RY-24732

ELECTRIC PROPULSION AND BRAKING SYSTEM

THE PENNSYLVANIA RAILROAD

HIGH-SPEED ELECTRIC M-U CARS

TRENTON-NEW YORK COMMUTER SERVICE

GENERAL ELECTRIC

BILL OF MATERIAL

Qty. Per Equipt.	Apparatus	Weight Per Equipt.	Typical Outline Drawing
4	*GEZ-5711 (GE-1252), 425 volt DC traction motors, each close-coupled to a GA-56 double reduction, parallel drive gear unit, with integrally assembled GAC5 flexible coupling and 17MM24 speed and slip relay alternator	9110	P-1006052-3488
1	*Pyranol-filled main transformer, type FOA-25/60-11000/23400-1755/440	9750	41C652652-SH1 Except 107" long 72" wide 30.5" high over cover
1	17EX46 main smoothing reactor	2380	41C630451
1	*5GMG176 motor-alternator set, to provide three phase, 60 cycle, 220 volt power to drive air (brake) compressor motor, air conditioning compressor, evaporation fan, fluorescent lights, vacuum cleaner outlets and battery charging	2940	41E903141 except without blower
1	*EX-48 smoothing reactor for m-a set	1200	41B531835
2	GYA-26 blower-motor with 7A20 blower for ventilating transformer and smoothing reactor (1) and rectifier group (1)	1060	41D730780
1	17KG206B1 main control group for side-sill mounting	1310	41C652866
1	17KG205B1 propulsion rectifier control group for center-sill mounting.	2040	41D751707
1	*17KG208 auxiliary control group for side-sill mounting	950	41C652820 except 134" long

*revised 9/12/66

Qty. Per Equipt.	Apparatus	Weight Per Equipt.	Typical Outline Drawing
1	17MCP1A4 pantograph and shoe, Faiveley type, with adapter	875	41C610759
4	Insulators for supporting pantograph	192	V-23170-Z-G1
1	Bushing for supporting pantograph cable	10	41A259002
2	Air line insulators for pantograph per 41A210464	10	L-1006040-1505
1	Pantograph pole	12	41A210871
1	17MD7 pantograph lockdown switch	76	41E905199
1	17GM1 ground switch for pantograph	23	41A254727
1	MacAllen Cat. 1601 air line insulator for pantograph ground switch, per SK583	2	
1	17ME15 magnet valve for pantograph ground switch	7	41A255622
1	17ME16 magnet valve set for pantograph	38	K-764658
1	JCP-0 primary current transformer for pantograph protection circuits	51	A-9925261
1	Pantograph hand pump, WABCO Pc 92939	13	
1	Set pneumatic details for pantograph, including:		
	1 - 10" x 14" reservoir, WABCO Pc 553301	30	

Qty. Per Equipt.	Apparatus	Weight Per Equipt.	Typical Outline Drawing
	2 - hanger, 10" reservoir, M-205577-P5	5	
	1 - 1/2" drain cock, WABCO Pc 7716	1	
	1 - reducing valve with cutout cock, strainer and check valve WABCO Pc A538444-0070	11	
	1 - 3-way valve (3/8"), WABCO Pc 20774	1	
1	Lightning arrester for main transformer	52	D1180L003
2	17KC7 master controller	62	41B551161
1	Controller reversing handle	-	
1	Set 17EWF103B6 starting resistors for m-a set	32	K-6725007
1	*Set surge protection resistors consisting of 3- 17EWR102 resistor units	26	K-6728042
12	17MB7B9 insulators for surge resistors	24	41B550178-G9
2	Motor cut-out switches	1	497A911-P1
16	Motor lead connectors (halves)	8	41A255002
2	Indicating lights, overload and ground relay	-	41B551536G3
2	Outer lens, overload and ground relay lights	-	P-8841471P124
1	Meter Jack 41C651048	1	41B551305

*revised 9/12/66

Qty. Per Equipt.	Apparatus	Weight Per Equipt.	Typical Outline Drawing
1	17BA29 junction box	34	41A255191
2	DB-17 Speedometer (0-120)	20	M-9885229
1	17FM192 speedometer resistor panel	1	41A250191
1	Set headlight dimming equipment including:	25	
	1 - 17FR101 resistor panel		K-9963888
	2 - 3 position dimming switches		41A252154P1
	Weight allowance for terminals and miscellaneous items	100	
	*Estimated Total Weight	32,483 pounds	4000# increase

*revised 9/12/66

*DYNAMIC BRAKE OPTION

Should the customer elect to specify dynamic braking, then the following additional equipment is included in the General Electric proposal:

Qty Per Equipt.	Apparatus	Weight Per Equipt.	Typical Outline Drawing
1	17KG braking control group	700	72"Lx26"H x 24"W
9	17EWF203H6 resistor boxes	1,330	41A251040
36	17MB7 insulators for resistors	72	41B550178
2	Dynamic brake cutout switch	1	
1	Indicating light with outer lens	-	
		2,103 pounds	

*revised 9/12/66

*PERFORMANCE

The equipment included in this proposal is capable of providing commuter vehicle speeds up to 100 MPH on the Pennsylvania Railroad tracks between Trenton and New York.

With six (6) cars in train, each car weighing a maximum of 131,000 pounds when carrying a seated load, with new 36 inch wheels, 11,000 volts a-c to ground at the transformer, using a train resistance no greater than that described by the Davis formula when modified to use a 0.0018 coefficient in the V^2 term of the lead car formula, with a 15 MPH headwind on a level tangent track, the equipment is capable of providing the following train performance:

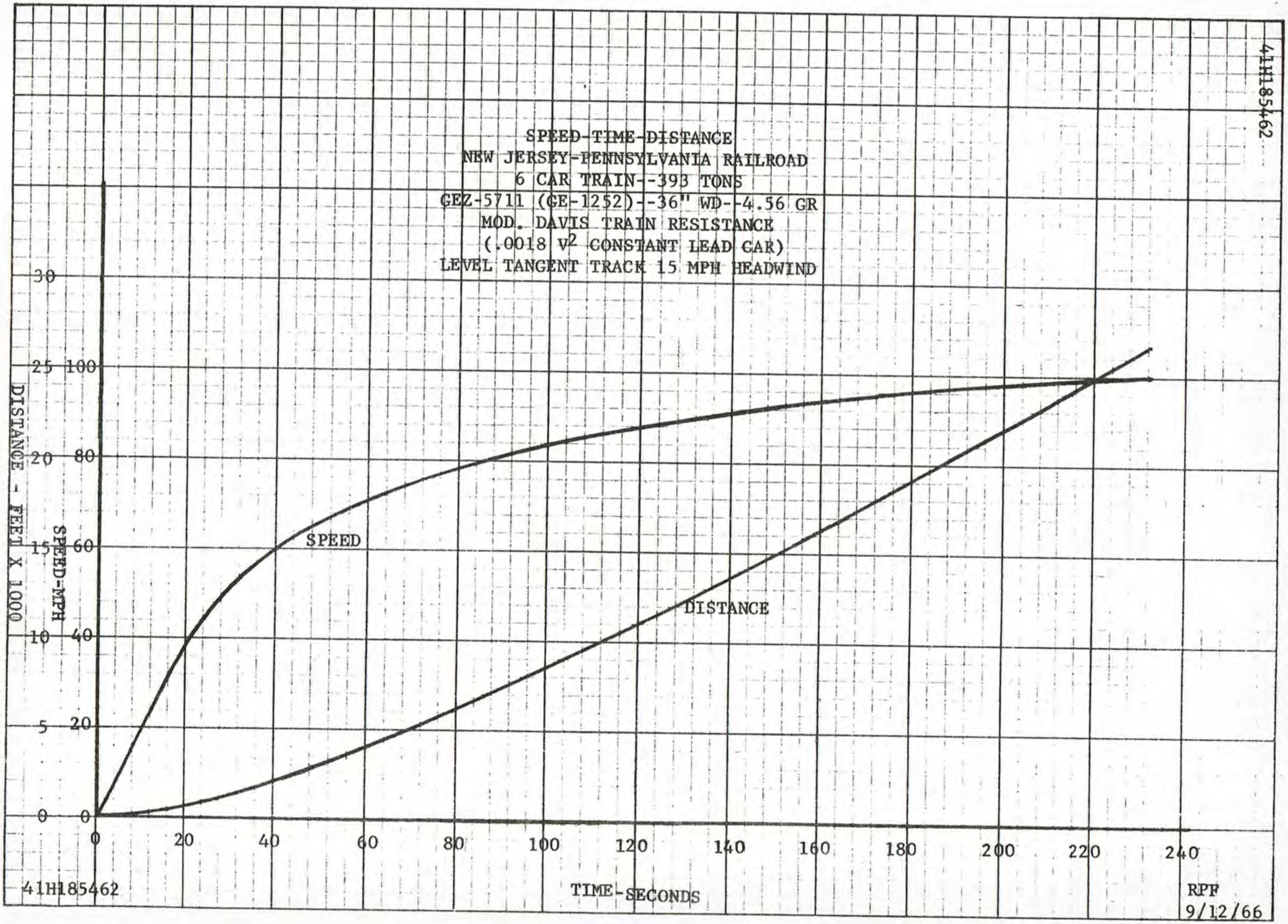
Maximum Operating Speed	100 miles per hour
Initial accelerating rate	2.0 MPHPS
Time to reach 80 mph	87 seconds
Distance traveled in 70 seconds from standing start	5000 feet
Speed reached in 70 seconds	75 MPH
Distance traveled in 120 seconds	11,000 feet
Speed capability on 1% adverse grade with <u>no</u> headwind	Balancing speed of approximately 87 MPH
Dynamic Braking Rate (when specified)	1.25 MPHPS from 75 to 20 MPH

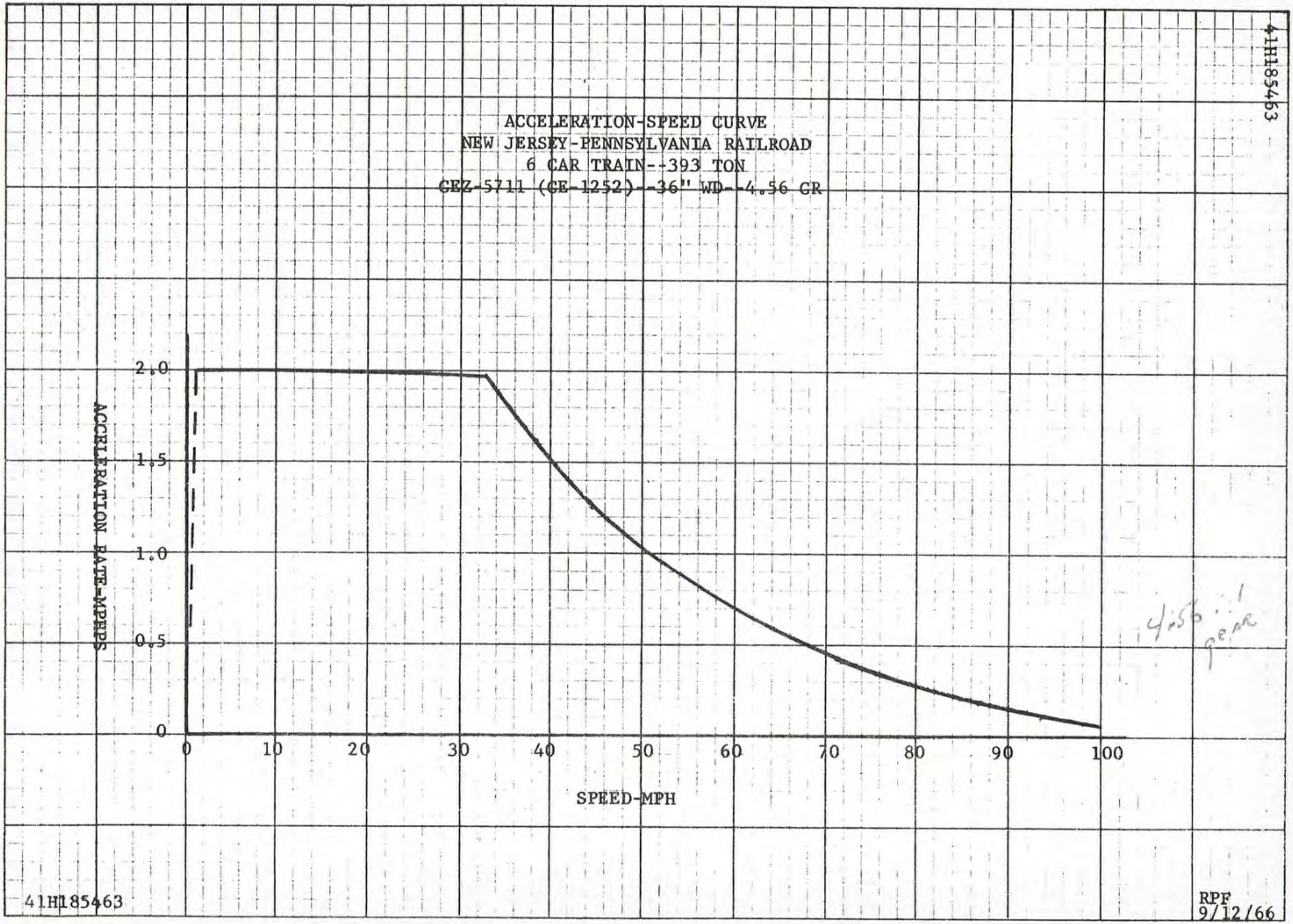
Speed-Time and Distance-Time characteristics for the considered conditions of train resistance, car weight and power supply voltage are shown on curve 41H185462. The acceleration-speed relationships are shown on curve 41H185463. Both curves are integral parts of Specification RY-24732.

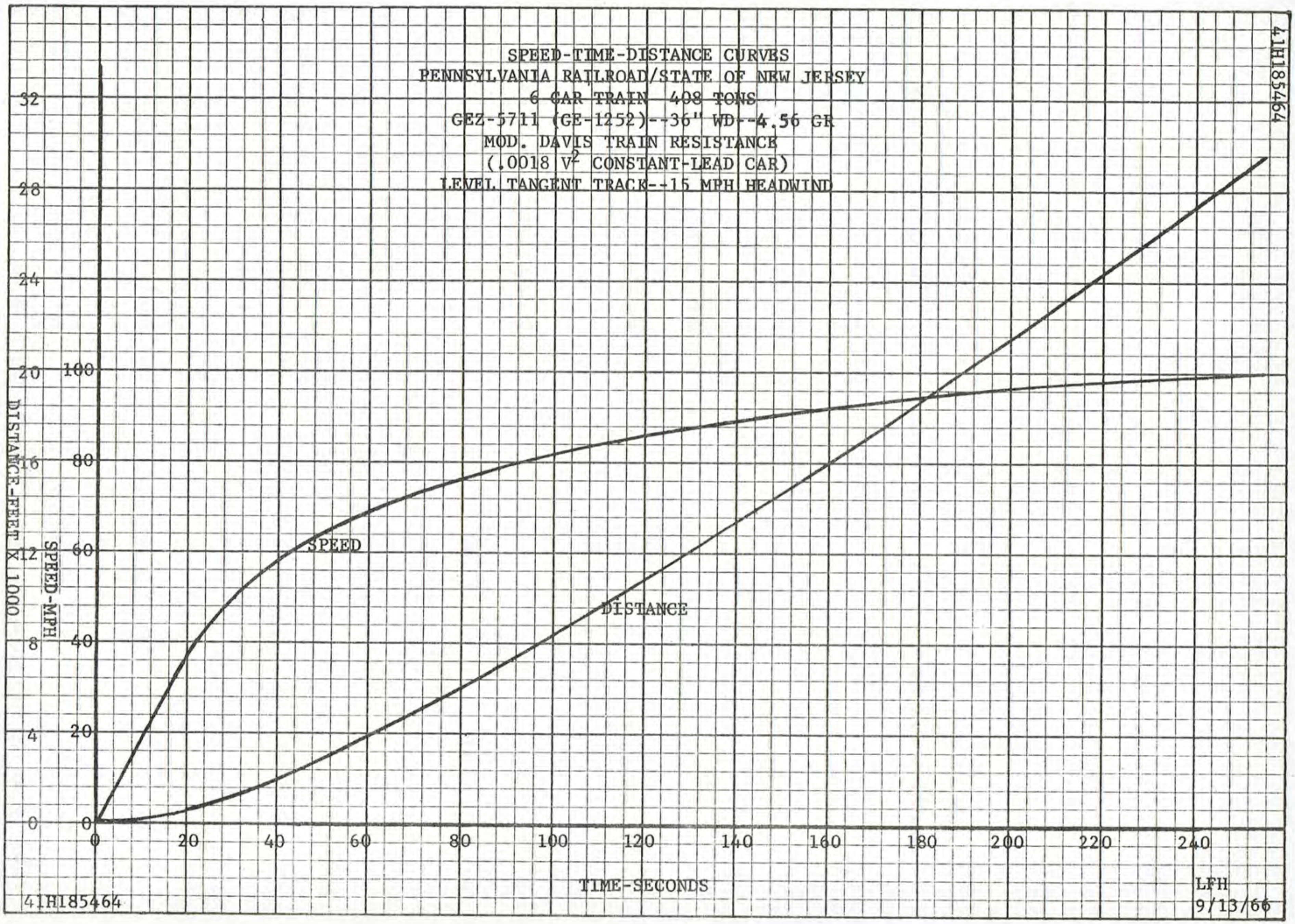
Performance capabilities will increase with a lighter train, and will decrease with a heavier train. For example, curves 41H185464 and 41H185465 show performance for a 6-car train with fully loaded cars weighing 70.0 ton each.

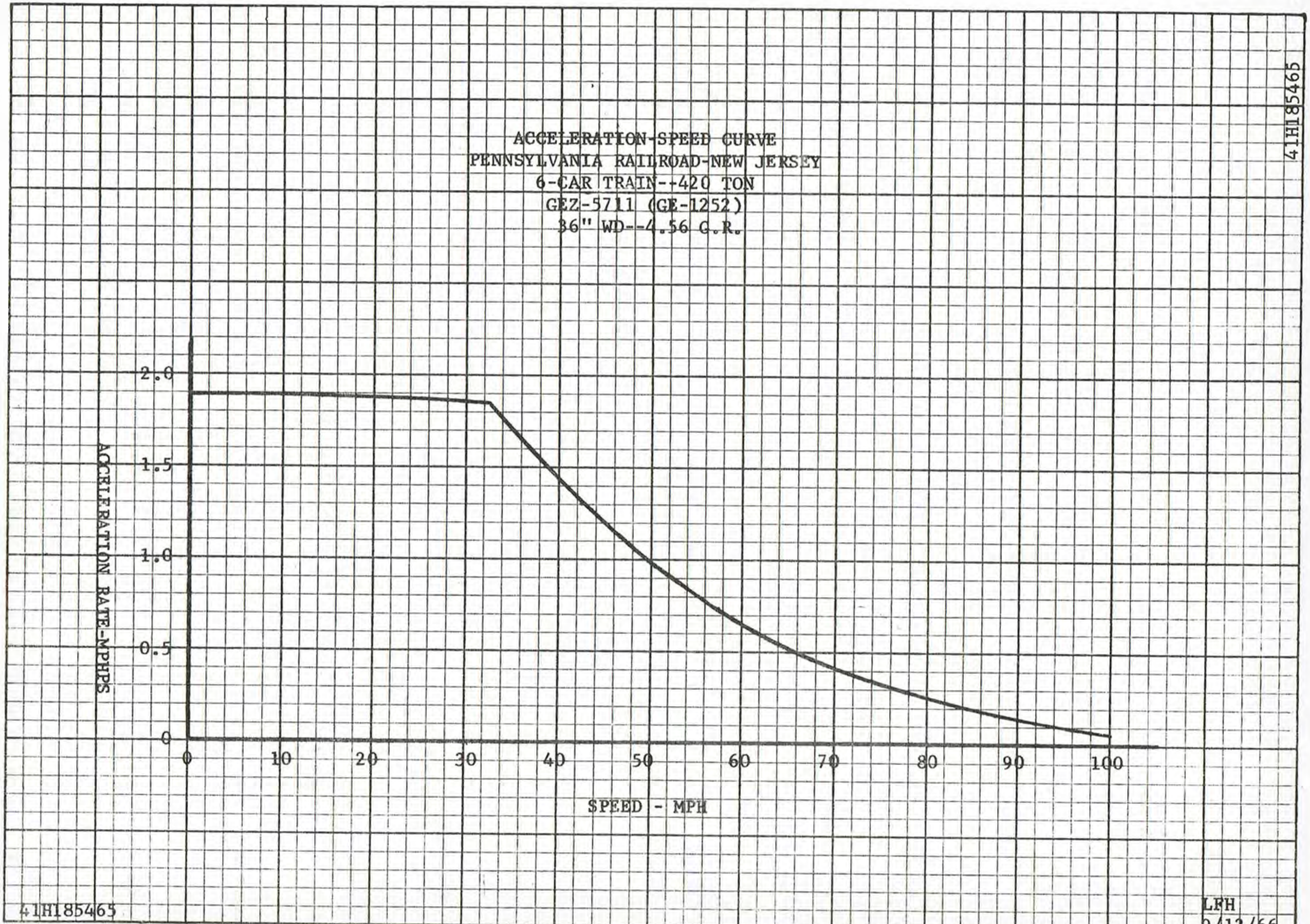
The car characteristic curve for this equipment is 41H155376.

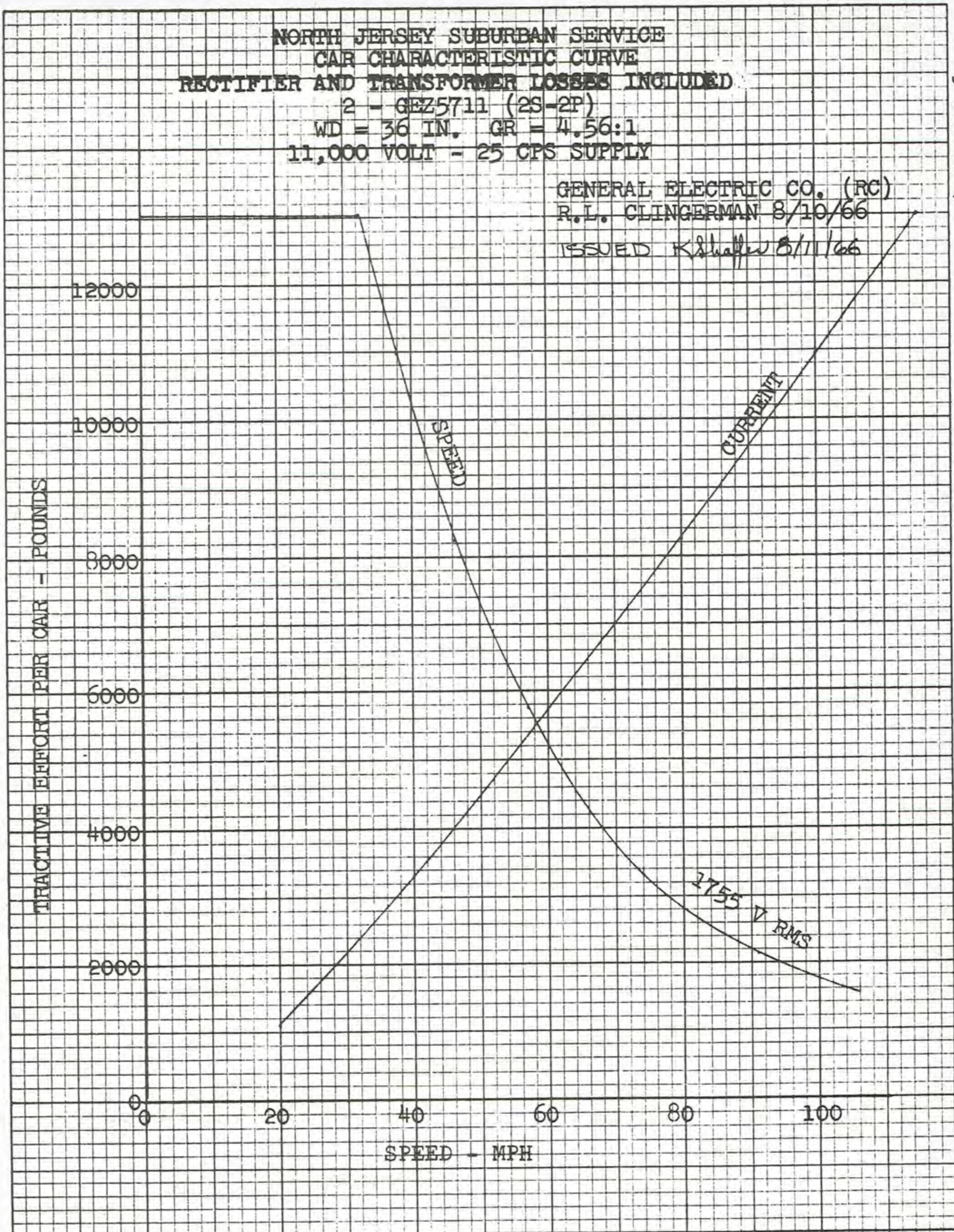
*revised 9/12/66


SPEED-TIME-DISTANCE
NEW JERSEY-PENNSYLVANIA RAILROAD
6 CAR TRAIN--393 TONS
GEZ-5711 (GE-1252)--36" WD--4.56 GR
MOD. DAVIS TRAIN RESISTANCE
(.0018 V2 CONSTANT LEAD CAR)
LEVEL TANGENT TRACK 15 MPH HEADWIND
SPEED
DISTANCE
SPEED-MPH
DISTANCE - FEET X 1000
TIME-SECONDS
0
20
40
60
80
100
120
140
160
180
200
220
240
0
5
10
15
20
25
30
41H185462
RPF
9/12/66


41H185463
ACCELERATION-SPEED CURVE
NEW JERSEY-PENNSYLVANIA RAILROAD
6 CAR TRAIN--393 TON
GEZ-5711 (GE-1252)--36" WD--4.56 GR
ACCELERATION RATE-MPHPS
2.0
1.5
1.0
0.5
0
0
10
20
30
40
50
60
70
80
90
100
SPEED-MPH
4.56 : 1 gear
41H185463
RPF
9/12/66


41H185464
SPEED-TIME-DISTANCE CURVES
PENNSYLVANIA RAILROAD/STATE OF NEW JERSEY
6 CAR TRAIN 408 TONS
GEZ-5711 (GE-1252)--36" WD--4.56 GR
MOD. DAVIS TRAIN RESISTANCE
(.0018 V² CONSTANT-LEAD CAR)
LEVEL TANGENT TRACK--15 MPH HEADWIND
SPEED
DISTANCE
SPEED-MPH
DISTANCE-FEET X 1000
TIME-SECONDS
0
20
40
60
80
100
120
140
160
180
200
220
240
4
8
12
16
20
24
28
32
LFH
9/13/66
41H185464


41H185465
ACCELERATION-SPEED CURVE
PENNSYLVANIA RAILROAD-NEW JERSEY
6-CAR TRAIN--420 TON
GEZ-5711 (GE-1252)
36" WD--4.56 G.R.
ACCELERATION RATE-MPHPS
2.0
1.5
1.0
0.5
0
0
10
20
30
40
50
60
70
80
90
100
SPEED - MPH
41H185465
LFH
9/12/66



41H155376

41H155376

A 791

PCI CONTROL SYSTEM

For this installation of high speed commuter service, the General Electric Company proposes to furnish the service-proven PCI control system. This is the same phase-controlled ignitron system which was designed for the City of Philadelphia specifically for high performance commuter service on the Pennsylvania Railroad. This control system has been outstanding in its low maintenance and high reliability. Pennsylvania Railroad personnel have worked with this system and are thoroughly familiar with the required inspection and maintenance procedures.

PROPULSION CONTROL OPERATION

11,000 volts, 25-cycle, single phase, AC power is collected from the overhead power distribution system by means of a Faiveley type pantograph and supplied to the primary winding of the pyranol-filled main transformer on the car. The transformer output comes from three separate secondary windings, A, B, and C.

Each of the three secondary windings is connected to a bridge circuit of silicon cell rectifier units. All three of the silicon cell rectifier bridge circuits are connected in series to form the main power rectifier, the output voltage of which is determined by how many transformer secondaries are connected to it. The output of secondary winding-A which is applied to the main rectifier bank can be varied from a small amount to full value by the use of two (2) mercury arc Ignitron tube rectifiers connected and controlled in such a manner that they act as a voltage "valve". The regulation of this "valve" is the fundamental principle of this unique and novel control system.

The output of the main silicon cell power rectifier is fed through main smoothing reactor coils to the traction motors, which are permanently operated two in series, and two such series pairs in parallel.

The fundamental principal of operation consists of timing (or phase-retarding) the point on the basic voltage wave at which the mercury arc Ignitron rectifier tubes are "fired" - or allowed to pass current - so as to control the effective voltage supplied. When the Ignitron tubes firing control is fully phase-retarded, a minimum voltage is supplied to the main rectifier. When the firing control is fully advanced, the maximum value of output voltage of secondary winding-A is applied to the main rectifier. The resulting voltage is then applied to the traction motors.

In practice, when contactor Al is first closed, the voltage of transformer secondary winding-A is applied to the Ignitron tubes with the Ignitron tube firing control fully retarded. The firing control is then advanced until the desired accelerating current is applied to the traction motors. Under control of the current measuring reactors in each motor circuit, the Ignitron tube firing control is regulated so as to keep the accelerating current constant.

When the firing control of the Ignitron tubes becomes fully advanced, the maximum voltage from transformer secondary winding-A is applied to the main power rectifier and to the traction motors. When this point in the complete accelerating cycle is reached, two events occur simultaneously; contactor A2 is closed to apply the full output voltage of transformer secondary winding-B to the main rectifier, and the Ignitron tube firing control is fully retarded. In effect, this substitutes the output voltage of transformer secondary winding-B for that of secondary winding-A for application to the traction motors.

In the next phase of the car acceleration cycle, the firing of the Ignitron tubes is again advanced until the full voltage of transformer secondary winding-A is again applied to the main rectifiers. This voltage is added to that of secondary winding-B. When this point in the acceleration cycle is reached, contactor A3 is closed to apply the full output voltage of transformer secondary winding C to the main rectifier while the Ignitron tube firing control is again fully retarded. In effect, this substitutes the combined output voltages of secondary winding-B and C for the summation of the output voltages of secondary windings A and B.

The final phase of the acceleration cycle consists of again advancing the Ignitron firing control until finally the full output voltages of all three secondary windings, A plus B plus C, are applied to the main rectifier. From this point on, it is no longer possible to maintain the maximum accelerating current through the traction motors. Acceleration of the car from here to balancing (maximum) speed will continue on a continually reducing rate in accordance with the inherent operating characteristic of the traction motors.

For speed control purposes, it is necessary to regulate the voltage applied to the traction motors. This is accomplished in the firing control by adding a simulated traction motor current signal to the actual traction motor current signal until the sum of the two equals the normal full accelerating rate motor current. When this occurs, the Ignitron tube firing control will not advance further, and voltage control will have been achieved. When holding a constant speed, the actual traction motor current will be that necessary to just balance the required tractive effort. Reduced accelerating rates may be achieved by similarly adding a simulated motor current signal so that the actual accelerating current is lower than normal.

A unique feature of this system is the use of a current measuring reactor in each of the two motor circuits. The reactor measuring the higher motor current controls the current regulation. Thus, the current regulation is not affected if either pair of motors is cut out for any reason (the effective rate of acceleration of the car is, of course, cut in half if half of the motors are not operating).

OPERATION OF PHASE-CONTROLLED IGNITRON RECTIFIERS

The diagram on the following page depicts the operation of the phase-controlled Ignitron rectifiers in applying the a-c voltage of transformer secondary winding A to its silicon rectifier bridge. Figure 1 of this diagram shows that, if the Ignitron tube is not fired until late in the half cycle, only a relatively low value of the available voltage is applied to the rectifier bridge. A phase delay in the Ignitron firing circuits of 145° results in about 70 volts average being available to force current through the traction motors. The phase delay is then gradually reduced on a simple time basis until sufficient voltage is available to force the desired accelerating current through the traction motors. At this point, the rate at which the phase delay is still further reduced is controlled by the current measuring reactors so as to maintain the desired accelerating current at a constant value as the car speed increases in proportion to continually increasing secondary voltage being applied to the rectifier bridge. When the phase control of the Ignitron firing circuits reaches its minimum delay (determined by minimum commutating period of the Ignitron tubes, which in turn is dependent upon the characteristics of the main transformer and the associated distribution system supplying a-c power to the car), all usable parts, or maximum value of the a-c secondary voltage wave of winding A is applied to the rectifier bridge.

When this occurs, secondary tap contactor A2 is closed to apply the voltage of secondary winding B to its rectifier bridge at the same time that the phase delay of the Ignitron tubes firing circuit is being returned to maximum delay of 145°. This, in effect, substitutes the voltage of secondary winding B plus the 70 volts minimum of winding A for the previously applied full voltage of winding A. The phase control of the Ignitron tubes firing circuit is then again advanced, as before, under control of the current measuring reactors, until the full voltage of winding A is superimposed on the voltage of winding B, as shown in Figure 2.

The third and final phase of the acceleration cycle as has previously been described occurs when secondary tap transformer A3 is closed while the phase delay of Ignitron tubes firing circuit is again returned to maximum delay of 145°.

GENERAL ELECTRIC

K-1006068-8012

CONT ON SHEET | SH NO.

REV NO.

CONT ON SHEET | SH NO.

TITLE
VOLTAGE REGULATION
BY DELAYED FIRING OF IGNITRON TUBES

FIRST MADE FOR 2781-B

REVISIONS

70 VOLTS TO 637 VOLTS
(ONE HALF OF AC SINE WAVE SHOWN)

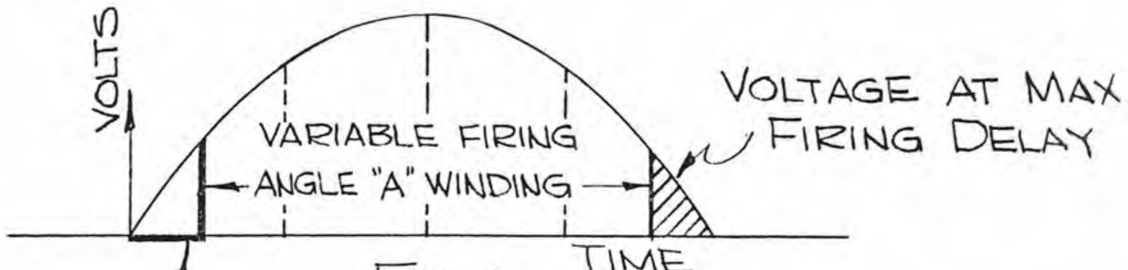


FIG. 1

637 VOLTS TO 1183 VOLTS

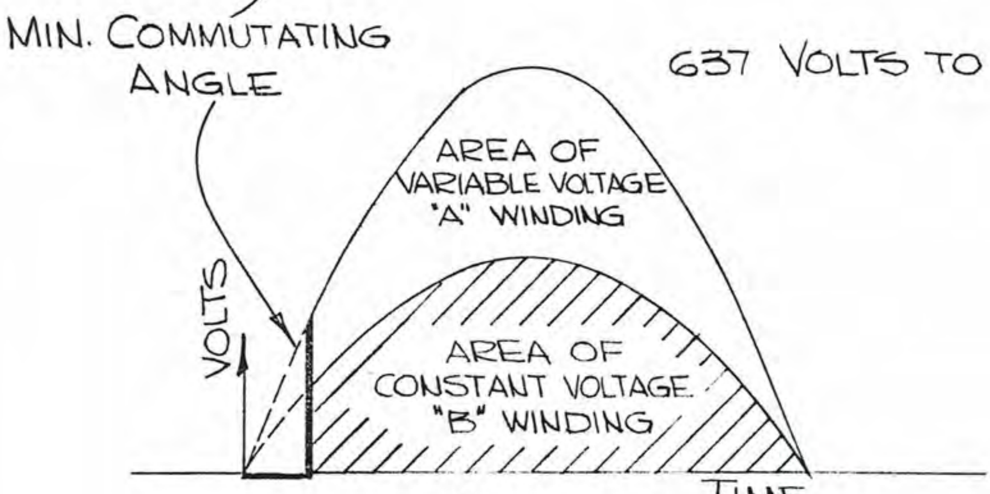


FIG. 2

PRINTS TO

MADE BY James Kinlo JUNE 7, 1966

ISSUED

APPROVALS VCB

CONTROL DIV OR DEPT.

ERIE LOCATION

K-1006068-8012

CONT ON SHEET | SH NO.

FF-803-WB (1-62) REV
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OPERATION OF MAIN SMOOTHING REACTOR AND RECTIFIER BRIDGES

To provide a better understanding of the operation of the main power circuit, refer to diagram on following page. Figure 1 is a basic circuit diagram showing two rectifier bridges, a smoothing reactor "MSX", and a motor "M". The upper rectifier bridge circuit includes a "battery". The currents which will flow through the branches of the rectifier bridge when switch "A2" is closed are indicated by arrows and plus (+) and minus (-) signs. Those signs enclosed in parentheses indicate current flow directions with one "battery" voltage polarity; the signs without parentheses indicate current flow directions if the polarity is reversed.

The lower bridge is similar except that an a-c transformer, in which the polarity is continually reversing, is substituted for the "battery". Thus, if the "battery" is applied to the upper bridge by closing switch A2, or if the transformer is applied to the lower bridge by closing switch A3, or if both A2 and A3 are closed, current will flow through both rectifier bridges, the smoothing reactor and the motor, since all are in series. In practice, with only a-c power available from the main transformer secondary windings, power will flow through the closed series circuit but it would normally be expected to pulsate from zero to the maximum value of the original a-c voltage wave, as shown in Figure 2.

Obviously, if another source of power should be injected anywhere in the circuit external to the rectifier bridges, current would be forced through the closed series circuit. In practice, the smoothing reactor MSX serves as such an additional power source. The main smoothing reactor is a copper winding on an iron core. As the alternating current wave starts to build up through the circuit, flux is built up in the iron core of the reactor. Then, as the alternating current wave tries to fall to zero, the collapse of flux in the reactor core induces a voltage in the reactor winding which tries to perpetuate the flow of current through the series circuit. Thus, the reactor serves as a temporary source of power to the traction motor during the interval when the pulsating voltage from the rectifier bridge or bridges would normally fall to zero, then build up again, as shown in Figure 2. The effect of the main smoothing reactor is shown in Figure 3. Here it is shown that the voltage from the main smoothing reactor is effective when the applied voltage would fall to zero; thus the system voltage applied to the traction motor is continuous, although rippling in nature. In practice, the effect of the main smoothing reactor is to decrease the peak value of the applied rectified voltage wave, due to energy stored in the reactor, and to discharge this energy to prevent the rectified voltage wave from falling to zero between waves. The resultant current wave rippling between maximum and minimum values (rather than pulsating between zero and maximum value), provides more even tractive effort from the motors and much better commutation conditions on the d-c traction motors.

GENERAL ELECTRIC

K-1006068-8011

REV NO.	TITLE: ADDITION OF VOLTAGES IN SILICON RECTIFIER	CONT ON SHEET / SH NO.
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REVISIONS

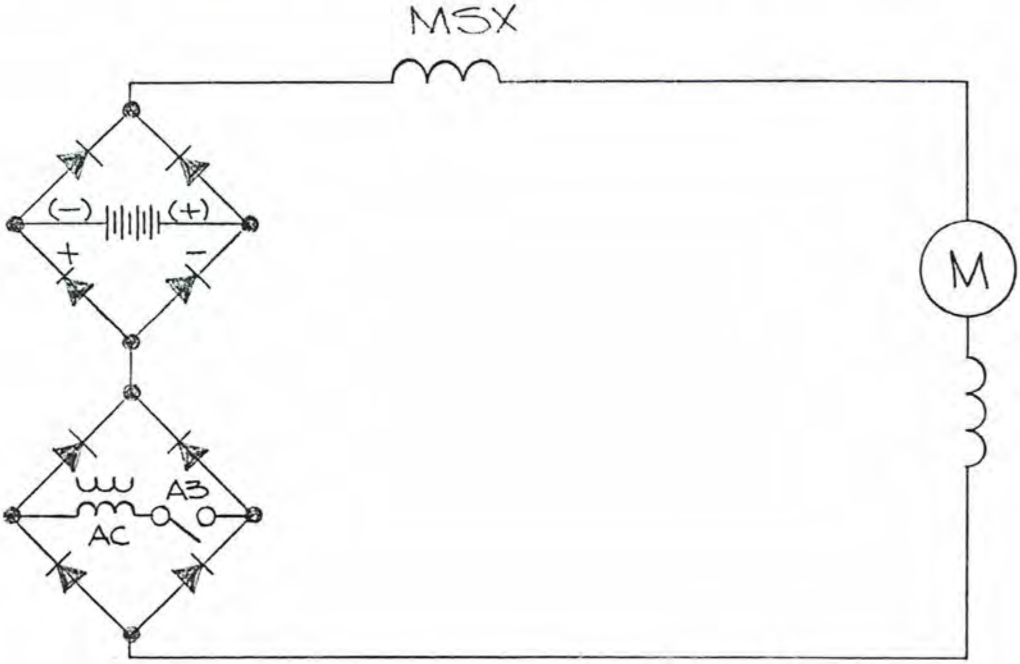


FIG. 1

RECTIFIER OUTPUT VOLTS

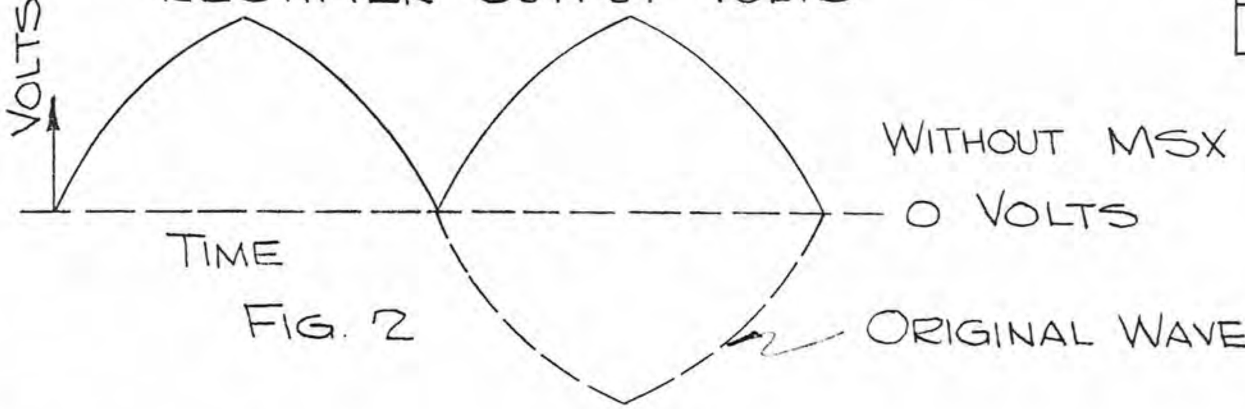


FIG. 2

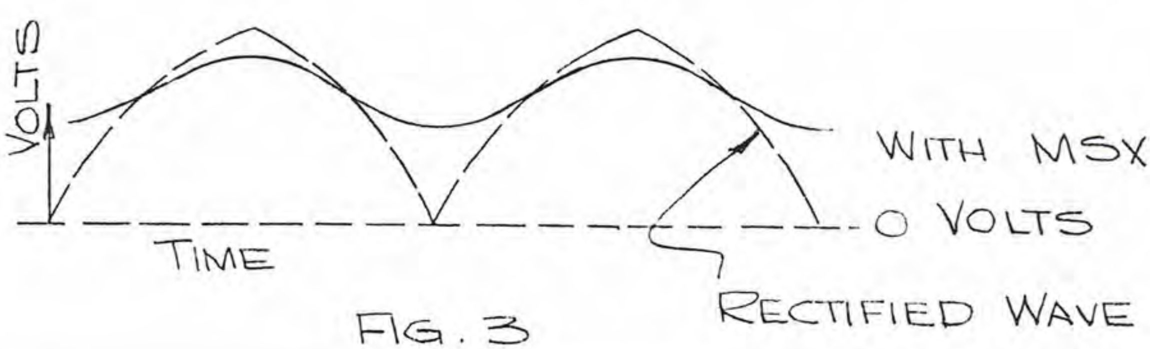


FIG. 3

PRINTS TO

MADE BY: James Kroto JUNE 7, 1966	APPROVALS: JCB	CONTROL (DIV OR DEPT.)	K-1006068-8011
ISSUED		ERIE (LOCATION)	CONT ON SHEET / SH NO.

FF-803-WB (1-62) REV
PRINTED IN U. S. A.

RC

MASTER CONTROLLER

There are four different running positions on the master controller, any one of which may be selected by the operator, depending upon the type of car or train operation desired.

The first running position on the master controller provides for short movements of the car at low speeds and a low rate of acceleration for switching, as in spotting a car for maintenance or storage, or in making up trains. With the master controller held in this first running position, maximum acceleration from standstill is at approximately 1 MPHPS, which will taper off as the car or train slowly picks up speed. Maximum speed attainable in this master controller position is about 25 MPH.

The second controller position permits development of the normal acceleration rate and the regulation thereof until the maximum voltage of transformer secondary winding-A is applied to the traction motors. With the master controller in this position, further acceleration of the car or train will continue at continually reducing rate in accordance with the motor and transformer characteristic.

The third controller position permits normal acceleration until the maximum voltage of transformer secondary windings A plus B are applied to the traction motors. With the master controller in this position, further acceleration of the car or train will continue in accordance with the second stage of the car accelerating characteristic curve.

The fourth master controller position permits normal acceleration until the full voltage of all three of the transformer secondary windings A plus B plus C are applied to the traction motors. With the master controller in this position, further acceleration of the car or train up to the maximum permissible speed determined by the overspeed relays will continue in accordance with the full voltage curve of the car accelerating characteristic curve.

From the foregoing, it is obvious that the second and third master controller positions provide intermediate operating speeds without continued manipulation or operation of control or power switching devices.

The master controller also operates a remote reverser to determine direction of motion of the car or train.

PROTECTIVE EQUIPMENT

Each car is protected with an 11000 volt lightning arrester on the roof and by a pantograph grounding switch. A primary current transformer supplies a signal to a pantograph lowering relay (PLR) and to a transformer thermal overload relay (THR). In case of moderate, sustained overloads, the thermal relay will operate to remove secondary loading from the transformer until it cools down. In case short circuit currents occur, the pantograph lowering relay will operate to first close the pantograph grounding switch. This action by-passes the short circuit current around the main transformer primary and causes the overhead power system circuit breakers to open. After power is removed, the pantograph is automatically lowered and latched in the down position. This informs the train crew that this particular car has been tripped off the power distribution system. Clearance of the short-circuit in this manner permits the overhead system circuit breakers to be reclosed and power restored. The train can then proceed with the one dead car whose pantograph has been latched down.

Each of the three secondary windings of the main transformer is provided with a resistor-capacitor circuit which serves a dual purpose. This circuit serves as a filter to absorb the unwanted frequency in the primary current which might cause telephone interference and also provides a surge absorption feature for protection of the silicon rectifier cells. Each transformer secondary circuit is protected by an overload relay which will clear its respective transformer tap contactor.

The traction motor circuits are provided with a ground relay. If there should be an accidental or a fault ground in the secondary propulsion circuits, the ground relay will operate removing all propulsion power from the car. In so doing, the relay disconnects itself from ground, leaving the car with only the fault ground present. The auxiliaries are protected by an auxiliary ground relay which will operate a warning light and will be manually reset. Operation of auxiliaries will continue.

With the ground relay tripped the car will receive power in the switching notch and the first notch only. Notches 2 and 3 and dynamic brake will be inoperative since possible high voltages to ground caused by the electrical location of the fault ground could be damaging.

Each of the two traction motor circuits is also provided with an overload relay to open the two line contactors in either motor circuit and isolate the faulty pair of motors. The motor overload relays are arranged for remote reset by the operators reset plug.

Wheel slip protection is provided by speed sensors driven from each motor. These provide protection against slipping of wheels on any axle of the car by signalling the current measuring circuit to reduce power on the car to a level which will not support continued wheel slip. When the slip ceases, traction motor current will slowly be reapplied to the pre-slip value. A per-truck slip signal is also made available to the air brake system. The wheel slip system is deactivated by an emergency brake application. In addition to providing the wheel-slip indication, these speed sensors also provide an overspeed indication. They will trip off power from the traction motors when maximum permissible car speed is attained, and will apply the brakes if the car speed increases further. The speed sensors, being applied directly to the traction motors, also provide slipped-pinion protection.

POWER SWITCHING COMPONENTS

Transformer secondary tap switches are of the rugged electro-pneumatic type because of the high currents involved in this duty. All other contactors, including those in the individual traction motor circuits, are of the individually operated magnetic type. All of these are equipped with arc chutes and blowout coils to interrupt heavy currents, since any of them may be required to open power circuits in response to signals from various overload relays.

The reverser is of the pneumatic type, remotely controlled from the master controller. It is not equipped with blowouts or arc chutes, since it will not be operated while it is carrying power.

PANTOGRAPH

The 17MCP1 Faiveley type pantograph proposed for this application can be expected to operate successfully by maintaining, as nearly as possible, continuous contact with the trolley wire under all conditions encountered in normal service.

The pantograph can also be expected to operate satisfactorily in both directions in the range between 15 feet and 25 feet, six inches trolley height.

For most satisfactory operation of the pantograph at high speed, tests show the air stream around the collector shoe should be horizontal without turbulence and the catenary wire should have minimum vibration. Location of the pantograph on the car roof, car roof configuration, and possible obstructions in the air flow path can contribute to air flow turbulence in the region of the pick-up shoe. It may be necessary to rearrange or eliminate the contributors to air turbulence and wire vibration to obtain the required current collection qualities for sustained high speed operation.

The Faiveley type pantograph shoe is included in this proposal.

*60 CPS CONVERTIBILITY

The equipment included in this specification is designed to operate on 11,000 volts, 25 cycle, single phase a-c power. It will also allow future operation over railroads or branches with either 11,000 volt or 25,000 volt, 60 cycle, single phase, a-c electrification systems with the addition of required switches, contactors, relays, insulators, control circuits, etc. Full operation is permitted on either the 11,000 volt, 25 cycle or 25,000 volt (nominal 23,400 volt), 60 cycle power supply. Operation on 11,000 volt, 60 cycle power is restricted to approximately 40% of transformer rating for traction purposes.

Changeover of the equipment for operation on either of the two mentioned power sources is to be made with the transformer primary deenergized or at a dead section in the catenary. The design permits conversion to be made in any customer's shop equipped for major class repairs. Modification instructions and/or drawings will be furnished at time of conversion.

In general this conversion will include installation, changing or modification of pantograph insulators, pantograph ground switch, pantograph ground hook, lightning arrester, changeover equipment box to be mounted on side of transformer (approximate dimensions 44" L x 19" W x 29" H), changeover relay box (approximate dimensions 30" L x 15" W x 29" H), modification of firing circuits either by changing circuits or by interchanging circuit cards, filter capacitors and pyranol pump motor. The estimated weight of this equipment will be 1200 pounds.

The transformer furnished as per Bill of Material will be rated 11,000/ 22,000-25/60 cps. The basic insulation level of the transformer will be selected in accordance with our interpretation of applicable ASA standards, protection of a 30 KV thyrite (standard station type) lightning arrester and a catenary insulated with three 5 3/4 x 10" discs of insulation.

The use of higher trolley voltage will mean that minimum distance between pantograph and roof will be increased from 5" for 11 KV to 10" for 22 KV. This means that if a conventional type car design is used the pantograph lockdown height will be increased by this amount unless the fact is taken into account in the original design.

*revised 9/12/66

*DYNAMIC BRAKING SYSTEM OPTION

A dynamic braking system is included only if specified by the customer. If the customer intends to add dynamic braking at some future date, then this fact must be stated in the contract for the original base equipment.

Master Controller

When it is specified that dynamic braking be provided, the master controller must operate in a different manner to provide for this additional function.

The master controller (an integrated, self-contained package suitable for either in-console or separate mounting) features a single operating handle for both braking and accelerating control.

This operating handle includes a "deadman" automatic tip-up feature for emergency brake applications. In addition to the operating handle, the master controller includes a removable reverse key, and two control plug receptacles.

The operating handle has the following positions: non-operative, emergency brake, braking sector (1/4 circle swing), coast, and accelerating sector (1/4 circle swing). Within the braking sector, movement of the operating handle counterclockwise results in increased braking rate. Within the accelerating sector, movement of the operating handle clockwise results in increased accelerating rate and higher maximum speed. The following operating handle positions are identified by detents (i.e. "click stops"): emergency brake, full service brake, coast, and the four running positions.

The master controller incorporates a reversing switch which moves in a horizontal plane such that the position of the switch is indicative of the position the car will travel. The reversing switch has a neutral position. It is possible to insert or remove the reverse key only with the operating handle in the non-operative position. It is possible to throw the reverse switch only in the coast (or zero speed) and non-operative positions.

The master controller incorporates two plug switches to receive a "standard P.R.R." control plug. These two plugs are for reset and control.

*revised 9/12/66

Operation

The braking system derives its input intelligence from a trainline signal generated by the master controller, except as overridden by brake pipe pressure reductions. A translator on each car converts the trainline signal to the proper local signal. A transducer monitors the service application pipe pressure, and its feedback signal is compared with the analog trainline signal by the dynamic brake control. The dynamic brake control responds to either the trainline signal or the service application pipe pressure, whichever is more restrictive.

When braking is initiated by trainline brake pipe reductions, modulation of dynamic brake is by the service application pipe transducer alone. A pressure switch monitoring the brake pipe puts the propulsion system into dynamic brake, no matter what the state of the analog trainline signal, if the brake pipe pressure falls below a preset value. Conversely, this same pressure switch prevents a power application unless the brake pipe is up to release pressure.

Dynamic braking is accomplished by reconnecting the traction motors as generators and dissipating the kinetic energy of the vehicle as heat energy in braking resistors. Regulation of retardation is by current limit; as car speed is reduced, the load resistance is reduced to maintain constant (or speed-tapered) dynamic braking effort. As the desired braking effort is increased or decreased, the load resistance is modulated accordingly to produce a smooth transition to the new level. A fast response static control system combines maximum smoothness with minimum response time to provide optimum operating characteristics.

If the trainline signal goes to zero for any reason (deadman, emergency valves, etc.), and an emergency brake application utilizing air brakes alone is initiated, dynamic brakes are cut out by a pressure switch on the service application pipe which opens when the service application pressure approaches its maximum value. As a safety backup, power is also removed on all cars simultaneously if brake cylinder pressure exceeds 25 psi. This is accomplished by interruption of the redundant power trainline wire.

*revised 9/12/66

The wheelslip-slide detection and correction system continuously monitors speed differential between axles and rate of change of axle speed. In braking, if differential or deceleration become great enough to indicate sliding wheels, the dynamic brake effort is reduced until the slide disappears, then is gently reapplied to avoid reinitiating a slide. A per-truck slip signal is also made available to the air brake system. The wheelslip system is deactivated by an emergency brake application.

Power circuit protective relaying in braking consists both of overload protection, in both braking loops, and differential protection. Thus if, because of a fault or flashover, braking current rises to an unsafe level, or an excessive differential exists between the two braking loops, the braking loops will be opened, resulting in an automatic transfer to air brakes. Although overload trips must be reset from the operator's cab, differential trips are automatically reset by the next brake release.

The dynamic brake control is also arranged that dynamic brake may be cut out on a trainlined basis from any car. An indicating light in the operator's cab will be lit whenever dynamic brake is cut out. Monitoring of the operation of dynamic brake is by means of the cab ammeter jack.

Dynamic braking is effective from about 75 mph car speed down to fadeout at approximately 20 mph. The fadeout point can be adjusted to meet the requirements of the application.

*revised 9/12/66

RELIABILITY

Reliability of the PCI control and its associated equipment is assured by:

- separate ground relay protection for propulsion and auxiliary circuits.
- single motor overload protection in both motor circuits to obtain maximum motor protection.
- proved in service margin of safety for the current carrying capacity and inverse voltage rating of the silicon diodes.
- use of a proven calibrated relay which senses line voltage and causes control to recycle should power be interrupted during motoring
- mechanical interlocking of static cards to insure proper positioning.
- providing a triple break in interruption of the motoring propulsion circuit.
- protecting ignitrons with an overtemperature thermostat.
- measuring current in both motor circuits with the higher signal overriding.
- full field operation of motors eliminating the need for field shunting contactors, thereby simplifying the control system.
- including static components to obtain a higher degree of control of the traction motors than is possible by resistance and/or tap changing.

MAINTENANCE AND INSPECTION

Maintenance and inspection of the PCI control and its associated equipment are reduced to a minimum by the following features:

- All electric control requires only electrical maintenance personnel and facilities. One man can check the complete sequence.
- The line breaker and overload relay are in a separately ventilated compartment, preventing consequent damage to other main control components during fault interruption.
- Packaging permits accessibility to all components.
- The arc interruption duty is distributed over line breaker and other devices for increased contact tip life.
- Sliding contacts have been eliminated in the interest of long life and lower maintenance.
- Stock replacement items are reduced by standardization of parts such as contact tips and shunts, arc chutes and coils, permitting maximum interchangeability.
- Static components are assembled functionally on "plug-in" cards which can be replaced easily without hand tools. Other control equipments are designed and constructed to provide for easy replacement of wearing parts such as contact tips, arcing horns, arc chutes and shunts.
- The power contactors, applied with a high margin of safety, are a rugged railway type long proven in locomotive service.

TRACTION MOTOR

The GEZ-5711 (GE-1252) motor is a four-pole, series wound, self-ventilated direct current traction motor with commutating poles. It is designed to give maximum tractive effort with minimum weight when used with a close-coupled gear drive unit. This motor is specifically designed for the propulsion of railroad passenger multiple-unit commuter cars. Its frame is fabricated of rolled steel plate. Anti-friction armature bearings are greased and sealed at the factory, so that no intermediate lubrication need be provided between major overhauls. There are four brush holders with two carbon brushes per holder.

Ratings:

	HP at Shaft	Volts	Amps	RPM	Rise by Resistance Arm.	Rise by Resistance Field
Hourly	156	425	300	1710	140°C	155°C
Continuous	140	425	270	1780	140°C	155°C

*Maximum Application Speed: 4500 RPM

*Weight: Approximately 1315 lb

*Characteristic Curve: 41H155376

Ventilation: Self-ventilated, but with air ducted by the car builder from as near the car roof as possible to minimize entry of dry snow.

Features: In addition to the features of this motor already stated in Section I, General, some of the other features are:

- teflon insulated brush-holder studs which discourage accumulation of dirt and are virtually impervious to moisture penetration and flashover damage.

- armature coils held in slots by wedges instead of banding wire, eliminating banding losses and providing greater mechanical strength.

- armature coils formed and installed in such a manner as to prevent telescoping of conductors when bound to the required tightness.

*revised 9/12/66

TRACTION MOTOR (Cont'd)

- an arch-bound commutator design which holds its shape under centrifugal forces.

- cartridge type bearing assemblies which allow removal of armature without exposing bearings to dirt.

- a design providing maximum space inside motor for inspection and maintenance.

- brush holders arranged to facilitate inspection and replacement of worn brushes.

*GEAR UNIT

The GA-56 is a double reduction, low profile, parallel drive, fabricated steel type gear unit incorporating ground helical gears. It can team with a variety of motors, utilizing the new flexible link suspension to provide reliable propulsion power for multiple unit passenger cars. The gear unit and the motor form a package that can fit within most new light-weight truck designs; narrow enough to fit between the side frames; short enough to fit between transom and axle; high enough to provide adequate rail clearance; and, low enough to allow for spring deflection and car floors.

The drive utilizes the new flexible-link suspension which allows the motor to float between the truck and the gear unit. This provides an ultra-soft ride for the motor, allows the motor to be replaced without disturbing the gear unit, and permits replacement of rubber suspensions without disturbing the installation. The coupling is a separately-enclosed gear type -- taking full advantage of the low misalignment inherent in the suspension system.

The gear unit has ground and hardened alloy steel helical gears of a design proved in service. It has tapered roller bearings throughout, lubricated by a system incorporating splash and gravity feed. The lube filler opening is designed to prevent overfilling the housing with oil beyond the optimum level. It is designed to withstand wheel skid, dynamic braking loads, and flashovers.

*revised 9/12/66

GEAR UNIT (Cont'd)

Weight of the complete gear unit, including suspension, is approximately 950 pounds.

The gear unit and motor are coupled together before shipment. The axle is installed by pressing it through the quill. Shimming of the quill bearings may be necessary after the unit is installed on the axle.

The ground brush holder is attached to the gear housing and its collector ring is mounted on the quill.

*revised 9/12/66

AUXILIARIES

*POWER SUPPLY AND CONTROL

The transformer secondary auxiliary winding provides power for the car heaters, transformer pyranol pump and the auxiliary power rectifiers. The output of the auxiliary winding is 202 volt, single phase, 25 cycle, a-c power.

Molded case circuit breakers protect all equipment operating from the 202 volt power supply. In addition, the alternator, battery charging circuit, air compressor, motor, blower motors, fluorescent lighting and cab heater blower circuits are protected by circuit breakers in the 220 V, 3 phase output supply of the MA set.

*MOTOR-ALTERNATOR SET

The GMG-176 motor-alternator set consists of a d-c motor driving a 220 volt, 3 phase, 60 cycle alternator and an exciter all on one shaft. The set provides power for the car air conditioning equipment, transformer and rectifier blower motors, air brake compressor motor, fluorescent lighting and, through another auxiliary transformer and silicon cell rectifier bank, power for the traction controls and charging the car battery.

The approximate weight and outline are as described in the Bill of Material, Section 2.

*MOTOR BLOWER SETS

There are two motor-blower sets per car. Each set consists of a GYA-26, 220 volt, 3 phase, 60 cycle motor driving a 7A20 blower. One set provides ventilating air for the transformer and smoothing reactor while the second set supplies cooling air for the rectifier group.

The approximate weight and outline are as described in the Bill of Material, Section 2.

EQUIPMENT VENTILATION

Equipment used on electric MU cars requires various amounts of ventilating air for cooling. This air is forced through the equipment by external fans, generally motor blower sets, and in this proposal is drawn into the traction motors with internal fans.

*revised 9/12/66

Experience has shown that clean, dry cooling air reduces vehicle maintenance costs and equipment failures. Higher speed commuter train operation creates so much air turbulence that cooling air should be drawn from as near the car roof as possible to reduce moisture and air cleaning problems. Clean ducted air to the motor-blower sets and to the rectifier group, smoothing reactor, transformer and traction motors must be supplied by the vehicle builder.

The air system for ventilation of the traction motors should be designed with a primary purpose of minimizing the amount of snow carried into the traction motors. The air system for ventilation of other equipment should be designed with a primary purpose of minimizing the pickup of leaves, paper, trash, etc., to the transformer and rectifier group. The duct system should also be designed to minimize the amount of snow carried into the reactor. In order to verify the design, a mock-up of the system should be tested to minimize last minute changes and ensure an optimum design.

General Electric will, of course, cooperate fully with the car builder in his development of all ducted air systems supplying our electrical equipment.

GENERAL ELECTRIC FACILITIES

Transportation Systems Division

The Transportation Systems Division is the land transportation propulsion systems-oriented division of the General Electric Company. It dates back to the founding of the Company in 1892. The Division determines drive system requirements, prepares system and component specifications and designs and manufactures these components. When components are purchased from other Company departments, the Division retains total system and compartment responsibility.

The Transportation Systems Division maintains the world's largest pool of engineering and technical people devoted solely to traction systems.

Control Engineering and Facilities

The Control Systems Engineering component has a staff of highly competent engineers, experienced in the analysis, development and design of complex systems for power and control of internally and externally powered vehicles and related apparatus for land transportation. This includes electrical systems utilizing solid state devices for regulating voltage, current and power; and mechanical and electrohydraulic systems for regulating speed.

The Control Equipment Engineering component is staffed with engineers experienced in the development and design and evaluation of pneumatic, magnetic, hydraulic and motor-operated devices for the systems, including such devices as power contactors, relays, electrohydraulic governors, control and power resistors, motor controllers, reactors, power switches, and solid state devices.

Control Engineering has a large development test laboratory with facilities for testing a large variety of control devices and systems. It is equipped with controlled power sources capable of handling up to 3,500 kva, 60 cycle, 3 phase, 11,000 volts; 3,500 kva, 25 cycle, single phase, 11,000 volts; d-c voltages up to 3000

Control Engineering and Facilities (Continued)

volts with short time capacity of 40,000 amperes. Other sources, both regulated and nonregulated, are available for testing both electronic and low power components. In addition, a low voltage supply is available for continuously supplying up to 20,000 amperes of direct current.

A life test area permits the simulation of actual application conditions for a wide range of equipment over varied and controlled types and cycles of operation. It is equipped with sensing devices which shut down the test at point of failure.

Flywheel combinations are available, ranging from 450 to 2600 lb ft^2 capable of speeds up to 6500 revolutions per minute. The flywheels are used to simulate dynamic loading of rotating equipment. Thus, systems used to control this rotating equipment, as well as the rotating equipment itself, can be tested and evaluated.

Dark room facilities are available for providing rapid development of oscillograph records or other photographic requirements.

Equipment for controlling and establishing temperatures ranging from -70 C to 300 C is available for environmental testing programs.

A power arcing chamber permits testing the interrupting capacity and ability of power contactors and line breakers. It is equipped to provide variable resistance and inductance loading of these devices.

Measuring equipment and tools are available for accurately measuring time, temperature, magnetic forces and characteristics, electrical and mechanical quantities.

A machine shop setup permits construction of small mechanical parts. It includes coil winding equipment for winding coils on spools, as well as winding small core toroidal coils.

Motor and Generator Engineering and Facilities

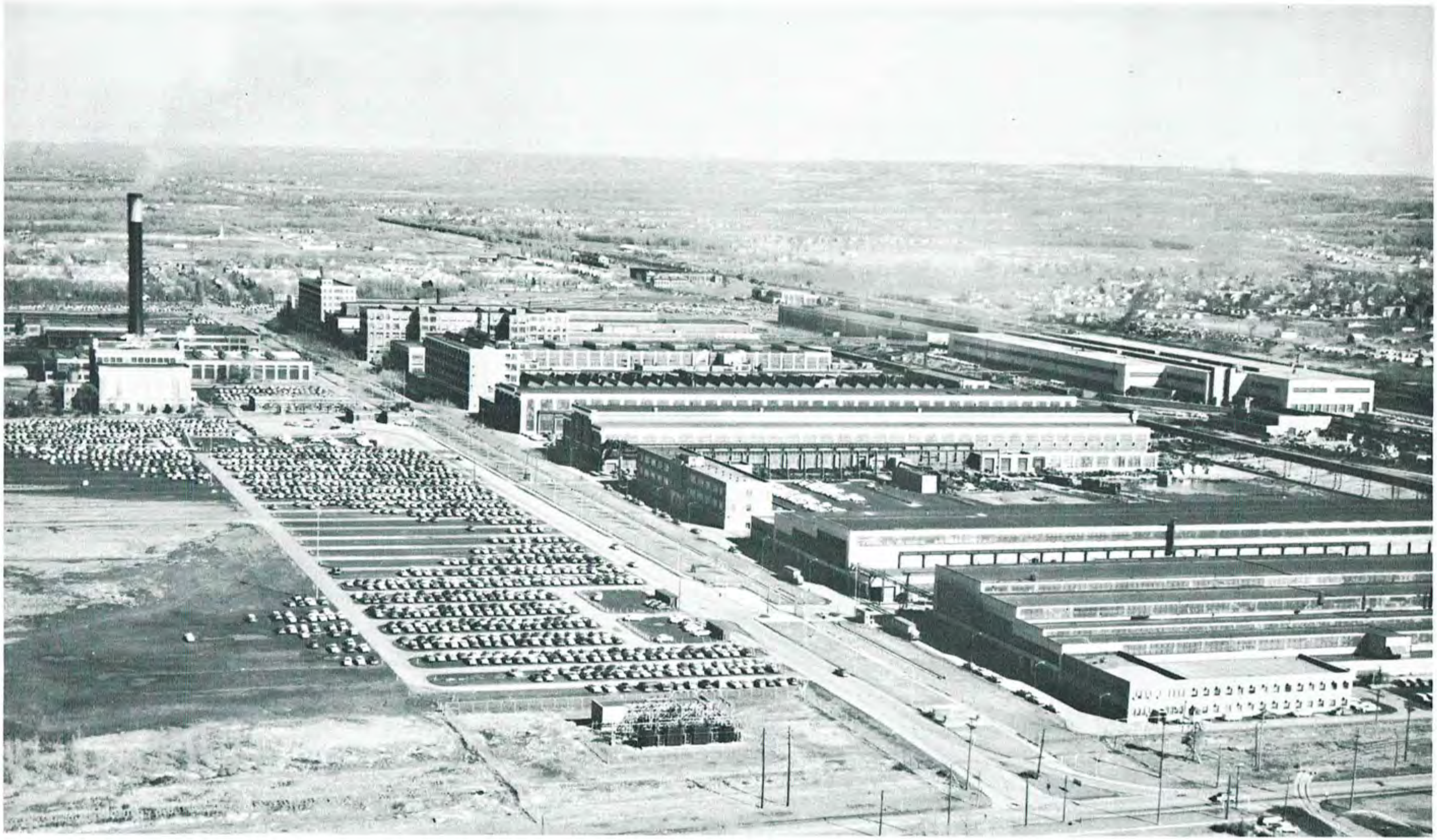
Motor and Generator Engineering is staffed with engineers experienced in the design of d-c and a-c traction motors and generators, auxiliary and exciting generators, gearing, fans, blowers, and other auxiliaries for application to land transportation vehicles and related apparatus.

Motor and Generator Engineering has a development test laboratory with a floor space of 20,000 square feet. The installation is equipped to test traction motors and generators for locomotives, rapid transit and commuter cars beyond the size of any now being built. Power is supplied from a substation which covers 4500 square feet. The facilities include 11 test tables, a soundproof room for noise-making tests, an air chamber for motor ventilation tests and various life test units. The test tables are all built with the same configuration of switches and controls, although each is designed to handle a particular type of equipment with enough flexibility so that each can be used to test other types as well.

The sound testing room, in which the sound level has been reduced to a point where it will not affect the test results, is used to investigate noise characteristics and to compare various designs of equipment. Walls are insulated with rock wool. The room floats on a two-foot bed of sand to isolate it from the building foundation.

A large plenum air chamber, partitioned into two 10-foot cubicles by a steel wall containing nine standard calibrated nozzles, is used to study air flow requirements for ventilating traction motors and generators and for studying the effectiveness of different fan and blower designs. Air flow can be accurately measured up to 30,000 cfm. Various conditions of intake and exhaust can be created. The difference in static pressure between the two chambers is measured by averaging pressures from 18 different locations in each chamber. A recently added facility is a wind tunnel for the testing of very large fans and blowers with air flows above 100,000 cfm.

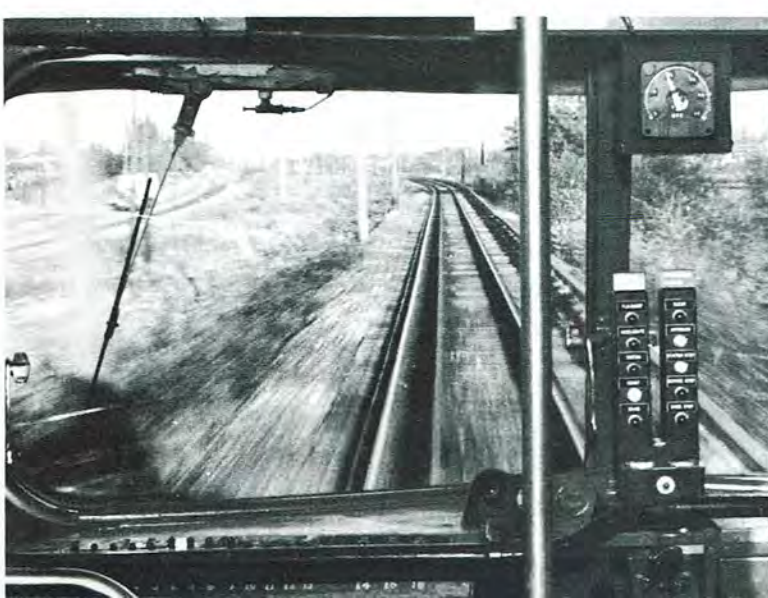
The life test facilities permit simulating actual service conditions for a wide range of equipment over varied cycles of operation.



GENERAL ELECTRIC ERIE PLANT

WORLD FAMOUS Research and Development Center in Schenectady, New York is continually developing new concepts for transportation applications. Examples of the Center's contributions are concepts for automatic train running, radar train separation, solid state circuitry, improved insulation techniques and advanced system design.

ELECTRIFIED 3-MILE G-E TEST TRACK is used to develop and evaluate new propulsion and automatic train control concepts under actual operating conditions.



COMPUTERS are used to provide design data, application information, system simulation and power supply studies.