organized tents were provided for living quarters, and a system of unloading and setting the poles was assembled as mentioned above.

A 4-ft., 2-pin creosoted cypress cross-arm was mounted near the top of each pole for carrying the two No. 4 twisted aluminum steel-cored conductors for the 4,400-volt feed. R. Thomas & Sons' No. 31 porcelain insulators with wooden pins were used for this circuit. An 8-ft., 6-pin creosoted cypress cross-arm with steel pins, wooden cobs and glass insulators was mounted 6 ft. below the top arm to carry the No. 10 bare Copperweld 110-volt signal control wires. The majority of the pole line hardware was furnished by Hubbard & Company, Pittsburgh, Pa. The line was well guyed at all curves and storm-guyed four ways about every half mile. Over certain bridges and viaducts it was necessary to put the line circuits in cable.

The pole line from Richmond to Norlina, 98 miles, was completed and power turned on on November 19, 84 working days after the start. The section of pole line from Raleigh to Hamlet was completed December 30.

It is the purpose of this article to cover only the construction methods used. A later article will describe the circuits, the unique features of the signaling and some of the results secured in improving train operation by means of the signals.

M. H. Cahill, operating vice-president of the Seaboard Air Line, is very appreciative of the splendid co-operation and co-ordination that has made possible this record in signal construction. *Railway Signaling* is indebted to W. D. Faucette, chief engineer, and F. H. Bagley, signal engineer of the Seaboard, and J. F. Talbert of the Union Signal Construction Company, for the information made available for publication in this article.

Norfolk & Western Train Control Approved

Union Switch & Signal Company's Three-Speed Continuous Induction Type Found to Meet I. C. C. Requirements

THE three-speed continuous induction type of the Union Switch & Signal Company's train control as installed on the Shenandoah division of the Norfolk & Western, between Shenandoah, Va., and Hagerstown Jct., Md., 106.1 miles of single track, has been approved by the commission with the exception of certain prescribed requirements. The final report was issued on January 2, 1926, an abstract of which follows:

On November 10, 1924, the installation was completed and on February 15, 1925, it was placed in service. That portion of the Shenandoah division equipped with train control is all single track. There are 41 locomotives equipped with the device. (An illustrated article describing this installation was published in *Railway Signaling* for June, 1925.)

"At our request," the commission says in its report, "the carrier furnished figures showing the cost of the completed installation. These figures cover the cost for the device as installed upon this carrier's road as affected by its particular track and operating requirements. It is understood, of course, that the cost of installing the same device upon any other carrier's road will in all probability be different because of differences in the number of locomotives to be equipped and differences in wayside apparatus that may be necessary to meet particular operating conditions. The inclusion, however, of the cost figures as compiled by the carriers and vouched for by them in each case as installations are completed and reported upon will furnish data from which conclusions may be drawn as to the comparative cost of the various types of devices under a great variety of operating conditions. They are valuable for this purpose and we deem it pertinent and in the public interest to set them forth in this and subsequent reports upon completed installations.

Description of Wayside Equipment

The absolute permissive block signal system throughout this territory consists of normal clear, three position, U. S. & S. Co., position light signals, with double instrument case, on concrete foundations. Two-post bracket signals are located at each end of each passing siding. These are absolute signals. Each absolute signal is distinguished by a marker light. The high signal on these bracket posts governs movements on the main line. The low signal governs movements from the passing siding. A one-arm or a two-arm pull-in stop-and-proceed signal is located in advance of passing siding switches. Intermediate signals between passing sidings are of the one-arm type. These signals are all of the stop-and-proceed description with the exception of those having the grade indication feature and the absolute signals located at the electro-mechanical interlocker at the Southern crossing at Riverton and the mechanical interlocker at the Baltimore & Ohio crossing at Charlestown.

Train Control Cost According to Railroad Figures

1. Total cost of the train control installation, less power lines, power apparatus, signals and cost of change in existing signal system, less salvage;	
Wayside train control apparatus, Labor and material	$ 194,200.00
Engine apparatus, 41 engines	182,002.85
	$ 376,202.85
2. Total cost of power lines and power apparatus for train control, less salvage: Three-phase 4400-volt 60 cycle, power transmission line, labor and material	162,415.76
3. Total cost of signal system installed in connection with train control, less salvage; Automatic signal system, position-light signals, A. P. B.	447,343.53
4. Total cost of change in existing signal system made necessary by train control, less salvage	(None)
5. Total all other costs; consisting entirely of highway crossing protection	36,958.73
Total cost of installation	$1,022,920.87

Power for the signal and train control systems is furnished from a high-tension line which parallels the track. This power is obtained from commercial companies at Shenandoah, Berryville and Hagerstown, and an emergency supply is provided for from an automatic substation at Stanley, and an auxiliary station of the railway shops at Shenandoah. The power is transmitted at 4400 volts, 3 phase, 60

cycle, over a triangular, transposed, 3-conductor No. 4 solid copper wire line carried on poles. The line is protected throughout its length by a stranded galvanized wire, attached to bayonet brackets on the top of the poles and grounded at every eighth pole. Air-break sectionalizing switches, located on the crossarms and operated by a long handle extending down the pole, are provided at each passing siding.

At signal locations and cut sections a 440/110-volt line transformer is mounted on the transmission line crossarm. This furnishes energy for the system at 110 volts. Choke coils, lighting arresters, grounds, and fused cut-outs are provided at these transformer locations. The bottom crossarm on this line carries the No. 10 copper clad weatherproof wires of the signal and train control circuits. The signals are operated by slow acting light relays controlled through two element line and track relays.

The roadside portion of the train control system consists of two alternating currents in the track rails.

One current, known as the axle current, is the usual track circuit current which flows from the track transformer down one rail, through the track relay, or the wheels and axles of an occupying train, and back in the other rail to the transformer. The axle current must be fed from a track transformer ahead of the locomotive and for this reason the reversible alternating current track circuit is employed. The other current, known as the loop current flows from a loop transformer through resistors and all or a part of the track circuit, in both rails in multiple, and through another set of resistors, returning via the line wire. There are three different conditions of the loop current relative to the axle current, namely loop current of one relative polarity, loop current of the other relative polarity, and no loop current, respectively.

There are usually three loop circuits for each block, one extending in the rear of the signal to the medium speed braking point, (which is termed the "B" point), another extending to the point where high speed braking is to be initiated (the "A" point) and another, (commonly termed the high speed loop), extending from the "A" point to the next signal in the rear.

Locomotive Equipment

The locomotive apparatus comprises the following according to the description given in the report:

1. An axle receiver, for picking up the current induced from the axle current in the rails. This element is substantially supported from the pilot beam, protected by the pilot, and carried between the pony truck wheels and the pilot, about 6¾ in. above the top of the running rails. It consists of a laminated iron structure extending transversely across the running rails and has a receiving coil mounted near each end just inside of the rails. The receiving coils are connected so that the induced current is additive if alternating current flows in opposite directions in the two rails, and hence current flowing in the same direction in both rails induces equal and opposing currents which are therefore neutralized.

2. A loop receiver, for picking up the current induced from the loop current in the rails. This element is substantially supported from the rear end of the engine tender and is carried about 6¾ in. above the top of the running rails. It consists of a beam, having laminated iron ends and an 18 in. wooden middle section, which extends transversely across the running rails, and has a receiving coil mounted near each end outside of the rail. This receiver differs from the axle receiver in that a wooden middle section is provided and the coils are placed on the outside of the rails. This arrangement offsets undesired effects from that part of the loop current that passes through the couplers. The receiving coils are so connected that induced currents are additive for alternating currents flowing in the same direction in both rails.

3. An equipment box, mounted on the right hand side of the locomotive, houses the various electrical units. These consist of (a) an amplifier set containing four vacuum tubes by means of which the alternating current induced in the axle and loop receivers is amplified to operate a two-element alternating current relay, (b) a two-element 3-position, vane type, alternating current train control relay, for controlling the various electrical circuits. This relay is so designed that when the normal polarity relationship exists between the axle and a loop current in the rails, as in a clear block, its contacts are swung to the right. When the reverse polarity relation exists between the A and B points, the contacts are swung to the left. When the loop current is absent as between the B point and stop signal, or when the axle current is absent, as in an occupied block, the relay is de-energized and the contacts are moved by gravity to the middle position. These three relay positions set up the high, medium and low speed limits respectively and illuminate corresponding "H" "M" and "L" indication lights in the cab.

4. A dynamotor, which receives direct current from the generator, for its operation and furnishes a 350-volt direct current for the plate circuits of the vacuum tubes. This dynamotor is mounted on the end of the equipment box.

5. A main switch, for controlling the direct current supply from the generator to the train control electrical apparatus. This switch is located on the cab sheet back of the engineman. There is also at this location a double throw time interlocked switch for switching the headlight and train control loads from one generator to the other or switching both loads to one generator.

6. A speed limit indicator, mounted at the front of the cab on the engineman's side. This indicator has three frosted light indications, "H" indicating high speed, "M" medium speed and "L" low speed. These lights are controlled by the contacts of the train control relay, the "H" light burning when the contacts are swung to the right, the "M" light when swung to the left and the "L" light when the contacts are vertical and the relay is de-energized.

7. A speed governor drive group, consisting of a main shaft driven by means of gears from the axle of the engine truck leading wheel on the engineman's side and operating the speed governor group of valves. A protection governor is also included in this group.

8. A governor valve group, mounted directly above the drive group and consisting of a number of air valves operated by the crosshead of the ball type speed governor. The speed governor is operated through a bevel gear from the drive shaft which extends from the valve group to the drive group. The governor valve group also includes the magnet valves which control the flow of air to ports in the governor; the relay valves; the timing valves, which regulate the delay time of the automatic application; the acknowledging pilot valve used in connection with the acknowledgment feature of this device; protection interlocking valves; and the speed limit change valve. The cover plate on the governor operated valves is provided with a seal to prevent unauthorized adjustment. The speed limit change valve has two positions, one for passenger speed limits and one for freight speed limits. Passenger speed limits are high 60, medium 40, and low 20, and freight speed limits are high 40, medium 30, and low 20 m.p.h. The handle of this valve is normally sealed in the position of the service in which the locomotive operates. All valves constitute a single group, air connections between valves being by internal passages or ports rather than by exposed piping.

9. A brake application group, consisting of a pilot valve for controlling the application valve; an application valve for effecting an automatic brake application; a reduction suppression valve for preventing an automatic brake pipe reduction while a manual application is being made; a reduction insuring valve to insure that the full service reduction shall be completed in cases where the engineman makes but a partial suppression, and the speed of the train is such as to require it; a reduction timing valve and a reduction holdback valve, operating in combination, to cause a split reduction in automatic brake applications; a reduction safety valve to neutralize the effects of a leaky equalizing valve. The equalizing valve formerly in the engineman's brake valve has been removed and is now included in the brake application group. This assembly of valves is bolted to a divided chamber reservoir which contains timing reservoirs No's. 1 and 2 and the first and second reduction reservoirs. A sealed cut-out cock is also provided so that the pneumatic apparatus may be cut out of service to nullify the action of the pneumatic part of the equipment when necessary.

The valves, reservoirs, etc., comprising this group, are connected by internal passages and ports and not by exposed piping. This group is attached to the boiler under and about midway of the run board on the engineman's side of the locomotive.

10. An acknowledging valve, mounted within easy reach of the engineman so that he may operate it and acknowledge a change of indication and prevent an automatic brake application if running under the low speed limit.

11. An engineman's modified automatic brake valve, having two rotary valves with certain ports necessary for the train control system. Within the brake valve housing is the release pilot valve, the purpose of which is to compel the engineman to move the brake valve handle to the lap position to reset the train control apparatus before releasing an automatic brake application.

12. An air supply group, consisting of a feed valve for supplying main reservoir air at 70 lb. pressure for the operation of the train control system; a centrifugal dirt collector for cleaning the air before it enters the various parts of the system, and a safety valve for preventing the pressure from exceeding 70 lbs.

13. Two air gages, mounted above the boiler within view of the engineman. The single hand gage indicates application pipe pressure, while the two hand (duplex) gage indicates the H-to-M and M-to-L blow down reservoirs' pressures.

14. Three reservoirs, the equalizing reservoir, the quick release reservoir and the suppression limiting reservoir, are suspended under the run board on the engineman's side of the locomotive.

15. One large three compartment reservoir, containing the H-to-M and M-to-L blow-down reservoirs and the stop reservoir, is mounted on the front of the locomotive near the pilot beam.

16. An acknowledging reservoir, mounted under the cab deck plate.

17. A combined relay brake pipe vent valve and pressure maintaining valve mounted inside the cab.

18. The necessary piping to insure the intended pneumatic operation of the device.

19. The necessary wiring in conduit to insure the intended electrical operation of the device.

Operation of the Train Control System

The system being properly installed, electrically energized and pneumatically charged, the operation is as follows:

In a Clear Block.—When the track is clear and axle and loop currents of normal relative polarity flow in the track rails, the currents induced in the receivers will be amplified and will energize the train control relay so as to close its right contacts. The H magnet valve will be energized, thereby maintaining the pneumatic apparatus in the high speed condition. The H light will be displayed indicating to the engineman that the block is clear and that he may proceed at authorized speed. As the train proceeds through the clear block and passes from one track section to another, each track section having axle and loop currents of normal relative polarity flowing in the track rails, the H light will continue to indicate a clear block condition.

Exceeding High Speed in a Clear Block.—If the train exceeds the high speed limit in a clear block, the speed governor pushes open the high speed application valve and initiates an automatic brake application which will bring the train to a stop. The engineman, however, can release the brake in the usual manner after the speed is reduced to that below the maximum. The H light burns during overspeed automatic applications and the only indications in the cab that an automatic application has been initiated are the drop of the application gauge pointer and the coinciding of the red (main reservoir) and black (brake pipe) pointers of the large duplex gauge. When the speed falls below the maximum, if meanwhile the brake valve has been lapped, the gage pointers will return to their normal positions, indicating that the brakes may be released in the usual manner.

Passing an "A" Point Unacknowledged.—On passing the A point for a stop signal, the train control relay will reverse, extinguishing the H indication and lighting the M indication, and de-energizing the high speed and energizing the medium speed magnet, causing the high speed relay valve to shift. By this movement the high to medium timing valve and reservoir are connected to the high-to-medium blow-down valve operated by the crosshead of the speed governor. This blow-down valve is so designed that between high and medium speeds, the size of the orifice is regulated by the governor so that it is very nearly proportional to the speed of the train. The pressure in the blow-down reservoir will decrease at such rate as to cause the timing valve to operate in 5 sec. for the maximum speed and in 40 sec. for the medium speed, and in proportional time for speeds intermediate between these two. When the timing valve operates, the application pipe is vented to atmosphere through the medium speed application valve and the application valve operates to initiate an automatic brake application unless the engineman is alert and delays, or prevents, the automatic application by properly reducing speed.

If the train is running below the medium speed limit, the medium speed application valve is closed and there will be no automatic application of the brakes at the A point, although the train must be reduced to low speed before reaching the stop signal.

Passing an "A" Point Acknowledged.—If the engineman, just before passing an A point above medium speed, makes a manual brake application, the application pipe will be blanked at the reduction suppression valve and no automatic application will result when the medium speed application valve in the governor opens. Therefore, while the brake valve is in service position or while the brake pipe is being vented by a manual application, as long as the brake handle is not returned to the release or running position the open medium speed application valve will not cause an automatic brake application.

In some cases an engineman retards the speed of the train by two or more reductions, each in turn being initiated after the brake pipe stops blowing; the engineman's brake valve being placed in lap position between reductions. The reduction insuring valve and timing reservoir are provided to insure that, during the actual discharge of the brake pipe as described, and for a sufficient time interval thereafter to permit the split reduction braking, an automatic brake application will be suppressed through the reduction suppression valve.

Another means of suppressing an automatic brake application is effective when a full service reduction has been made, whether this application is split or made by a single reduction. This is accomplished by the reduction insuring valve and the suppression limiting reservoir and is effective until the engineman's brake valve is moved either to running or to release position.

If a suppression of the automatic brake application is maintained by one of these methods until the train has decelerated to medium speed, the medium speed application valve will be closed, and the brakes may be manually released without an automatic application. However, should the train then be accelerated to speed above medium, the medium speed application valve will open and initiate an automatic application unless again suppressed by a manual application.

Passing a "B" Point Unacknowledged.—On passing the B point for a stop signal the train control relay will be de-energized, due to the absence of loop current, and its middle contacts will close. The indication will change from M-to-L and the medium speed magnet will be de-energized. By this action the medium-to-low timing valve and reservoir are connected to atmosphere through the medium-to-low blow-down in the governor. The pressure in the blow-down reservoir will so decrease as to cause the timing valve to operate in 5 sec. at the medium speed and in 40 sec. for the low speed and in proportional time for speeds intermediate between these two. When the timing valve operates, the medium speed relay valve shifts and vents the application pipe to atmosphere through the low speed application valve, and also allows it to discharge into the stop reservoir. The drop in pressure in the application pipe initiates an automatic full service application of the brakes which stops the train. In order to effect a release of the brakes, the engineman must place the brake valve handle in lap position and allow it to remain there for a short period of time, until the train control valves have been restored to normal, after which the brakes may be released in the usual manner.

Passing a "B" Point Acknowledged.—If the engineman on passing a "B" point acknowledges the change in conditions by

operating the acknowledging valve and makes a manual application so as to bring the train below the low speed limit, the automatic application will be prevented. If the engineman attempts to exceed the low speed limit, the application pipe will be vented to atmosphere through the low speed application valve in the governor and an automatic application will result, which cannot be released until the speed of the train has again been reduced below the low speed limit.

In a Stop Block.—When the train passes the insulated joints at the stop signal and enters the track sections beyond the stop signal, these track sections to the potential stopping point, i. e., train in the block, open switch, or other obstruction will be devoid of either or of both loop and axle currents. The apparatus on the locomotive will therefore remain in the same condition in which it was just before passing the stop signal.

Change From Lower to Higher Speed Limit.—If the train is running below a restrictive speed limit and the conditions which caused such restriction are removed, the train may accelerate to the new speed limit indicated by the cab light, no valve manipulation being necessary. If the train is above the lower limit and the change occurs with the brakes manually applied, they may be released immediately. If the brakes are applied automatically, the engineman's valve can be placed in lap position to restore the train control valves and then the brakes can be released.

Running Backward.—When a locomotive is running backward and its movement has established the traffic direction, an I. indication is carried and a low speed restriction is imposed. However, when the movement of the locomotive has not established the traffic direction, a more favorable running indication may be carried.

Approval Granted With Exceptions

As a result of this inspection and test, it was found that the installation meets the requirements of the commission's specifications, except as noted below, and it, therefore, is approved, except as hereinafter indicated:

1. Provision must be made requiring enginemen to acknowledge at succeeding stop signals.

2. During the tests, which were made during very warm weather, both pressure regulating valves stuck open, the safety-valve, under these circumstances, failing to prevent an increase in the train control system pressure. The effect of an increase in train control pressure is to increase the time of initiating an automatic application after a change of indication to a restrictive speed occurs, and therefore, it is imperative that provision be made to maintain the train control pressure constant at the required amount without fail.

3. The pneumatic portions of this device containing the functional parts essential to brake application, and which are located outside of the cab, must adequately be protected against freezing because if these valves should be sealed closed in normal position the result might be serious.

While the results obtained during the past winter with the housings now being generally applied were reported as satisfactory, it is not felt that the experience thus obtained was extensive enough to be conclusive, and the matter should have very close attention on account of its manifestly great importance.

The Norfolk & Western is expected to comply at once with the above-stated requirements and promptly and currently to inform the commission as to the progress made in conforming thereto.

Inspection and Maintenance Requirements

The Norfolk & Western is expected to comply at once with the following requirements as to inspection, tests, and maintenance:

1. The train control equipment on all locomotives operated in train-control equipped territory should be carefully inspected and tested upon arrival at and before departure from designated inspection and repair points. The importance of such inspection and tests was demonstrated on September 21, 1925, when locomotive 598 did not receive an automatic brake application at the "B" point for signal 1413 at stop. Investigation developed that the suppression valve was stuck in the suppressing position due to several particles of metal wedging the valve stem in its guide. The inspection and test should include all parts of the apparatus, and before each trip all seals should be inspected to see that they are unbroken and the apparatus properly cut in for service. A daily report as to the condition of the apparatus should be made on a form provided for that purpose and forwarded by the inspector to a designated officer.

2. The roadside apparatus should be frequently inspected and tested for broken or crossed wires, grounds and foreign current and the insulated joints frequently inspected to insure that they are in proper operative condition; reports thereon being made on a form provided for that purpose and regularly forwarded by the inspector to a designated officer.

3. A form should be provided for and used by each engineman in reporting failures of the apparatus and any irregularities in the operation of the device. All such information should be reported in detail.

Precautionary Recommendations

In the following specific respects the railway company should promptly take the necessary action to carry into effect the recommendations made:

1. It should be definitely determined that the interval between the A and B points and the signal in advance is sufficient in all cases to provide adequate braking distance.

2. During the inspection, evidence was noticed of momentary influences of foreign current upon the locomotive equipment, and since stray currents could, under certain circumstances, cause serious trouble, the matter is mentioned here inasmuch as it would be necessary, should such trouble develop, to promptly employ adequate means for overcoming the difficulty.

3. The roadside circuits should be modified so as to conform to the revised circuit plans at those points where an H indication may be carried in a stop but unoccupied block.

4. The type of fouling protection employed should be given careful consideration with a view to possibly providing increased protection.

5. The circuits at Riverton and Charlestown interlockers should be arranged to prevent a towerman displaying a clear signal for a Norfolk and Western train when a crossing train occupies the track between the home signals at these crossings.

Inasmuch as the split reduction feature repeatedly failed to function during the tests (although in such cases it increased but slightly the time consumed in automatically reducing brake pipe pressure, as compared with a manual reduction) the carrier may desire to consider whether the simplification which the elimination of this feature would permit is desirable.

The attention of the Norfolk & Western officers accordingly has been called to these matters.

By the Commission, Division 1:

GEORGE B. McGINTY, *Secretary.*

(SEAL)

Abolition of Grade Crossings in New York

Governor Alfred E. Smith in his annual address to the New York State legislature on January 6, speaking of railroad grade crossings and the amendment to the Constitution authorizing the expenditure of three hundred million dollars for the elimination of crossings, urged the legislature to proceed as rapidly as possible. "The legislature has the mandate of the people themselves." . . . "I feel that I should touch upon the necessity of careful study by the legislature of an agency for the carrying out of the constitutional amendment. I would suggest that a program for elimination be prepared by the Public Service Commission because of the contact with the railroad system of the state.