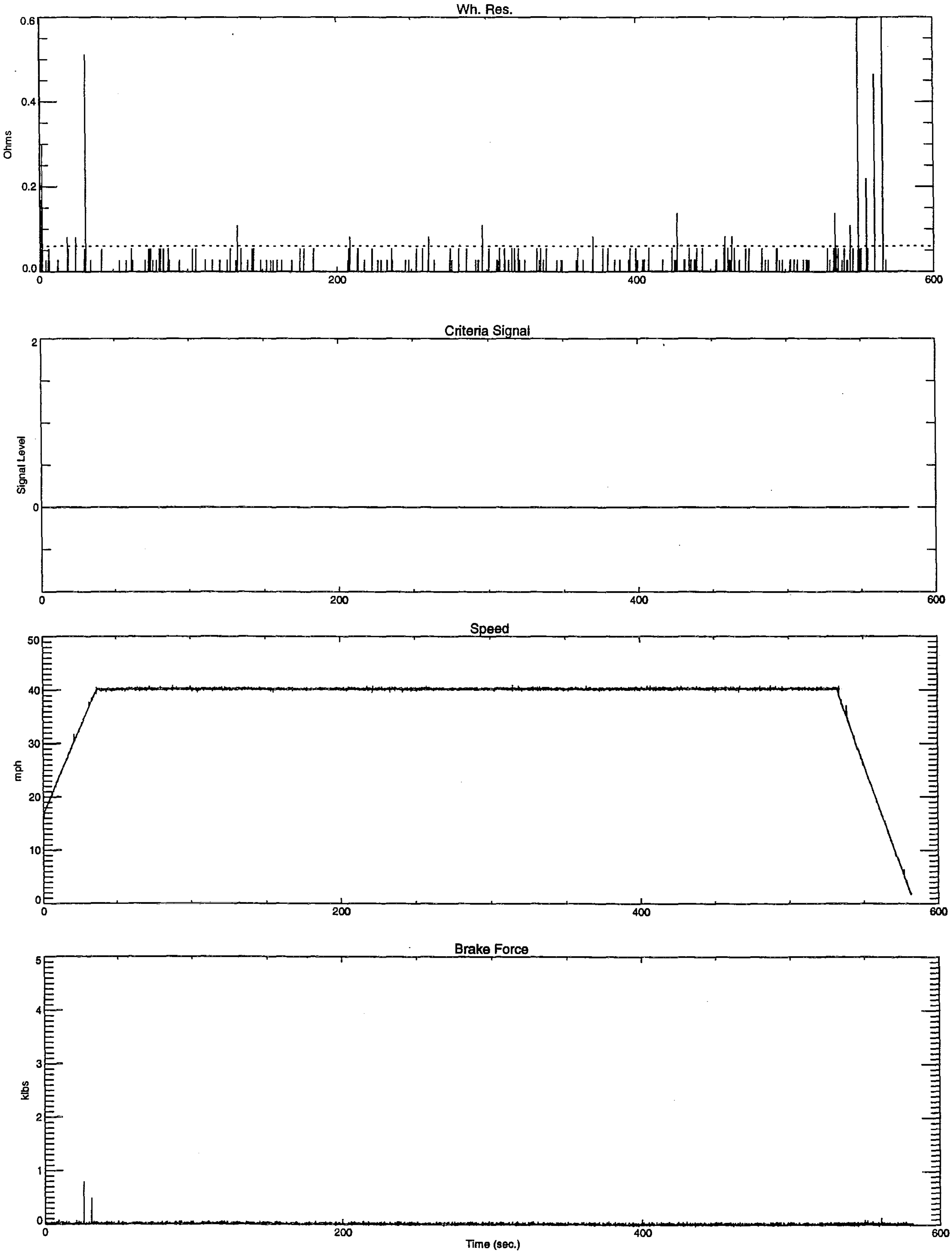
Run 016 C - Wheel Load 6,300 lbs.



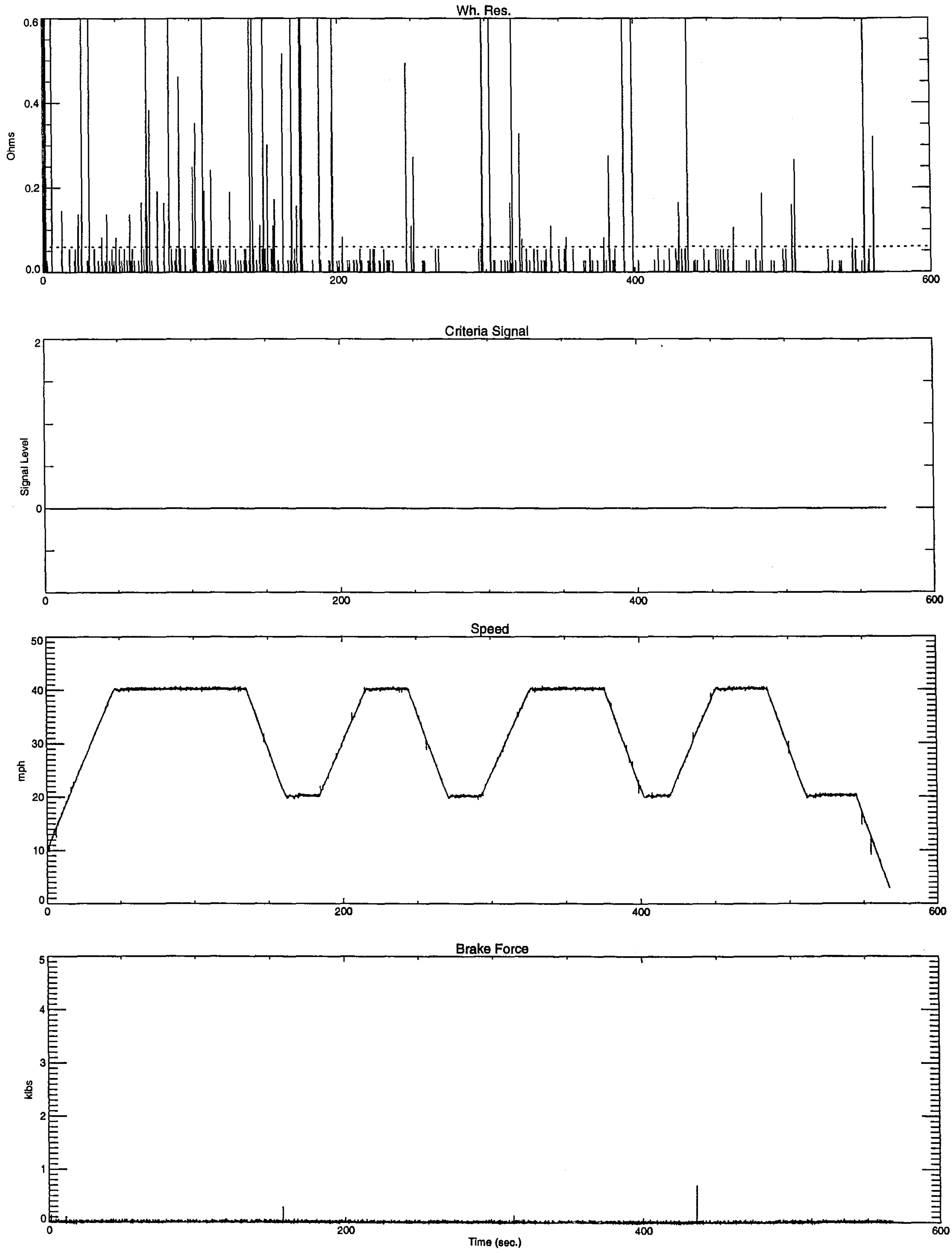
Run 017 C - Wheel Load 6,300 lbs.



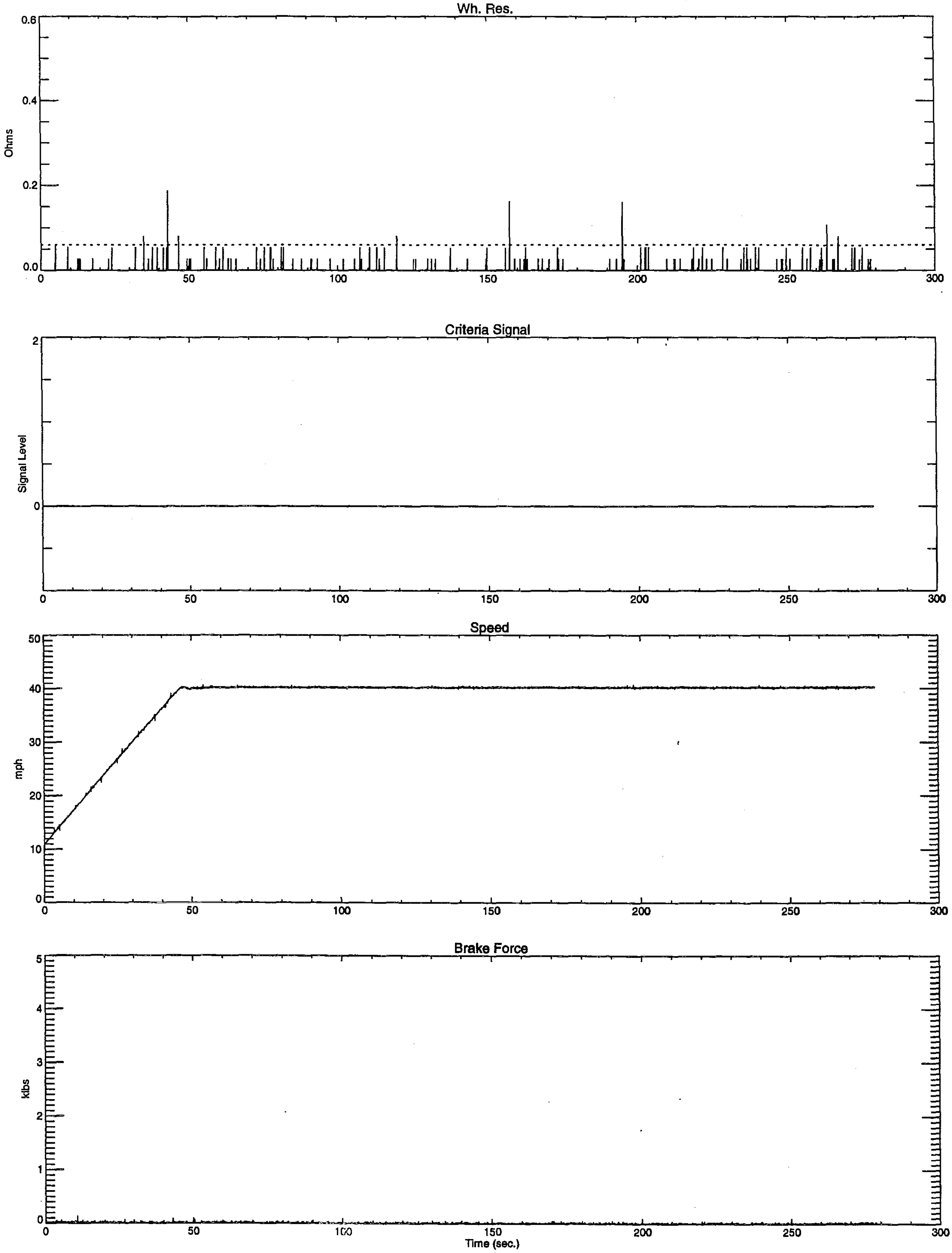
Run 018 C - Wheel Load 6,300 lbs.



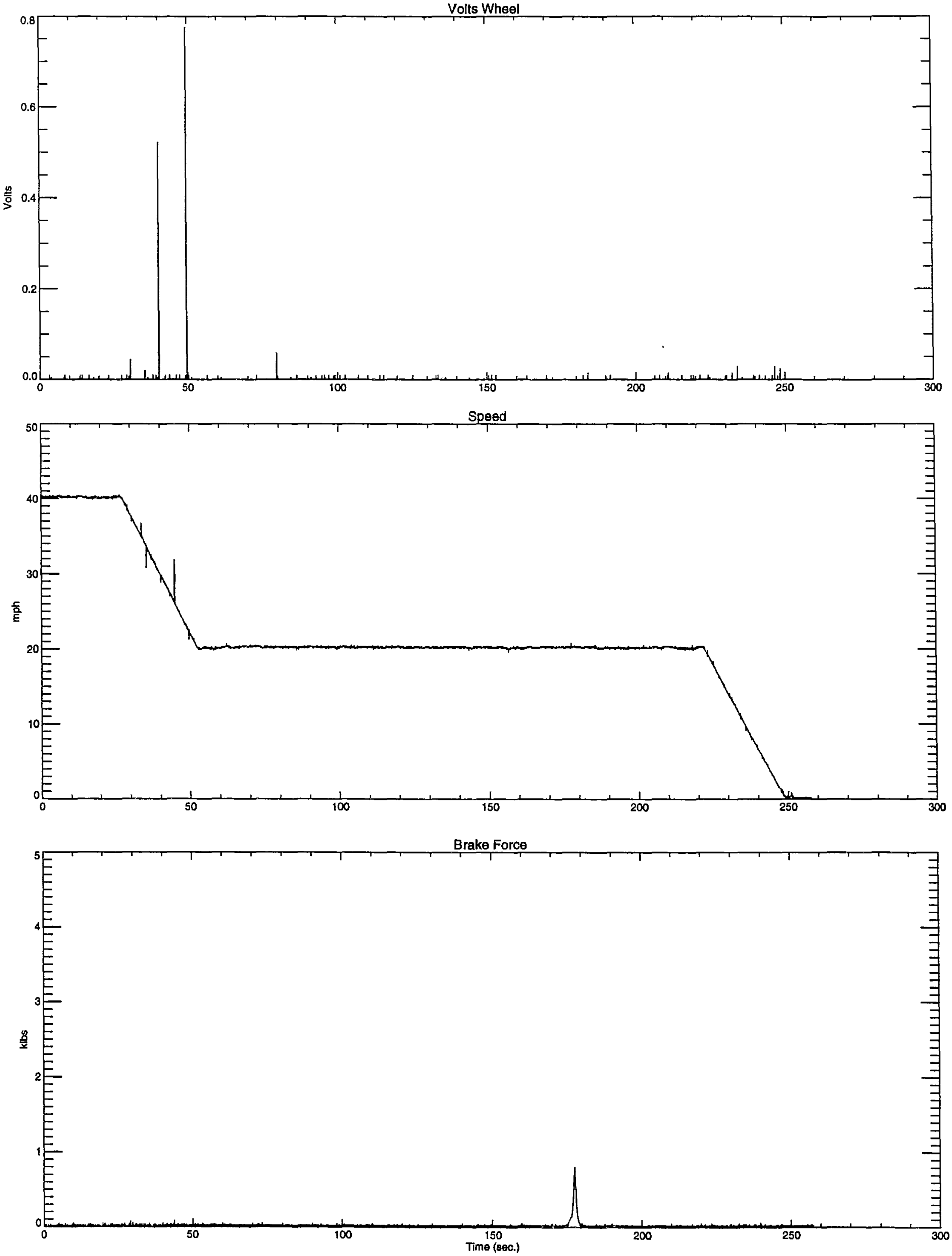
Run 019 C - Wheel Load 6,300 lbs.



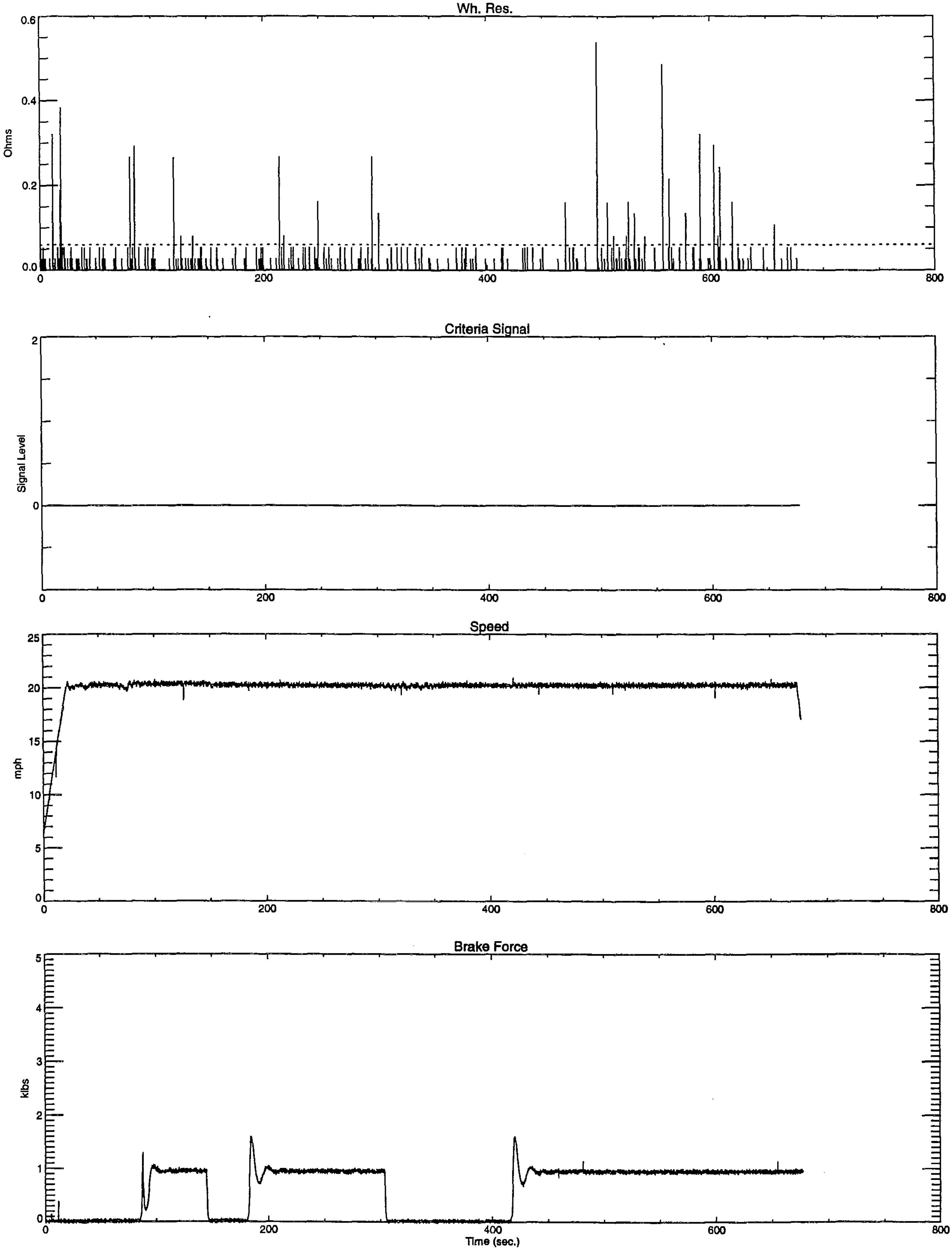
Run 020 C - Wheel Load 6,300 lbs.



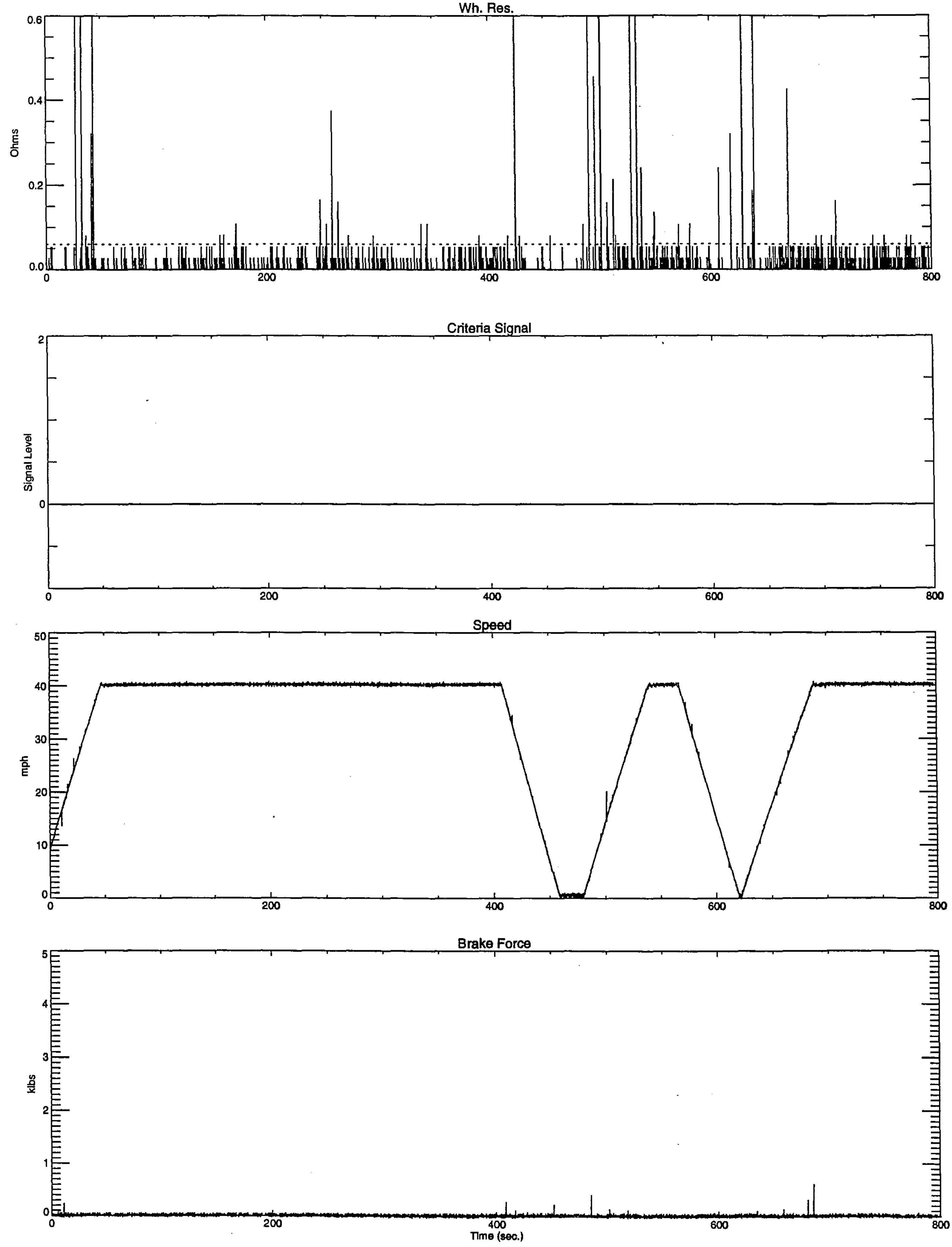
Run 021c - Wheel Load 6,300 lbs



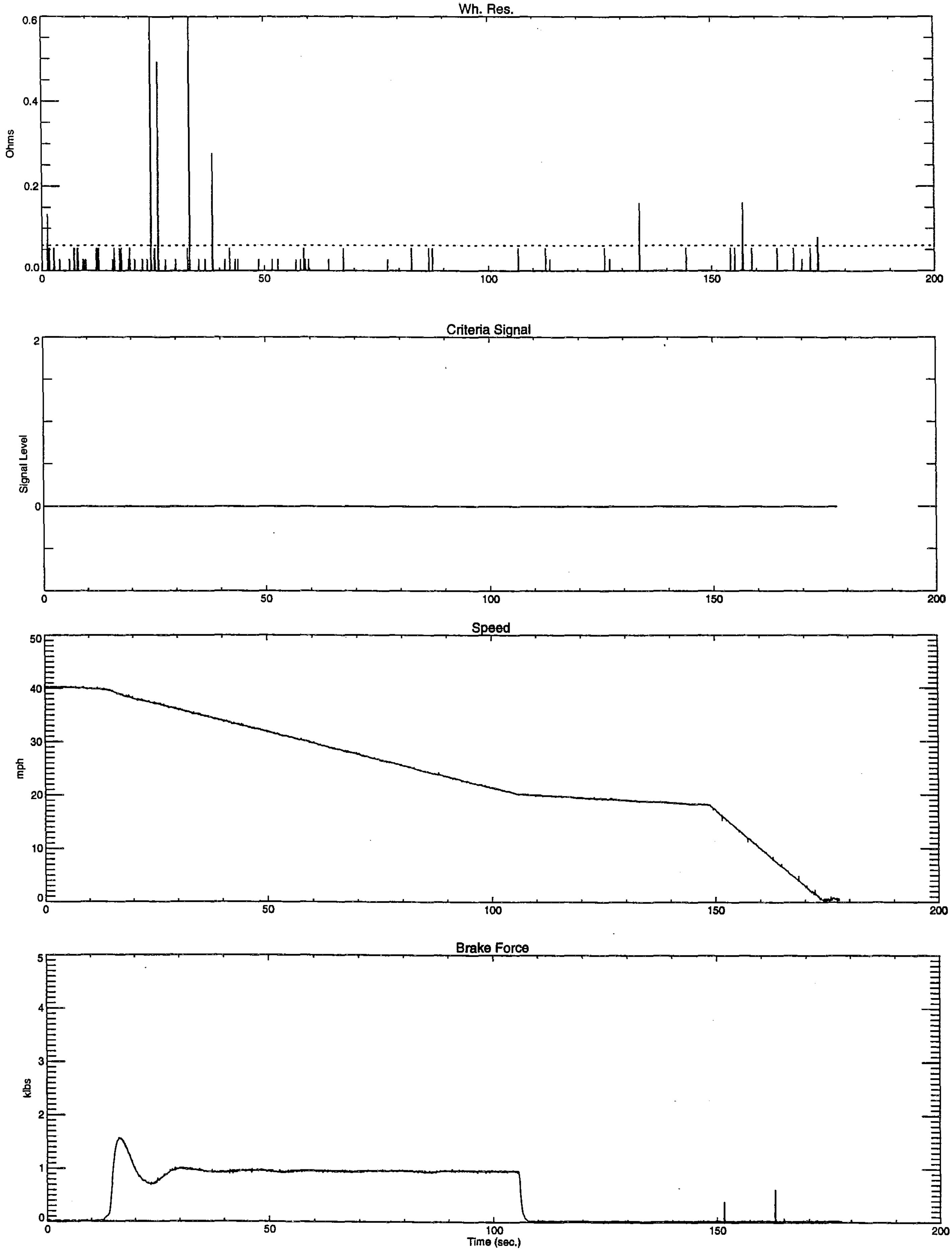
Run 022 C - Wheel Load 6,300 lbs.



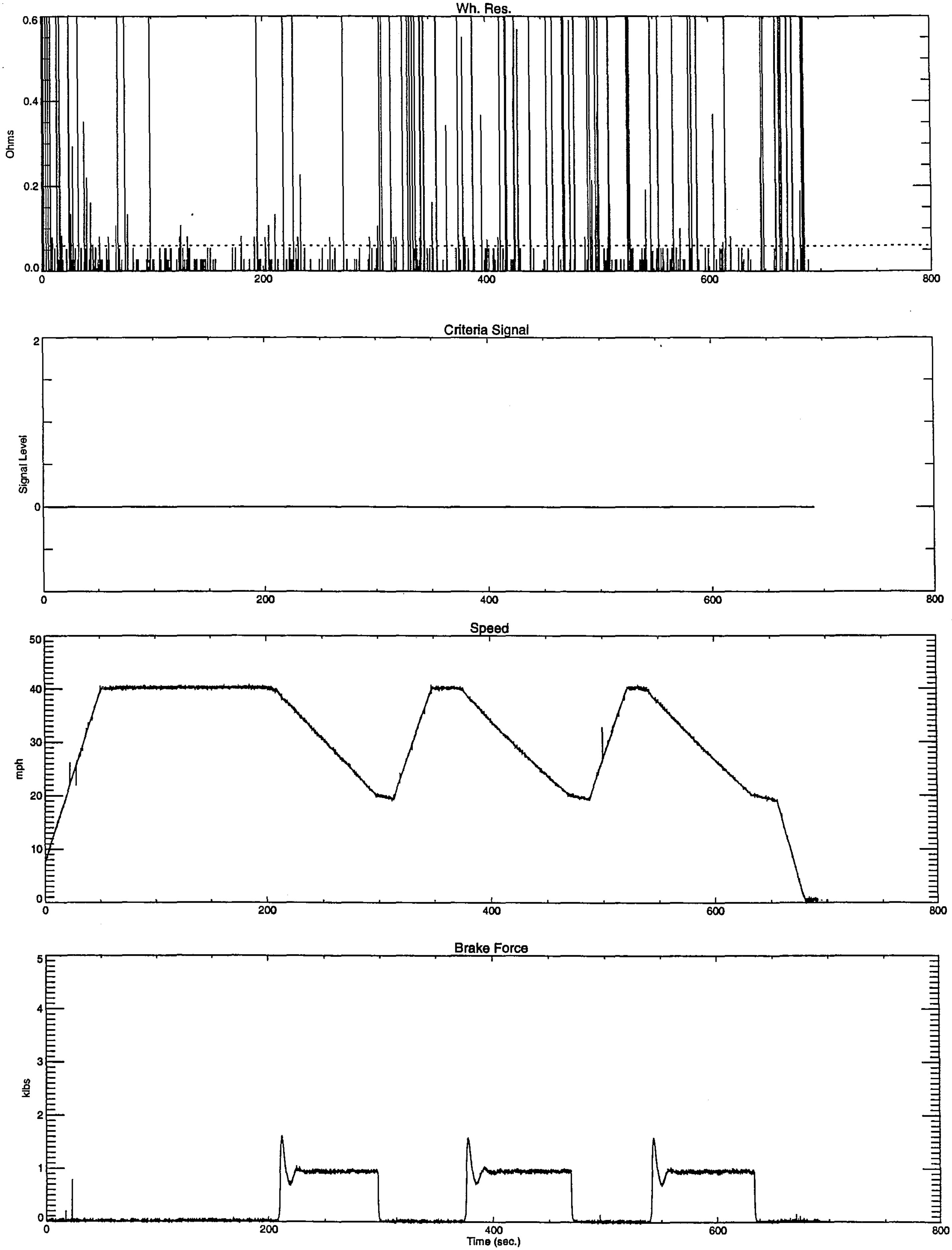
Run 023 C - Wheel Load 6,300 lbs.



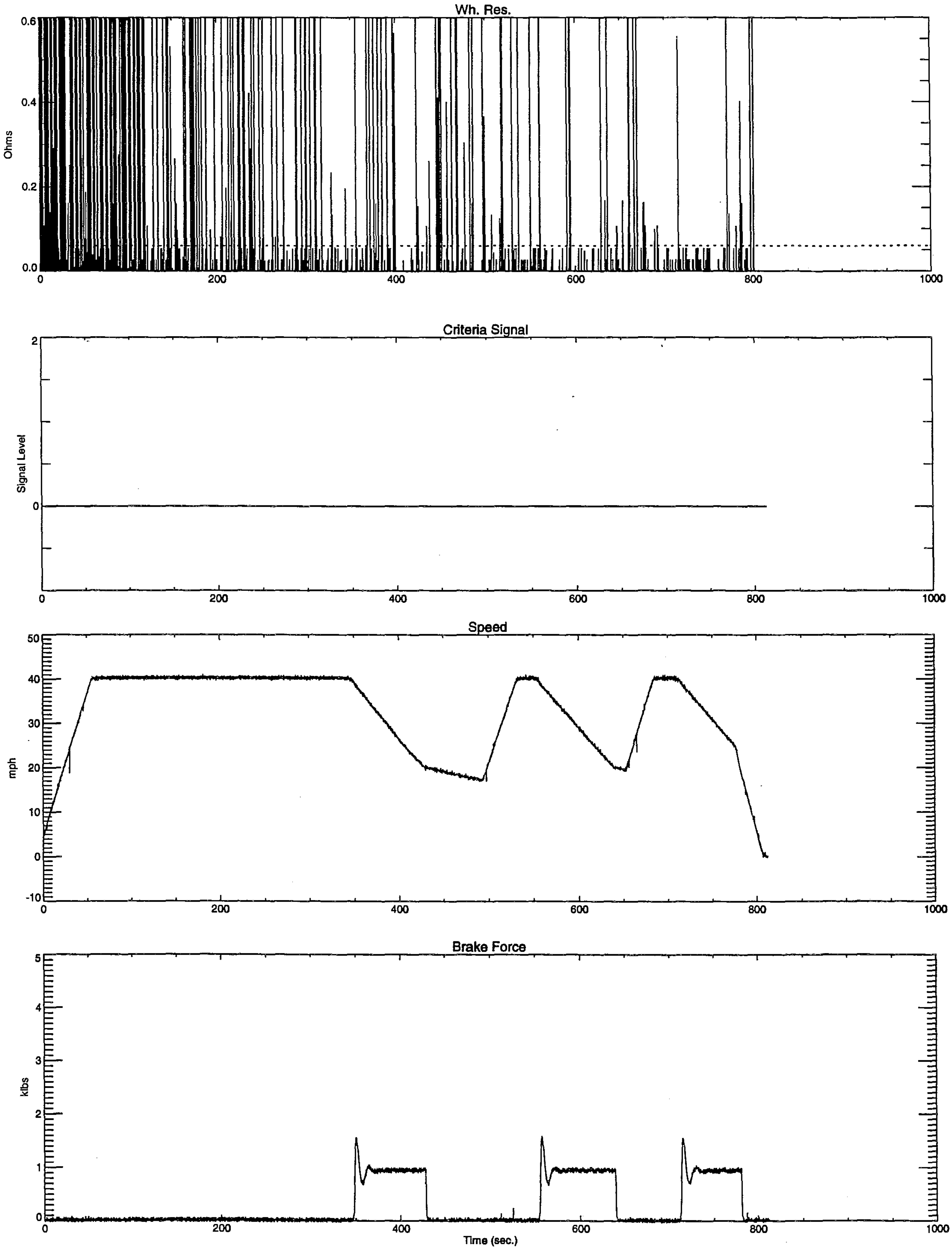
Run 024 C - Wheel Load 6,300 lbs.



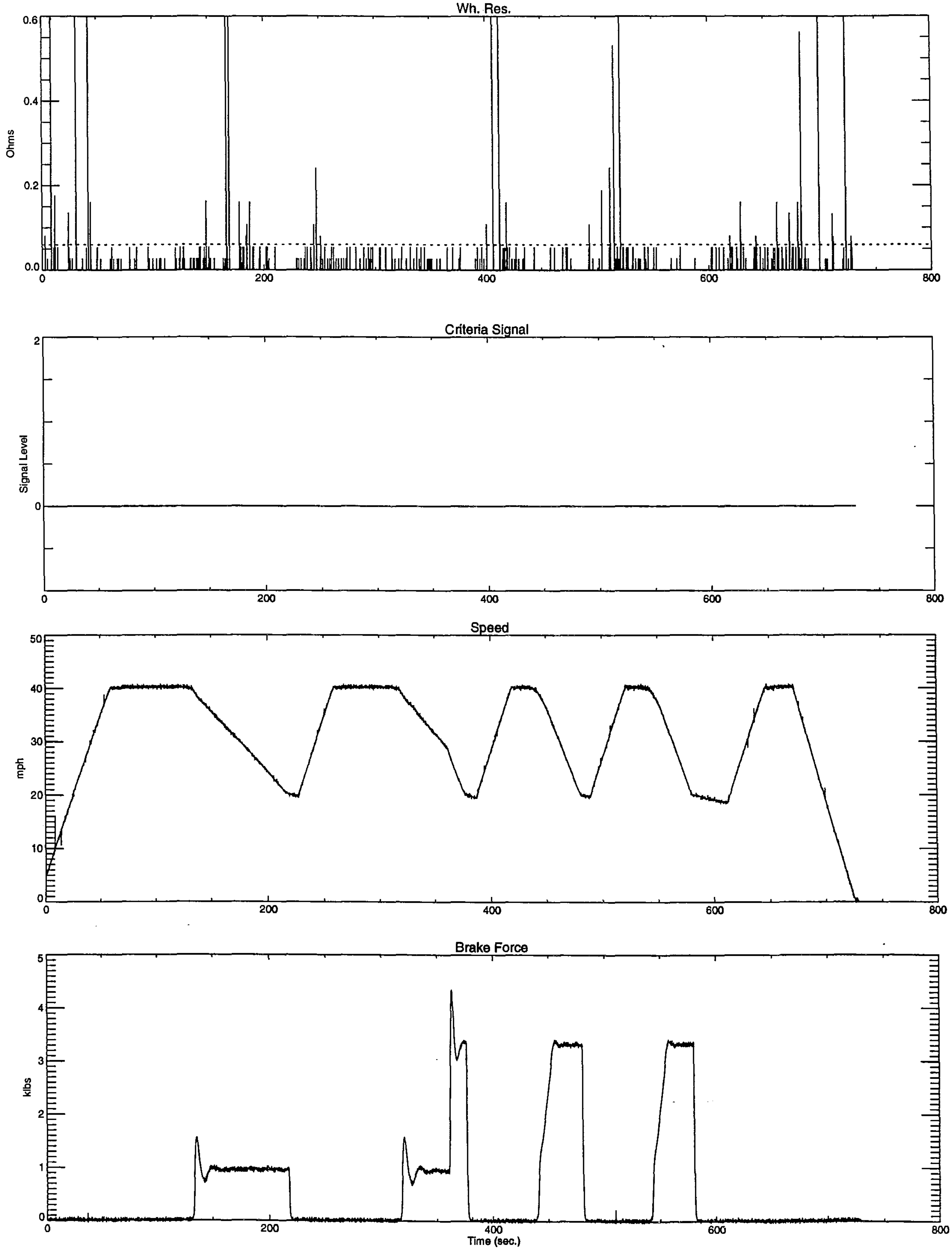
Run 025 C - Wheel Load 6,300 lbs.



Run 026 C - Wheel Load 6,300 lbs.



Run 027 C - Wheel Load 6,300 lbs.



APPENDIX E

Task Force Comments

February 28, 1996

File: C&S 3.12.1

To: R. Reif
From: W. Etter

Ref. LOS Plots and response analysis

Attached are synopsis of the committees observations and comments given by J. Murphy of UPRR and CN Labs. It is my understanding that CN Labs may submit more information, however Terry Therrien will be vacationing for the next three weeks. Therefore, I'm not certain when their report will be available. Jim Moe will also be submitting his comments which I believe sometime this week.

As you can read, the perspectives given in each paper is quite diversified and tends to keep the research results in a questionable flux. Quite a few view points are given and for honesty of analysis, all have merit.

Attachments:
1. Committee Synopsis
2. CN Rail Labs report
3. UPRR, J. Murphy report

Track Circuit Parameter (Loss of Shunt)
Evaluation of Wheel Dynamometer Plots
Highway Railroad Grade Crossing Committee Synopsis

The following listed members of Committee D who are assigned to the Task force held a teleconference on January 29, 1996 to review the revised wheel dynamometer plots supplied under Richard Reif's cover letter of December 19, 1996.

J. Murphy - chairman, UPRR
T. Therrien - CN Rail
M. McNichols - CSXT
F. Ballinger - Harmon
J. Moe - Consultant Safetran
W. Etter - AAR
C. Johnson - NS

The re-drafted plots with the consistent and equal scale readings and .06 ohm scale eliminated the discrepancies of interpretations as found on the previous plots.

Go-no-go feature

This feature which was added per the Signal Committee's recommendations and specifications appears to have eliminate questionable shunt loss areas as compared with earlier plots. The go-no-go parameters recommendations are arbitrary. In certain plots such as #13b where the resistance and time durations appear as a full loss of shunt, the signal level (go-no-go) indicates that the sample rate may be set to tight and not accurately replicate true conditions. Nevertheless, we believe changing the go-no-go parameters will not expand the findings or prove any new conclusions.

60 mili-ohm scale

This scale reveals the presence of resistance which hovers just below or above the 60 mili-ohm level during or following the application of lubrication and also following cyclic braking activity when insignificant amounts of lubrication are on the wheel. This is significant in itself because the wheel rail interface resistance is consistently at the threshold level. A small increase of resistive elements can raise the threshold level above the Loss of Shunt level.

Run A

The most unique discovery is that the plot patterns are basically the same and are fairly consistent and repeatable such as found in plots 15a, 17a, 18a, 19a, 20a, 21a, 22a. These patterns reveal intensified resistance and full LOS under braking applications plots 23a and 24a, and repeated again during cyclic braking in plots 25a, 26a, and 36a, 38a. The patterns indicate less shunt loss with the heavier axle loads. It should be noted that these heavy axle load patterns are similar and consistent to the light load patterns.

Run B - Brake shoe #1

The members determined that run B can not be accurately compared with run A or C due to the differences of brake shoe manufacturers, irrespective if this a conformal brake shoe. Also

the members observed that the MPH braking cycles patterns are different than run A. Although the brake shoe types are not the same as in run A, the pattern can again be observed. Braking cycle patterns 8b, 9b and 15b, 17b, 19b are again similar to braking cycles in Run A. The signal level (go-no-go) sampling rates in Runs 13b & 19b appear tight. The resistance remains above the threshold for long time durations.

<u>Run C - Brake Shoe #2</u>

The members again concluded that this test could not be accurately compared with runs A & B because of the brake type differences. Also the MPH braking cycles patterns are different than run A and B. Although the brake shoe types are not the same as in run A or B, the pattern theme continues to be evident for the braking cycles with lubrication present on the wheel. See runs 16c, 17c and 27c.

<u>Conclusions:</u>

- Los of shunt occurs within the same plot patterns.
- There are significant problems with small residue of grease with repeated braking cycles.
- Does this LOS only occur with a particular brake shoe, IE: manufacturer, conformal?
- Does LOS occur only with a given manufactures lubricant?
- Were brake shoes 1& 2 in run B & C the significant factors for not replicating the cyclic braking shunt loss as found in the first run?
- What did occur at the wheel rail interface to cause LOS during cyclic braking?
- Cyclic braking LOS was repeatable in run A, but not in run B & C. Why the inconsistencies? Note: Runs B & C did show cyclic braking LOS tendencies but not to the extent as found in run A.
- What extent does conformal and non-conformal brake shoes contribute to LOS?
- The collected data has indicated unique correlations between brake cylcles and lubrications. Unfortunately the research could not be carried out to satisfy or clarify these distinct findings with the rail/wheel contact patch phenomenon. The research has been left open ended.

Date: Friday, 2 February 1996 1:21pm ET
To: THERRIEN
Cc: CHAPMAN, TRUONG02
From: TRUONG02
Subject: TTC L.O.S. Test & Comments

Terry,
After going through your thick memo, I have come up with several observations

1. First of all, the LOS criteria developed by TTC is a very precise one to track resistance. Out of 64 graphs, I have seen 12 cases of LOS but we should only discuss the 5 cases whose duration is higher than 5 seconds.
These 5 cases are: 017A, 022A, 023A, 024A, 026A, and 019b of the report. The causes of LOS can be grouped into two category:

a. Main cause: sand, leaves, grease and lube. An EXCESSIVE amount of any of this material can cause LOS when the wheel equipped with new brake shoes is:

a. Accelerating;
b. At constant speed; or
c. At low speed (skidding at less than 0.1mph).

b. Secondary cause: wheels with new brake shoes are more likely to cause LOS if condition (a) exists. Braking can help deminish LOS.

2. Conformal brake shoes tend to remove grease/debris from wheel/rail interface and reduce chances for LOS to occur.

By observing so many test results, I would like to conclude that the LOS is not prevalent. Braking tends to deminish LOS caused by big chunk of grease as per graph 015A. Nevertheless, this test was done for one type of wheels, I'm not sure whether one can generalize his observation. I believe that LOS depends on the rail/wheel oval footprint. If we perform the same test for two types of wheels (the smallest and the biggest one), we may be able to derive something out of it.

Duy(7043)

TO: WAYNE ETTER

FROM: JIM MURPHY

DATE: FEB 27, 1996

SUBJECT: DYNAMOMETER - LOSS OF SHUNT TESTING

DURING BRAKE CYCLE TESTING, WITH CERTIAN AMOUNTS OF GREASE ON THE RAIL, THERE WAS SUBSTANTIAL LOSS OF SHUNT WHEN THE BRAKE WAS RELEASED. THEN LOSS OF SHUNT IMPROVED DURING THE BRAKING, AND THEN WENT BAD AGAIN WHEN THE BRAKE WAS RELEASED. THIS CYCLE REPEATED SEVERAL TIMES.

WHEN THE BRAKE WAS APPLIED TO THE GREASY WHEEL, I BELEAVE A FILM WAS CREATED WHICH WOULD CAUSE LOSS OF SHUNT. AT THE SAME TIME THE FRICTION BETWEEN THE BRAKED WHEEL AND THE RAIL WHEEL, CAUSED BY THE BRAKED WHEEL SLOWING THE RAIL WHEEL DOWN, CREATED GOOD SHUNTING. THEN AS SOON AS THE BRAKE WAS RELEASED, THE SLOWING FRICTION WAS GONE AND THE FILM THAT WAS CREATED FROM THE BRAKING CAUSED LOSS OF SHUNT.

YOU REPORT OF OUR TELECONFERENCE WAS GOOD, AND I BELEAVE WE ARE ALL IN AGREEMENT THAT FURTHER TESTING IN THIS AREA SURELY WOULD BE MERITED, AS WE HAVE FINALLY FOUND A CAUSE OF LOSS OF SHUNT THAT COULD BE CONTROLLED.

James E. Moe
Consulting Engineer
55 East Golden Lake Road
Circle Pines, MN 55014
Phone 612 786-6609
Fax 612 786-2752

FAX Message

To: Wayne Etter

Company: AAR C&S Division

Date: March 4, 1996

Re: Track Circuit Parameters Task Force - Dynamometer tests

The following are my observations concerning the data developed during the Chicago Test Center tests and subsequent data reduction using criteria developed at the last Task Force meeting in Columbus:

Run 000A

This run with the rusty track wheel is typical of what we see in the field with rusty rail conditions and indicates that the test method used at Chicago appears to be duplicating actual field conditions fairly well. It also shows how effective our modern island circuit equipment is in rejecting "noise" voltages due to loss-of-shunt. This is based on the island circuit criteria that we supplied at Columbus which is typical for state-of-the-art conventional island circuit design.

However, note that there are a number of island relay pick-ups during the run. While of short duration, any one of these could result in a gate "pump" which could encourage a motorist to start out toward the tracks. Further, if the crossing warning is circuited to either provide a time delay or force the gate to rise to its vertical position upon island recovery (as many are), each of these island relay pick-ups would result in a gate-up situation.

Runs 003A - 010A

These runs with relatively clean and close to ideal conditions still show some loss-of-shunt "spikes" in the wheel-rail voltage. Despite these, a modern island circuit would not pick up.

Run 011A

This run with constant braking shows quite a bit more momentary loss-of-shunt events. While none of these result in an island pick-up, it does indicate that something is happening to deposit brake shoe material on the wheel that results in periodic loss-of-shunt. This is not too significant in itself, but is significant in view of what occurs in subsequent braking tests.

Run 015A

With a significant amount of lubricant present, there is also significant loss-of-shunt. In the 0-200 second time frame, there are loss-of-shunt events which result in fairly long island pick-ups. The time scale is too tight to determine the actual time, but it appears that some of

these could be as much as 5-10 seconds in duration.

The loss-of-shunt mitigation in our "ideal" theoretical island circuit deals very well with the "firestorm" of loss-of-shunt spikes in the T=400 second time frame. Nevertheless, this still shows the significant effect on high levels of wheel-rail lubrication, at least with the grease which was used in this test.

Run 017A

Even with a higher wheel loading, the addition of heavy lubrication resulted in significant loss-of-shunt. The island pick-up at around T=250 seconds appears to be around 10 seconds or more in duration which would result in a gate-up situation, or very noticeable cessation of flashing light operation, at any crossing.

Runs 018A-020A

As wheel loading is increased, the effects of lubrication are, as would be expected, reduced. However, there is still significant loss-of-shunt even with the higher wheel loading and the tests indicate that high wheel loading does not eliminate loss of wheel-rail contact due to high levels of lubrication.

Runs 021A-022A

Here again, heavy lubrication resulted in a very significant loss-of-shunt. In run 021A there is an island pickup which is well in excess of 10 seconds at around T=480-490 seconds. Note that the time scale here is 800 seconds for the total run, so an island pickup which shows any width at all is of very significant duration. Even with wheel loading increased to 12,000 lbs in run 022A, we still have an island relay pickup of several seconds around T=150 seconds.

Runs 023A-024A

These are perhaps the most significant of all the testing done in this series as it is the first that appears to explain and quantify some of the loss-of-shunt phenomena which we are experiencing in the field in the absence of heavy lubrication or obvious contaminants. When the tests were being run, it was obvious that we were experiencing the sort of dramatic loss-of-shunt that has shown up at several locations around the country over the past few years.

The physical parameters should be noted: First, a small residue of lubricant on the wheel (and rail wheel) which is what we would expect to find in the field if a rail mounted lubricator is some distance away or an onboard lubricator is metering a small amount of lubricant. Second, braking with a composition brake shoe. Third, everything else is clean and would otherwise give the expectation of excellent shunting.

In run 023A, there is good shunting from the start of the run until braking occurs at around T=150 seconds. There is no loss-of-shunt during braking. However, after the brake has been released at T=180 seconds, significant loss-of-shunt occurs about 20 seconds later. Shunting becomes progressively poorer over the next minute as speed increases, resulting in an island relay pickup at T=260 seconds which lasts continuously until T=310 seconds. This is a track circuit pickup of 50 seconds which could occur at an island circuit, detector section or, if a locomotive or short train were affected, result in losing a train entirely in signal territory.

Only when the brake was reapplied at T=305 seconds did the shunting return to normal as the brake shoe apparently cleaned whatever film was present from the wheel. Unfortunately, the test was not continued beyond this time without reapplication of the brake as it appeared that whatever was causing the loss-of-shunt incident was continuing to get progressively worse. Certainly, only the cleaning action of brake reapplication was responsible for achieving a shunt again and it is reasonable to assume that loss-of-shunt and track circuit pickup would have continued for some longer time otherwise.

This was no isolated phenomena, as the same thing was repeated following the second brake application and started to occur after the third brake application. Unfortunately, again the run was terminated before the longer-term effects could be determined.

While in retrospect one could conclude that the testing should have been continued at the time to determine the longer term effects of these phenomena, it must be realized that we were at the time somewhat blindly trying different possibilities and combinations of lubrication, contaminants and braking to see what contributed singly and collectively to loss-of-shunt. The significance of what we saw in run 023A was immediately apparent, but we did not have time to do any analysis on the spot to fully realize what was unfolding. Also, time available for the tests was running out and we still had many more runs to make to carry out our original test plan.

Run 024A was a continuation of run 023A with the same parameters present at the start. The loss-of-shunt event during the first cycle from T=10 to T=190 was essentially the same as run 023A and corroborates data collected from that run. Loss-of-shunt was even more severe, resulting in a track circuit pickup of around 125 seconds. Also, on this cycle, although the brake was applied at T=150 seconds, severe loss-of-shunt continued, though somewhat diminished, and track circuit pickup continued throughout the brake application portion of the cycle. Apparently the non-conductive film had become more difficult to clean off during brake application.

It is not clear just where the addition of more lubricant occurred, but it was likely at around the T=190 to 200 second point as there is a marked change in shunting characteristics at that point. Further, during the brake applications at T=300 seconds and T=480 seconds, there is no loss-of-shunt at all. Evidently, the presence of large amounts of lubricant has the effect of aiding the brake shoe in cleaning any non-conductive film from the wheel.

Runs 025A-026A

We wanted to determine whether or not the results seen in runs 023A and the first cycle of run 024A were repeatable so tried to reconstruct the same wheel-rail parameters. In run 025A, the loss-of-shunt phenomena previously observed were less pronounced, but grew progressively more noticeable in subsequent braking cycles.

Consequently, run 026A was done to see the effect of additional braking and, presumably, leaving only a small residue of lubricant. The results of runs 023A and the first cycle of run 024A were essentially repeated. The island relay showed significant pick-ups in the second cycle and almost continuous pickup during the third and fourth cycles between brake applications. This definitely indicates that the combination of a small residue of lubrication together with repeated braking action can result in a significant loss-of-shunt and track circuit relay pickup and corroborates the data from runs 023A and the first cycle of run 024A.

Runs 027A-030A

Wheel loading was increased to see what effect this had on the loss-of-shunt phenomena seen in runs 023A to 026A. Apparently, heavier wheel loading cut through whatever film was causing the problem in runs 023A-026A, as only minimal loss-of-shunt was noted. Also, once the film had been removed by the heavier wheel load, no loss-of-shunt recurred even when the wheel load was again reduced to 6300 lbs in run 029A. Also, adding a small amount of lubricant in run 030A had little effect on shunting, which remained relatively good with only occasional short "spikes" greater than .06 ohms.

Runs 032A-034A

These runs introduced sand, dirt and leaves with a small amount of lubricant to aid in adhering the contaminants to the wheel and track wheel. In all cases, it was apparent that some contaminant particles did result in loss-of-shunt "spikes," but it was not severe and did not result in island relay pickup. The greatest incidence of these "spikes" was for dirt and leaves. Brake application appeared to quickly clean the contaminant residue from the wheel.

Runs 036A-038A

These runs introduced water after a small amount of lubricant early in run 036A along with braking cycles. Run 038A used significantly higher braking force. In both of these runs, loss-of-shunt events became more numerous with subsequent cycles, as it had in runs 023-A-034A and 025A-026A, but to a much lesser degree and without any island relay pickup. The presence of water did not seem to have any significant effect.

Runs 002B-007B

Run 002B was presumably to determine a "base line" for subsequent tests and the graphical data was not included. In run 003B, lubricant was added. There are a number of loss-of-shunt "spikes" indicating some shunting problems but no island relay pickup. In run 004B, excess lubricant was wiped off which resulted in significantly poorer shunting and heavy loss-or-shunt "spikes." However, no island relay pickup resulted. In run 006B, more lubricant was added and in run 007B the excess was removed.

There appears to be no conclusion to be drawn from runs 003B to 007B, other than to note that with whatever film remained on the wheel from the previous braking tests and the presence of varying amounts of lubricant, quite a few loss-of-shunt "spikes" did occur. Shunting was not generally as effective as it was in the previous "A" series tests under ideal conditions. However, adding lubricant did not have as serious an effect on shunting as it did in the "A" series tests with the same wheel loading.

Runs 008B-009B

Both of these runs utilize regenerative braking to decelerate. In run 009B, lubricant was added. There is significant loss-of-shunt in run 008B, particularly in the second cycle. Also, there are more "spikes" of higher amplitude during acceleration and deceleration than at a steady speed and almost no loss-of-shunt at low speed between cycles.

Runs 010B-013B

Contaminants were introduced in these runs. In run 010B, sand was used with some lubricant as a binder, presumably at the start of the run at very low speed rather than during the run at speed, as was done in the "A" series tests. Loss-of-shunt is significant initially with island relay pickup of unknown duration (though the one at T=100 during acceleration could be fairly long). This cleans itself up after about three minutes and dynamic braking appears to improve shunting quite rapidly. There are loss-of-shunt "spikes" immediately following brake applications at around T=700 seconds and T=850 seconds, but these do not appear to be particularly significant. The continuous brake drag in run 011B has no significant effect.

The lube, sand and dirt applied in run 012B (again apparently applied at low speed at the start) again resulted in significant loss-of-shunt initially. However, it cleaned up quite a bit with dynamic braking and almost entirely with friction braking as it had in run 010B.

When leaves and organic material was added to the mix in run 013B, the effect was significant with a "firestorm" of loss-of-shunt "spikes." Dynamic braking appeared to exacerbate the problem rather than improve it as it did with only sand or sand and dirt. There are significant island relay pickups from T=500 to T=650 seconds which are of indeterminable duration as the time scale of 1200 seconds makes even a 10 second pickup appear as a "spike."

Friction braking was not tried here although it had been in the two previous runs. This begs the question of what would have been its effect? Also, even though the loss-of-shunt event was still very evident at the conclusion of run 013B, no further runs were made using organic contaminants.

Runs 015B-019B

Run 015B was done presumably using a dry wheel and rail wheel without lubricant as it was noted that they had been cleaned in run 016B. Brake application did not appear to have a significant effect on loss-of-shunt. In run 017B, some lubricant was added though the amount and time are not specified. Looking at the resistance graph, it would appear it was applied before the start as there is a distinct increase in loss-of-shunt "spiking" from the previous run with a dry wheel.

In run 019B, which appears to mix friction and dynamic braking, there is a distinct increase in loss-of-shunt following the first friction braking cycle. This is accompanied by island relay pickups of significant duration, particularly during steady-state running just before the second brake application. Although the tight time scale (1200 seconds) used here as opposed to the longer time scale (600 seconds) used in run 023A makes it more difficult to compare, the wheel-rail resistance graphs appear to look very much alike. The dynamic braking applied at T=650 appears as it might have helped to clean up whatever film was causing the shunting problem.

Runs 013C-027C

These runs with light braking loads and other variations on the previous runs do not appear to introduce any further significant information concerning loss-of-shunt phenomena. In run 015C lubricant was introduced with some additional loss-of-shunt "spiking." In run 016C this lubricant was spread around further with friction braking also introduced. The braking did result in some increase in loss-of-shunt spiking, but not nearly as much as it had in runs 023A-034A and 019B.

In run 017C, friction braking appears to have cleaned up the increasing loss-of-shunt problem caused by multiple lubricant applications in runs 015C-017C. The amount of lubricant present is indeterminant, but there apparently was quite a bit of residue.

It is interesting to note that the steady-state conditions observed in run 013B were not repeated in run 018C despite the similar contaminant mix containing organic material and other nominal parameters being the same. However, when this same contaminant mix was merely redistributed in run 019C, it resulted in a significant increase in loss-of-shunt spikes.

Runs 025C-027C appear to show that light braking does not clean a dirt-lubricant (apparently dirt-diesel fuel) mixture nearly as effectively as a heavy brake application as would be expected. Also, when lubricant (I assume grease lubricant) is added to the existing dirt-lubricant mixture in run 026C, there is significant loss-of-shunt "spiking."

General conclusions:

The loss-of-shunt and island relay pickup phenomena which we observed in runs 023A-024A and run 026A is unquestionably the most important finding to come out of these tests. It is further corroborated in run 019B so is not a transient phenomena. This appears to occur with a small amount of lubricant residue following several heavy braking cycles. Neither lubricant nor braking alone produce such significant loss-of-shunt results. However, the actual mechanics and parameter interactions that cause the phenomena remain a question.

Heavy lubrication does have an effect and it is apparent that this can contribute to loss-of-shunt if the amount of lubrication is significant. Wayside lubricators should be located away from short track circuits such as islands and detector sections. However, the small trace lubricant which appears to be highly beneficial in reducing wheel-rail friction does not appear to be itself a problem.

The effect of contaminants is about as would be expected. Gross application of any kind of contaminant is detrimental to shunting but most appear to clean out rapidly, both by running and by braking. Organic material seems to pose the greatest problem and this is what we also see in the field, particularly in the spring of the year when the trees are shedding or if we ever have a grain car leaking.

There is no indication that dynamic braking is a contribution to the loss-of-shunt problem from these tests. In fact, it appeared to have a somewhat beneficial effect when applied where there were contaminants and/or lubricant which caused loss-of-shunt "spiking." However, this is not conclusive and it is possible that replacing friction braking with dynamic braking could result in a film buildup on wheels as occurred with the Amfleet cars before retrofitting tread brakes.

Other considerations:

No distinction was made as to what type of lubricant was used in the tests. A graphite grease was used in the "A" series tests and it is not known what type was used in the "B" and "C" series tests. Certainly it is reasonable to expect that different lubricants would act differently.

The brake shoe used in the "A" series tests was, I have been told, not the same as was used in the "B" or "C" series tests. It is reasonable to assume that if there is some connection between the brake shoe and loss-of-shunt events as these tests strongly suggest, it may well be

dependent upon brake shoe composition. If this is the case, this variable should be isolated.

There was a considerable concern during the testing regarding "conformal" and "non-conformal" brake shoes. While some comparative testing was done, it was not established what effect this had upon actual loss-of-shunt results. The new brake shoe used in the first tests had "broken in" by run 023A so there was about 75% contact and the car wheel showed uniformity of contact and no striations indicating missing contact areas. If this is an important parameter, its effect should be isolated. On an actual train, it would be reasonable to expect most shoes to be "conformal" but certainly some could be "non-conformal" either due to newness or wheel and/or brake shoe anomalies.

Another interesting observation made during the "A" series tests was the presence of large flakes of a shiny, black surface deposit on the brake shoe. These appeared coincidentally with the runs 023A-026A, when we experienced our significant loss-of-shunt and had not shown up previously. Whether this is significant or not is unknown.

Definitions:

There seems to be some confusion regarding "loss-of-shunt" and "track relay pick-up." Actually, loss-of-shunt technically occurs anytime the rail-wheelset-rail resistance, when measured at around one volt open-circuit, goes above 0.06 ohms (60 milliohms). It doesn't matter whether an associated track circuit picks up or not. This is a specific industry definition. Consequently, any time the trace on the resistance curve in these test reports rises above the 0.06 ohm line, that is, by definition, a loss-of-shunt.

In the test runs in Chicago, we used a single wheel-rail contact patch. This is electrically equivalent to a series-parallel circuit made up of two wheelsets in parallel, each with two contact patches. Thus, the values in the test report are representative of one two-axle truck in a short track circuit.

Track circuit component manufacturers have long been aware that there are periodic loss-of-shunt events which occur in the field under even normal conditions. This has been taken into consideration in the design of their equipment. Thus, some "spiking" of the resistance curve over the 0.06 ohm level can be tolerated by equipment in service.

When this built-in tolerance is exceeded, a "track relay pick-up" will occur. As there are no industry definitions for the tolerance to loss-of-shunt "spiking," neither in duration or amplitude, any significant loss-of-shunt event could potentially result in a relay pick-up. Thus a loss-of-shunt which results in a track relay pick-up with one track circuit may or may not with another.

The parameters used for the analysis of the contact resistance data in these tests represent industry shunt threshold/persistence criteria used in the best current island track circuit equipment and, as is apparent from the test runs, are very effective in preventing relay pick-up, even under adverse loss-of shunt conditions. However, there are many track circuits in use which are many years old and may not incorporate as effective false relay pick-up mitigation as modern equipment does.

Consequently, any loss-of-shunt event, other than occasional and isolated "spikes," should be regarded as a potential for false track relay pick-up in the context of this test program.

Further action:

The testing done to date on the AAR Test Center dynamometer has provided some valuable insights concerning shunting and isolated a number of variables which have been impossible to determine in other forms of test and evaluation of track circuits. It is essential that these leads be explored to further isolate variables and determine just what it is that caused the severe loss-of-shunt events of runs 023A, 024A, 026A and 019B.

Hopefully, the brake shoe which was used in thee "A" series tests and the one used in the "B" series tests are available for further runs. The same, of course, is true for the insulated car wheel, slip rings and instrumentation.

The effect of various types of lubricants in common use, both alone and in conjunction with friction braking, should be explored further. The previous tests indicate that the types of lubricant (of lubricants) which we used caused some problems when concentrated. However, we should determine the effects of both quantity and lubricant makeup in a controlled test.

A test plan should be drawn up to define further testing and decide how best to follow up on these tests. This must be based both upon the specific areas which look most promising and limitations of the dynamometer and test equipment.