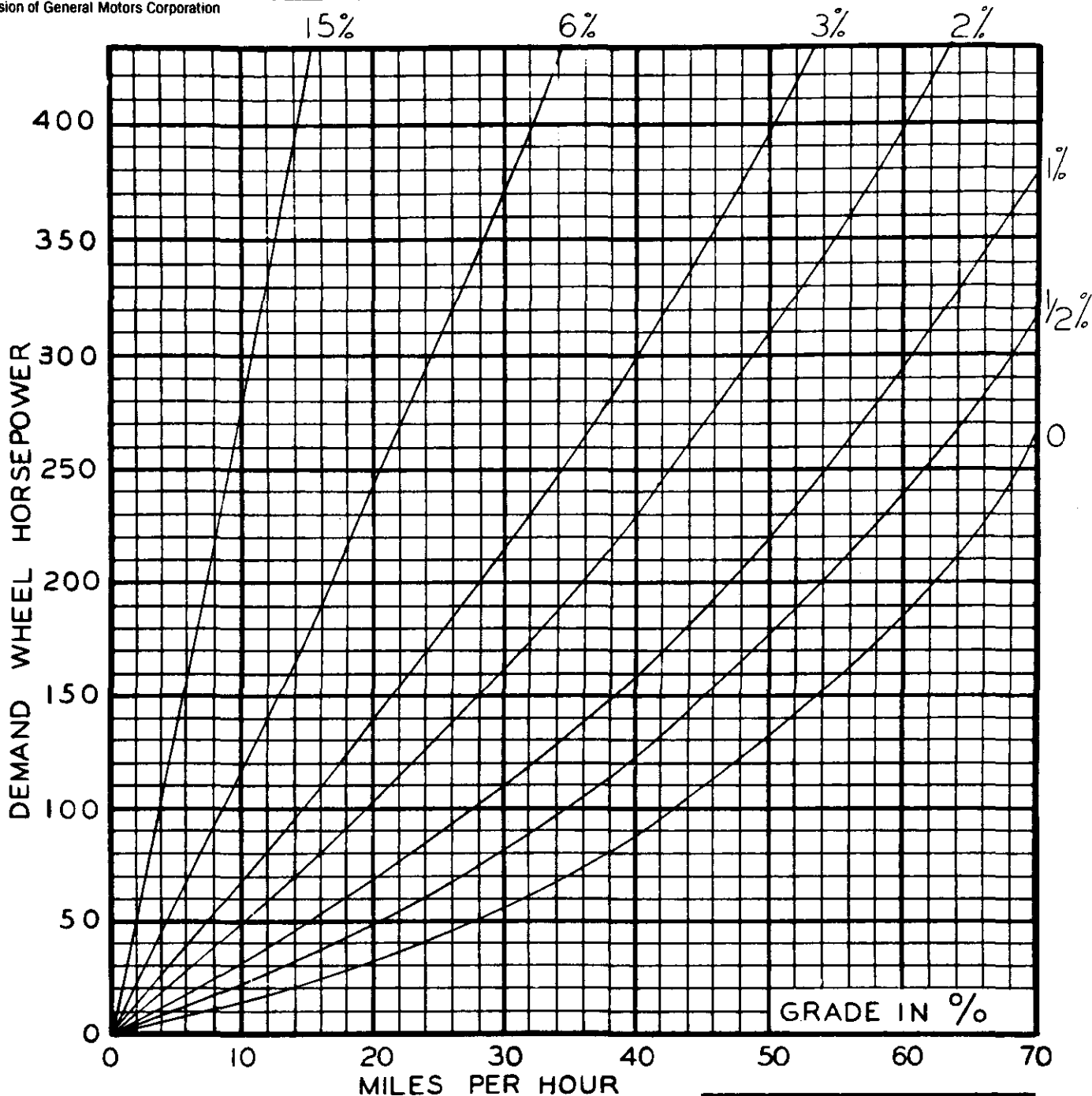




Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS

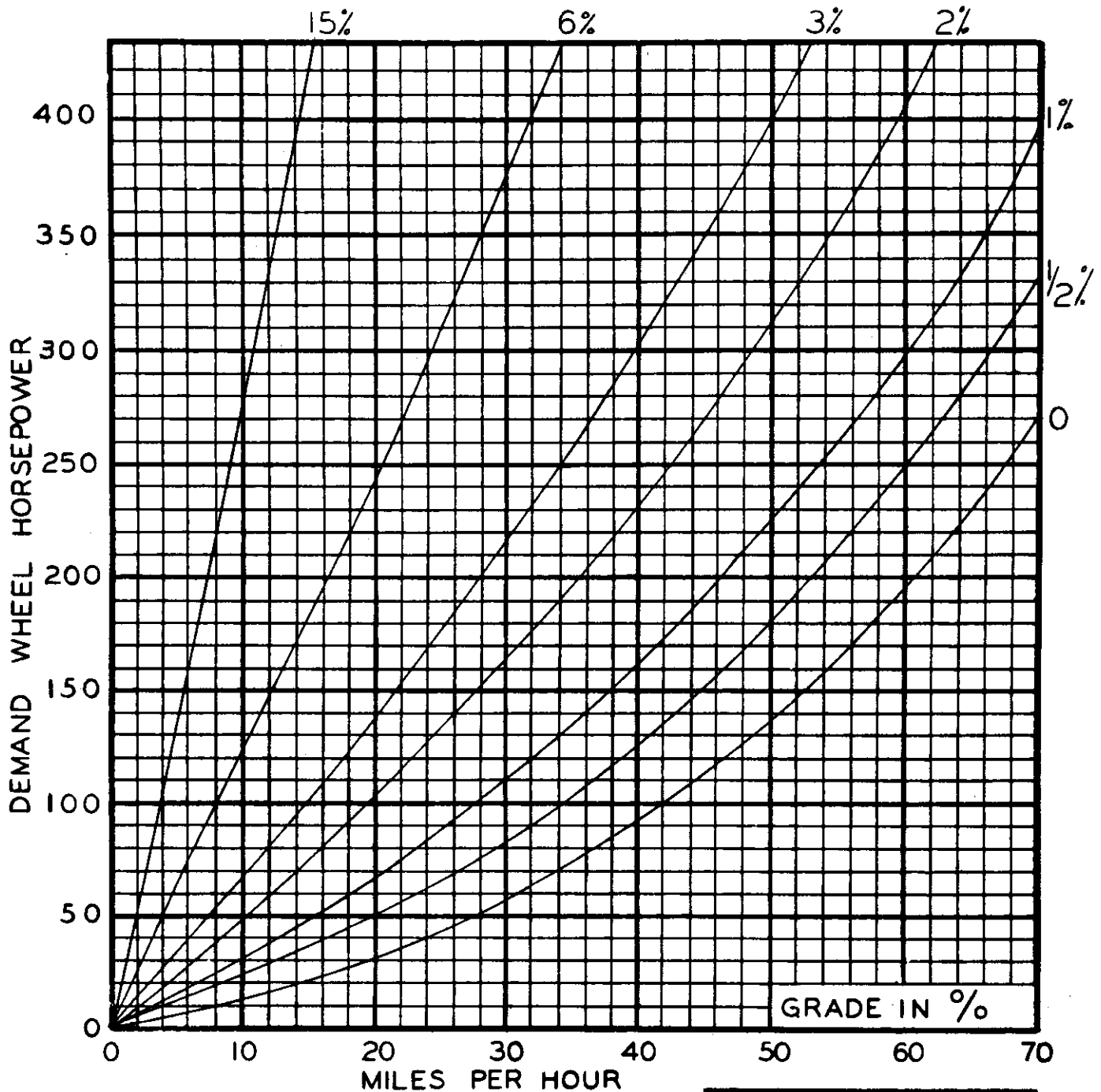


VEHICLE _____
ENGINE _____
GOV. R.P.M. _____ INJ. _____
TRANS. _____
AUX. TRANS. _____
REAR AXLE _____
TIRE SIZE _____
TIRE REVS/MILE _____

GCW. 66,000 LBS.
HEIGHT 9 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
ENGINE _____
GOV. R.P.M. _____ INJ. _____
TRANS. _____
AUX. TRANS. _____
REAR AXLE _____
TIRE SIZE _____
TIRE REVS/MILE _____

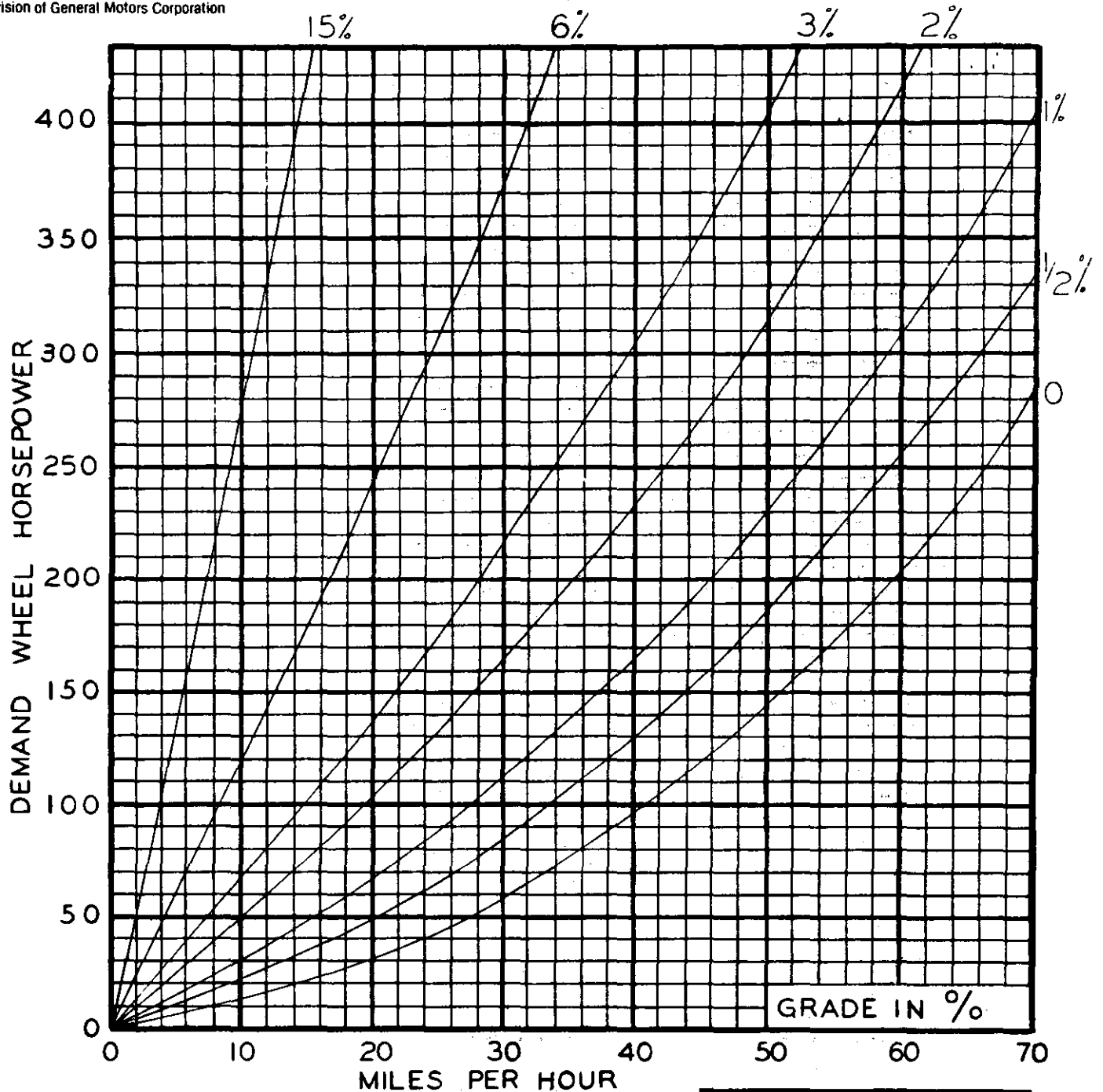
GCW. 66000 LBS.
HEIGHT 10 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

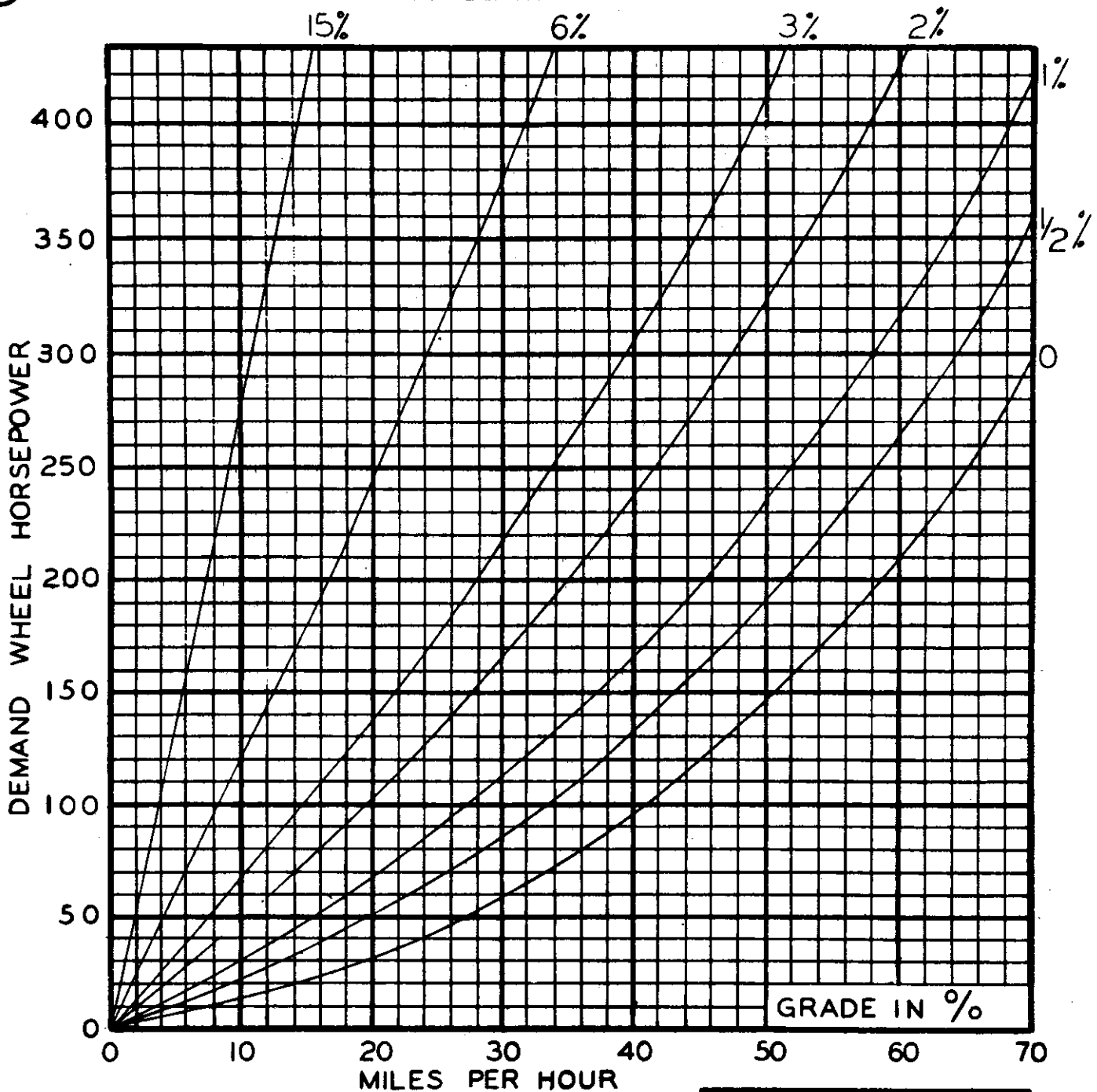
GCW. 66000 LBS.
HEIGHT 11 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. RPM. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 66000 LBS.

HEIGHT 12 FT.

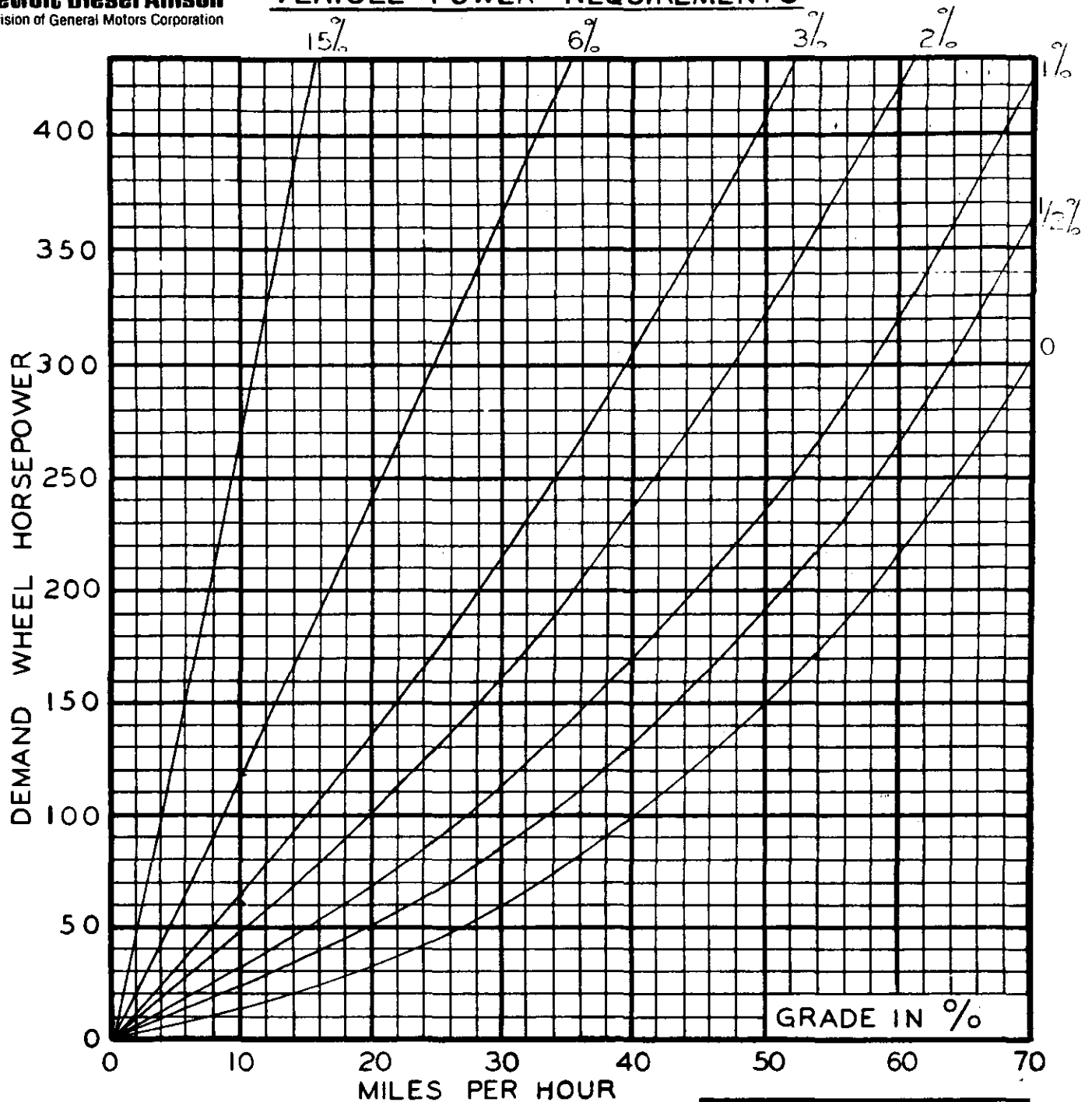
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

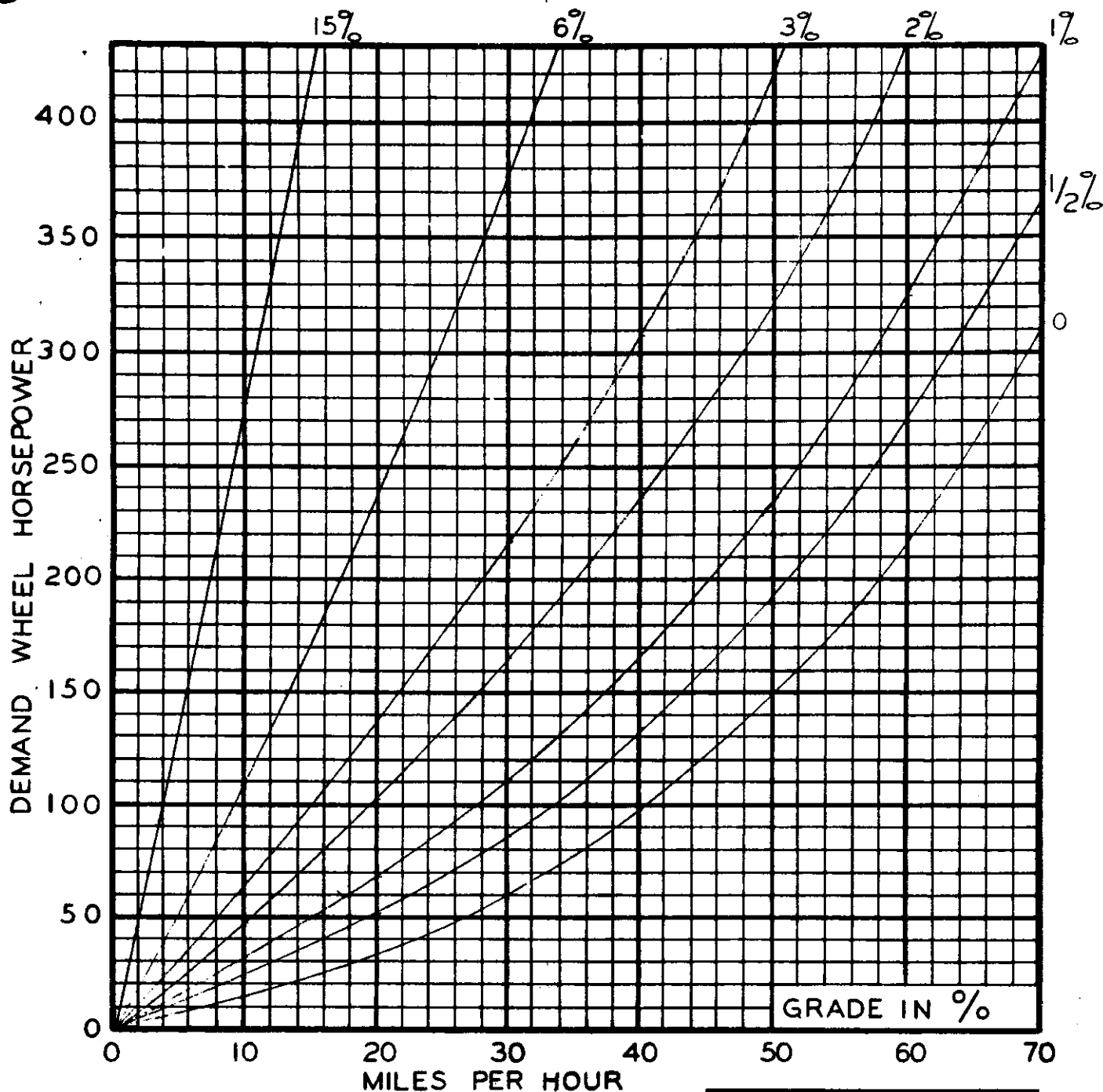
GCW. 66,000 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

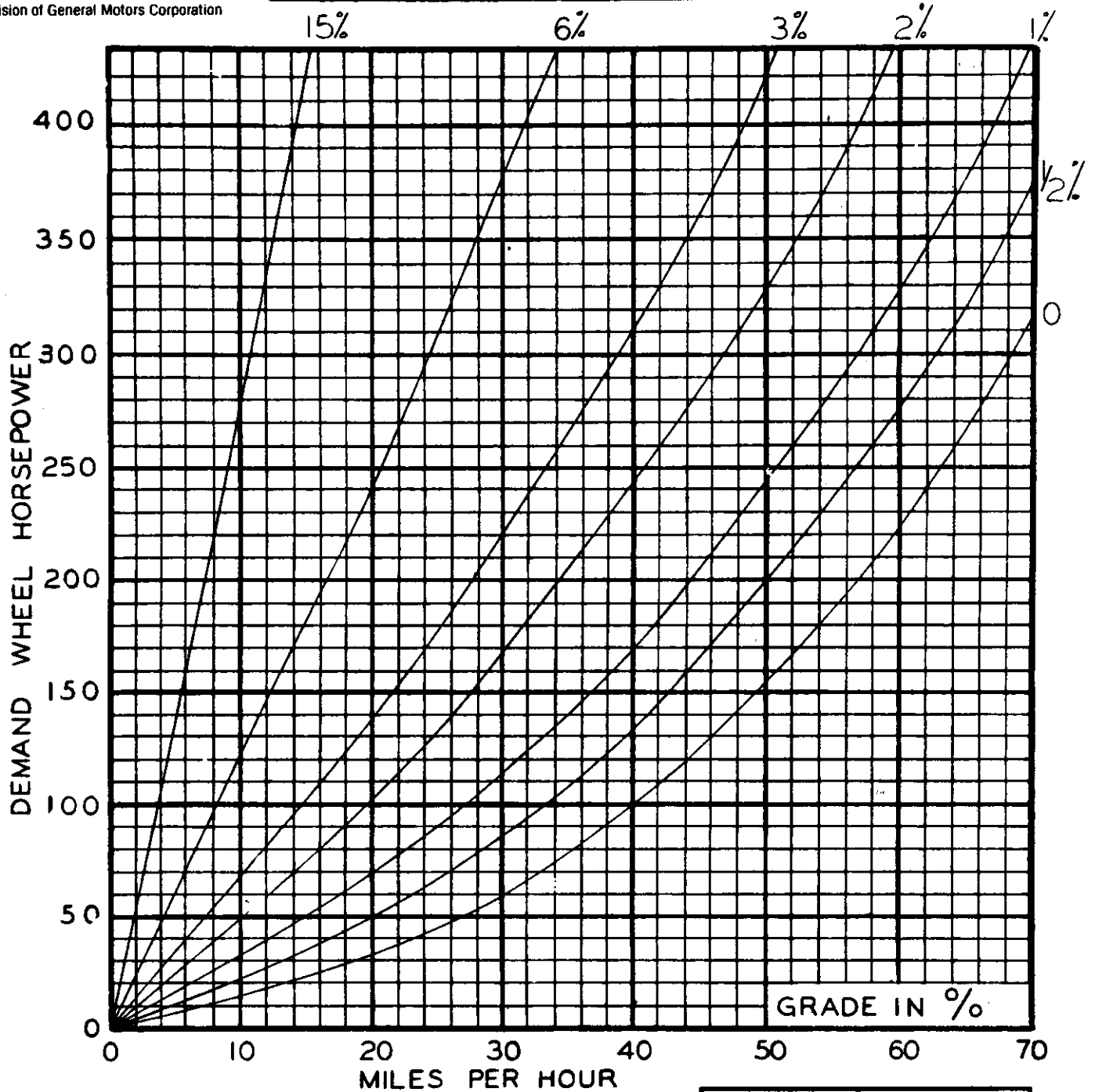
GCW. 66,000 LBS.
HEIGHT 13 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

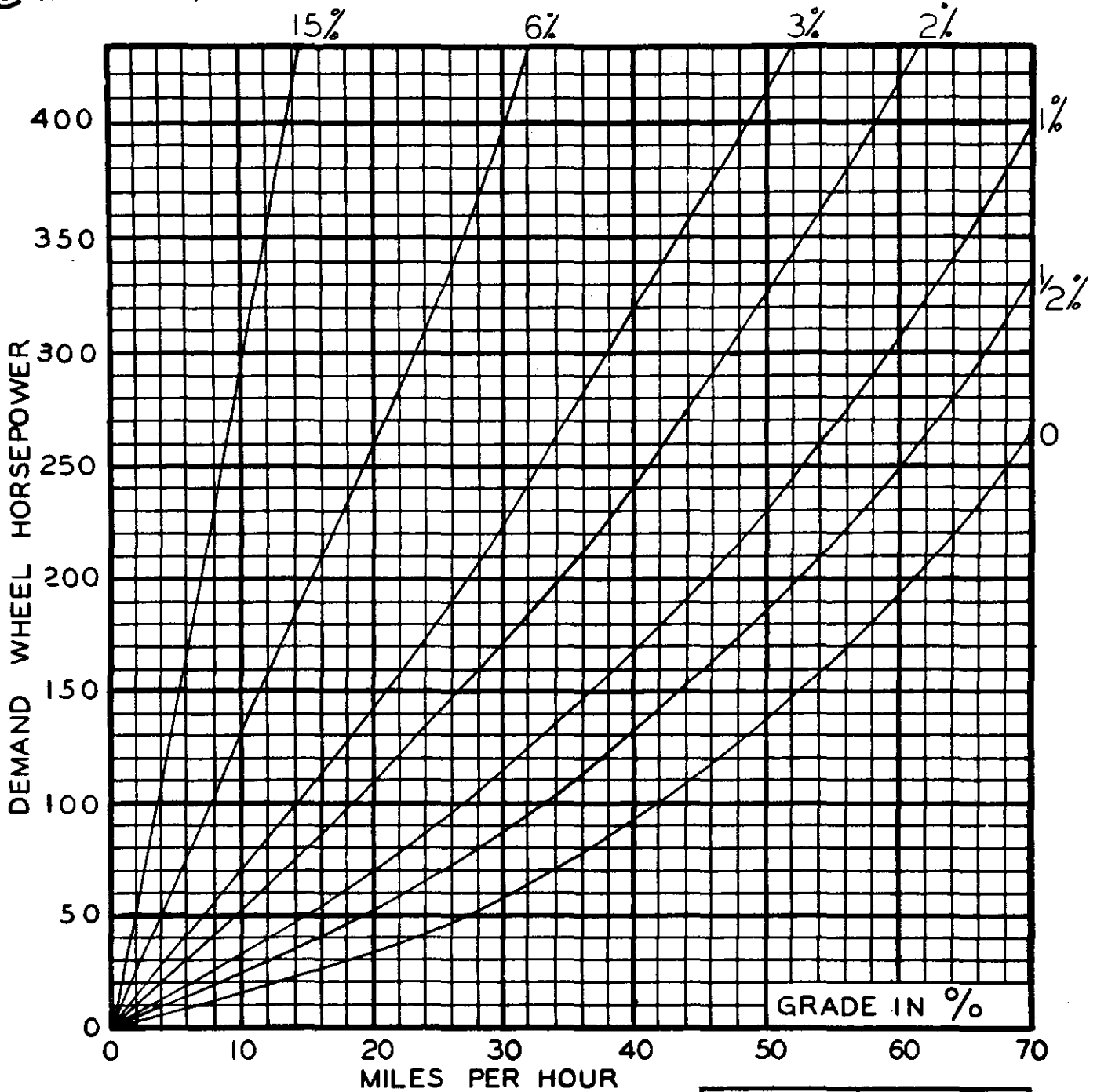
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 66000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
ENGINE _____
GOV. RPM. _____ INJ. _____
TRANS. _____
AUX. TRANS. _____
REAR AXLE _____
TIRE SIZE _____
TIRE REVS/MILE _____

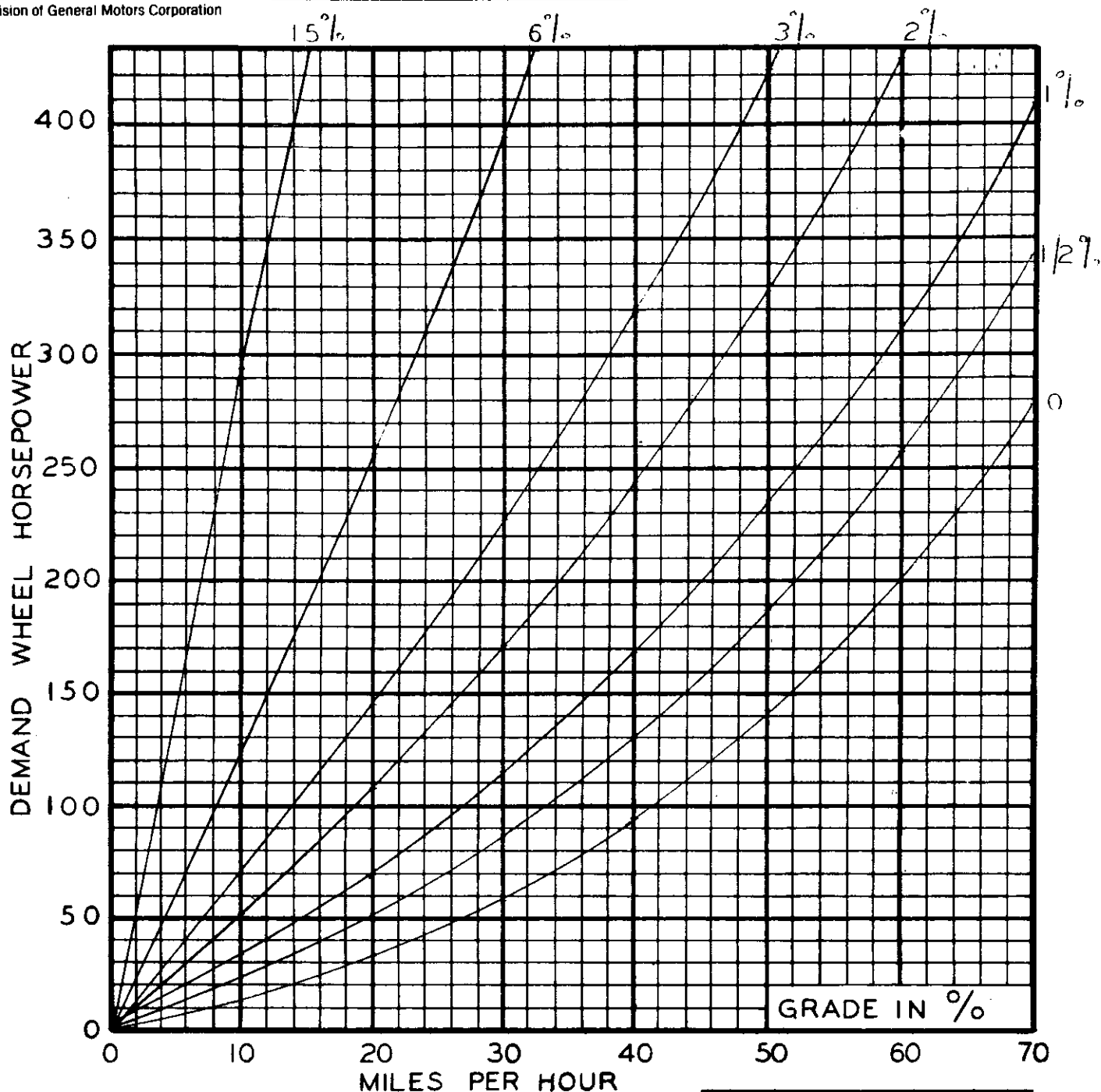
GCW.	70,000	LBS.
HEIGHT	9	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

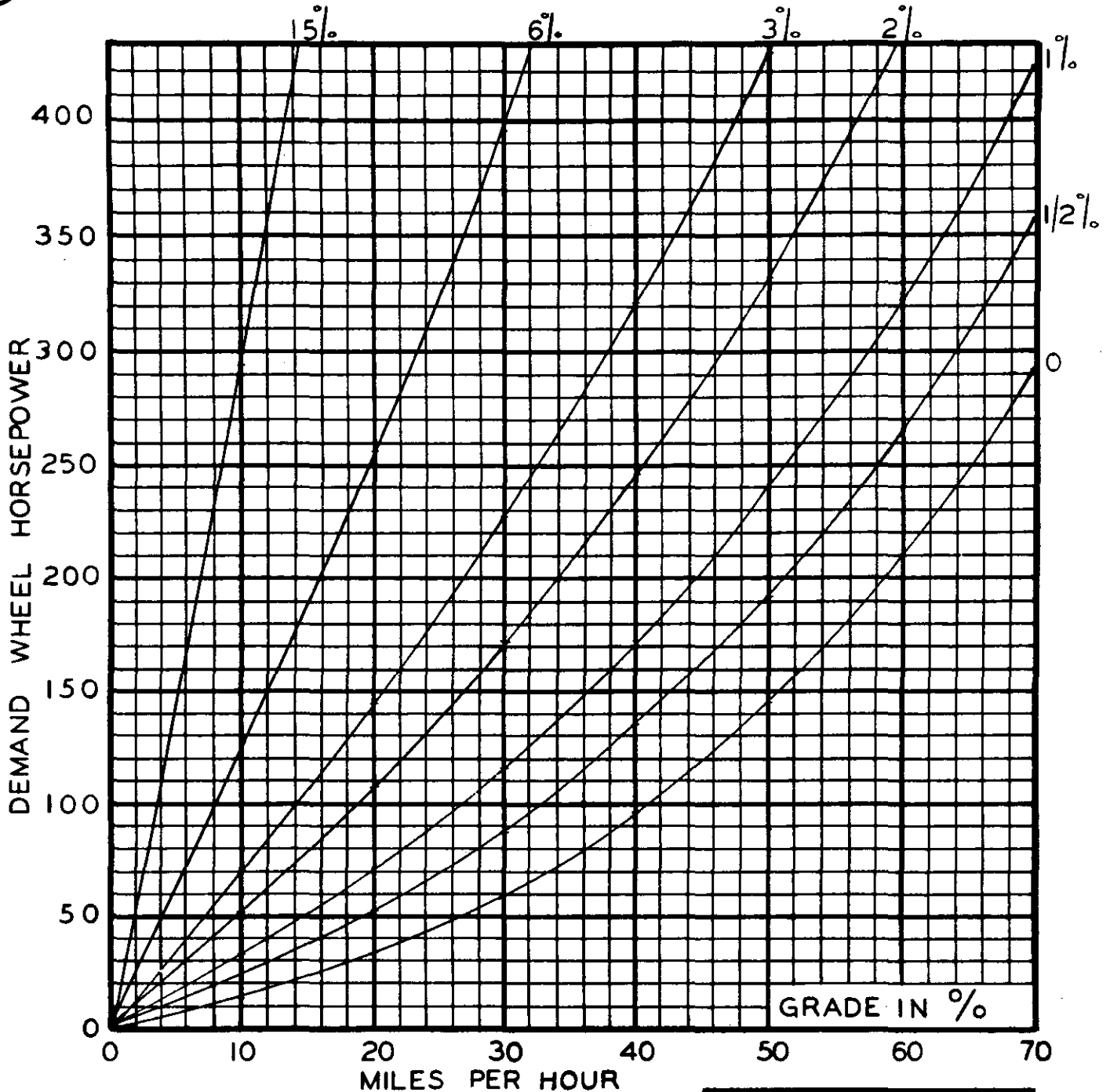
TIRE SIZE _____

TIRE REVS/MILE _____

GCW 70,000 LBS.
HEIGHT 10 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. R.P.M. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REVS/MILE _____

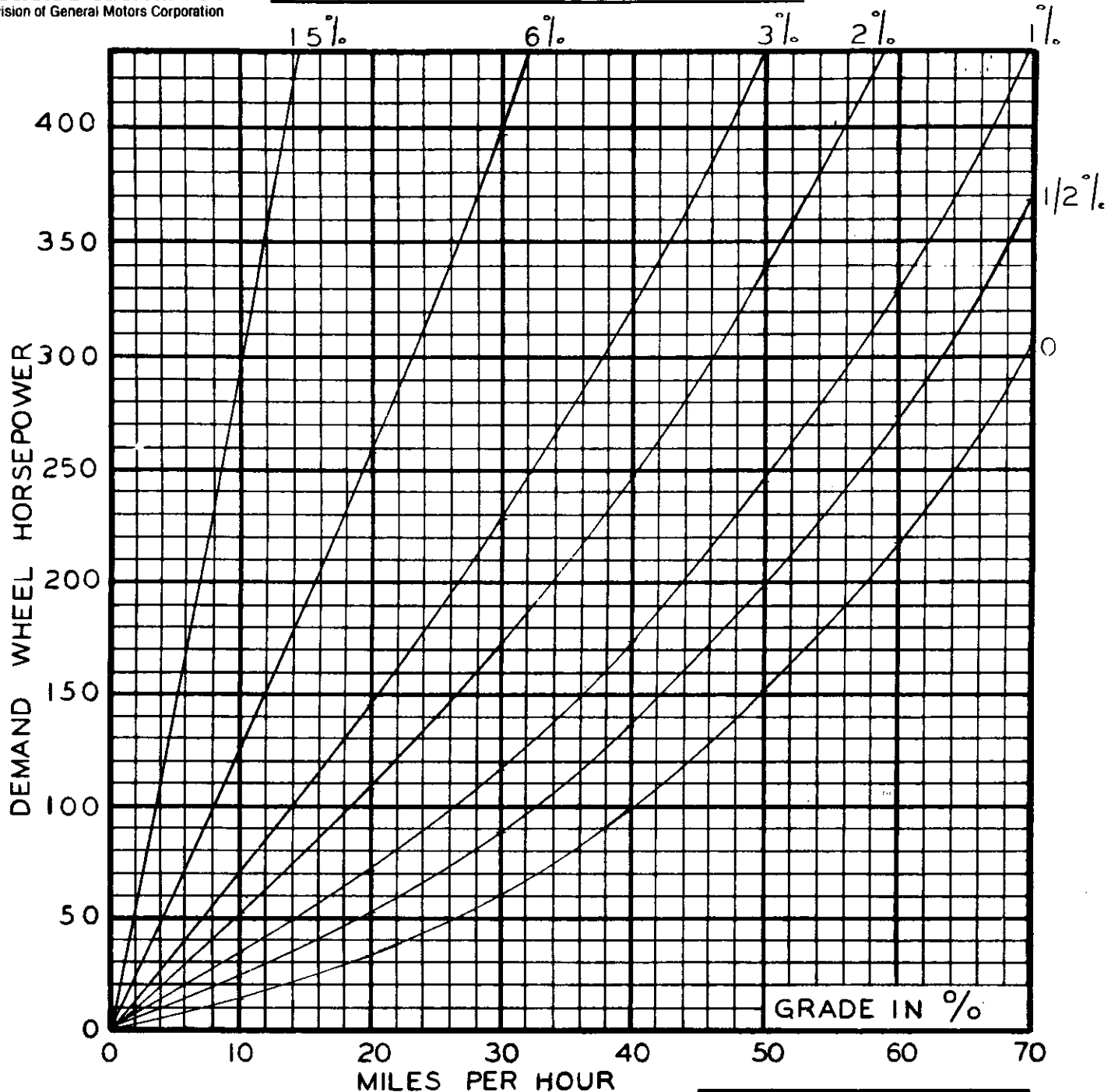
GCW. 70,000 LBS.
 HEIGHT 11 FT.
 WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

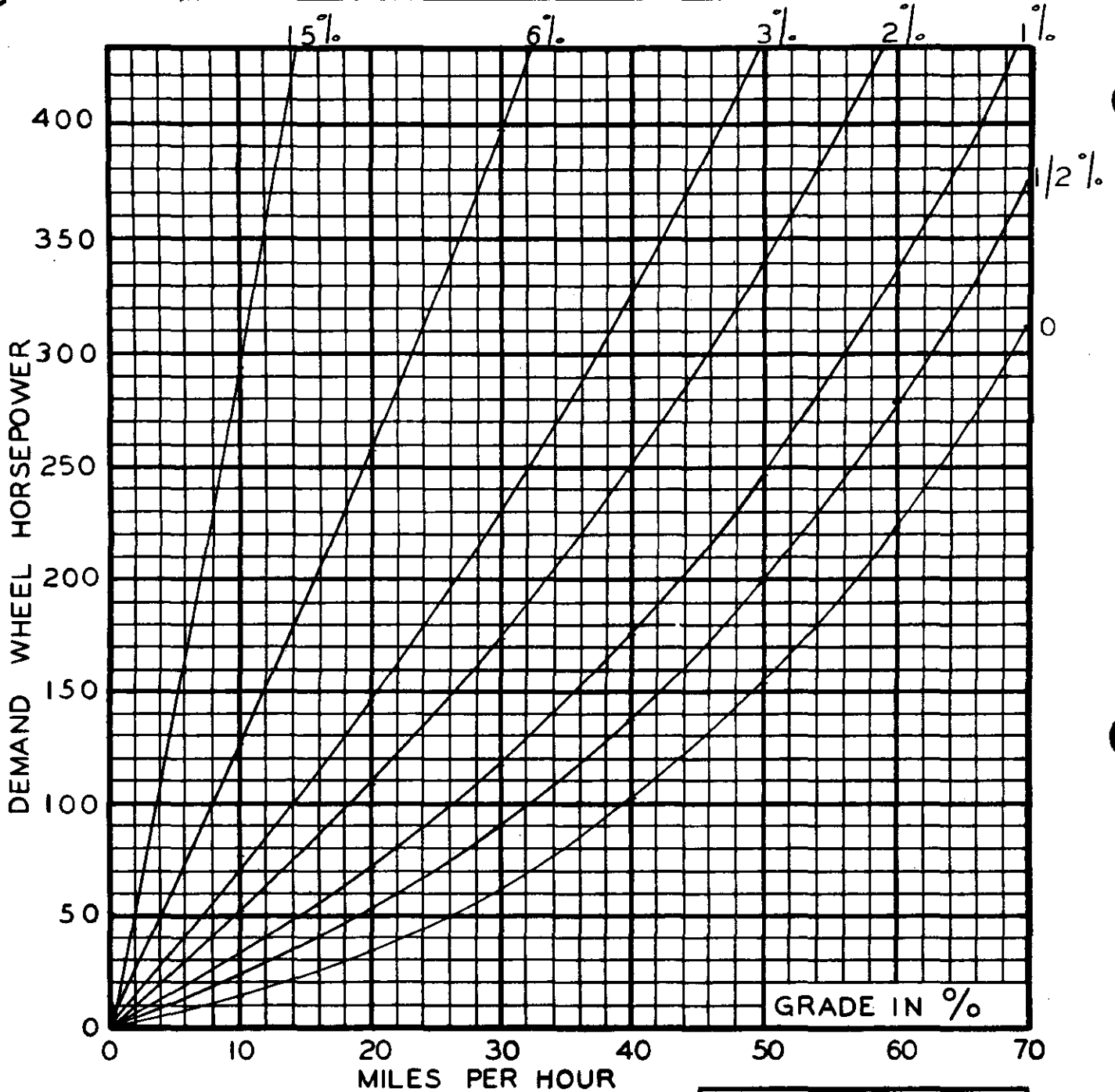
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 70000 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

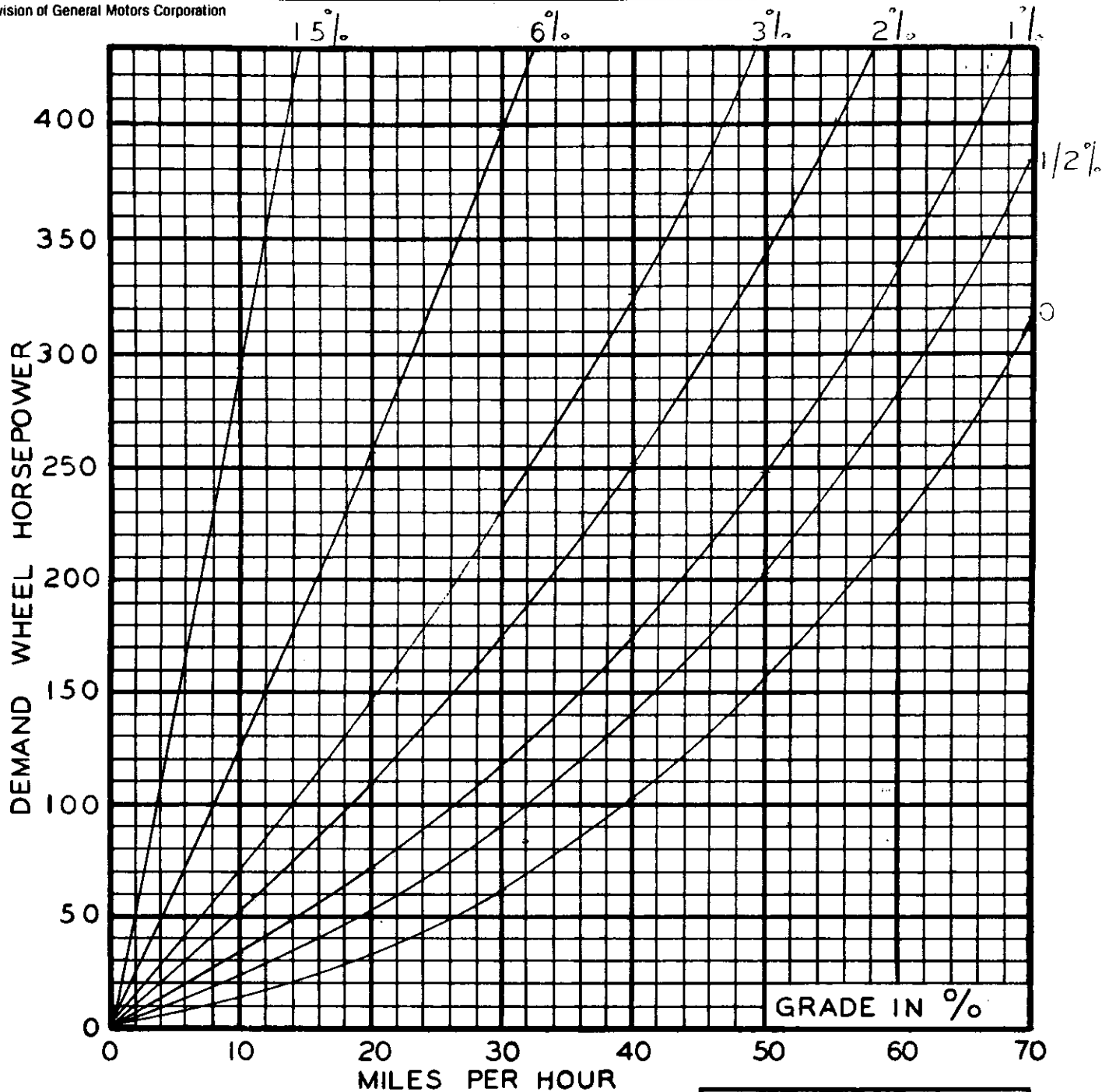
GCW. 70,000 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

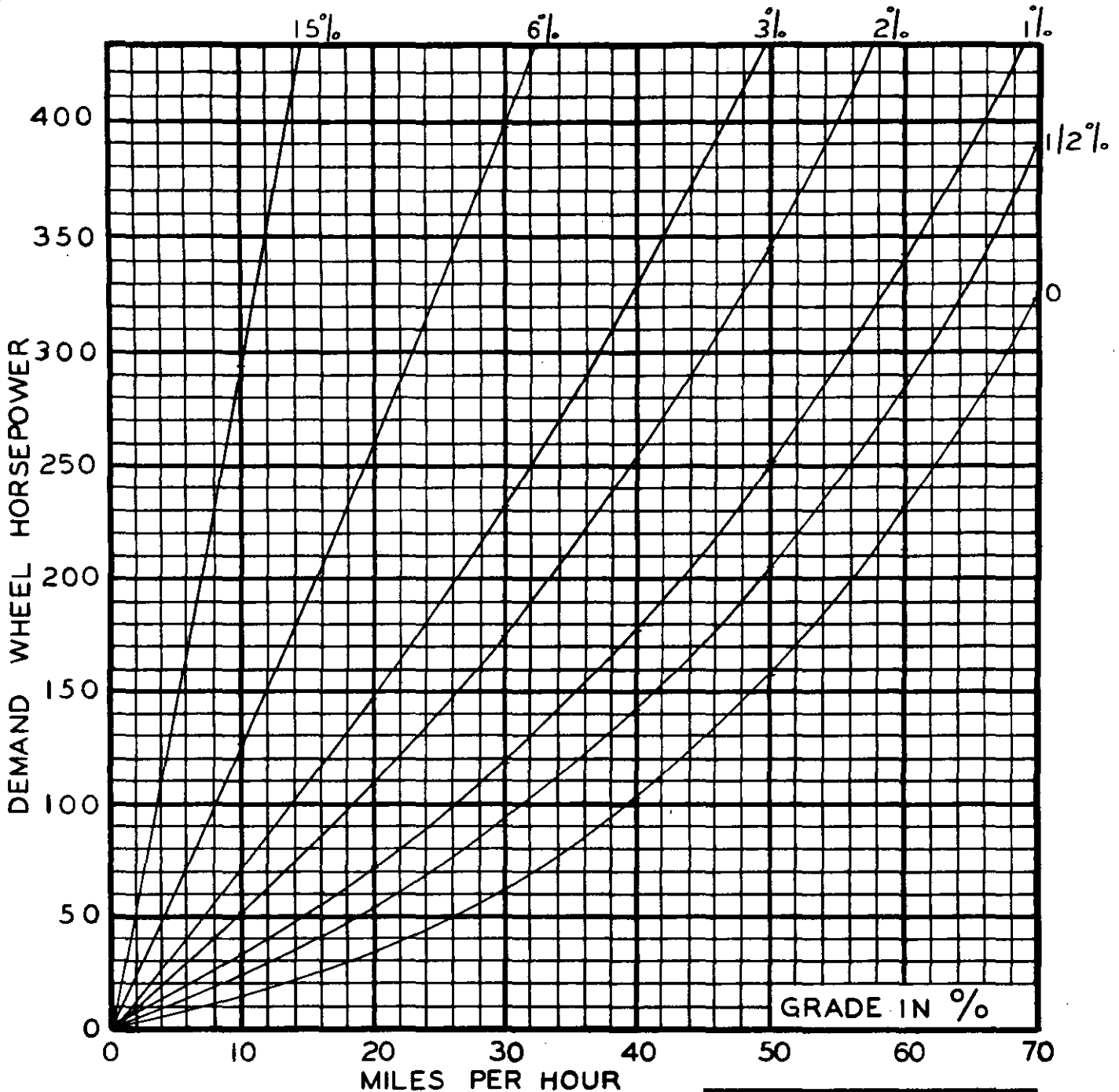
TIRE SIZE _____

TIRE REVS/MILE _____

GCW	70,000	LBS.
HEIGHT	13	FT.
WIDTH	8	FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

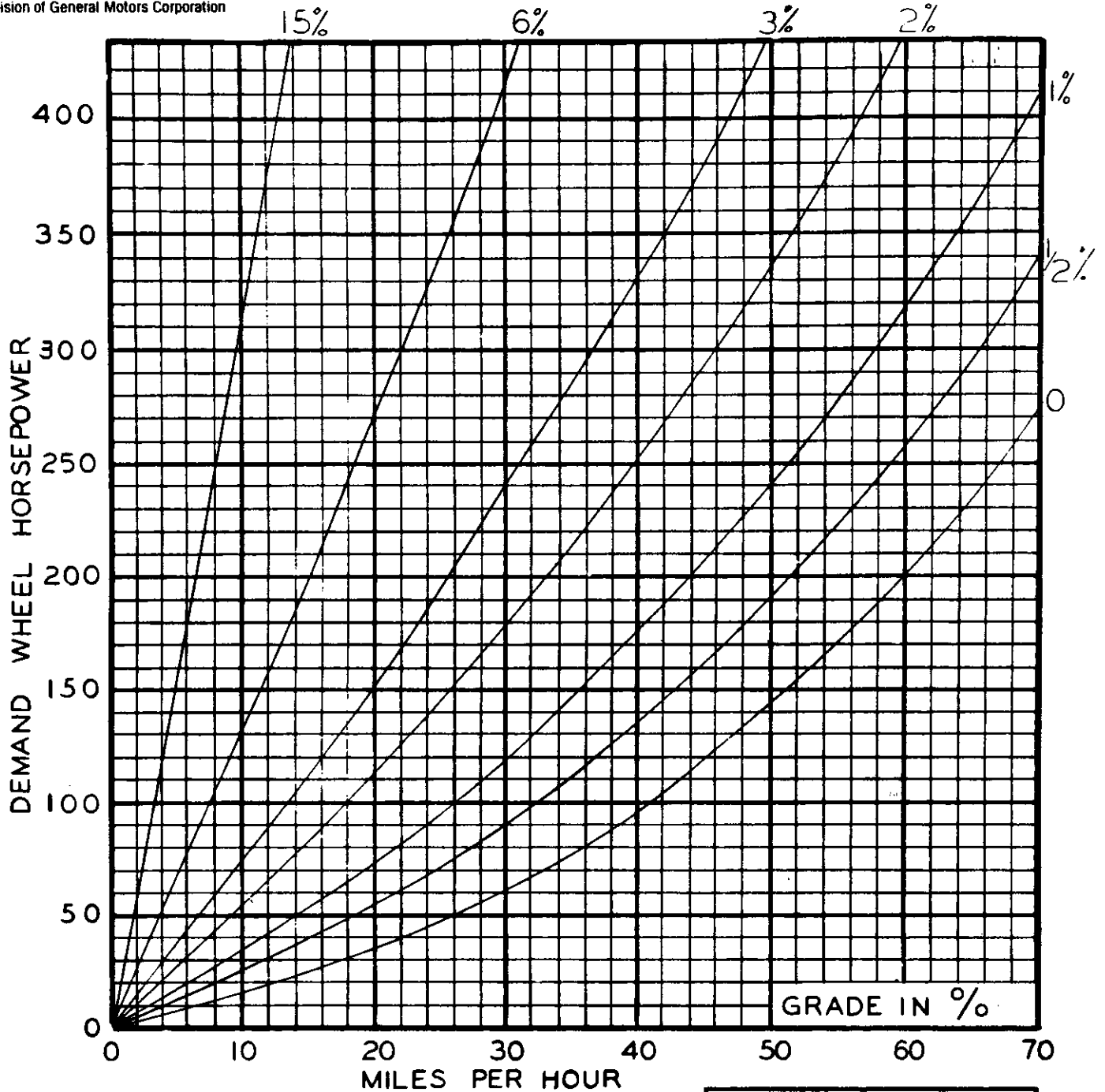
GCW. 70,000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

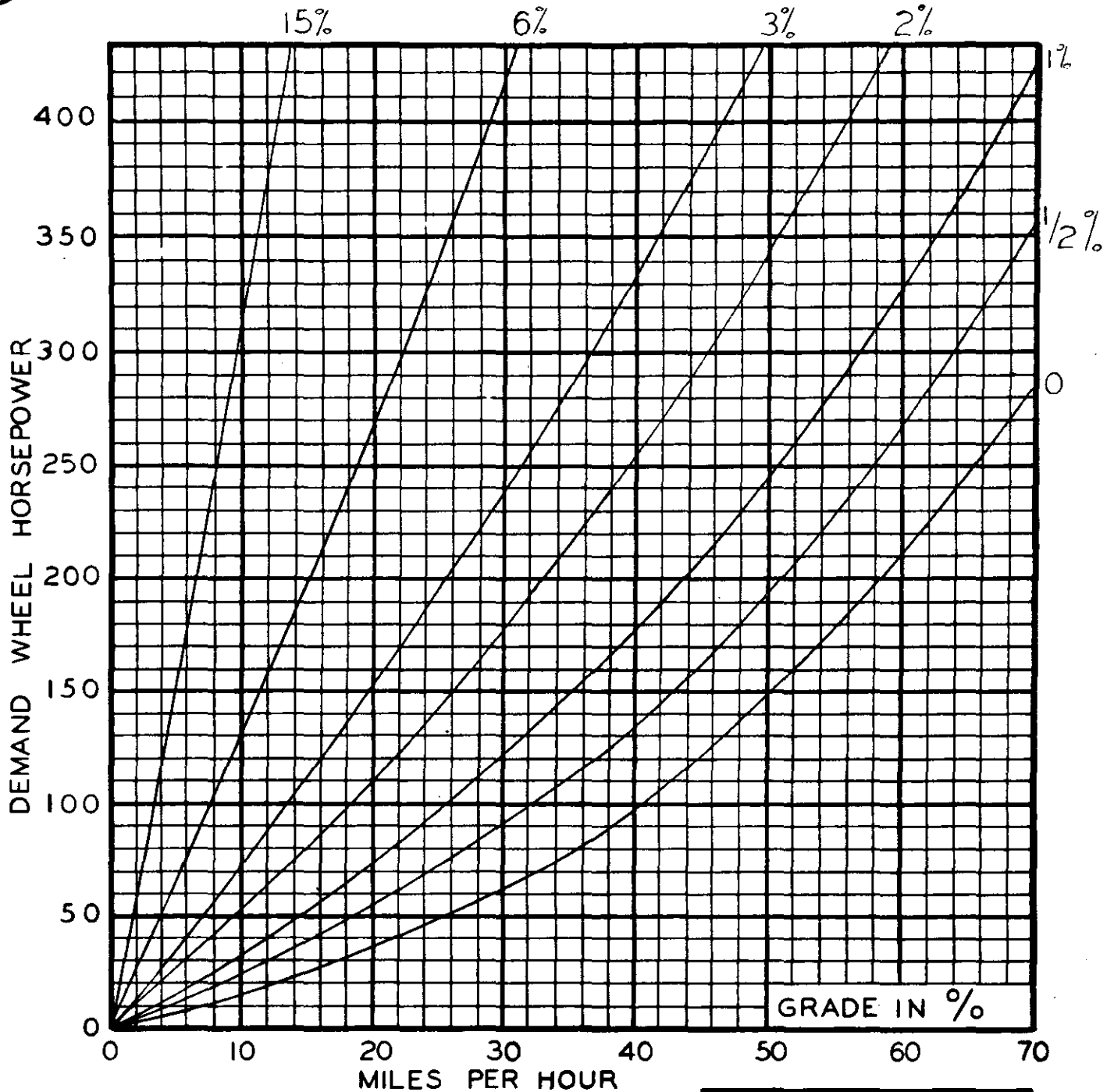
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 73280 LBS.
HEIGHT 9 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. R.P.M. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REVS/MILE _____

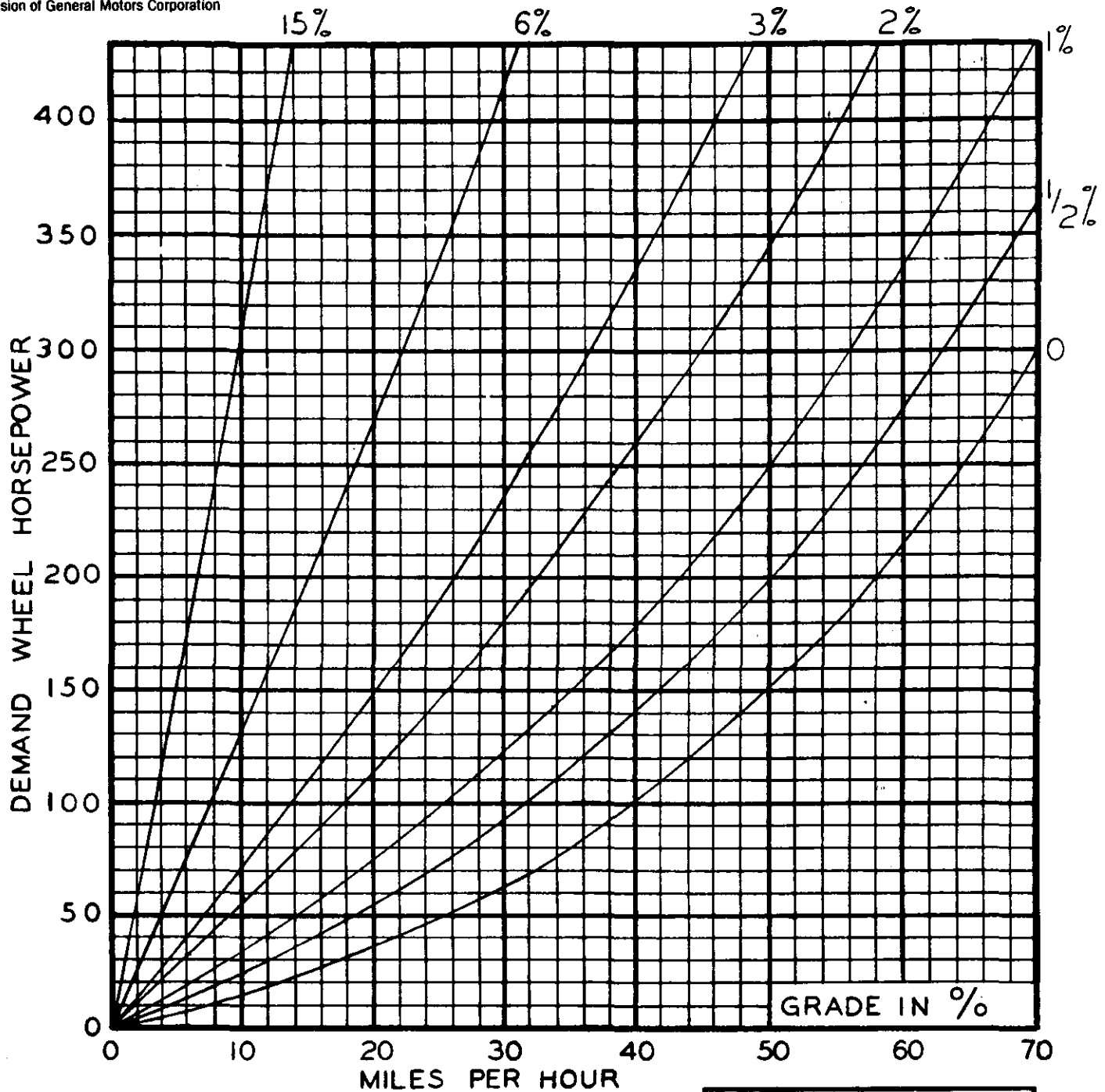
GCW. 73280 LBS.
 HEIGHT 10 FT.
 WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____
ENGINE _____
GOV. R.P.M. _____ INJ. _____
TRANS. _____
AUX. TRANS. _____
REAR AXLE _____
TIRE SIZE _____
TIRE REVS/MILE _____

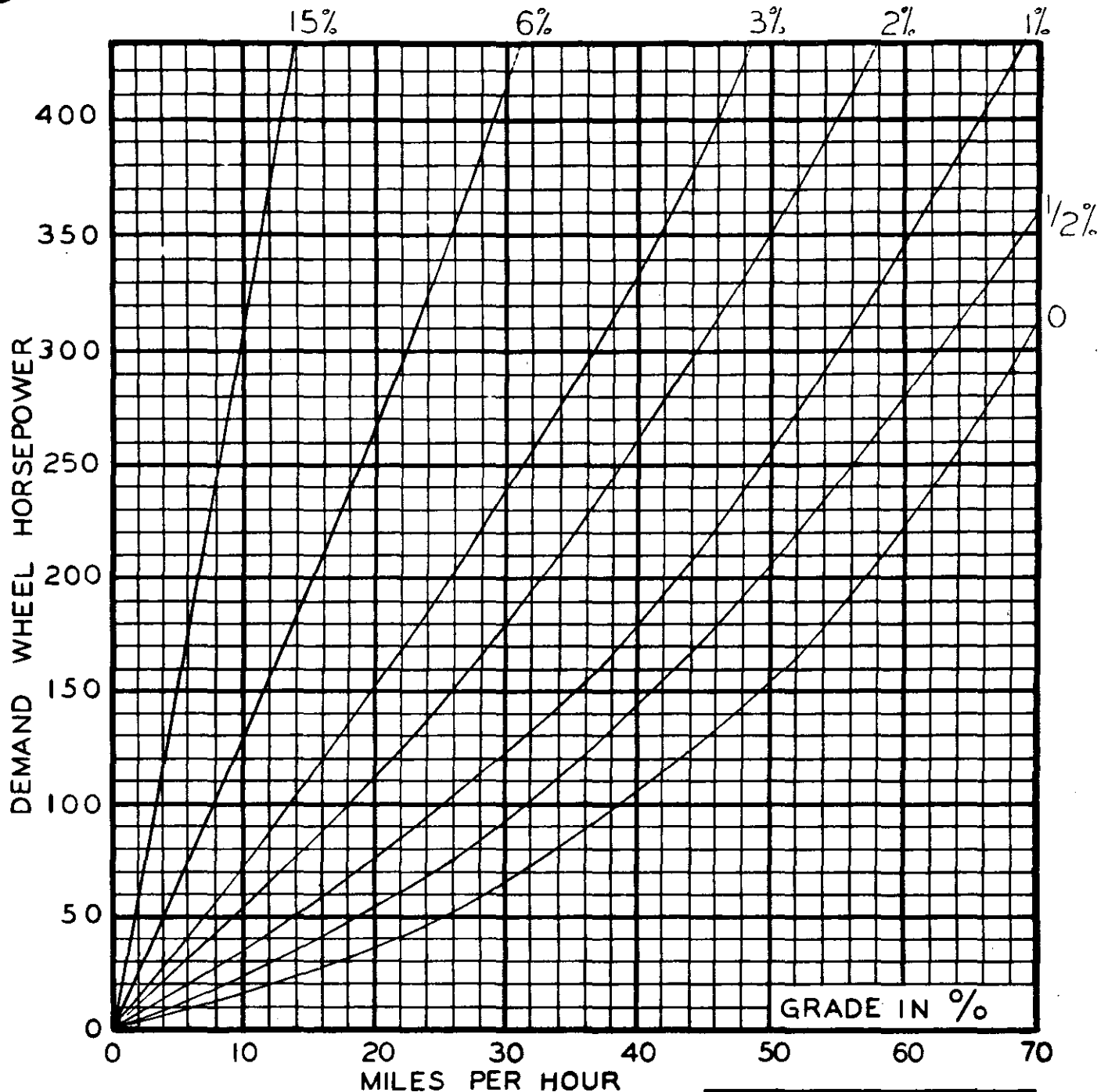
GCW.	73,280	LBS.
HEIGHT	11	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. RPM. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

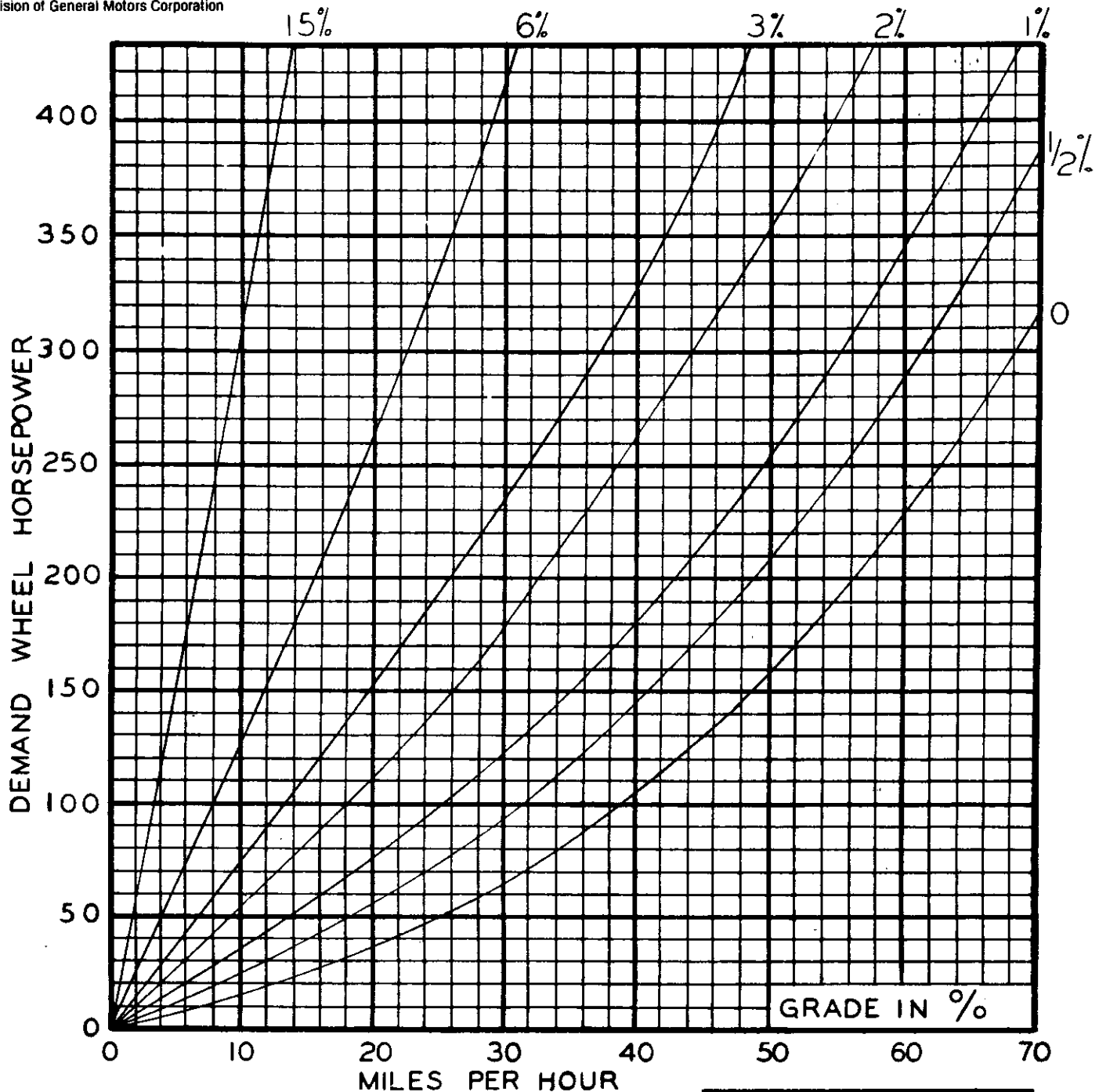
GCW. 73,280 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

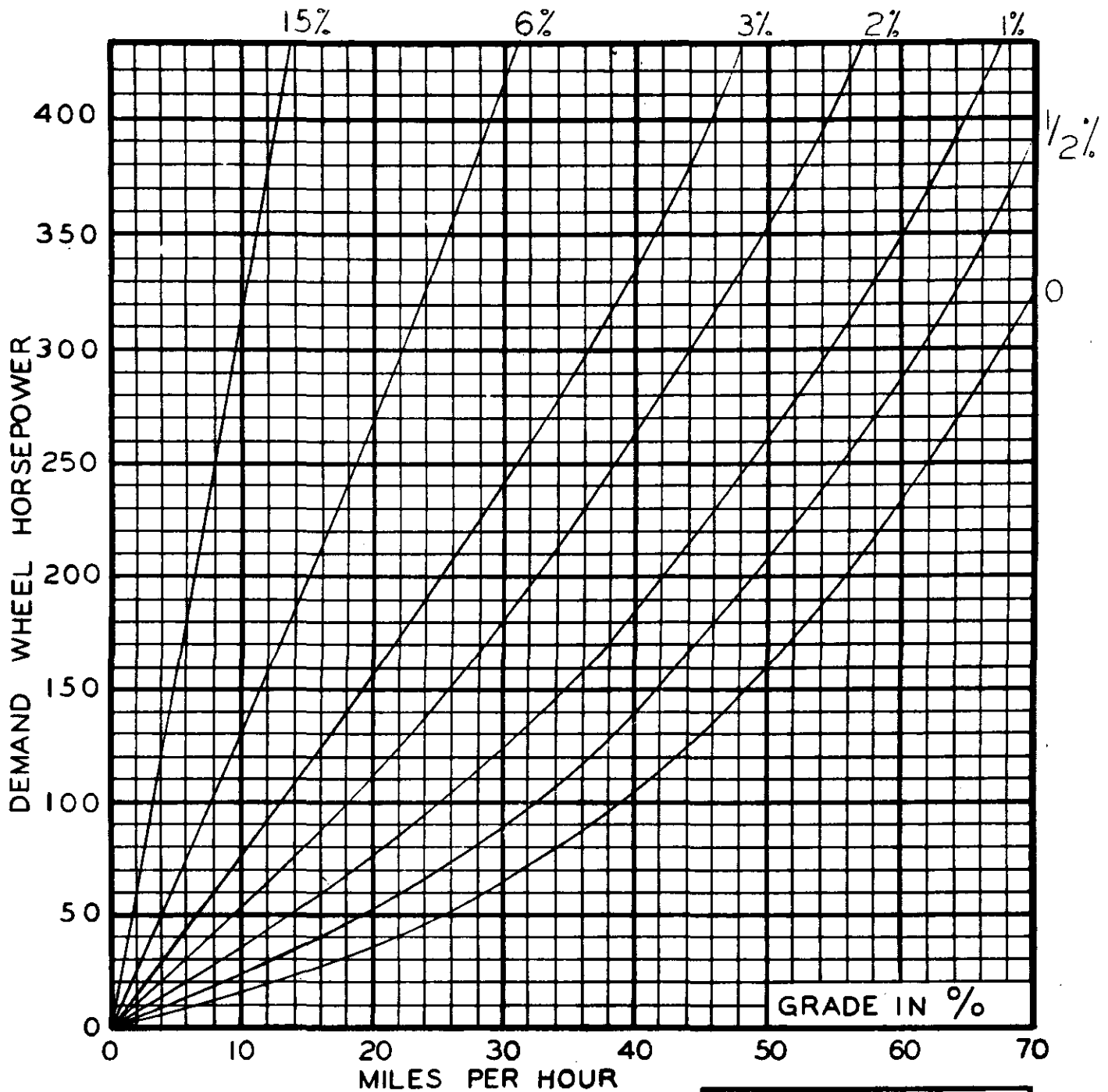
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 73280 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. R.P.M. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REVS/MILE _____

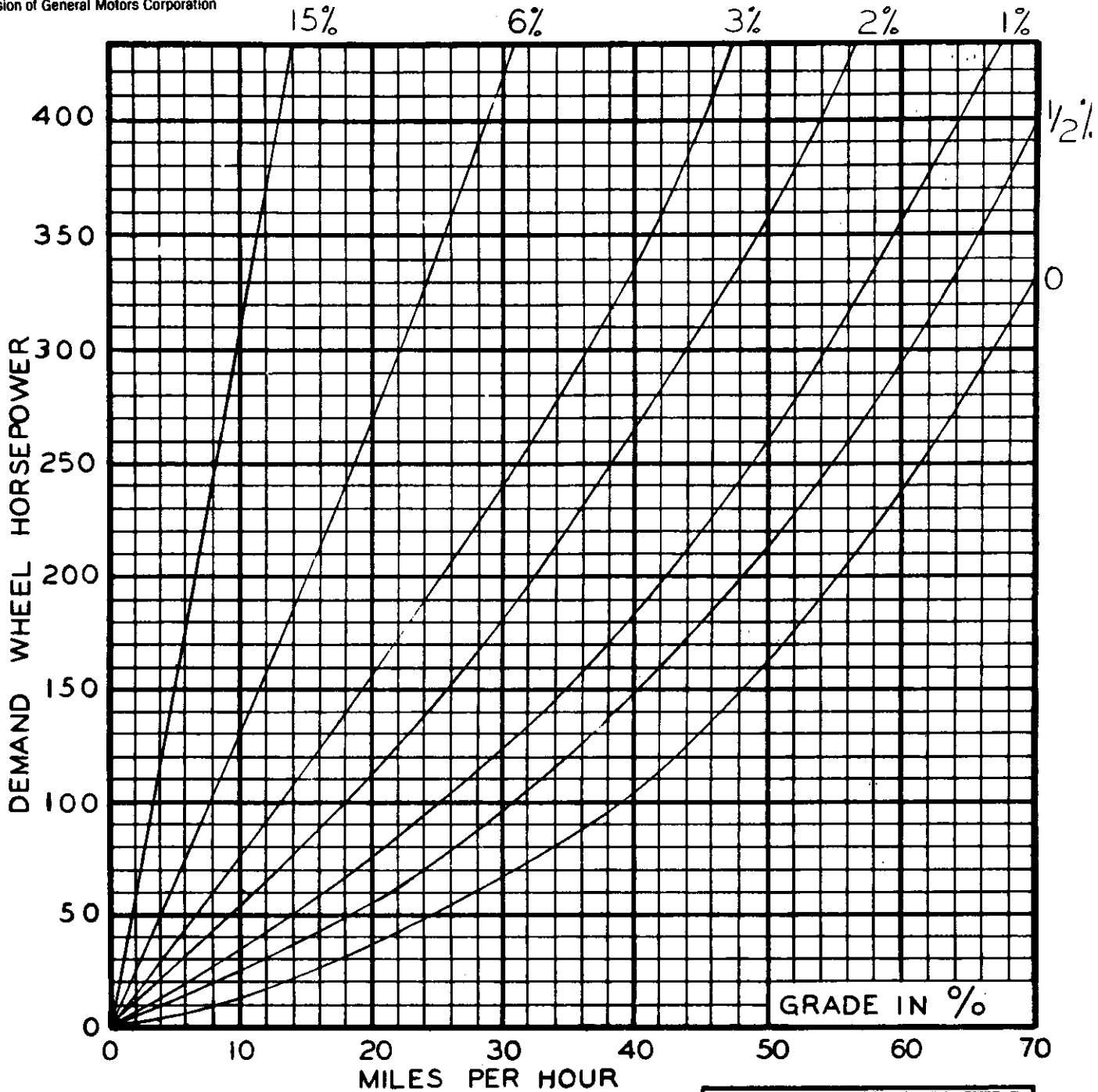
GCW.	73,280	LBS.
HEIGHT	13	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. RPM. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

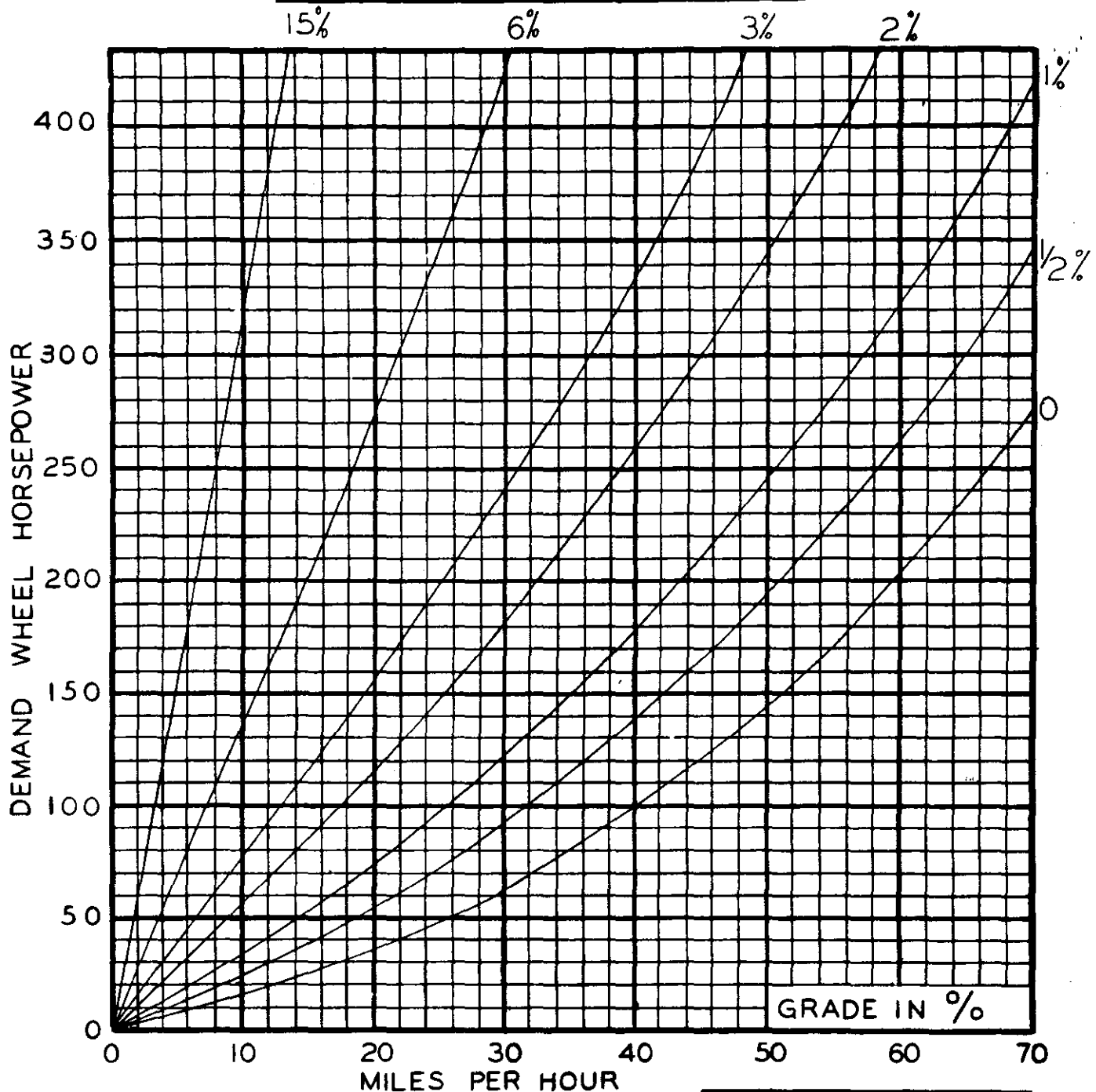
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 73,280 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
ENGINE _____
GOV. R.P.M. _____ INJ. _____
TRANS. _____
AUX. TRANS. _____
REAR AXLE _____
TIRE SIZE _____
TIRE REVS/MILE _____

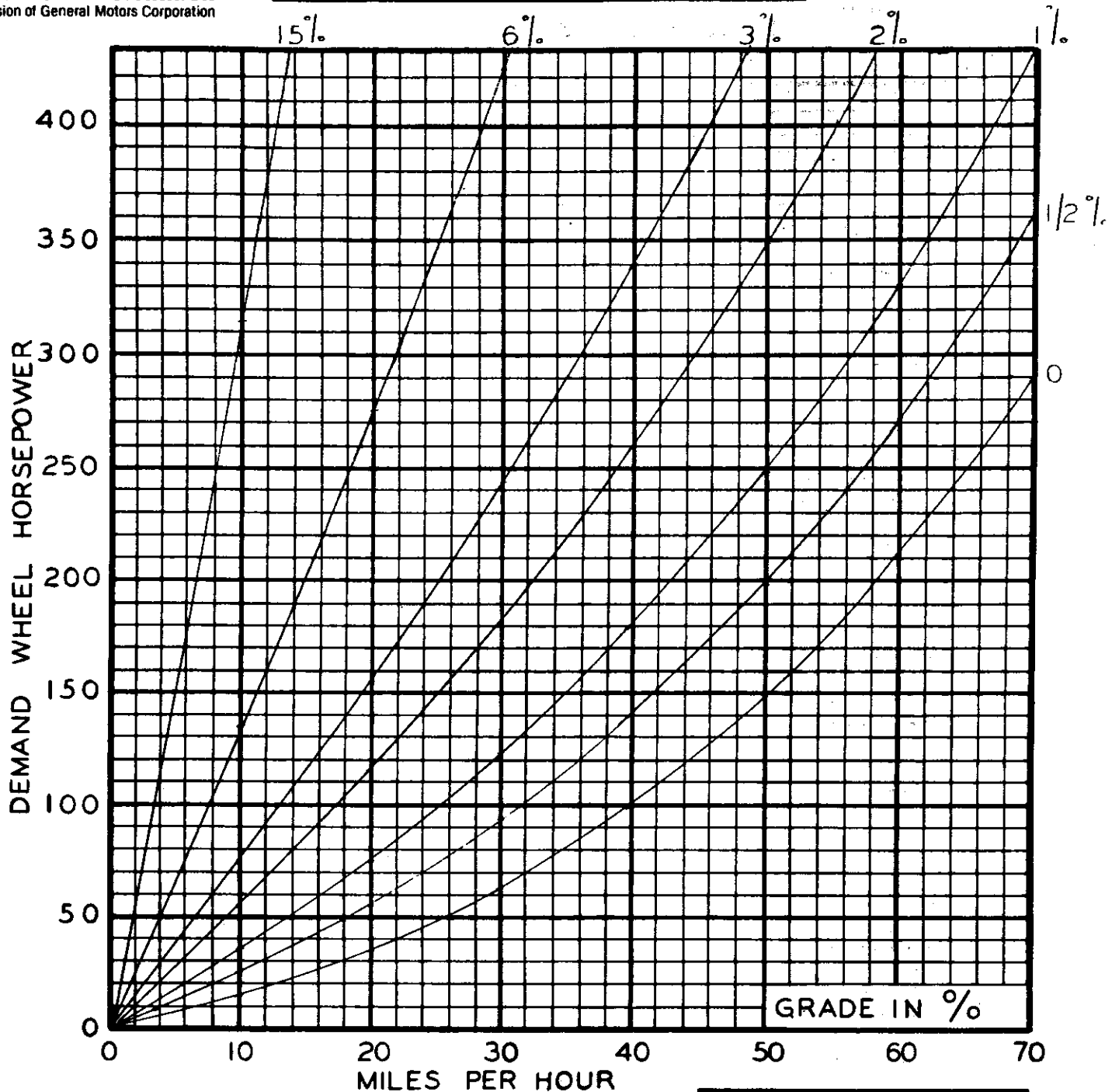
GCW. 75000 LBS.
HEIGHT 9 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

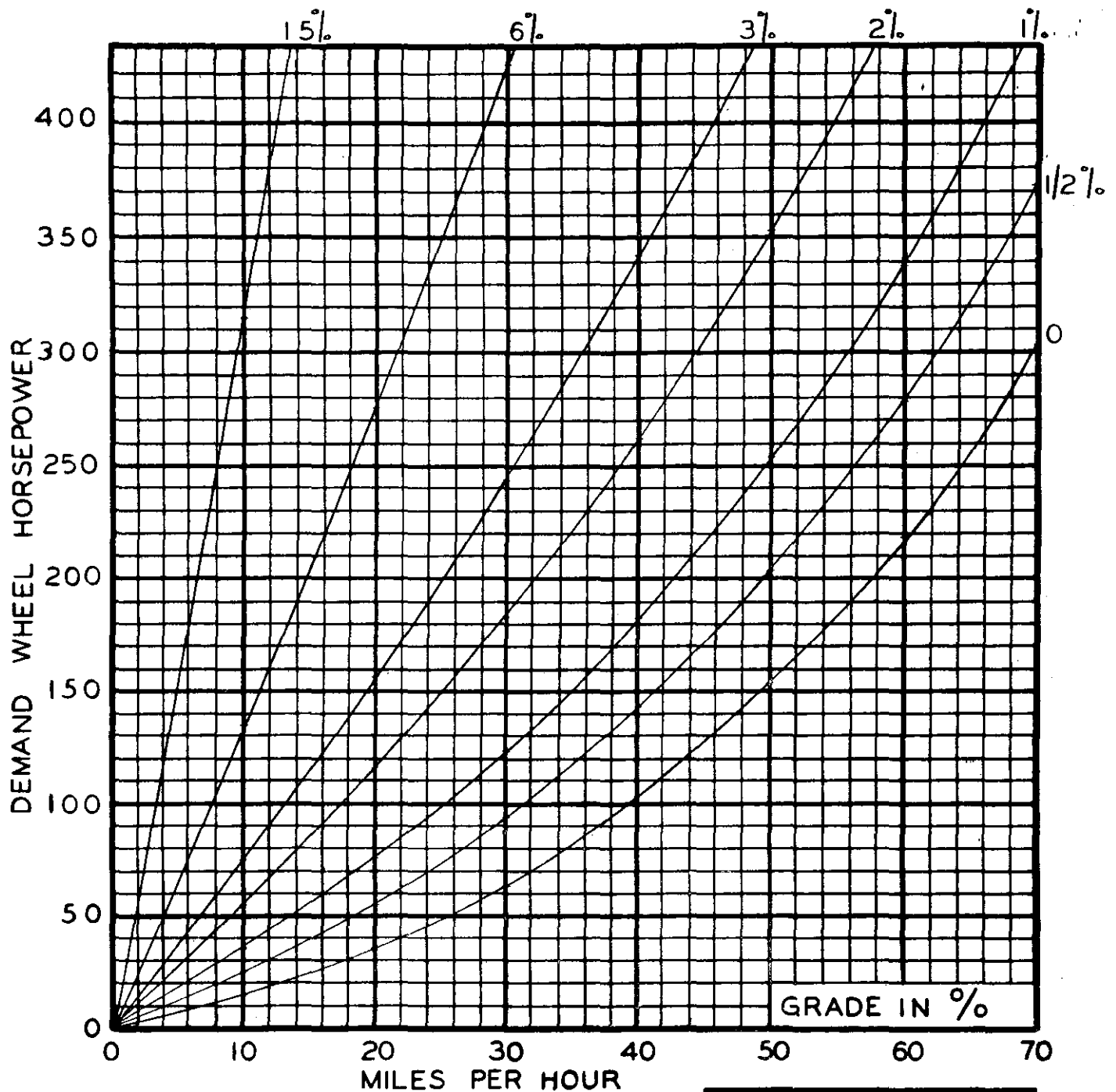
TIRE SIZE _____

TIRE REVS/MILE _____

GCW	7 5,000	LBS.
HEIGHT	10	FT.
WIDTH	8	FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

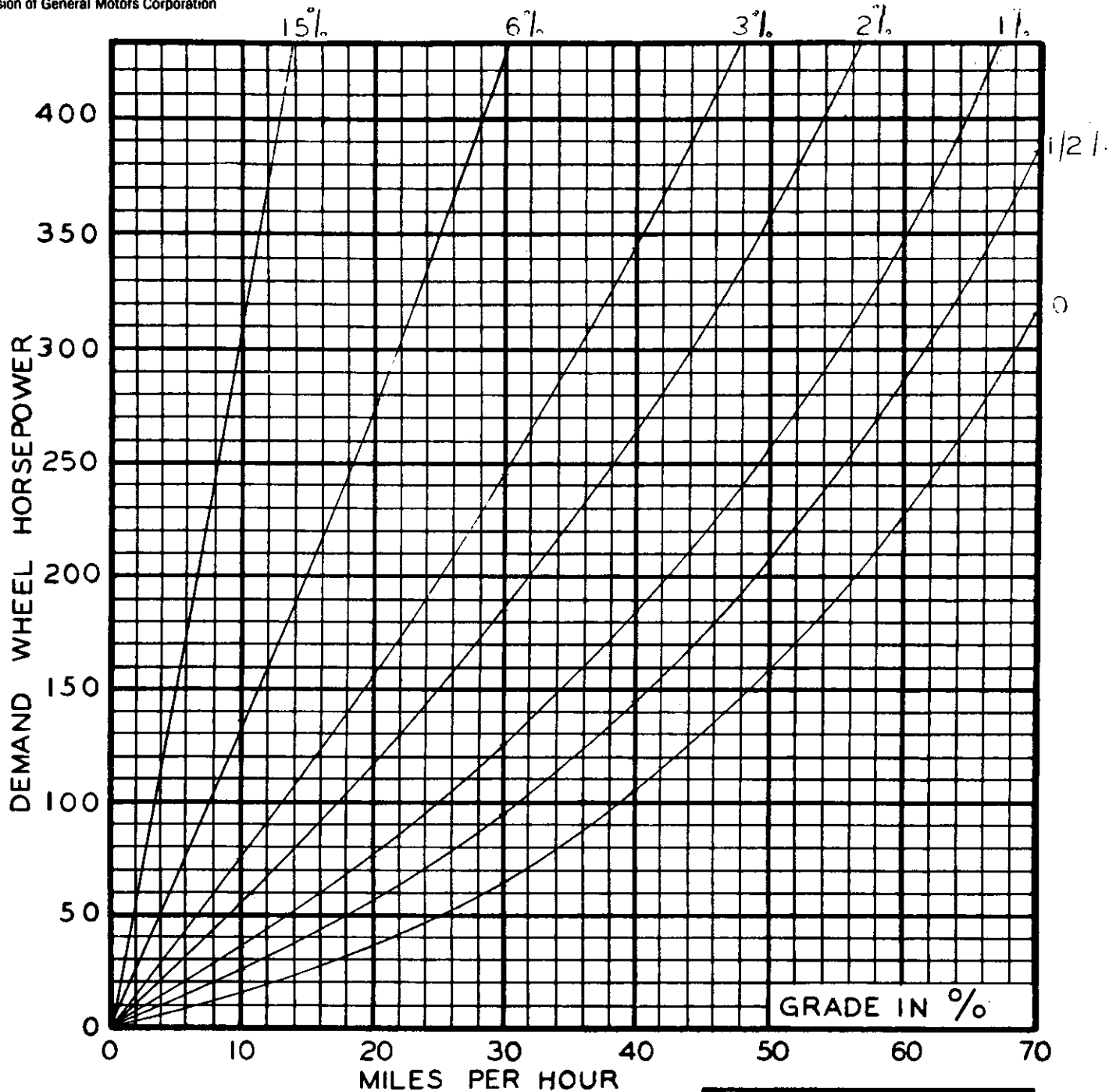
GCW	<u>75,000</u>	LBS.
HEIGHT	<u>11</u>	FT.
WIDTH	<u>8</u>	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

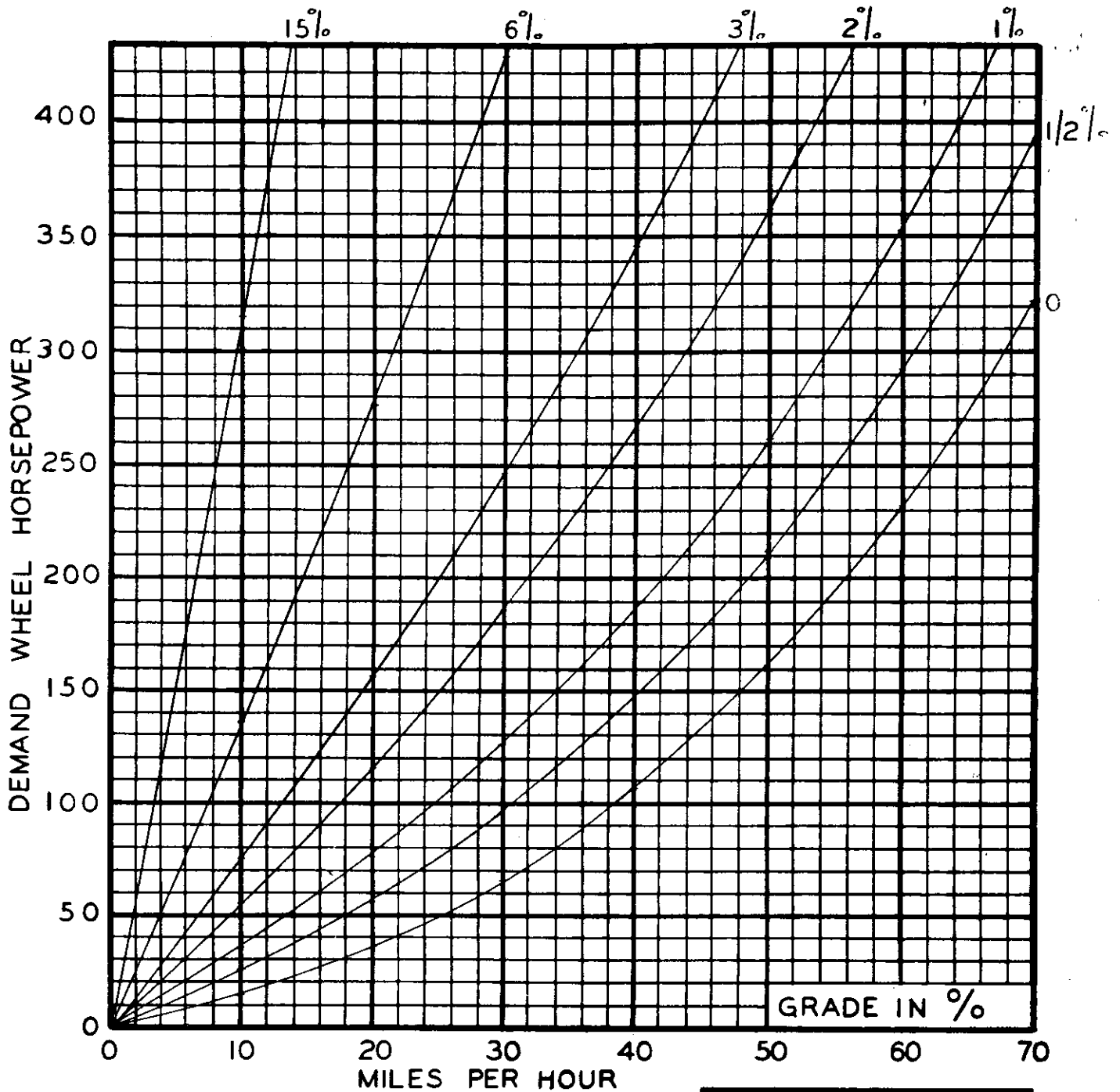
GCW 75,000 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

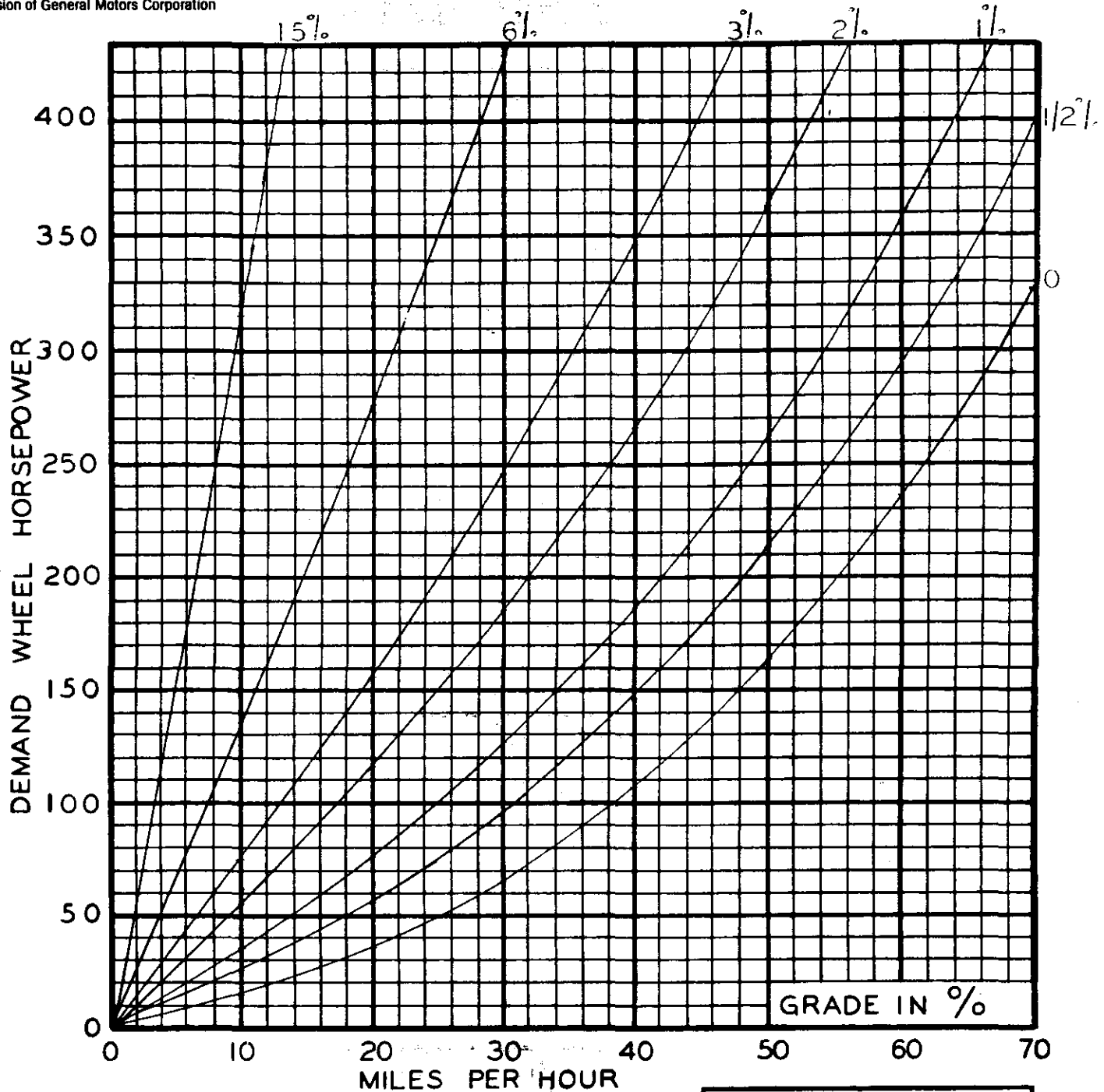
GCW 75,000 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

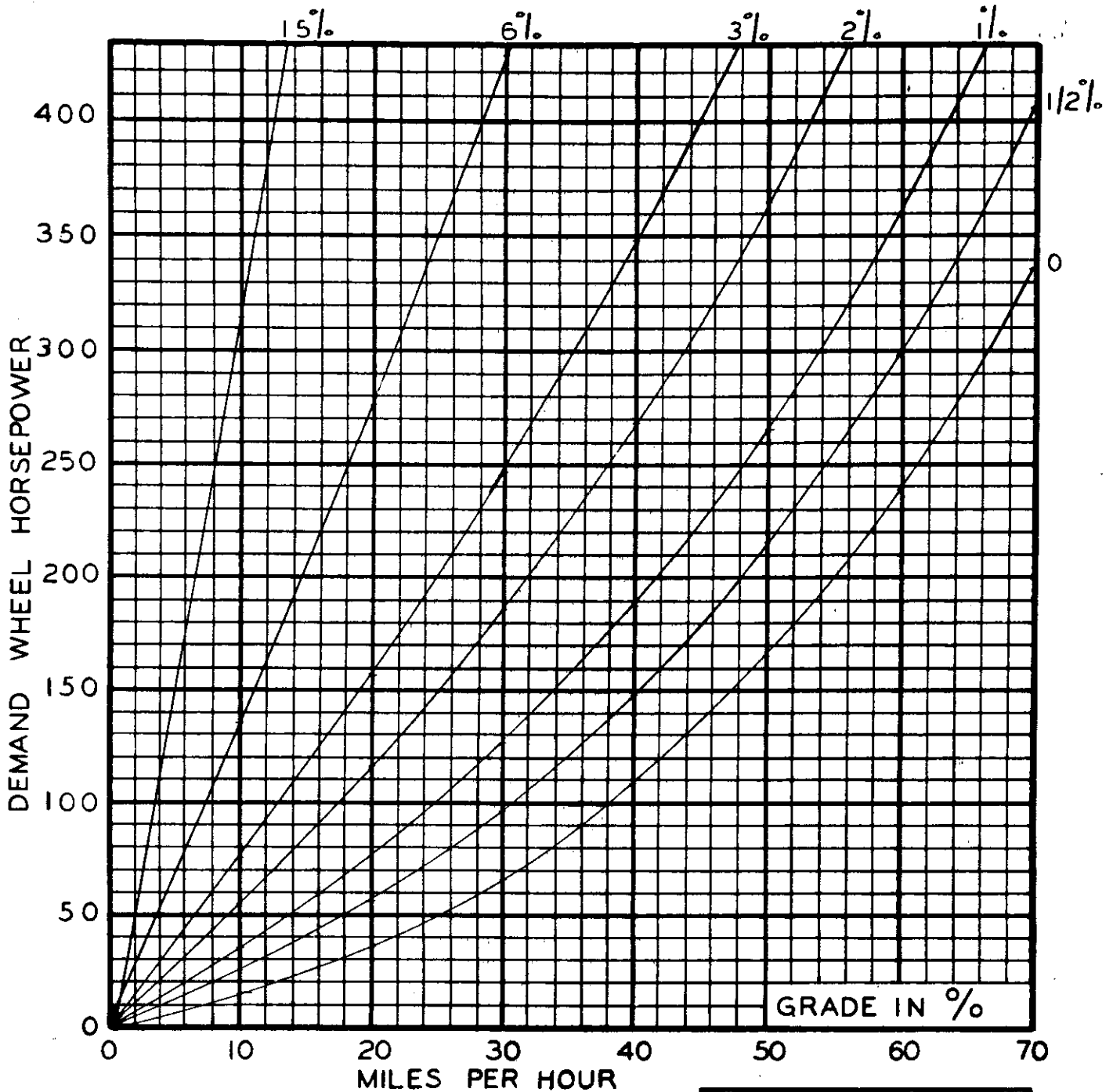
GCW	75,000	LBS.
HEIGHT	13	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

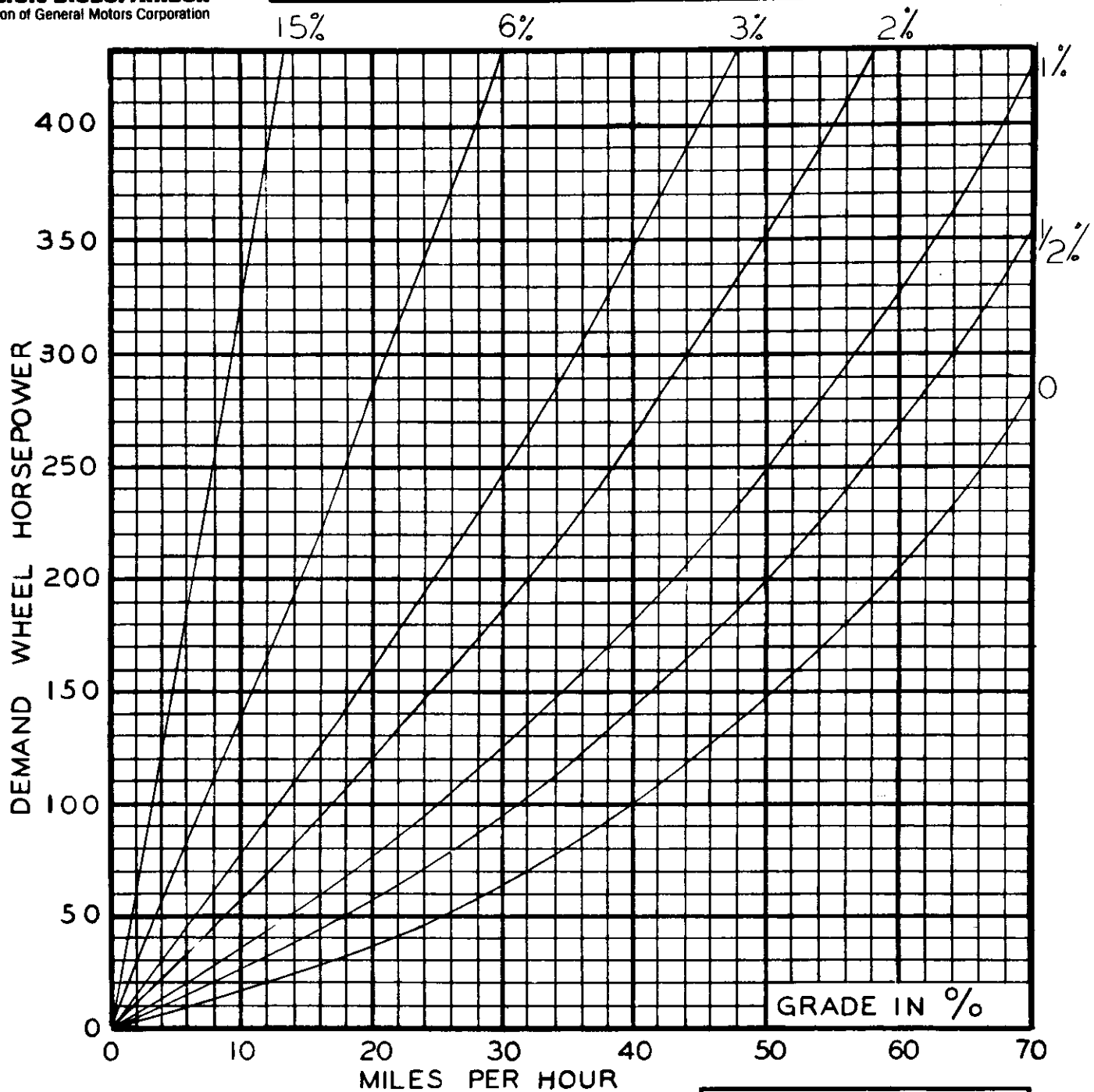
GCW 75000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

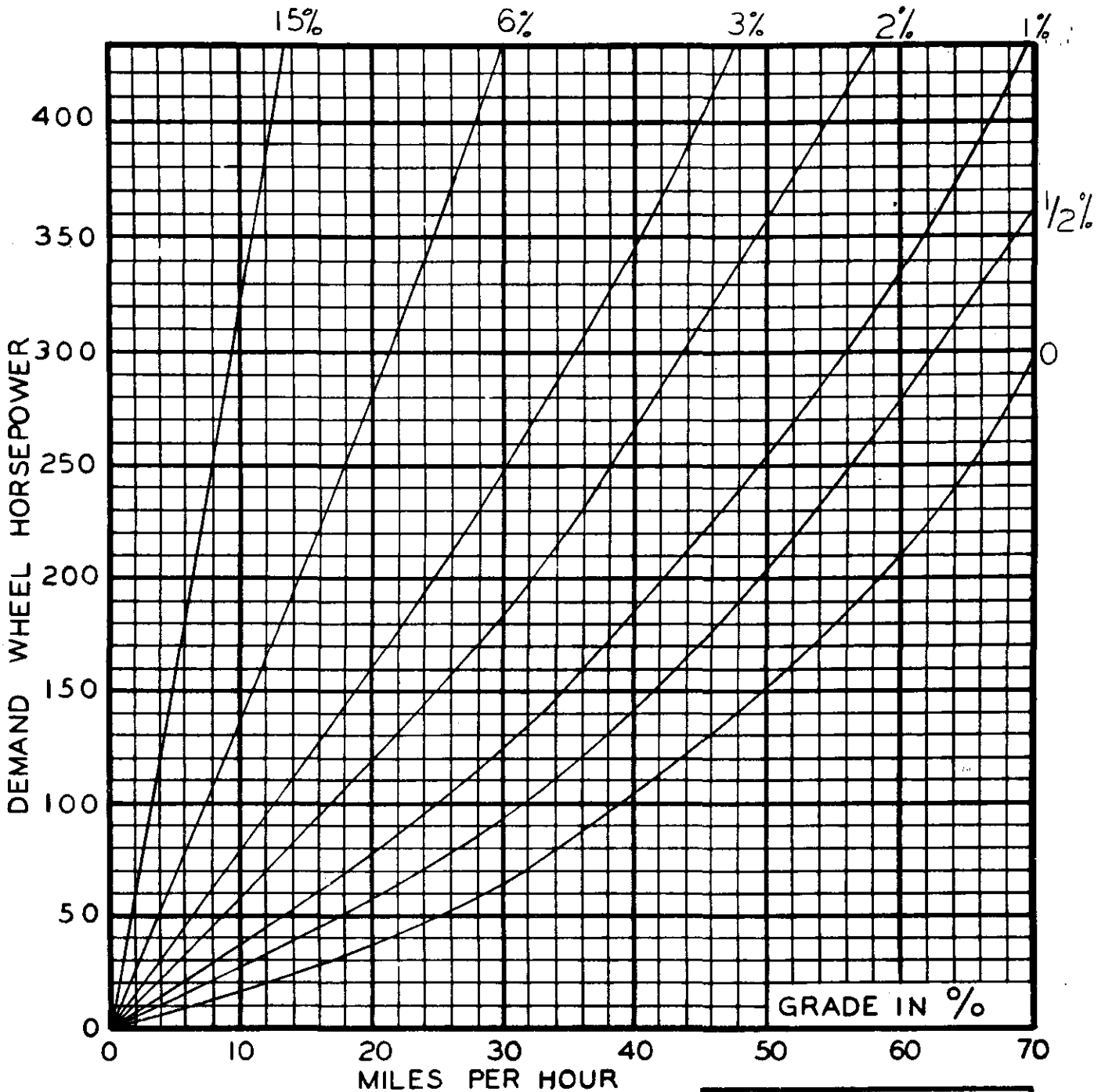
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 76800 LBS.
HEIGHT 9 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 76,800 LBS.

HEIGHT 10 FT.

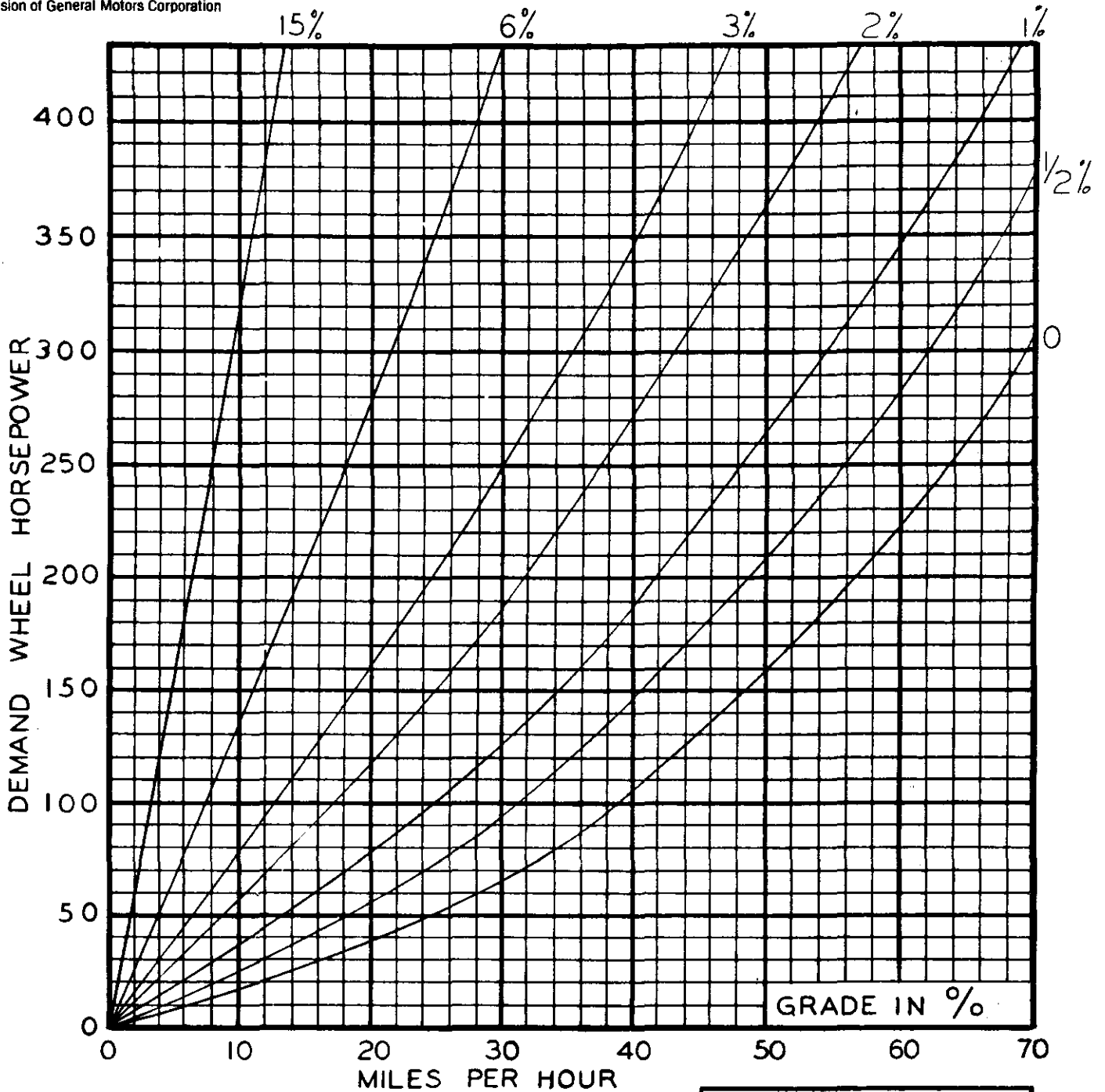
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. RPM. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

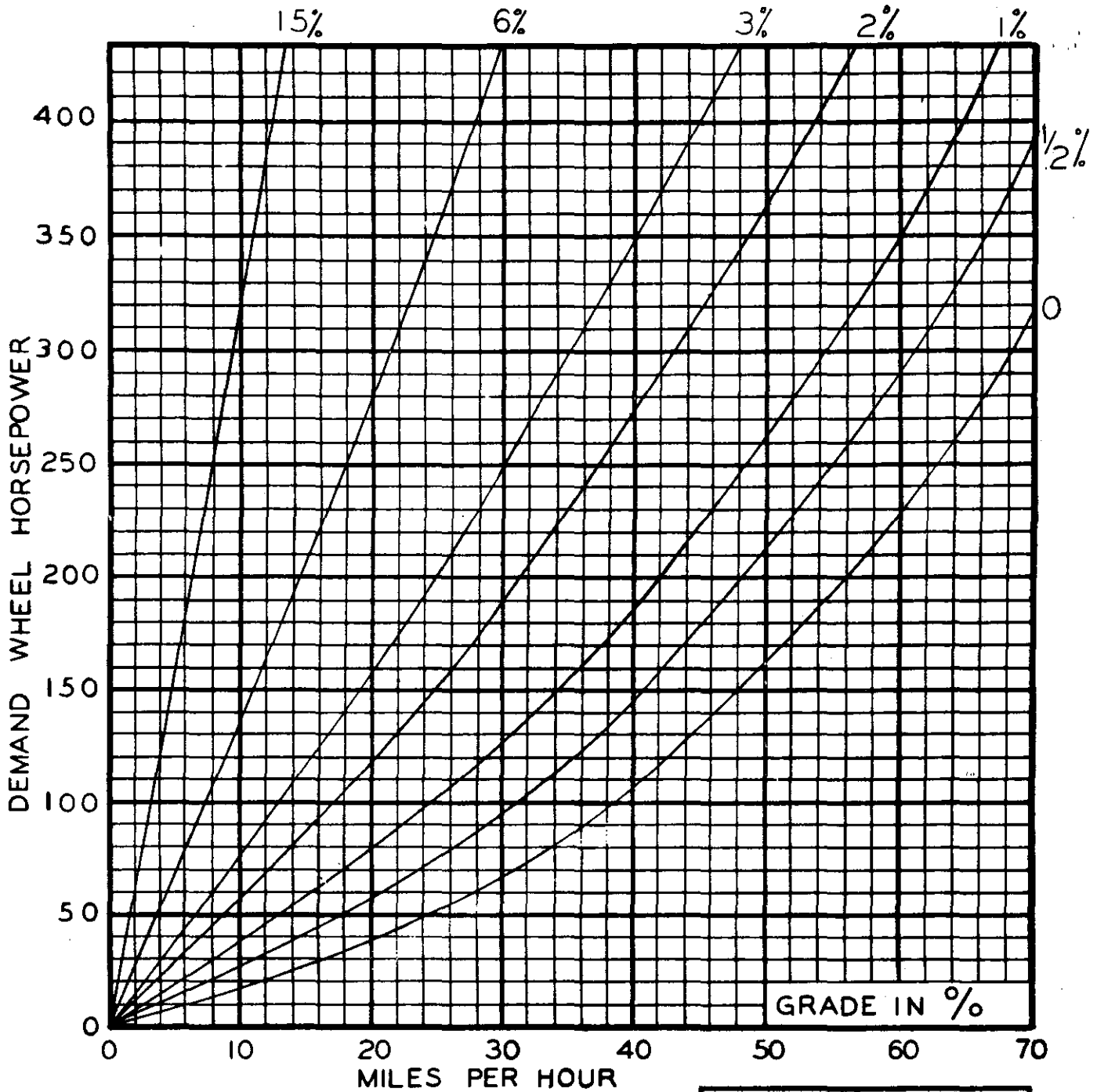
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 76800 LBS.
HEIGHT 11 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
ENGINE _____
GOV. R.P.M. _____ INJ. _____
TRANS. _____
AUX. TRANS. _____
REAR AXLE _____
TIRE SIZE _____
TIRE REVS/MILE _____

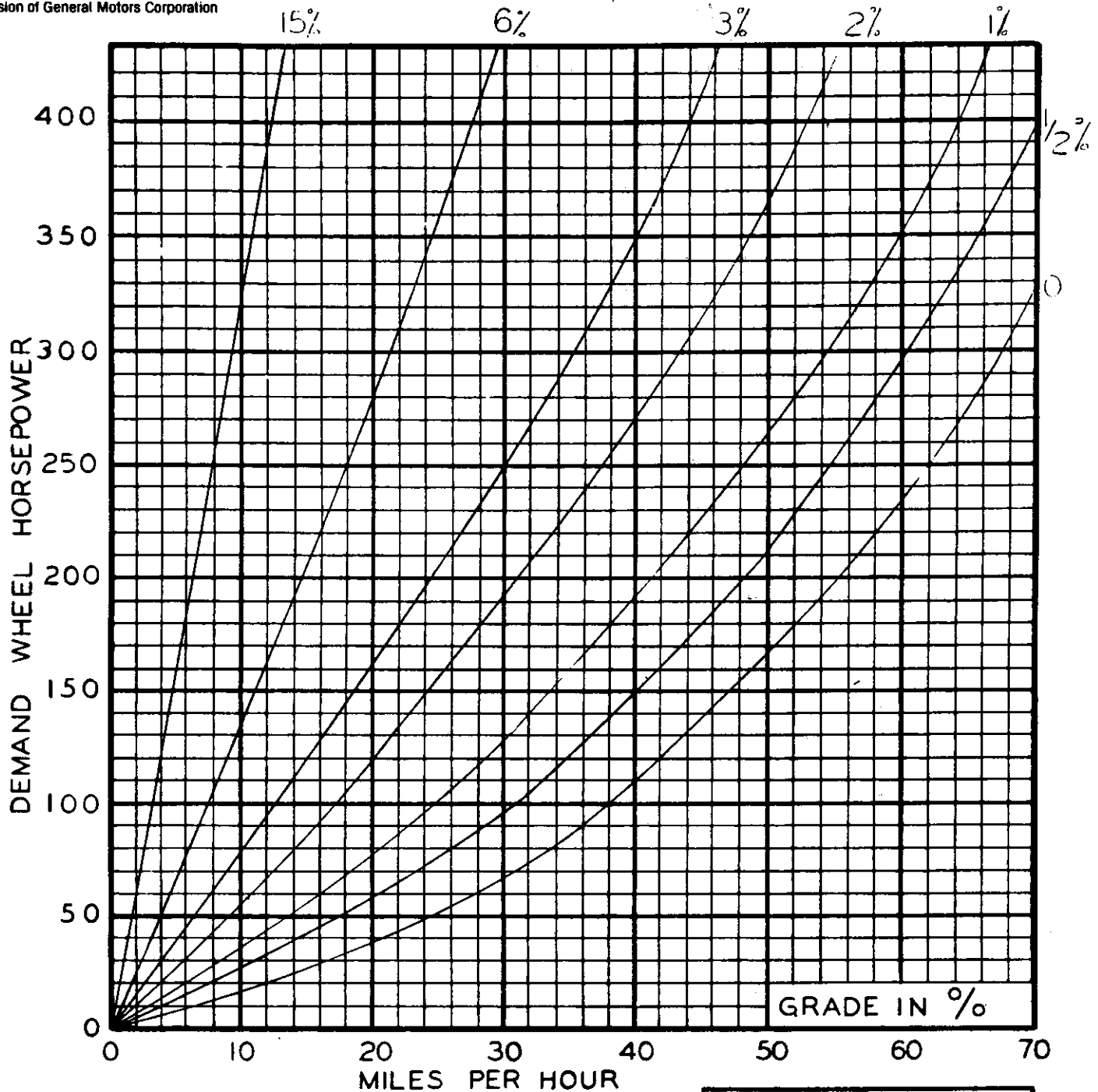
GCW.	76,800	LBS.
HEIGHT	12	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

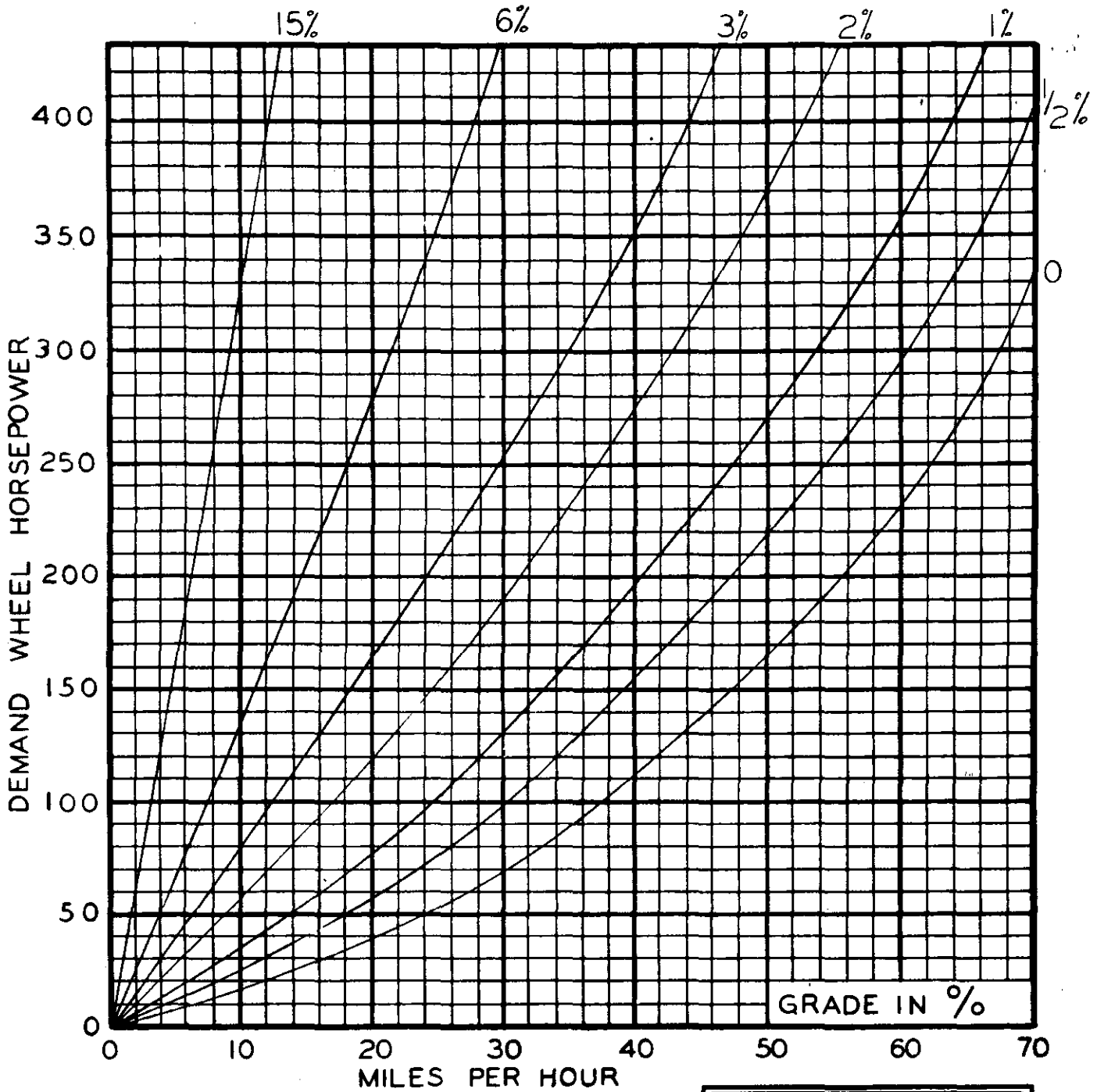
TIRE SIZE _____

TIRE REVS/MILE _____

GCW.	76800	LBS.
HEIGHT	12 1/2	FT.
WIDTH	8	FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. RPM. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REVS/MILE _____

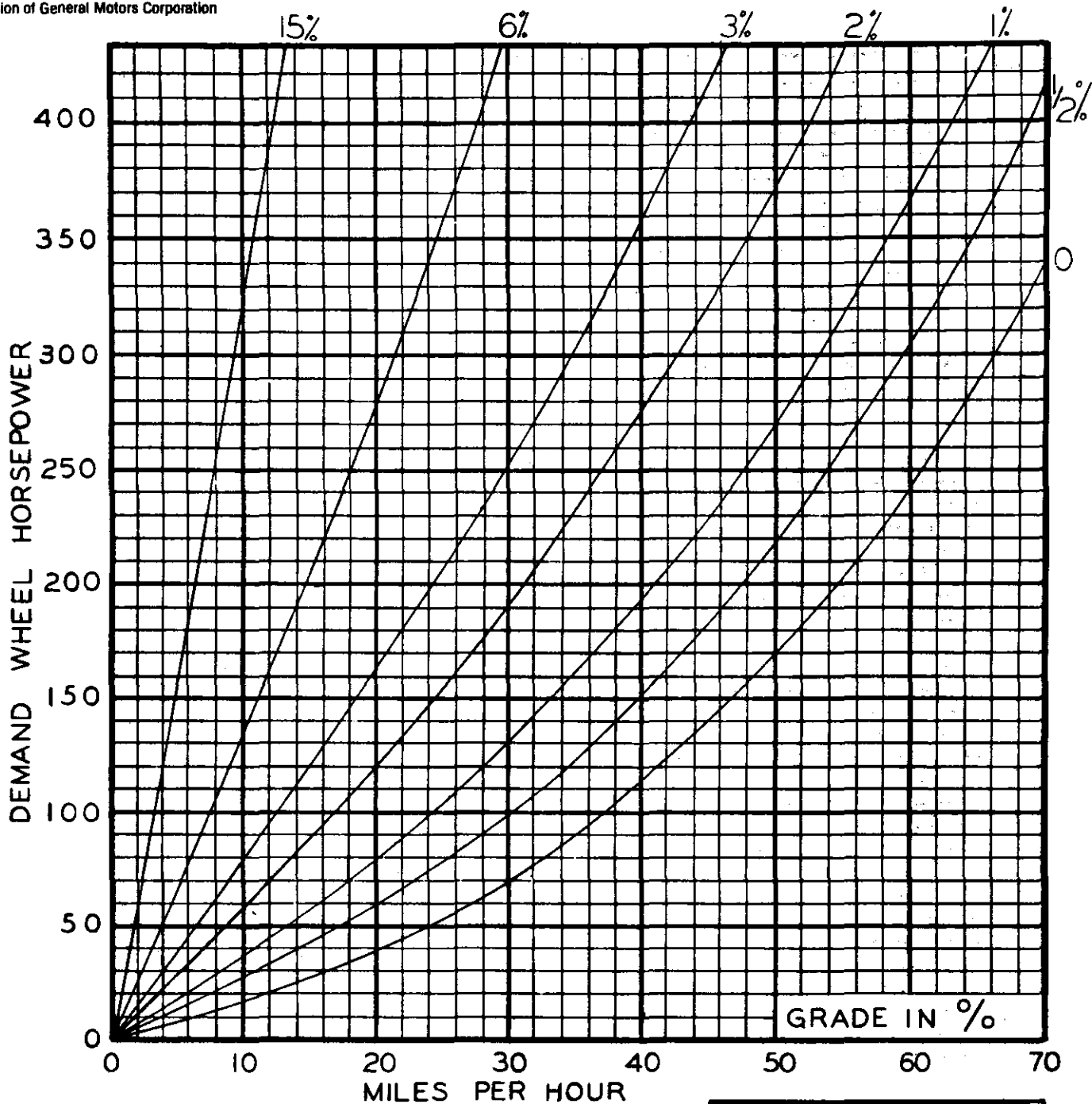
GCW. 76800 LBS.
 HEIGHT 13 FT.
 WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

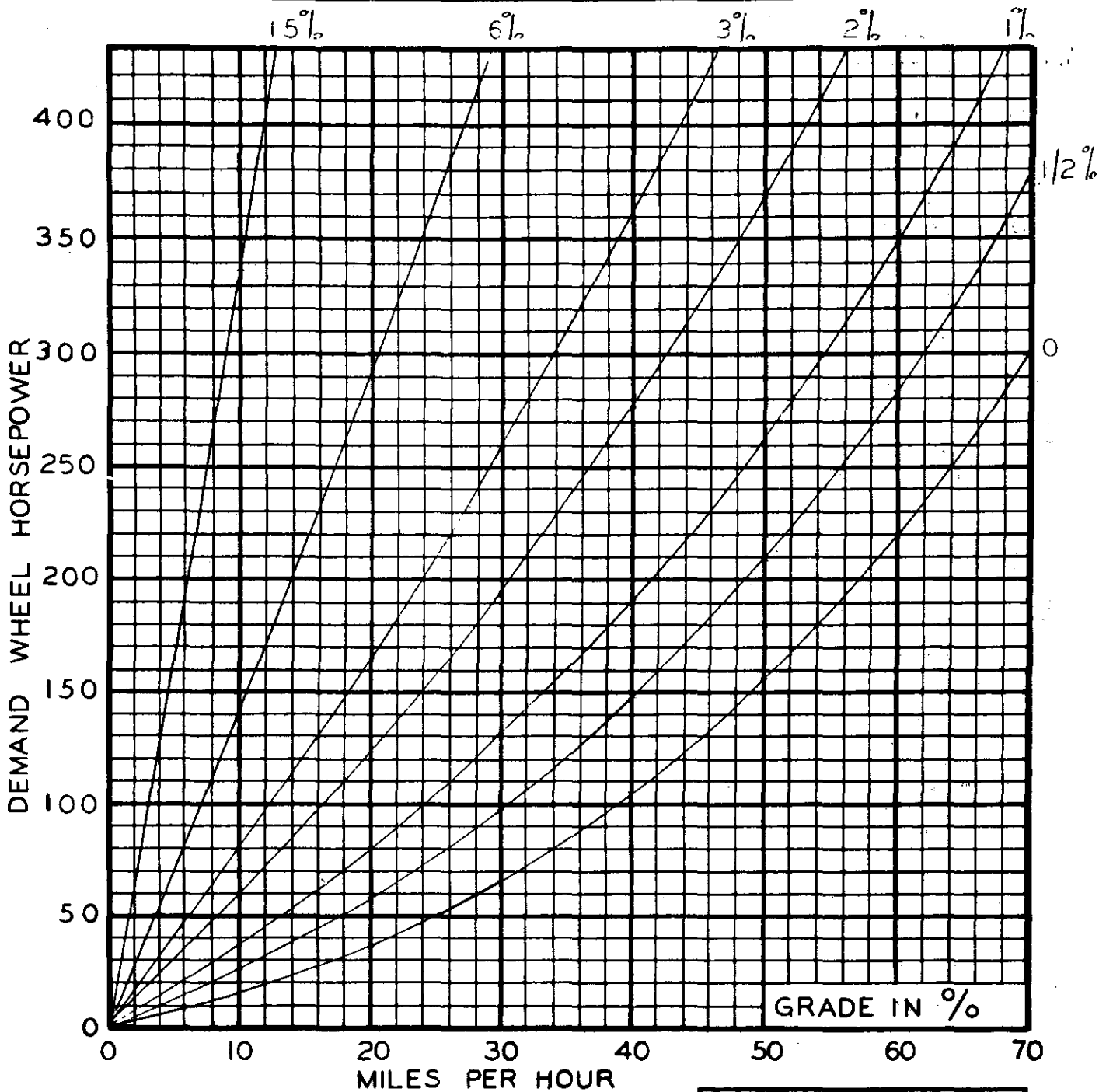
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 76800 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. R.P.M. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REVS/MILE _____

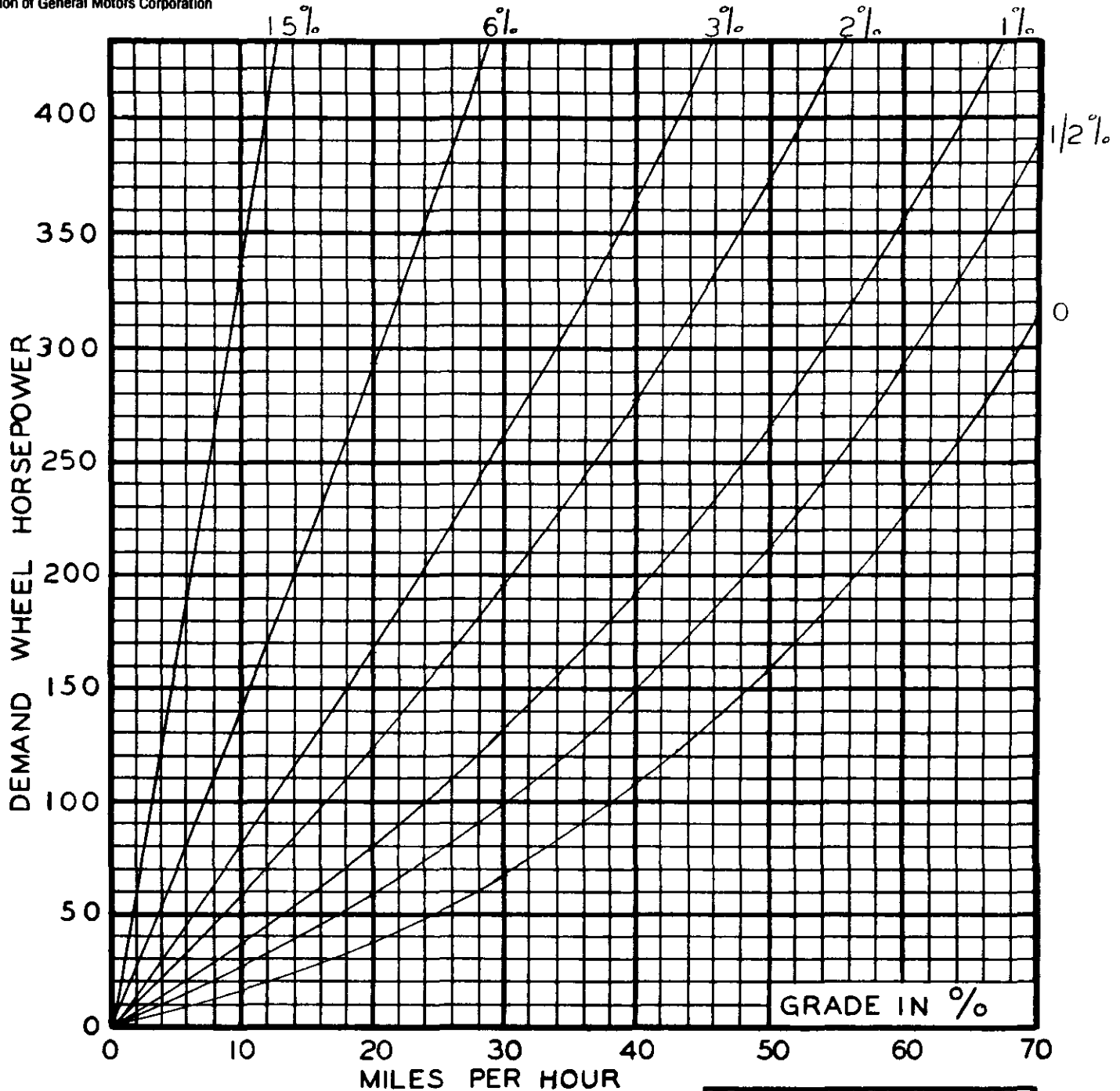
GCW	80,000	LBS.
HEIGHT	10	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. RPM. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

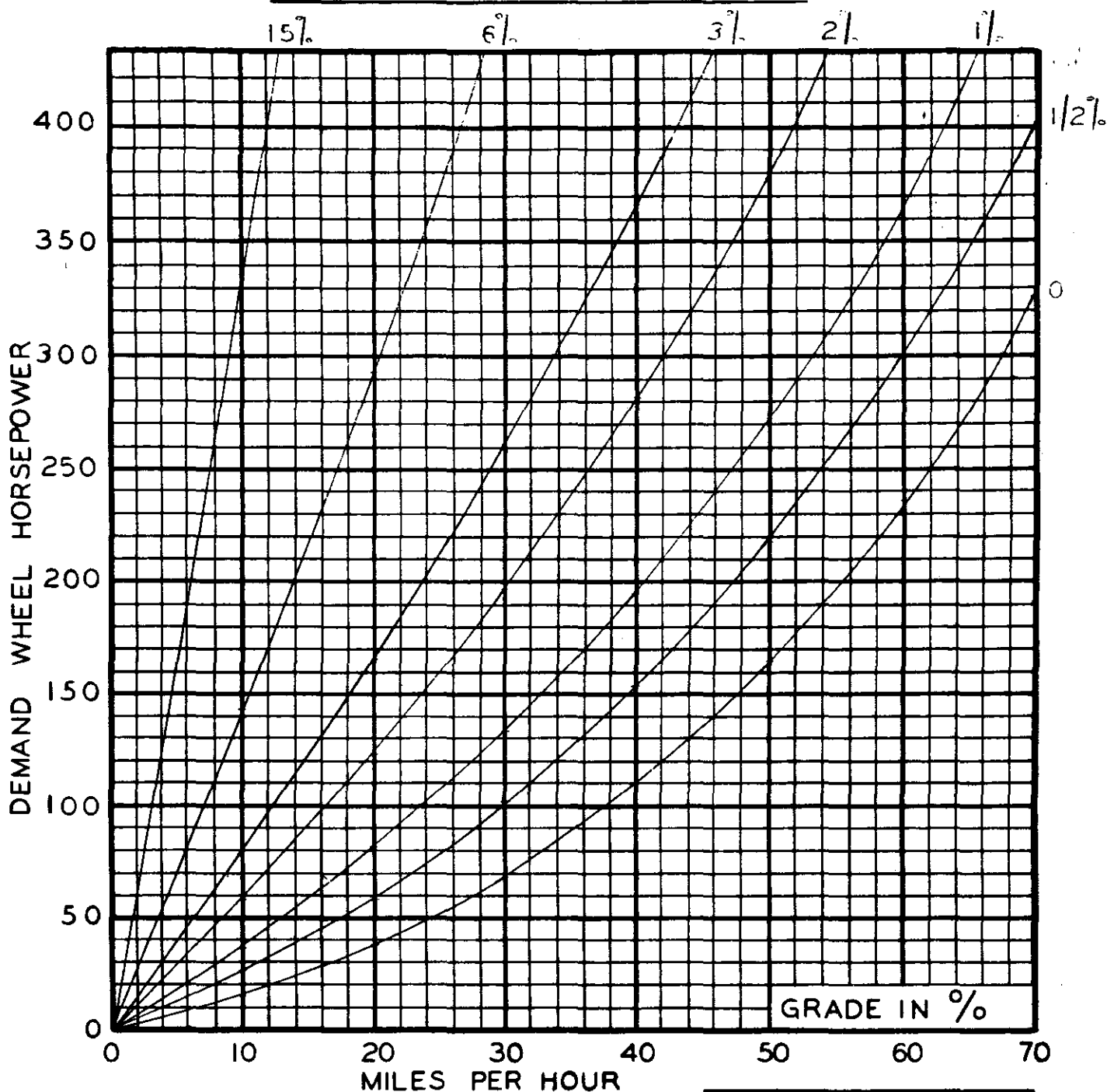
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 80000 LBS.
HEIGHT 11 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

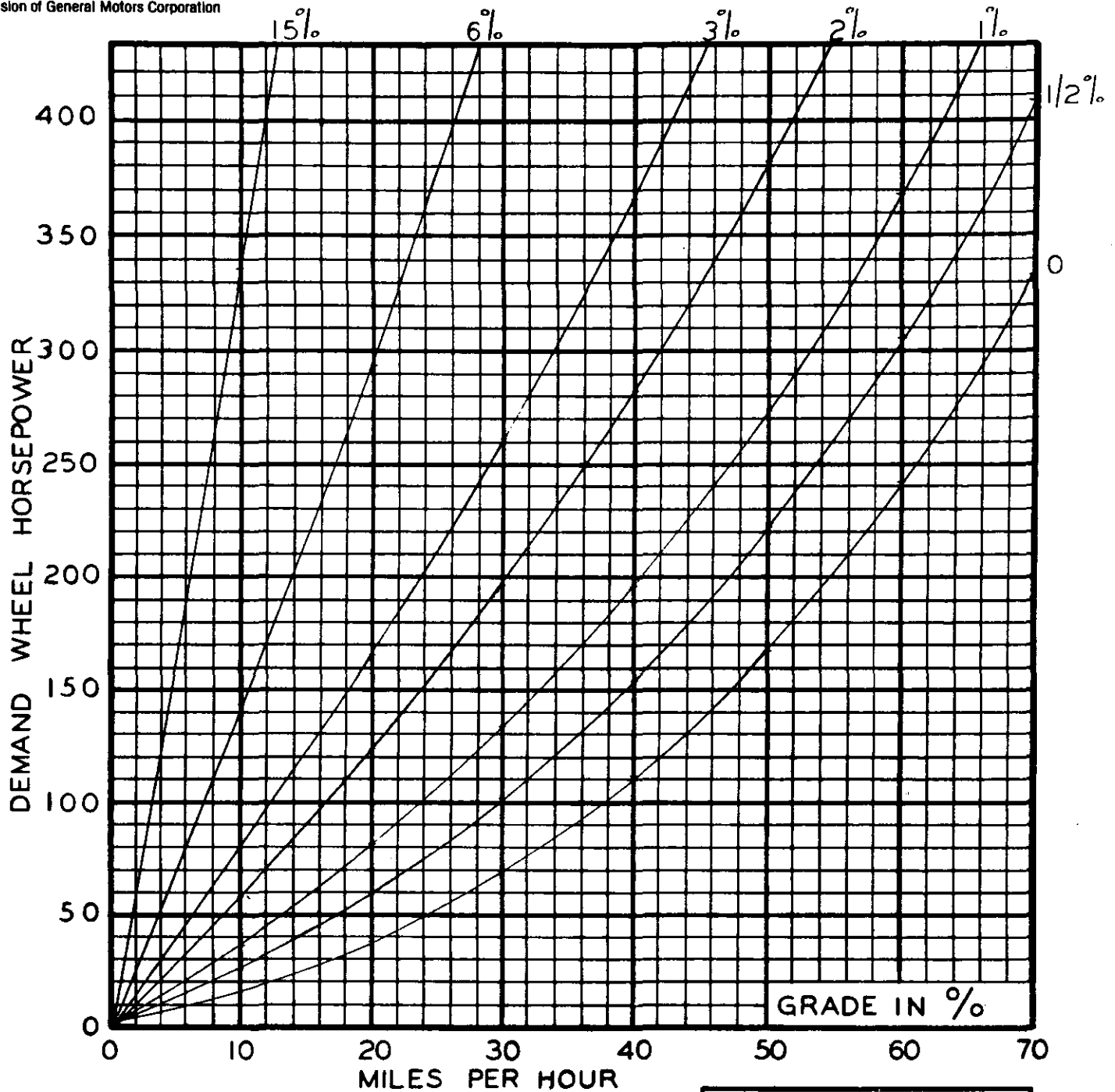
GCW	80,000	LBS.
HEIGHT	12	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

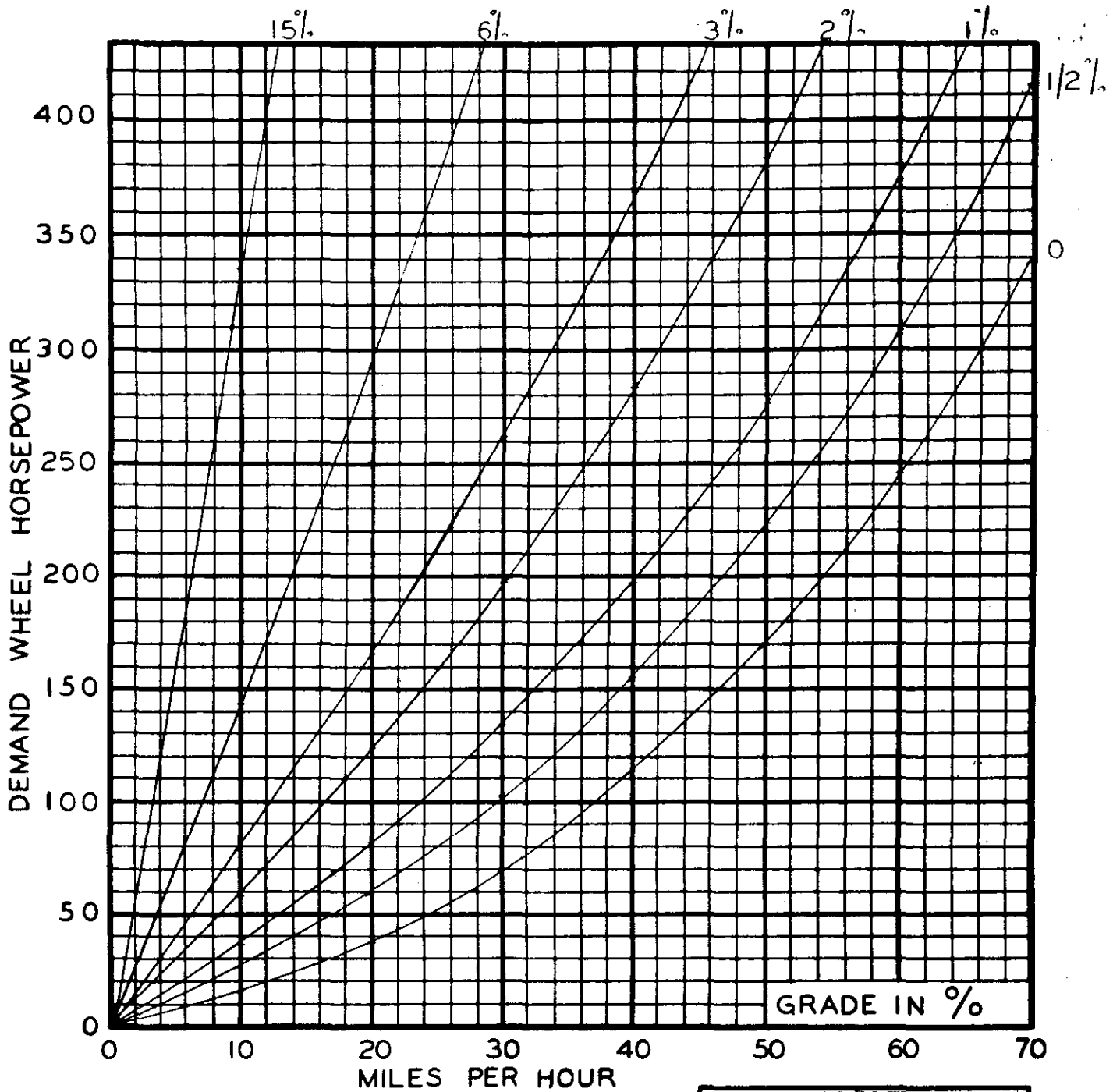
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 80,000 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

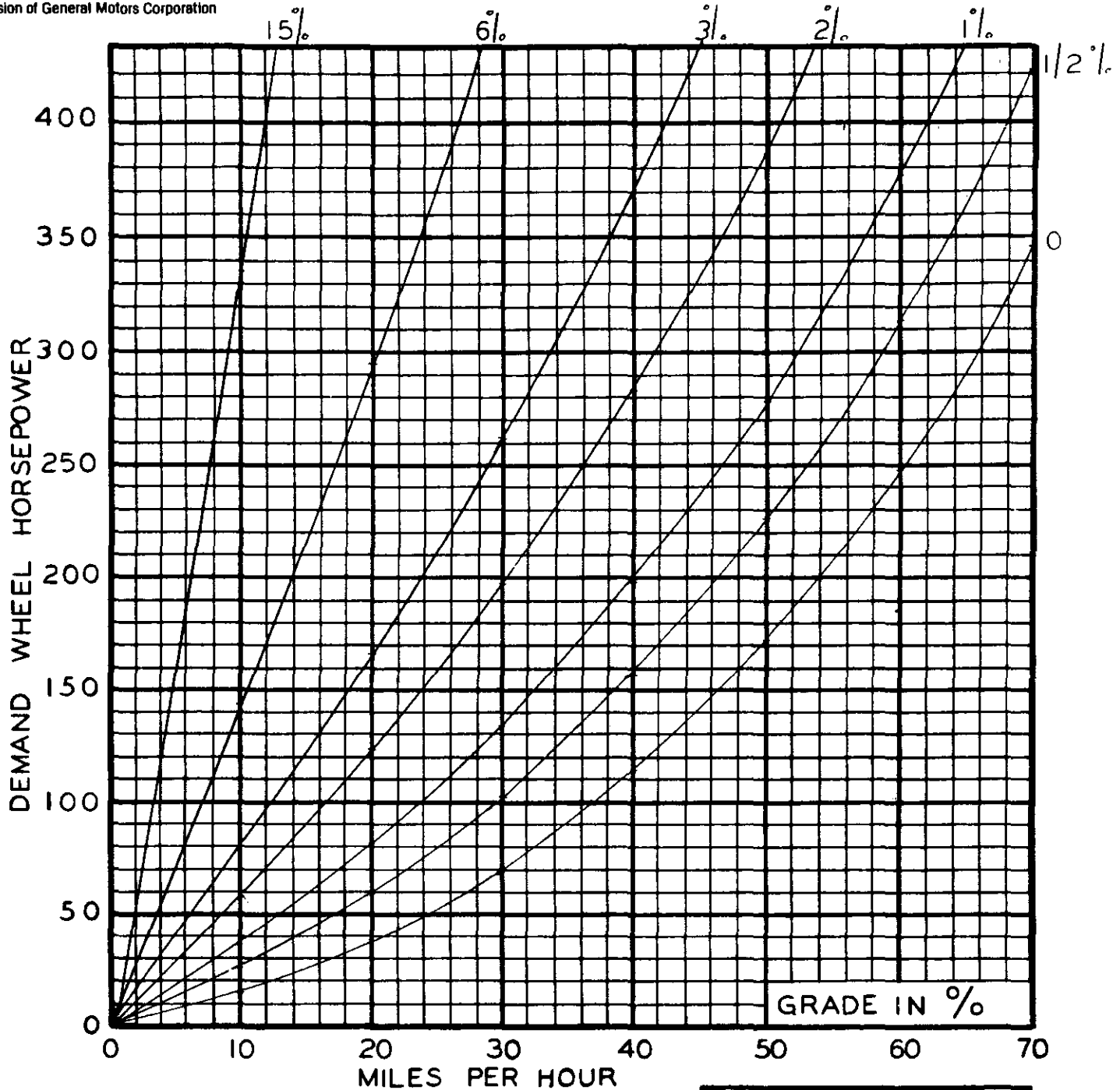
GCW 80,000 LBS.
HEIGHT 13 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

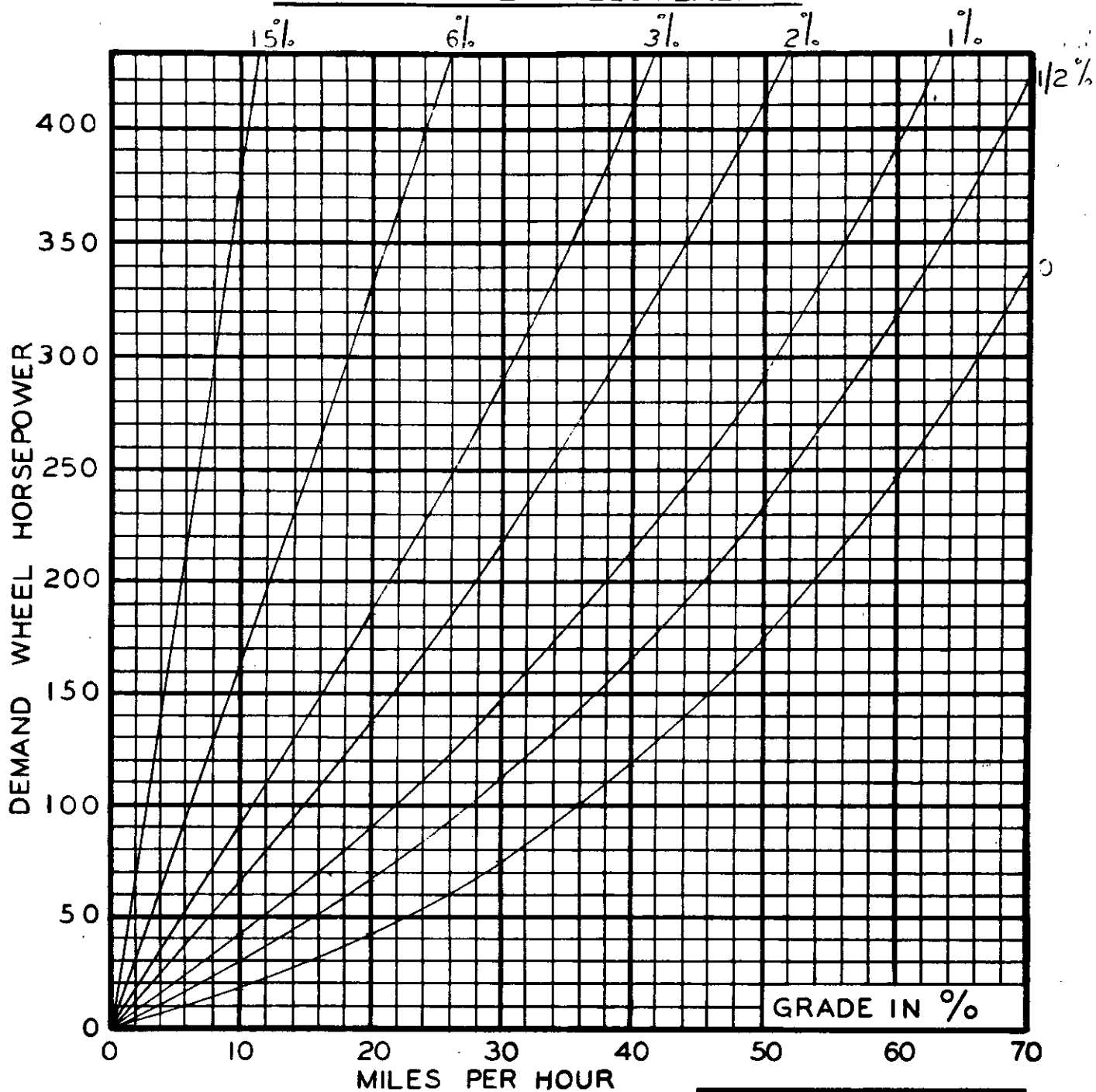
GCW. 80,000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

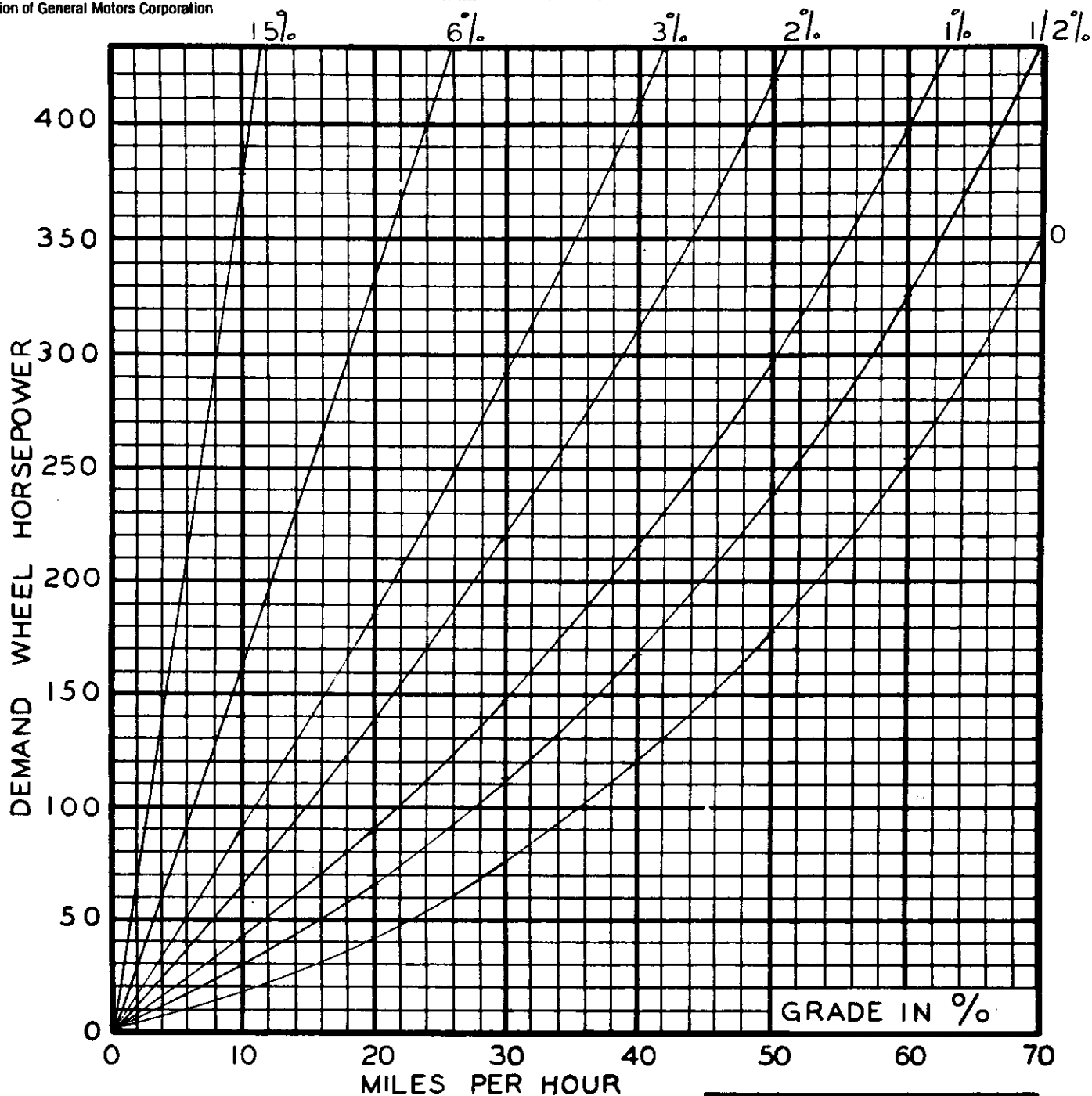
GCW 90,000 LBS.
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WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

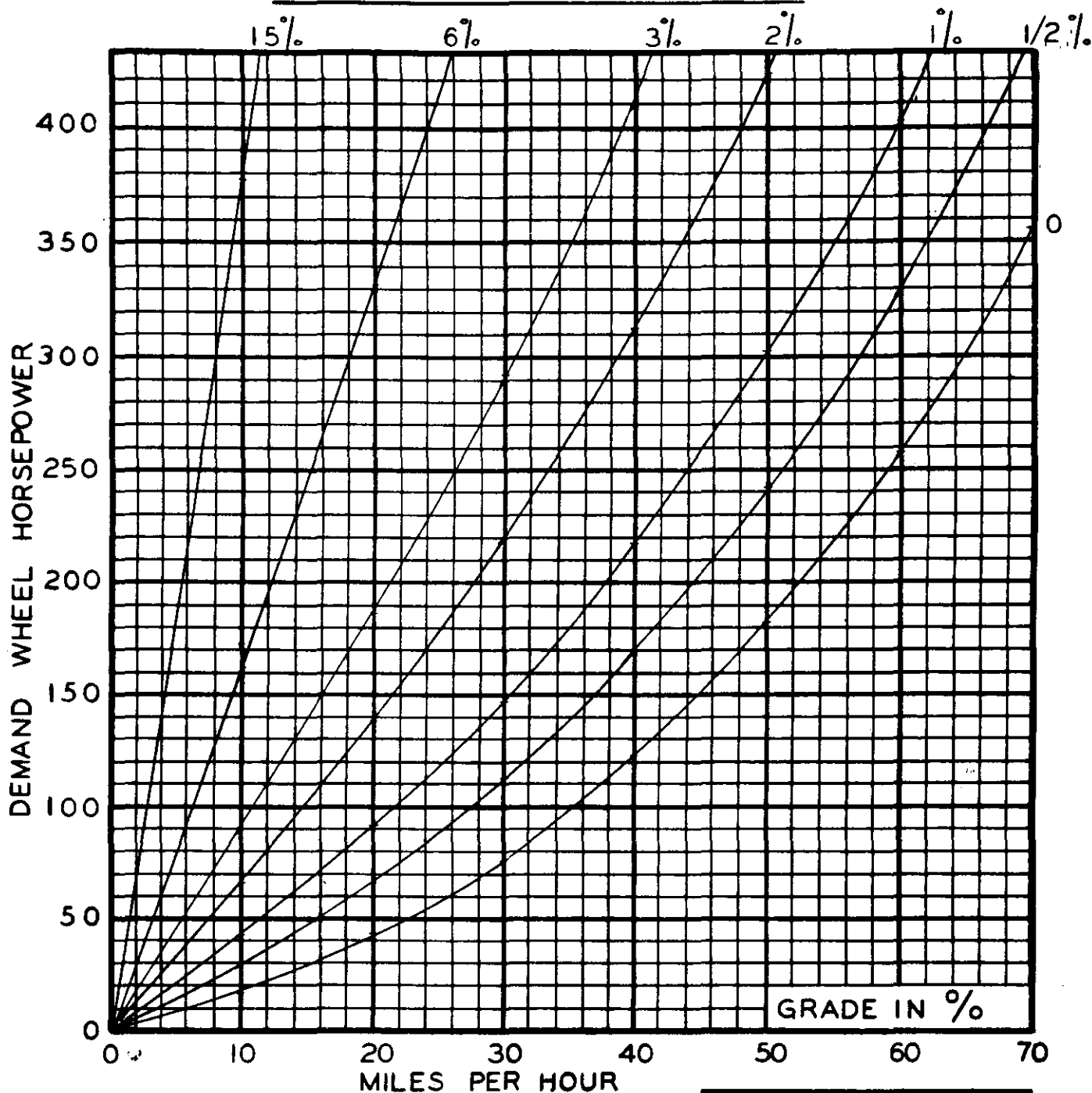
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 90000 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REV'S/MILE _____

GCW 90,000 LBS.

HEIGHT 12 1/2 FT.

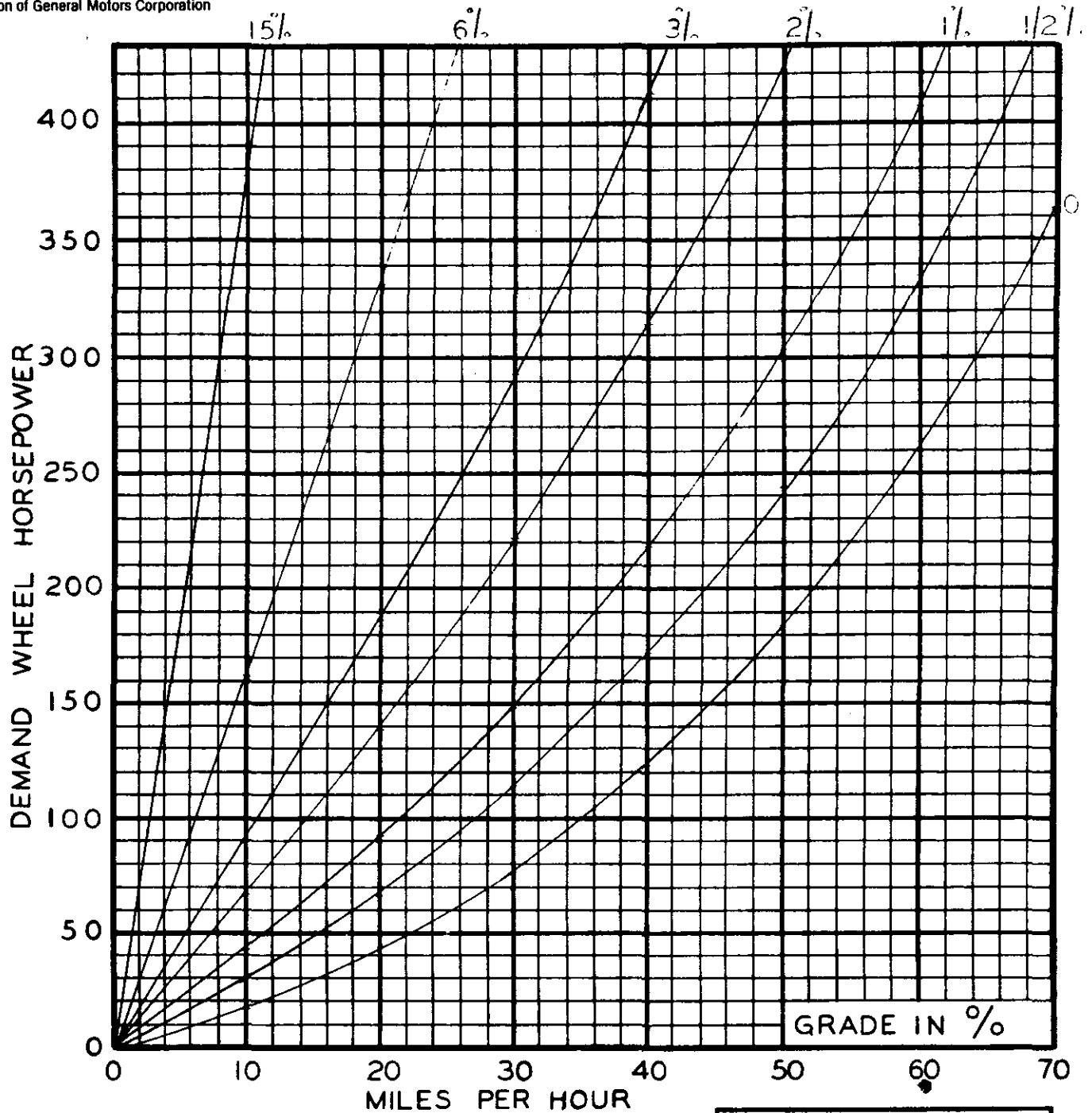
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

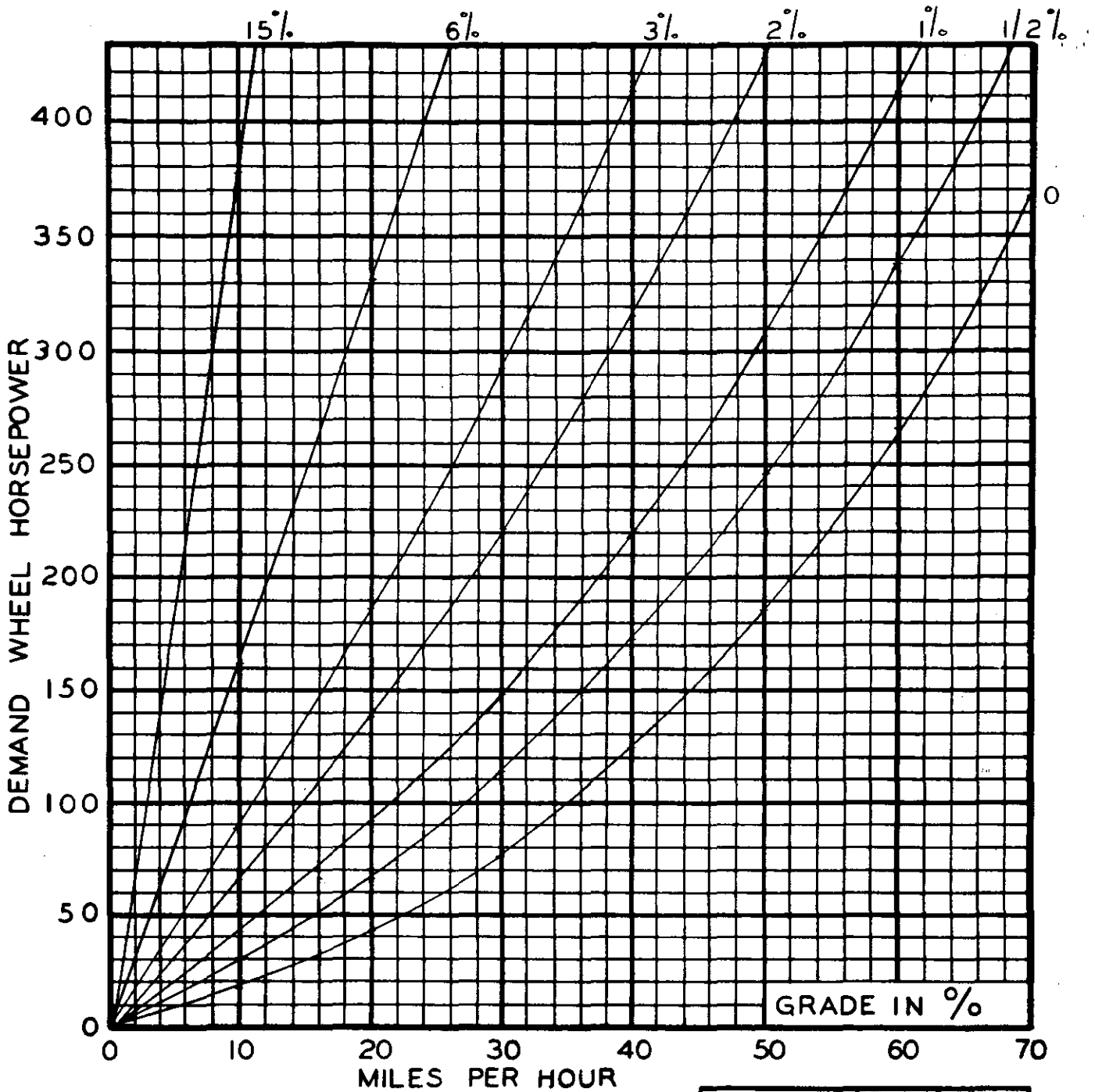
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 90000 LBS.
HEIGHT 13 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

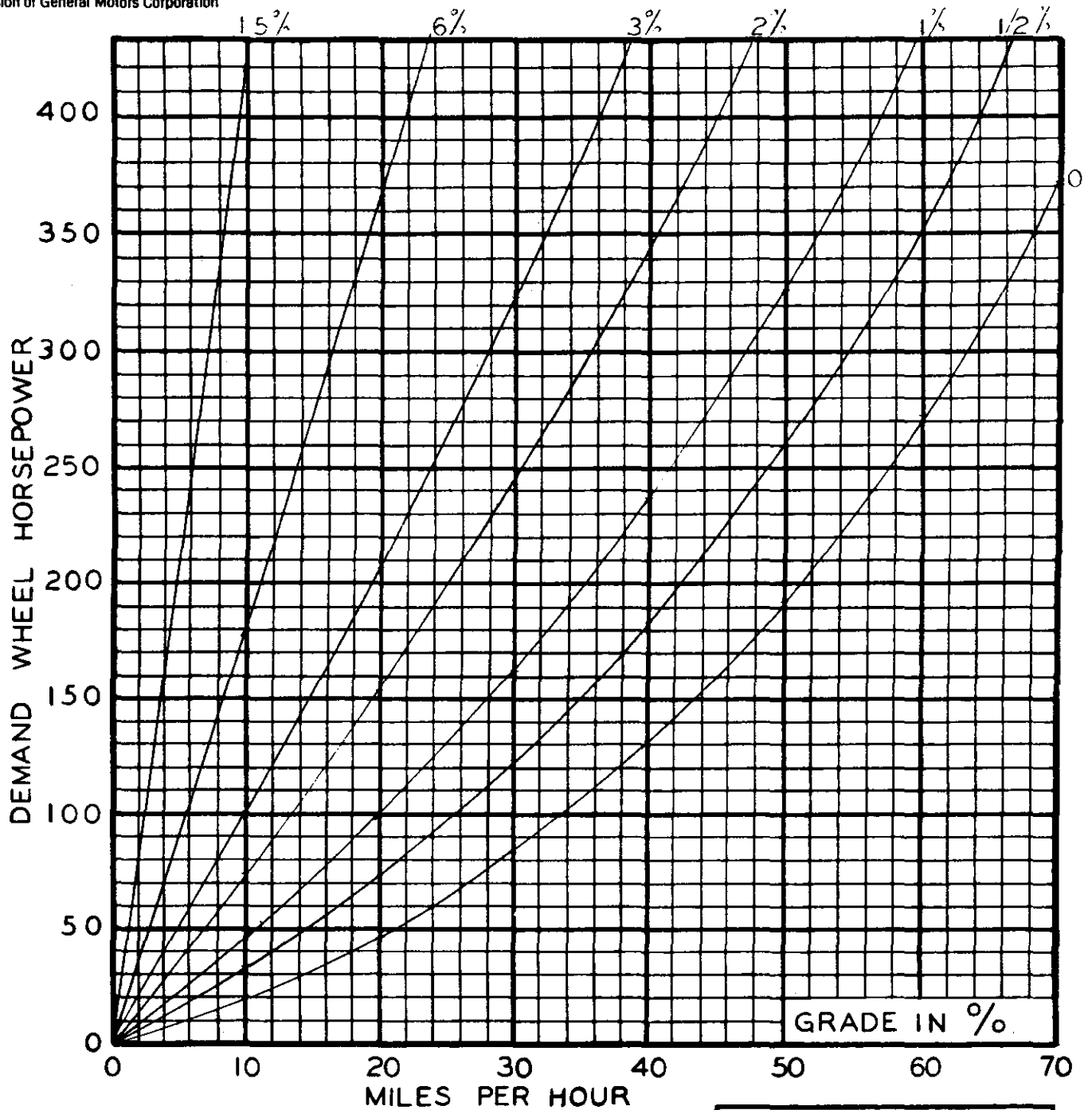
GCW. 90,000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



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ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

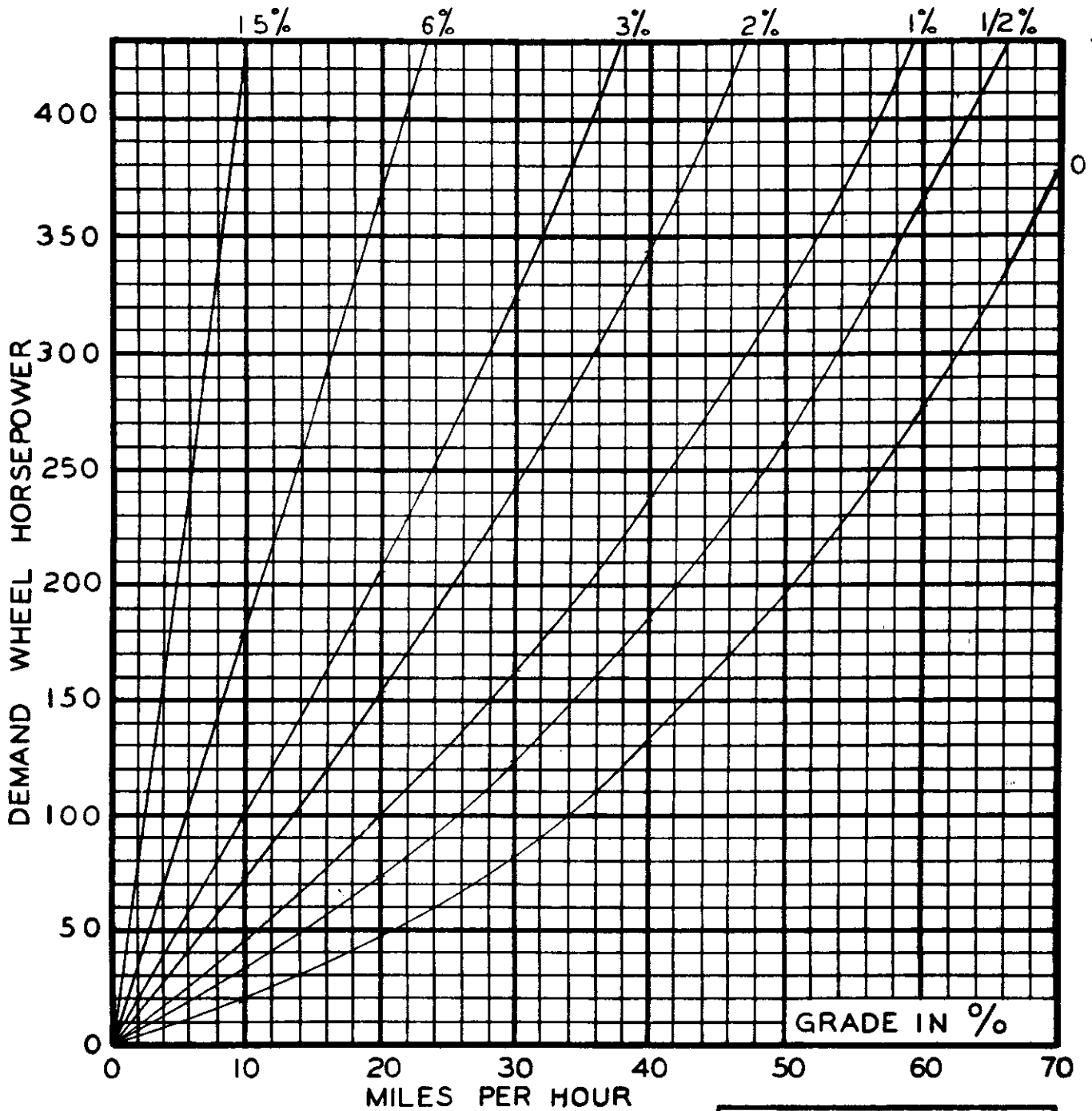
TIRE REVS/MILE _____

GCW 100,000 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____



VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

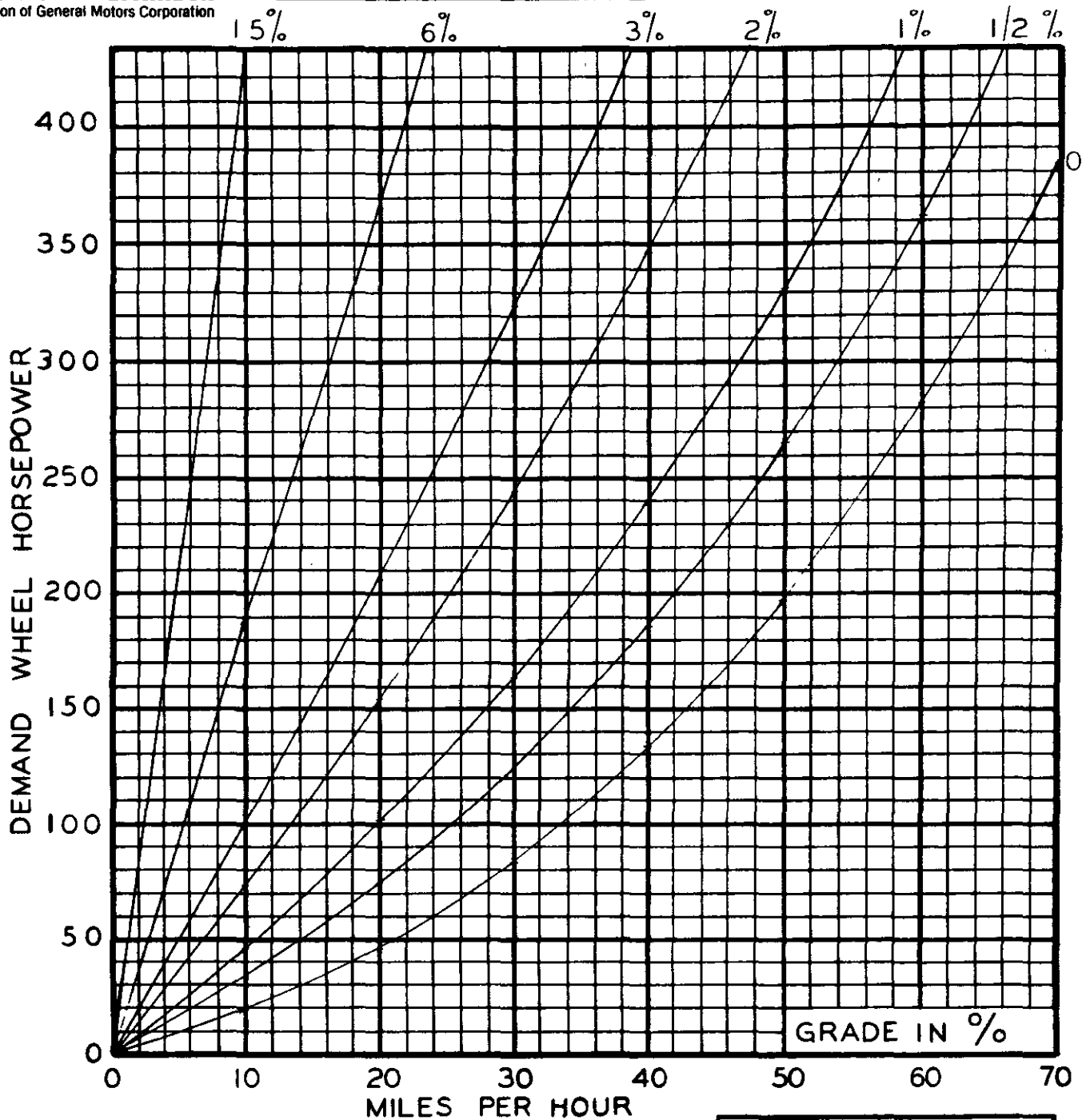
GCW	100,000	LBS.
HEIGHT	12 1/2	FT.
WIDTH	8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

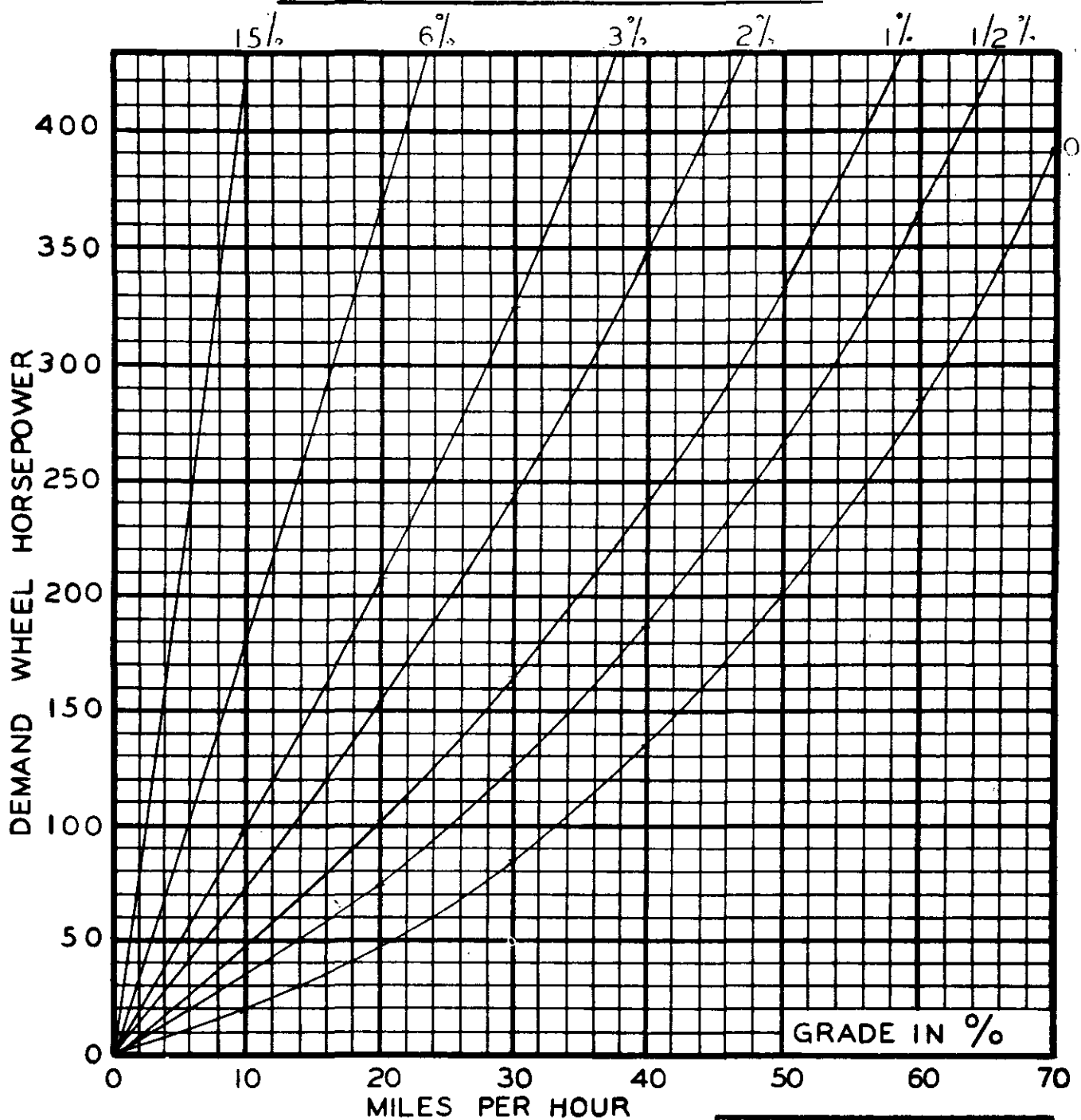
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 100,000 LBS.
HEIGHT 13 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

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TIRE SIZE _____

TIRE REVS/MILE _____

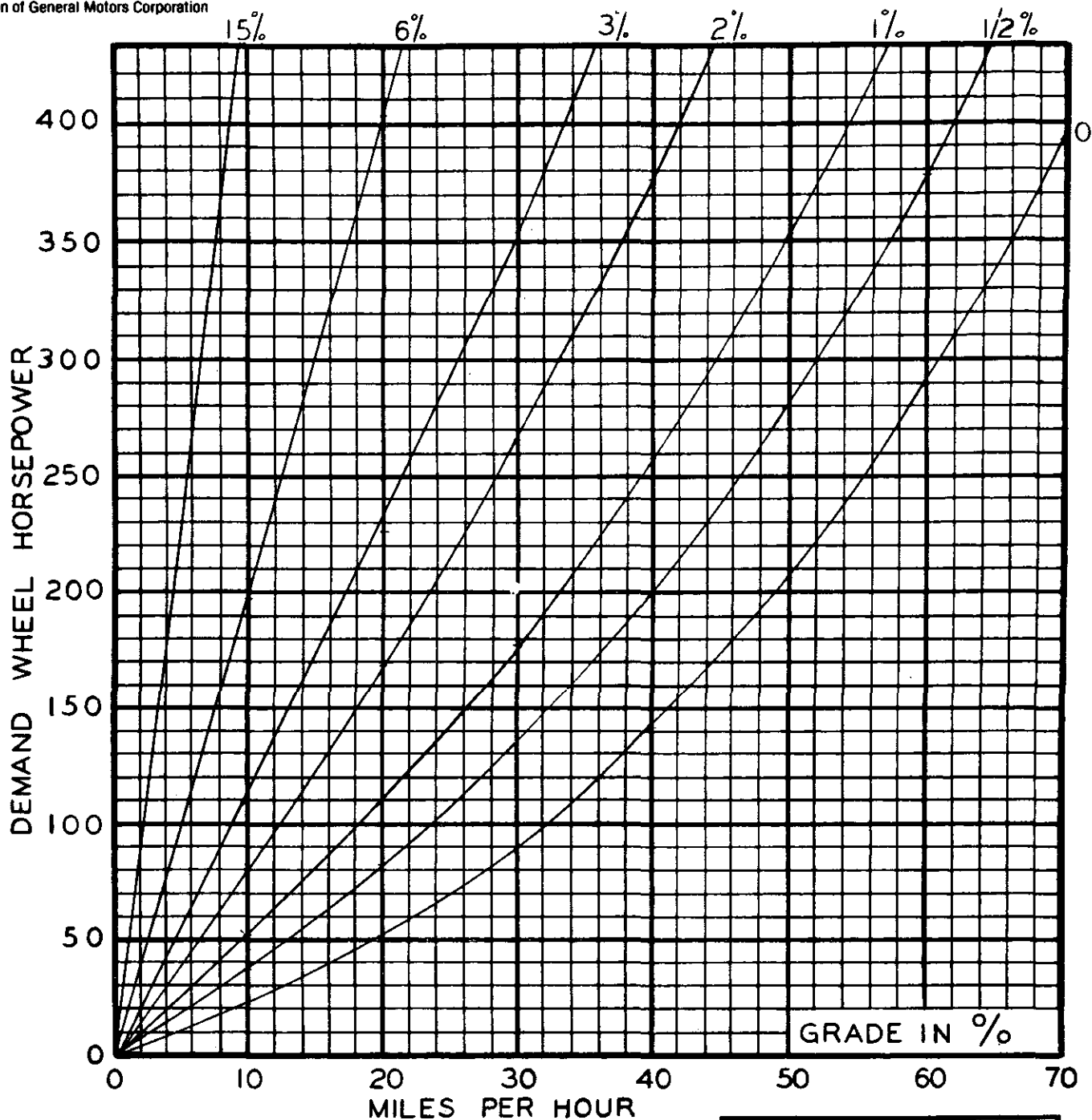
GCW. 100,000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

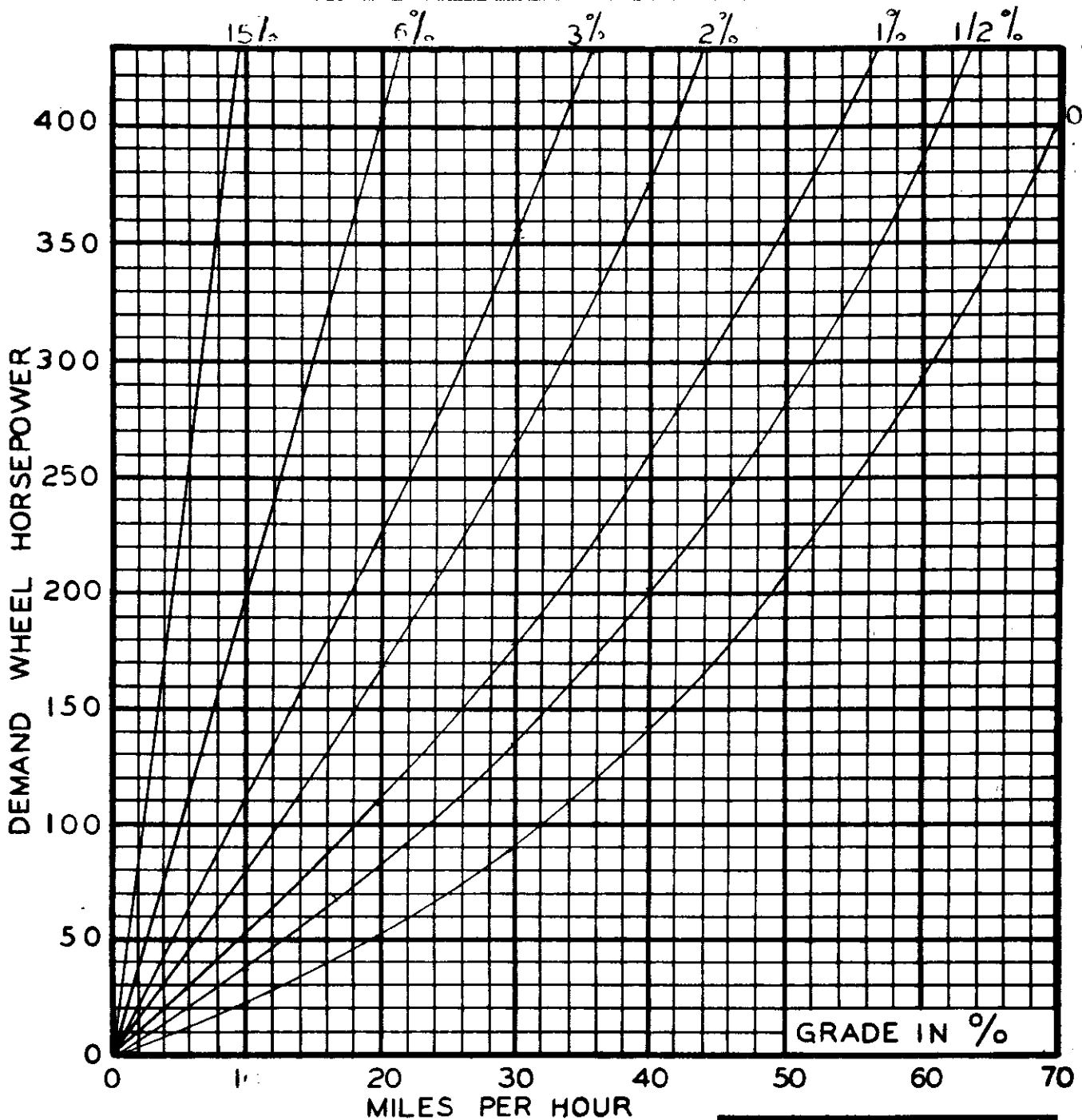
GCW. 110,000 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

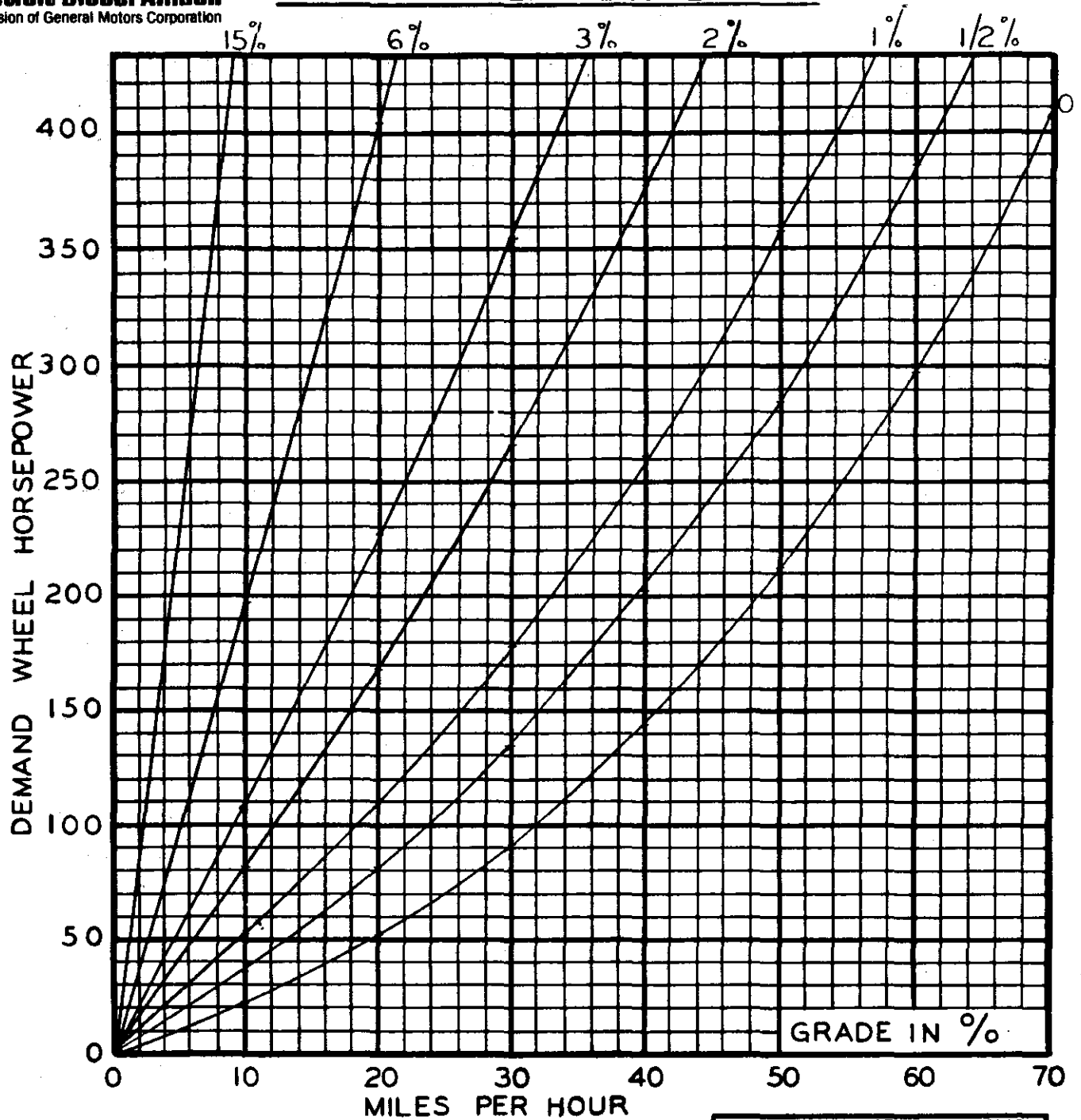
GCW. 110,000 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

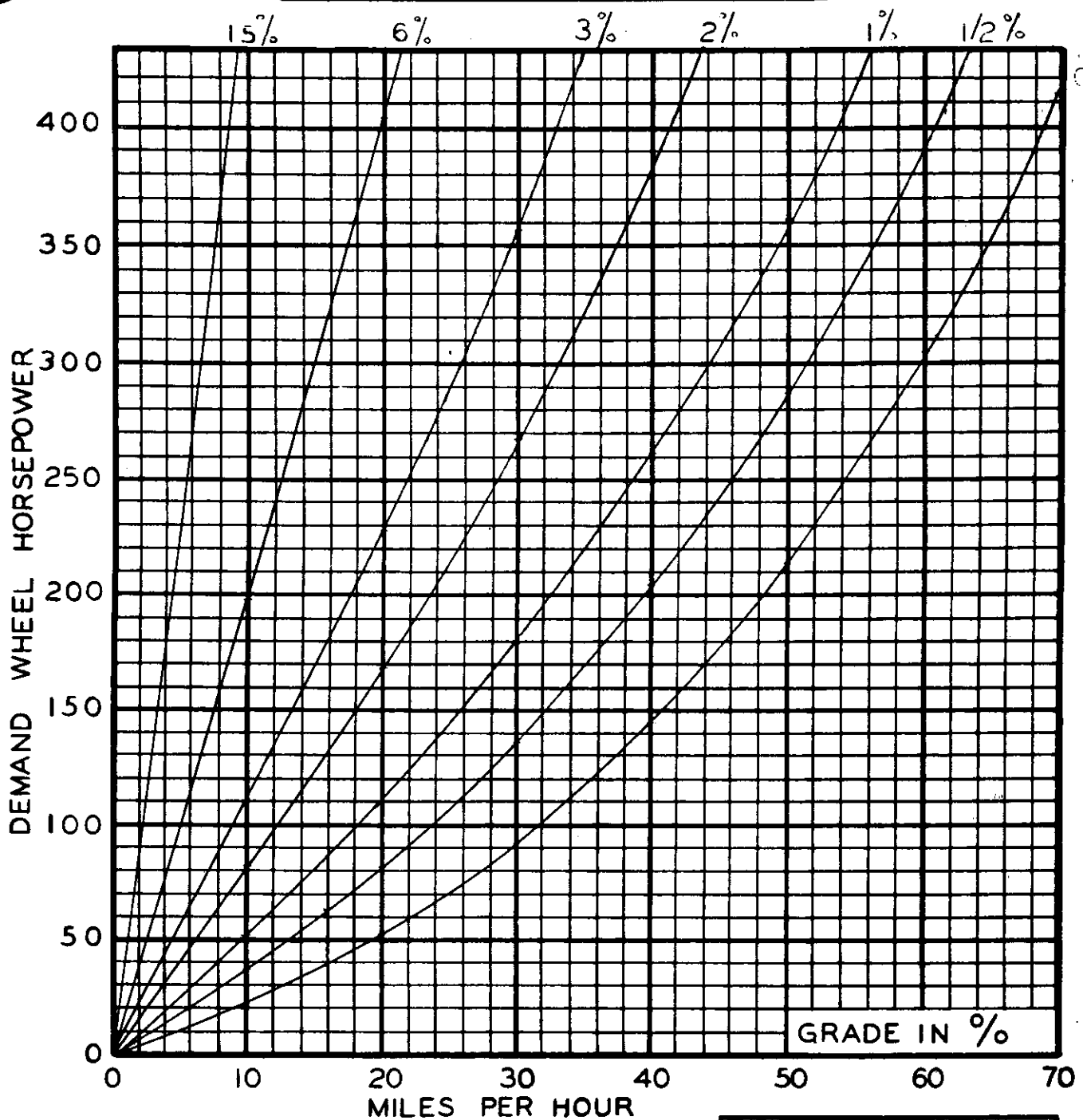
GCW 110,000 LBS.
HEIGHT 13 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

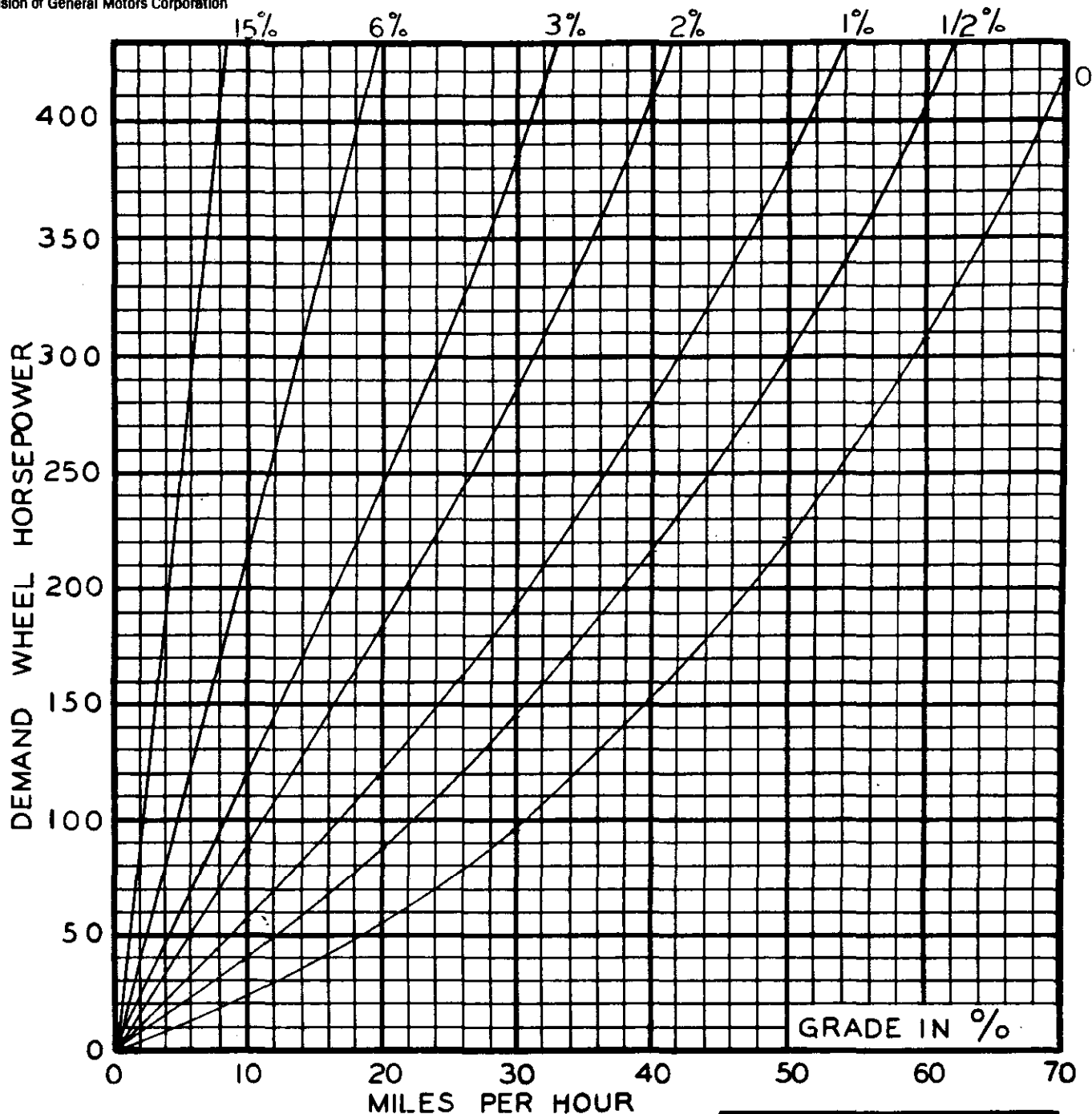
GCW 110,000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. RPM. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

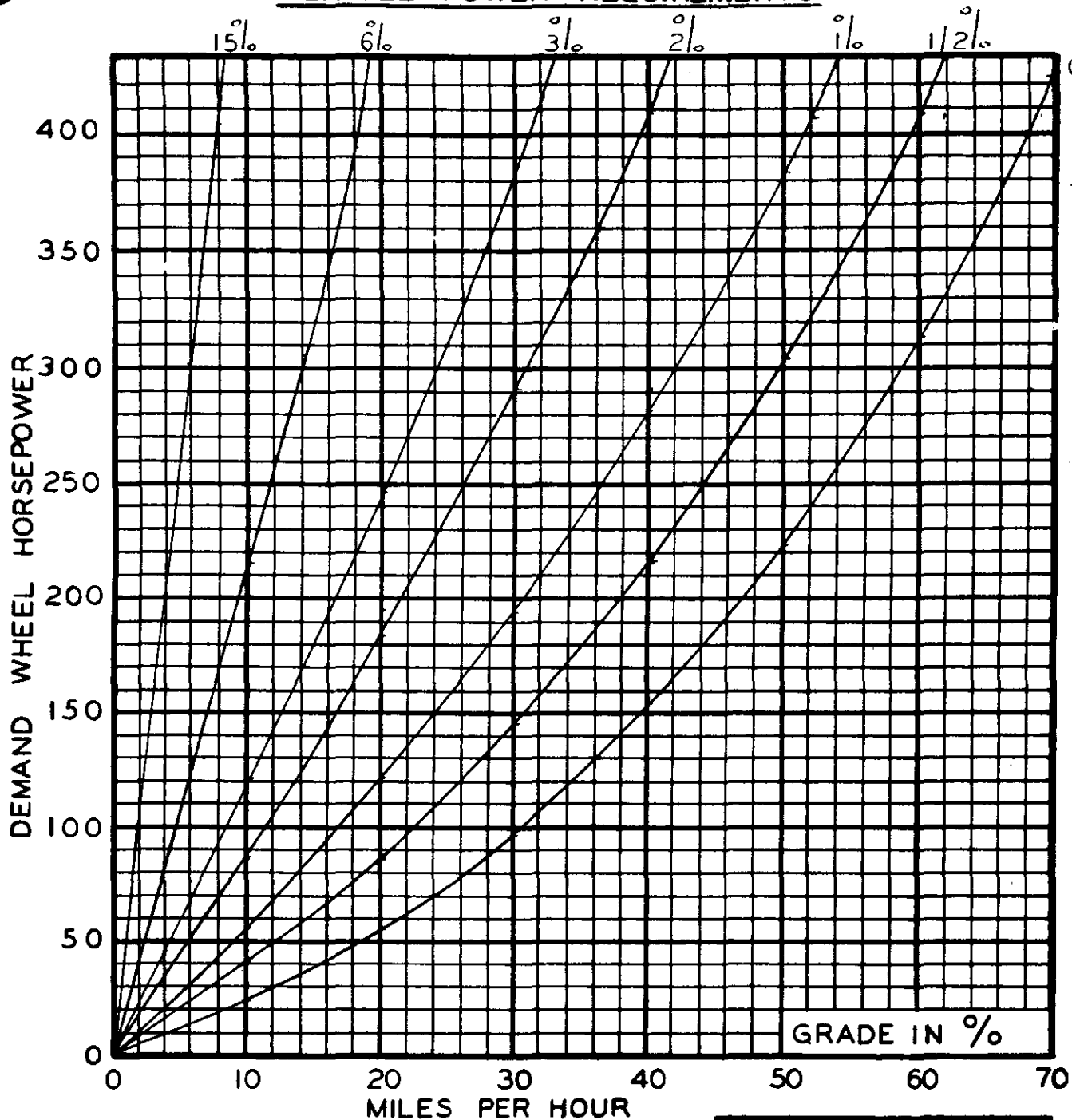
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 120,000 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

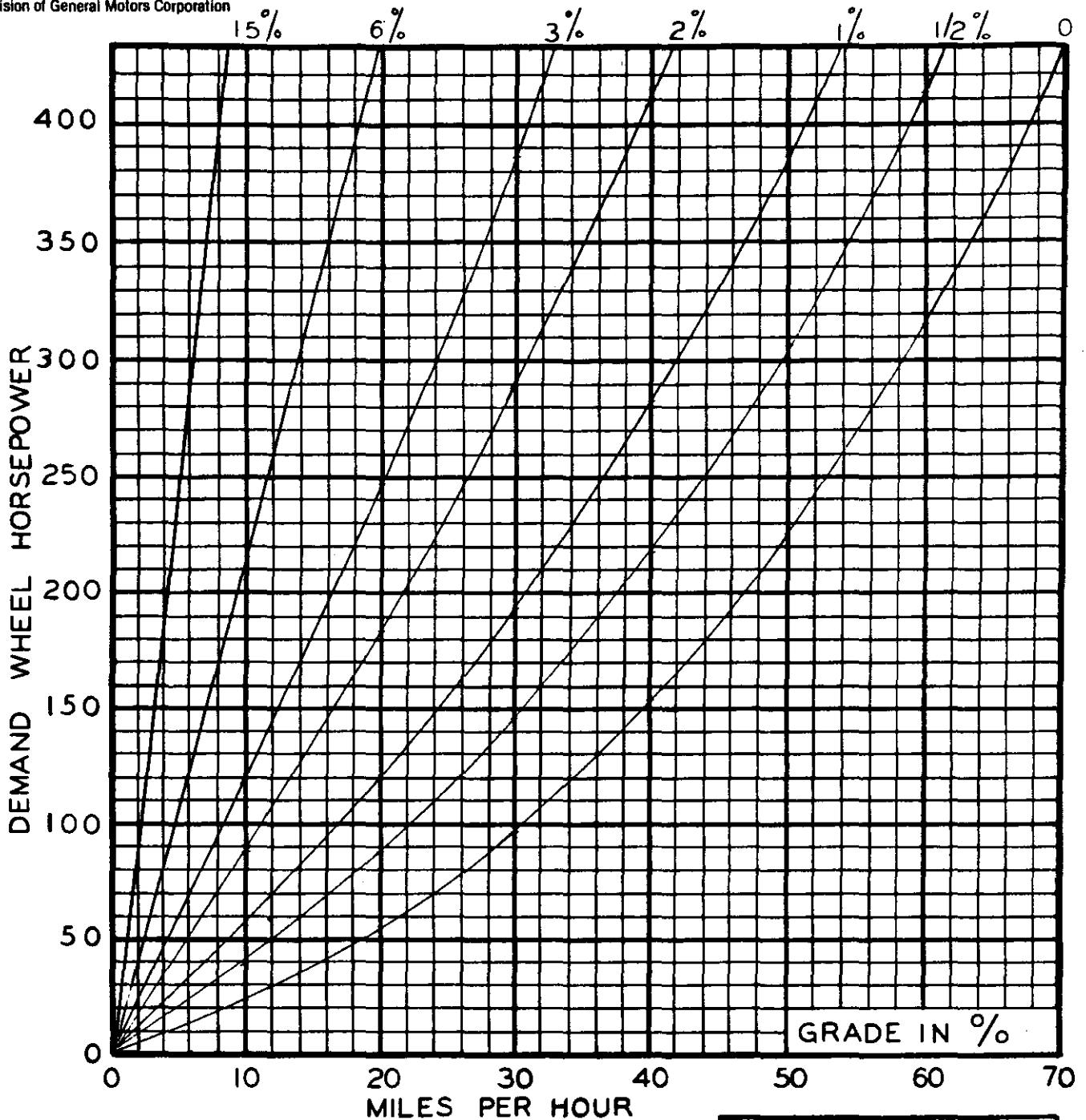
GCW. 120,000 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

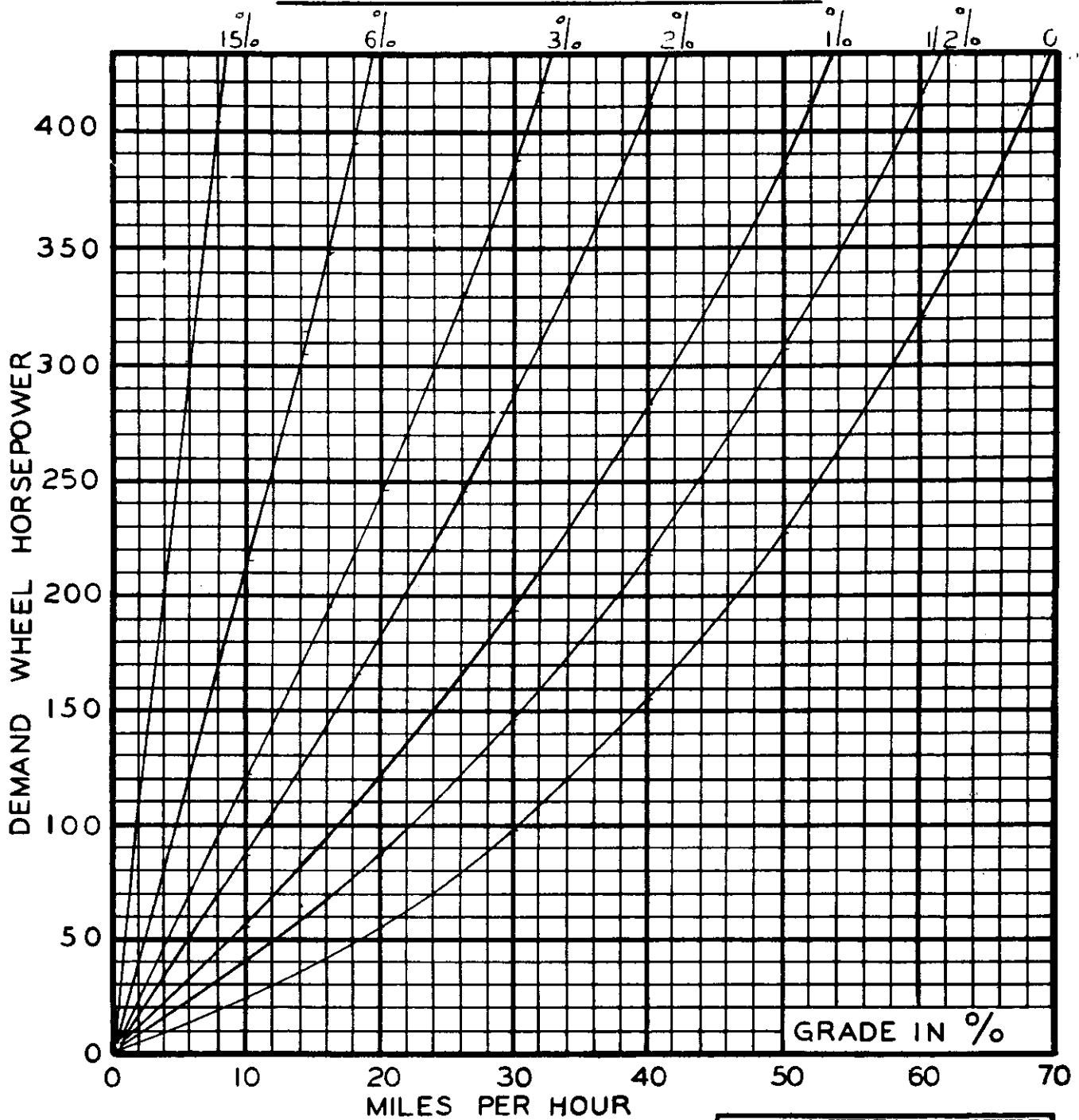
GCW 120,000 LBS.
HEIGHT 13 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 120,000 LBS.

HEIGHT 13 1/2 FT.

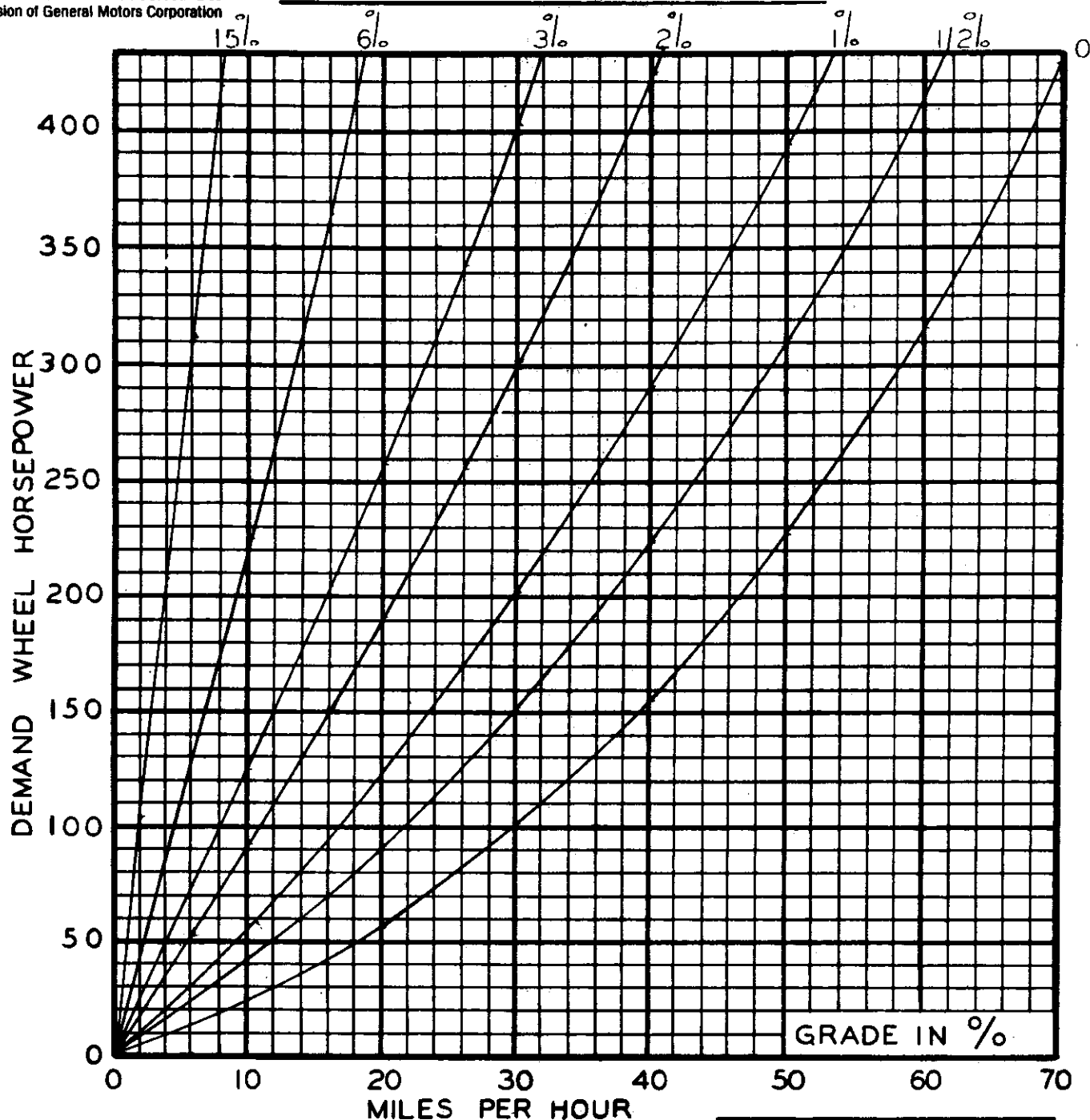
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

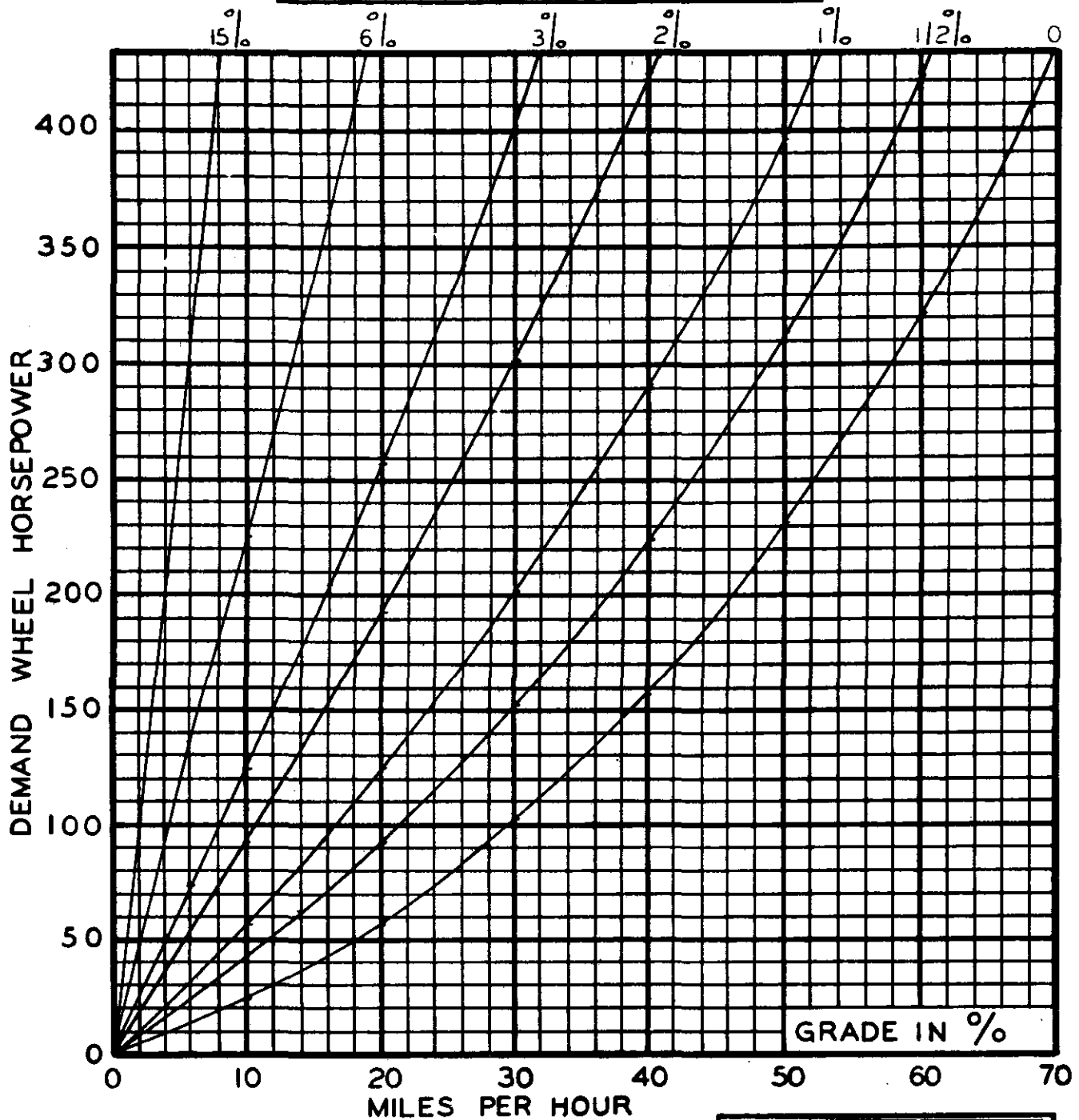
GCW. 125,000 LBS.
HEIGHT 12 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

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TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

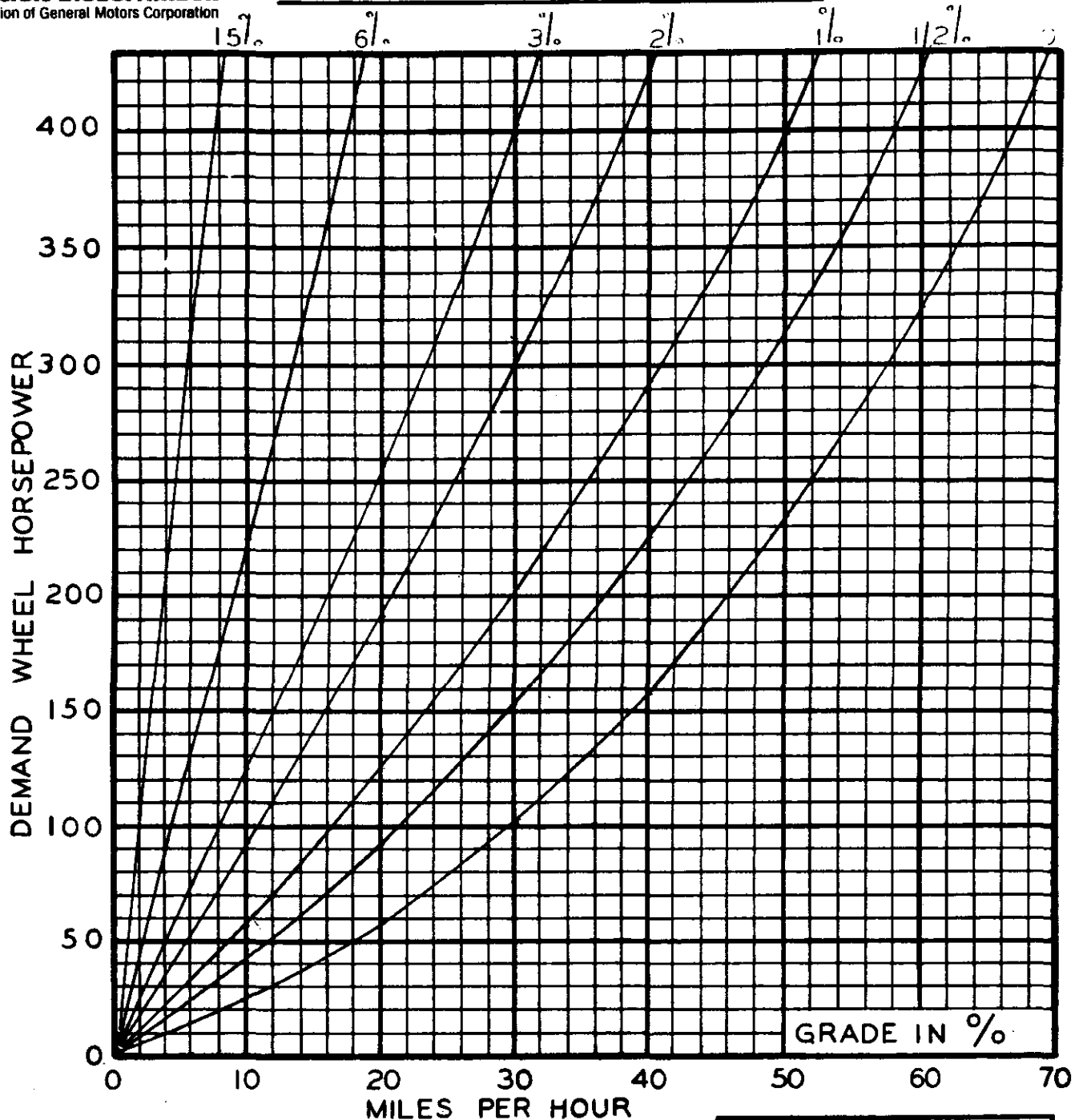
GCW. 125,000 LBS.
HEIGHT 12 1/2 FT.
WIDTH 8 FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

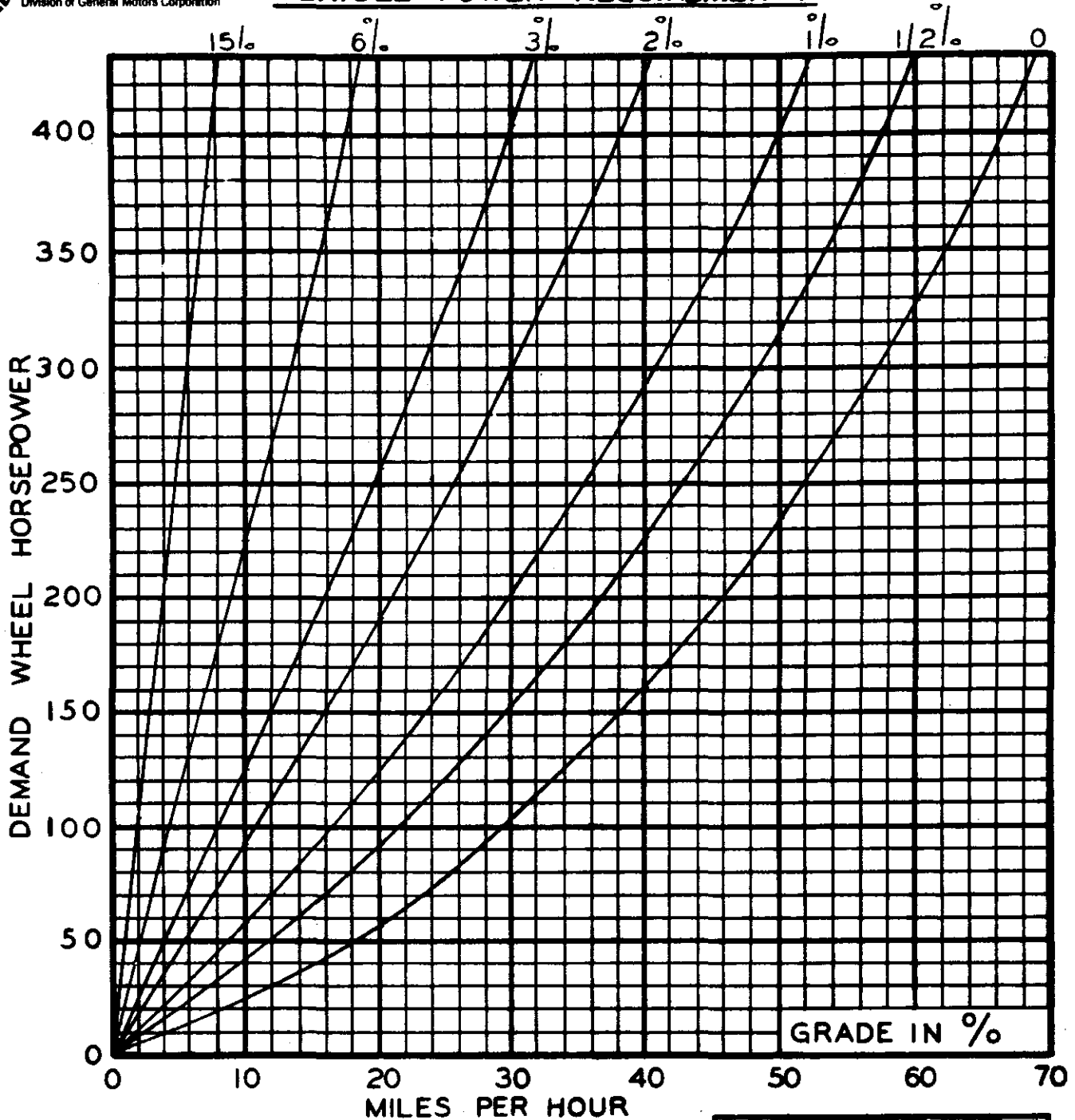
TIRE SIZE _____

TIRE REVS/MILE _____

GCW 125,000 LBS.
HEIGHT 13 FT.
WIDTH 8 FT.

REMARKS _____

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. R.P.M. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REVS/MILE _____

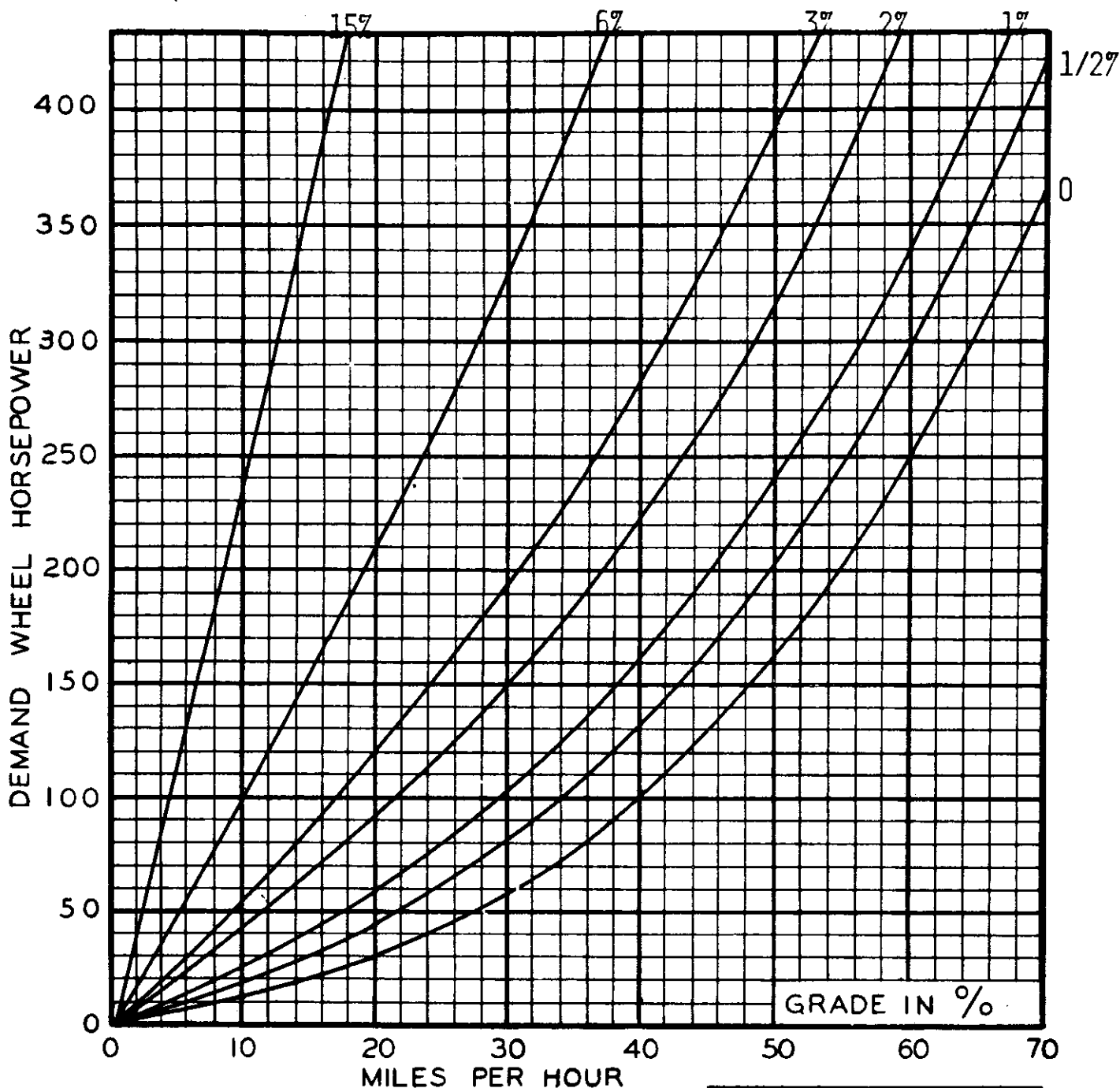
GCW. 125,000	LBS.
HEIGHT 13 1/2	FT.
WIDTH 8	FT.

REMARKS _____



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

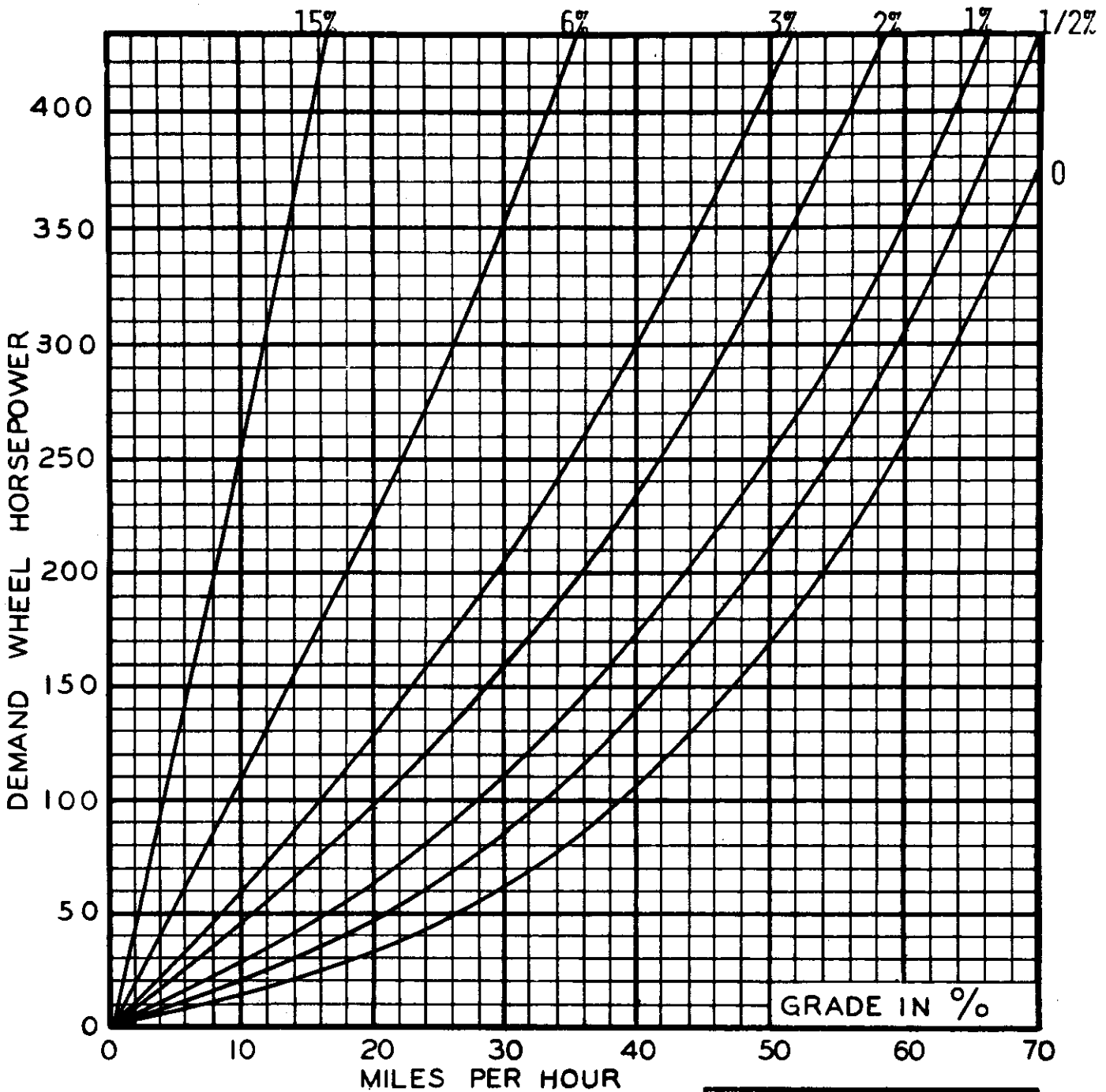
TIRE SIZE _____

TIRE REV'S/MILE _____

GCW 57,000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS AUTO TRANSPORTER

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. R.P.M. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REV'S/MILE _____

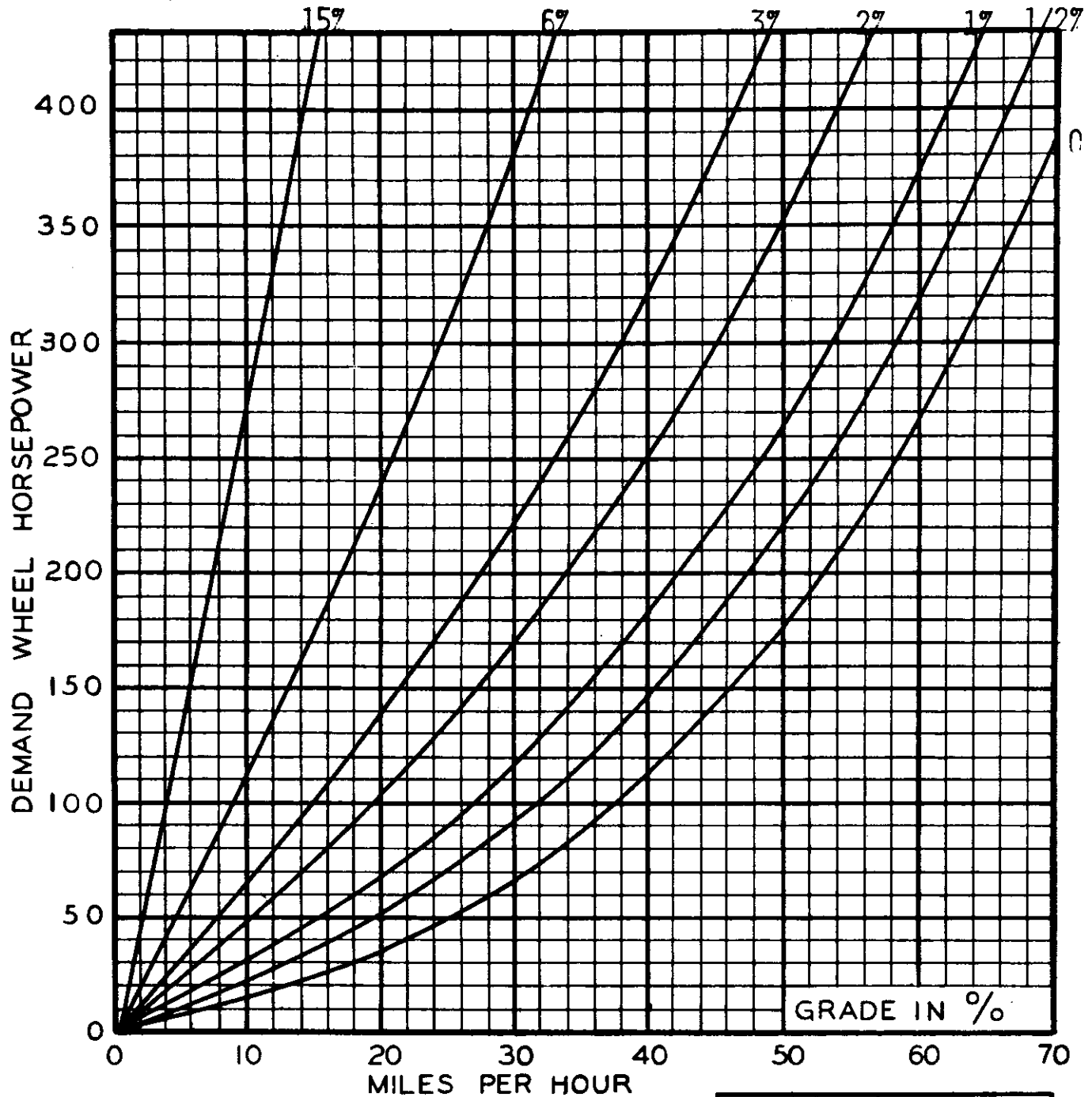
GCW. 61,000 LBS.
 HEIGHT 13 1/2 FT.
 WIDTH 8 FT.

REMARKS AUTO TRANSPORTER



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. RPM. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

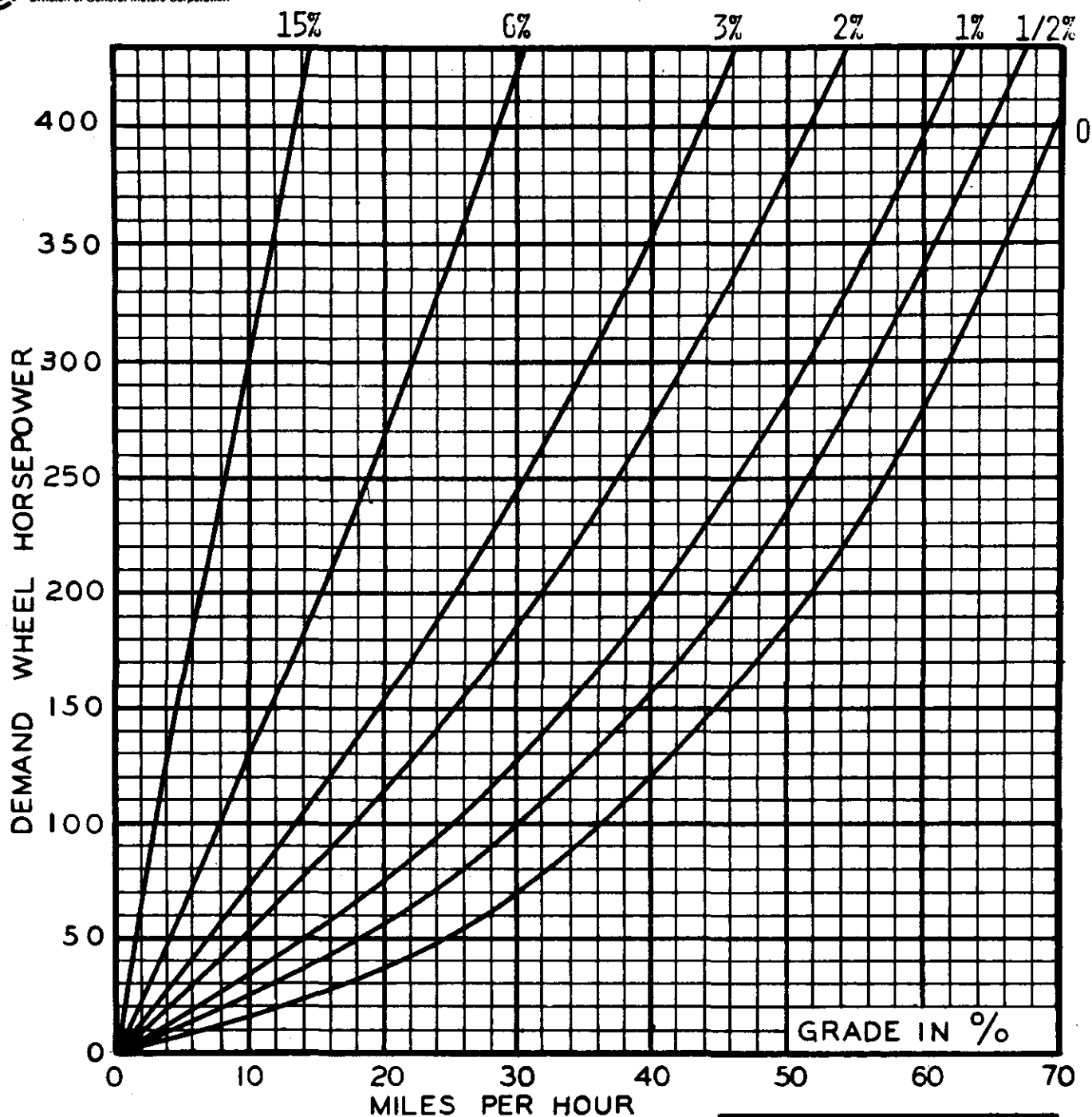
TIRE SIZE _____

TIRE REVS/MILE _____

GCW. 66,000 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS AUTO TRANSPORT

VEHICLE POWER REQUIREMENTS



VEHICLE _____
 ENGINE _____
 GOV. R.P.M. _____ INJ. _____
 TRANS. _____
 AUX. TRANS. _____
 REAR AXLE _____
 TIRE SIZE _____
 TIRE REV'S/MILE _____

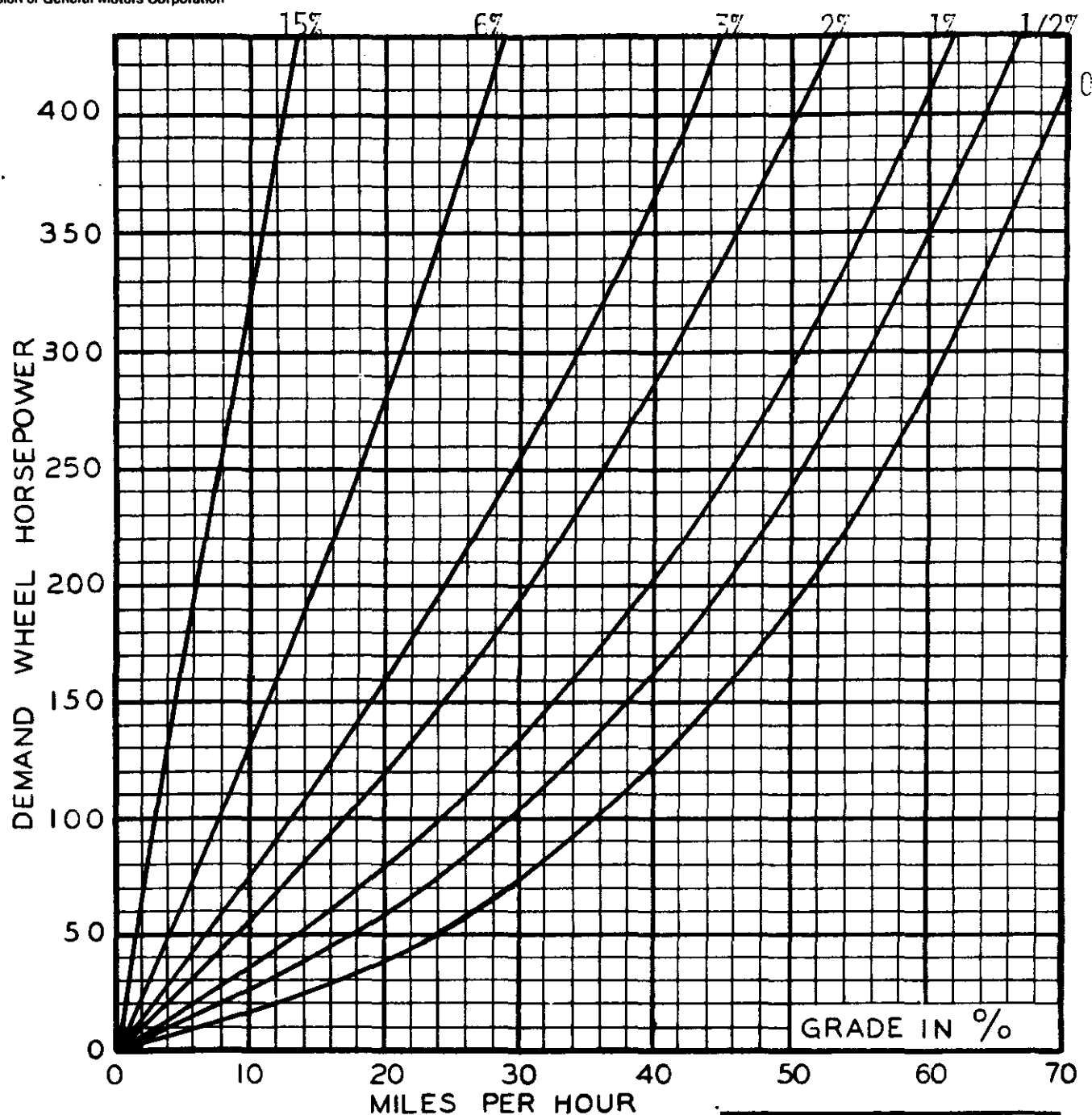
GCW. 73280 LBS.
 HEIGHT 13 1/2 FT.
 WIDTH 8 FT.

REMARKS AUTO
TRANSPORTER



Detroit Diesel Allison
Division of General Motors Corporation

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

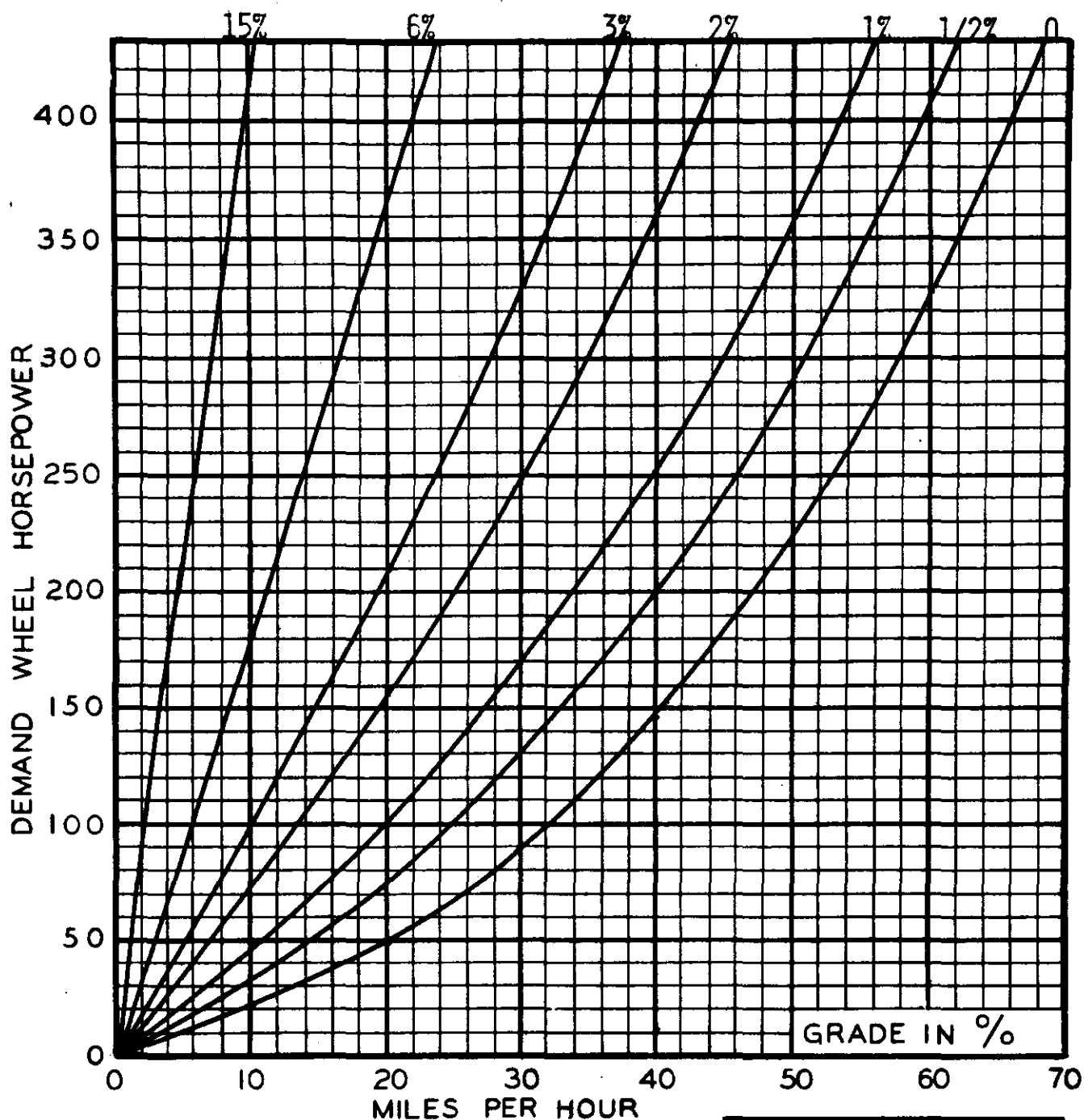
TIRE REVS/MILE _____

GCW. 76800 LBS.
HEIGHT 13 1/2 FT.
WIDTH 8 FT.

REMARKS AUTO

TRANSPORTER

VEHICLE POWER REQUIREMENTS



VEHICLE _____

ENGINE _____

GOV. R.P.M. _____ INJ. _____

TRANS. _____

AUX. TRANS. _____

REAR AXLE _____

TIRE SIZE _____

TIRE REVS/MILE _____

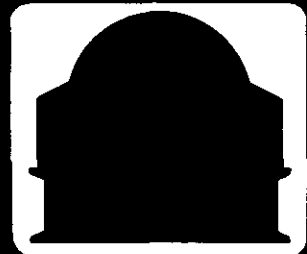
GCW	100,000	LBS.
HEIGHT	13 1/2	FT.
WIDTH	8	FT.

REMARKS AUTO

TRANSPORTER

Detroit Diesel Allison

**electric set
system
planning**



FOREWORD

Since 1938 Detroit Diesel Allison has sold some 50 million kilowatts of diesel-powered electric sets which are operating continuously or standing alert for that moment when power from the normal source is interrupted.

Detroit Diesel Allison electric power generating systems have been accepted because they provide the performance, quality and durability required in engine-powered electric generating plants . . . and because of the continuing service backup and customer services we provide.

This manual is another of our customer services. Its purpose is to call to your attention all the factors you must consider when specifying and installing an electric set to insure that the electric power system will provide the performance and operating efficiency required to meet the demands of a given installation. While the information presented is directed mainly to standby

emergency power plants, much of it is applicable to prime power and other applications.

The manual is divided into three volumes. This volume guides you in planning the components, capacity and characteristics of your electric power generating system. A second volume helps you plan and size the installation, covering such subjects as electric set location and mounting, room ventilation, engine exhaust outlet, and fuel supply. A third volume presents a sample Specification that you can use as a time-saving device to specify the electric set, switchgear and auxiliary equipment that make up the electric power system.

Should you require additional information beyond the scope of this manual, please contact your local Detroit Diesel Allison Distributor. With his assistance you will be able to plan an electric power generating system tailored for your application.

Table of Contents

	Page
1. How To Specify An Optimum Electric Generating Plant.....	1
2. Electric Set Configuration.....	2
3. Electric Set Capacity.....	4
4. Generator.....	7
5. Voltage Regulator.....	20
6. Power Transfer Devices.....	27
7. Engine.....	32
8. Frequency Control.....	35
9. Air Cleaners.....	41
10. Engine Crank-Start Systems.....	42
11. Exerciser for Standby Systems.....	48
12. Automatic Electric Set Protection Systems....	49
13. Operating Status Instrumentation.....	52
14. Control Cabinets and Switchgear Enclosures...	56
15. Uninterruptible Power Systems.....	58
16. Noise Control.....	60
17. Glossary of Terms.....	61

How to Specify an Optimum Electric Generating Plant

Diesel-driven electric generating plants are required for a variety of purposes. An ideal generating plant has adequate capacity and performance to meet the requirements of the load it serves. It does not have excess capacity or unneeded functions that would unnecessarily increase original cost and operating cost. Specifications of an optimum electric generating plant for a given installation are established by the purpose, operating conditions and load characteristics. If these are properly taken into account, an economical electric power system will be planned, suited to the specific application, with all necessary functions and adequate capacity.

Generally speaking, a diesel-electric generating plant is installed for one of these five basic applications:

Standby—an emergency electric power system which normally stands unused; it starts and assumes the load when the normal electric power source fails.

Supplementary Standby—an engine or electric set that normally drives a given piece of equipment and is used to supply electric power to the other load when the normal electric power source fails.

Peaking Power—an electric power system which is used to supplement the normal electric power source during periods of peak demand.

Prime Power—an electric power system that is the sole power source, or provides a special type of power.

Total Energy—an electric power system that is the sole electric power source and also a heat source.

The selection of controls and instruments and the design of distribution systems largely depend on the purpose of the diesel-electric generating plant and on the operating circumstances. The principles of calculating load and selecting electric-set capacity and performance characteristics are basically the same, regardless of the purpose of the electric set.

Once the existing electrical load is known, the basis for the electric set's capacity is established. The capacity usually must exceed the maximum running load to allow for the additional KW required for load starting. Keep in mind that a diesel-electric generating system is not an infinite bus. Its frequency and voltage are momentarily affected by abrupt load changes. The extent and duration of voltage or frequency variations that are acceptable depend on the type of load. Sensitive loads require minimum deviation of frequency and voltage.

If the limits of voltage and frequency deviation are specified along with anticipated abrupt load changes, the electric-set manufacturer will determine the power

margin required and the quality of voltage regulator and frequency control (engine speed control) that will meet the performance requirements. In order to achieve optimum efficiency and cost saving, the margin of KW capacity over maximum running demand should be held to a minimum. As the ratio of capacity to demand increases, so does the initial cost and operating cost.

Since afterthought changes to an installation can be expensive, you want to be sure you're right when you specify the characteristics of an electric power generating system. The system and its components are dictated by the required performance, operating conditions, and special functions that must be provided. Therefore the operating requirements should be carefully determined before writing specifications. The objective is to get all of the performance, sophistication, reliability and capacity that you need—but no more than you need so you don't waste money either in initial investment or in operation and maintenance of an oversize, over-automated, or over-sophisticated electric plant.

While it's costly to order more than you need, it's also wasteful to invest in an electric plant that won't do the job. Reliability is essential, especially in a standby electric power system. Only high-quality components offering the utmost reliability should be specified for an emergency electric plant that may be called on to safeguard lives, perishable goods, essential services or critical equipment. Power must be adequate. Performance must be matched to the type of service. When serving sensitive loads, you need quick response and close control of frequency and voltage. An electric set that won't deliver what you need is a wasted investment.

With adequate performance, power and reliability in mind, it may seem that the safe thing is to overdesign the plant, but this is costly and moreover may work against reliability because the plant would not function in its best operating range. Operating and maintenance costs are raised by adding complexity or by operating oversize equipment at low efficiency. An electric set custom assembled for your exact requirements may be more economical and more reliable than some "standard set" that has built-in excess capacity or does not offer all of the performance or functions you really should have.

To obtain adequate performance and reliability in your electric power generating system, with optimum overall economy, it is recommended that you state specifications in terms of performance desired rather than attempting to specify a certain size, type or make of equipment. To help you determine the characteristics and performance required for your application, the following sections discuss the major components and subsystems of diesel-electric power systems.

Electric-Set Configuration

Single Engine/Single Generator Configurations

The usual diesel-electric set consists of one diesel engine coupled directly, without gearing, to one generator. The two are mounted and aligned on a rigid base made of steel I-beams or channels.

The generator rotor is supported in the generator frame by either one bearing or two. The single-bearing type saves cost and space. Either type is satisfactory. The two-bearing type has one bearing supporting each end of its rotor, properly centering the rotor within the stator. The rotor shaft is connected to the engine flywheel by a flexible coupling.

The single-bearing type has a bearing supporting the rear end of the rotor, with the opposite end attached to the engine flywheel through a flexible disc coupling. It is necessary for the engine and generator to be aligned so that the generator rotor is properly centered within the stator. Usually the proper alignment is assured by an adapter that connects the generator frame to the flywheel housing of the engine. Since one end of the rotor is supported by the engine's rear bearing, a very heavy rotor might impose an undesirable bending load on the engine crankshaft. In such a case, a two-bearing generator would be preferred. The electric-set supplier can be relied on to select the type best suited to the conditions and the engine.

Multiple Engine or Multiple Generator Configurations

A very large generator might be driven by two or more engines, or multiple engines might be employed to improve reliability. Two engines can be mounted side-by-side (twin) and connected to the generator through clutches and transfer gears. An alternative is a tandem arrangement with one engine at each end of the generator, connected through clutches. The tandem arrangement eliminates the transfer gearing. Four engines can drive a single generator in a quad arrangement, with two engines side-by-side at each end of the generator, connected through clutches and transfer gearing. The clutches permit an engine to start unloaded and permit one engine to start the electric set, with other engines being started when needed by clutch engagement. During off-peak periods, the generator can be driven by a single engine for greater efficiency.

A different type of need might be met with one engine driving two generators. A simple arrangement would have one generator coupled to each end of the engine, or the generators could be tandemed at one end of the engine. One engine driving two generators might be practical if two different types of generators (for example, one A.C. and one D.C.) are required serving different types of load. However, this would be unusual

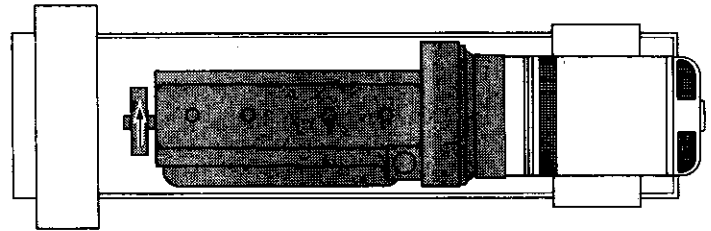


Figure 1-1. Single Engine Drive Arrangement

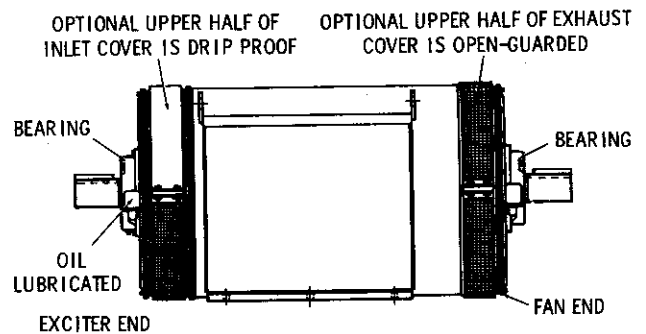


Figure 1-2. Double Bearing Generator

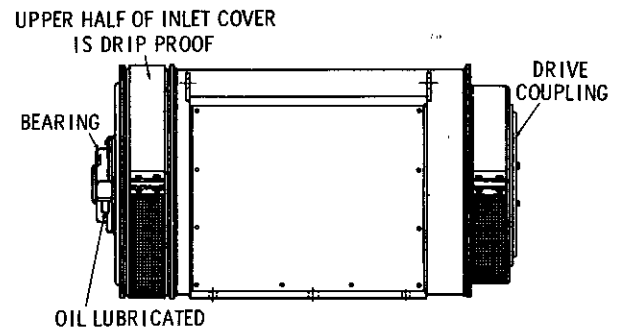


Figure 1-3. Single Bearing Generator

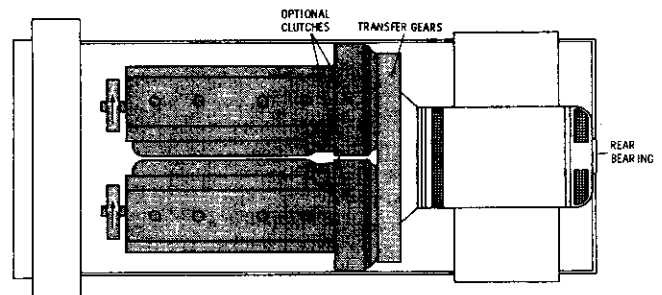


Figure 1-4. Typical Twin Engine Drive Arrangement—Single Bearing Generator

since most applications are A.C. and a single generator is normally satisfactory for serving both single-phase and polyphase loads.

Multiple engine drives add a measure of redundancy that improves reliability, particularly where two or more engines add starting reliability. However, true redundancy exists only with multiple electric sets connected to form a parallel power system, provided the remaining electric set or sets are capable of serving the total load when one is out of service. During off-peak periods, individual units can be shut down to increase load factor and efficiency.

Some very special applications require Uninterruptible Power Systems (UPS), also known as "no-break" systems. The requirement is not merely to have standby power available but to have it on the line without a moment's hesitation. There are different types of systems for this purpose. All are costly and complex. There can be substantial difference in both cost and reliability between different types of systems. UPS systems are discussed in a later chapter in this manual. If one is planned, contact a Detroit Diesel

Allison Distributor for information on designing a system with utmost reliability at minimum cost.

Torsional and Flexural Vibration Control

The power output of a piston engine is in the form of torque pulsations that tend to cause variable rotating speed. The torque pulses and speed oscillations are smoothed out somewhat by the engine's flywheel. However, if the pulsation frequency is near the natural frequency of the rotating mass, torsional resonance could greatly increase the amplitude of the oscillations and generate stresses that might cause fatigue failure or be otherwise damaging to the engine crankshaft, generator shaft or other internal components of the generator.

The electric-set manufacturer has the system factory-analyzed to establish the torsional and flexural integrity of the engine crankshaft, generator shaft, fan, rotor windings and exciter. The electric set manufacturer obtains assurance of the generator manufacturer that other internal generator components will not be endangered by the vibratory conditions listed on the analysis. All generator and engine systems are analyzed and should be approved before electric sets are built.

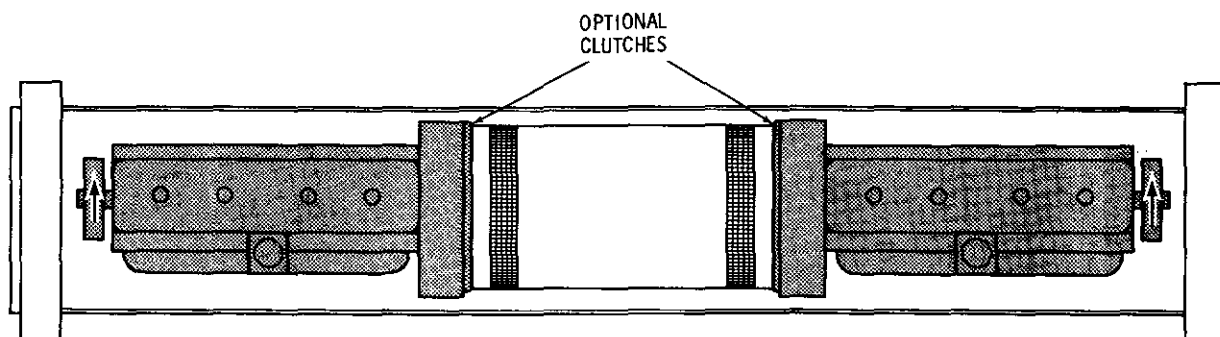


Figure 1-5. Typical Tandem Engine Drive Arrangement—No Bearings in Generator

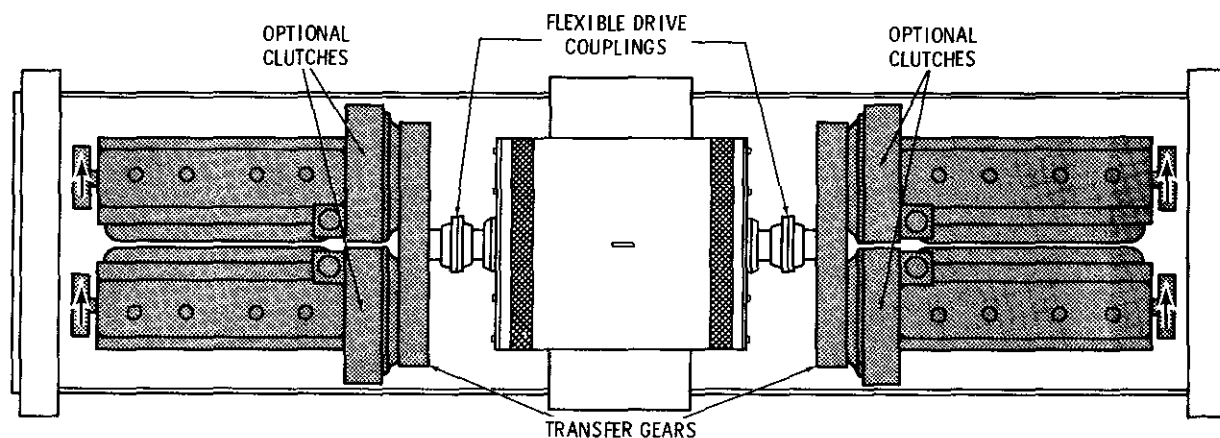


Figure 1-6. Typical Quad Engine Drive Arrangement—Two Bearing Generator

Specifying Electric-Set Capacity

The basic requirement of an electric set is to provide enough KW capacity to serve the peak load. The peak load (also referred to as maximum demand) is the maximum load in kilowatts that the electric set will be expected to serve. It may be the total KW load connected to the generator, but it is often less than this total because there will never be a time during the day when all connected loads are operating.

The total load connected to the electric set may be the complete load in a building or complex, or it may be selected essential loads connected into an emergency circuit separate from other load circuits. The ratio of the peak load to the total connected load is the *demand factor* or *diversity factor*. The peak load can be determined by measurement or by selecting a reasonable demand factor for the type of installation and multiplying the demand factor times the total connected load.

When determining the peak load by measurement, it is defined as the maximum load in KW experienced over a 24-hour or longer period. Obviously, such measurements should be made during days of the week when full activity can be expected. Since the peak load, or maximum demand, may vary with the seasons, it is important to determine when it is greatest and to use that value in the Specification.

Effect of Motor Starting on Peak Load

When motors are started at full voltage, they draw more power than their maximum running load KW, until they accelerate to operating speed. The difference between starting KW and running KW makes the peak demand greater than the maximum steady load if motor starting can occur during high demand periods of the day. If motors start only during low demand periods of the day, the extra starting KW does not increase the peak demand.

When peak load and demand factor are determined by measuring the actual demand profile of the installation, the effect of motor starting is taken care of automatically in the measurement. If motor starting occurs during a peak period of the day, its effect will be included in the measured peak load.

If peak load is estimated rather than measured, it should first be determined if it is possible that motors will start during a high demand period. This is likely to occur in a standby application since a standby electric set takes on the total active load in one step. If all motors automatically start at the same time, their extra start-up KW demands would add to the total KW being imposed on the electric set. This can only be avoided if motors are disconnected and restarted in sequence.

The rule of thumb for estimating motor start-up KW is 1/2 KW per starting KVA. To allow for the motor start-up effect when summing loads, use the start-up KW instead of the running KW for the motor being started.

Another aspect of motor starting is that the high inrush current causes a momentary drop in generator voltage. To keep this voltage "dip" within specified limits, a generator of high KVA capacity may be required. The relationship of generator KVA capacity and voltage dip is discussed in the GENERATOR chapter.

Specifying Load Requirements

Information listed in the Specification should enable the electric-set supplier to determine the required size of engine and generator and the characteristics of the voltage regulator and speed-control governor that will give the required plant performance. The following information should be listed:

1. Application (standby, prime power, peaking power, or continuous)
2. Peak load in KW
3. Power factor of load
4. Voltage and phase (e.g., single phase, 3-phase)
5. Ambient conditions (temperature and altitude -- also humidity and other environmental conditions if unusual or severe)
6. Limits of frequency variation and response to load transients
7. Limits of voltage dip and recovery time
8. List of motor sizes and starting characteristics
9. Information as to amount of load that could be on the line when any of the large motors is started

Information about application, phase, voltage, and the ambient conditions enables the manufacturer to determine the type of generator required. The peak load and power factor establish minimum generator capacity. The motor information along with voltage dip and recovery limits enable the manufacturer to determine if generator capacity should be based on voltage dip requirements rather than on peak load. If voltage dip requires greater KVA capacity, he will evaluate the economics of employing a high-performance voltage regulator to limit generator size.

Once the generator capacity is established, its efficiency at peak load is known. The peak load, ambient conditions, generator efficiency and transient response requirements (frequency dip and recovery) establish the engine horsepower and type of speed-control governor required.

By presenting requirements and conditions in this way, you put the burden on the supplier to propose a power system that will do the job. You also help him to determine the most economical combination of engine, generator, and frequency and voltage regulators that will achieve the desired performance. It is advisable, however, to make your own determination of generator capacity to make sure the load conditions are as practical and economical as you can make them and to be sure that every supplier's proposal is adequate for all requirements. This is explained in the GENERATOR chapter.

Effects of Excess Capacity

To make sure the electric set has sufficient capacity for the load and adequate performance under all conditions, the temptation is to build excess capacity into the electric set. But excess capacity increases initial cost unnecessarily, and it introduces inefficiency, which increases operating and maintenance costs.

Since an electric set seldom operates at full load, the engine and generator normally operate in a part-load condition where both are less efficient. Because the engine is less efficient at part load, it takes more fuel to produce a given horsepower output. Because the generator also is less efficient at part load, it requires proportionately more horsepower to produce a kilowatt at part load than at full load. Consequently the fuel cost of a kilowatt-hour is greater at part load. If either the engine or generator is oversize, the part-load inefficiency is worsened, which further increases operating cost per kilowatt-hour.

Fuel consumption is not as important a cost factor in a standby application as it would be in prime power or continuous service. But there are other drawbacks to part-load operation. Unburned fuel resulting from inefficient combustion can contaminate lube oil or invade the exhaust system. The condition obviously is aggravated with an over-capacity engine, which is operated at a smaller fraction of its capacity under any part-load condition.

Avoid Wasteful Load Specifications

To avoid unnecessary cost, specify the actual measured or estimated peak load rather than a rating found in some supplier's catalog. For example, if the peak load is 94 KW, the architect might be tempted to round it off to 100 KW because that happens to be an electric-set supplier's next standard size. Since a power margin

usually is needed to fulfill performance specifications, such a rounding-off might cause suppliers to propose engines or generators larger and more costly than actually needed. If you're sure of your load, state it exactly. The supplier then will propose an engine and generator that will produce the required KW and will meet the performance requirements under the conditions specified.

In writing load specifications for electric sets, it has been traditional to state a certain peak load KW plus a percentage overload. Usually, it is not clear whether this is done in anticipation of a real overload or merely as a safety factor to make sure the load estimate is high enough.

Since overload capacity is not fault protection, what is to be gained by specifying overload? An overload specification can confuse the electric-set supplier because he doesn't know if transient response must be achieved with the overload. Sometimes motors can be overloaded, and this becomes an electric-set overload if it occurs during a peak period. However, if the specified peak load includes an allowance for motor starting power, there already is a margin of capacity in the electric set that might be sufficient for the extra running load of an overloaded motor.

If it is known that a real overload can occur, or if it is anticipated that equipment will be added to the load, allowance for these extra loads should be included in the peak load specification. 100 KW plus 10% overload is 110 KW. In such a case, it is preferable simply to specify 110 KW peak load.

Even without knowing of any possible overload or anticipated added load, the specifying engineer may think that an overload specification will provide excess capacity to insure quality, durability and performance. Or, where the peak load occurs rarely or briefly, it may appear economical to specify a lower KW and depend on an "overload" specification to serve the intermittent peak load. Such methods of specifying load are unnecessary and undesirable. The peak load should be specified at the maximum level that will be encountered, including overload or added equipment load if necessary. Durability and performance are assured by the engine and generator ratings based on peak load and type of service. Economy is assured because both standby and prime power ratings assume that operation at peak load is intermittent. Thus, you get as much engine or generator as you need, with adequate performance and durability, but not wasteful excess capacity.

Performance Margin

The engine must have enough power for the peak load plus an extra margin of power to aid speed recovery after a load transient. The required ratio of rated horsepower to peak KW depends in part on the inherent responsive-

ness of the engine. Since a 2-stroke cycle engine is more responsive than a 4-stroke engine, a 4-stroke engine requires a greater HP-to-KW ratio to recover in a specified time from a specified step load application. This is true for comparable naturally aspirated engines or comparable turbocharged engines.

Therefore do not specify HP-to-KW ratio. Rather, specify the exact peak KW along with transient response requirements and let each supplier determine the HP-to-KW ratio required by the type of engine he proposes to use. Knowing your peak load and performance specifications, the supplier will make sure he has enough engine to do the job.

The required HP-to-KW ratio depends on the specified amount of load that the electric set must accept in one load step and the specified time limit in which it must return to a steady-state frequency. Thus, if the electric set is required to accept the full load in one step and return to a steady-state condition in one second, the HP-to-KW ratio must be greater than if it is only required to accept a half load in one step and recover in two seconds.

The required transient response is established by the type of equipment being powered by the electric set. Some electrical equipment requires closer frequency control than others. The size of load application that must be accepted depends on the type of service. A one-step application of full load is likely to occur in a standby installation unless sequential motor starting or other provisions have been made to prevent an abrupt full-load application after a power outage.

It is desirable to keep the horsepower-to-kilowatt ratio as small as possible to avoid extra initial cost and to improve part-load efficiency. Therefore performance specifications should be no more severe than actually required, and an arbitrary HP-to-KW ratio should not be specified. Let the supplier determine the power margin he needs to give you the performance you need.

Providing for Load Growth

If there is a possibility of adding equipment in the future, you may want to add that into the peak load specification. Bear in mind that usually the peak demand load occurs only for a short interval during a typical 24-hour operating period, and the electric set will be producing less than its rated KW in the off-peak periods. When new electrical equipment is added to the load, it only increases the peak demand if it will come on the line during the peak demand period or if it is large enough to cause an increased peak demand to occur at some other period.

If the anticipated peak demand increase is upwards of 30% of the present peak load, it is in the realm where it may be more economical to install an electric set sized for the present load and leave space for another

electric set to be installed later when the new loads are added. That may not be practical if the loads are to be added gradually. A compromise would be to provide some extra capacity in the present electric set. Then a second set would be added when the load approaches the capacity of the first set. When the second set is installed at some later time, the two sets can be paralleled to the full load circuit, or perhaps one could be connected to the more sensitive circuits while the other serves the balance of the loads.

Improving Load Factor

Operating an electric set at a fraction of its rated capacity is inefficient and may create problems in maintenance of the engine and auxiliaries. Some electrical equipment may not operate full time so that there is seldom a full load on the line. Thus, an electric set installed to serve a 100 KW peak load may operate at 50 KW or less much of the time. If the electric set has a capacity of 150 KW in anticipation of load to be added in the future, it would be operating regularly at one-third or less of its rated capacity. This is uneconomical both in operating cost and in use of the investment. It would be preferable in such a case to install a 100 KW or 110 KW electric set for the present loads and leave space in the generator room for future installation of a 40 KW or 50 KW electric set. In stand-by applications, the need for extra capacity for a second set can be avoided by not connecting the extra equipment to the emergency bus.

When a standby electric set serves an emergency circuit and not the total building load, its load factor can be raised during low-load periods by connecting it to other circuits. Either an artificial supplemental load or one or more circuits within the building can be equipped with manual or automatic transfer switches, and these circuits are thrown on the line when the load on the primary circuit is low. The artificial supplemental load is disconnected when the real load increases.

A way of providing efficient part-load operation is to use two paralleled electric sets, one for normal off-peak loads and a smaller set that comes on the line during peak load periods. Depending on the relative size of the minimum, normal and peak demand loads, the smaller auxiliary set may be able to operate during the minimum load period, permitting the master unit to shut down.

Since the master unit does not have to be large enough for the peak demand period, it operates efficiently at a high load factor during the normal part-load periods. The smaller auxiliary set operates efficiently at a high load factor when serving the minimum load demand. Even if the auxiliary set has excess capacity to allow for future increased peak load, so that its efficiency is somewhat reduced, the effect on kilowatt-hour cost is minor because this set produces the smaller fraction of the power and also operates for a smaller fraction of the total operating time.

Generator

A diesel-electric generating set may be equipped with either an A.C. or D.C. generator. However, since A.C. power is the most common, the usual diesel-electric set employs an A.C. generator. Therefore, the following descriptions and comments apply to A.C. generators -- or, as they are commonly called, alternators. The words "alternator" and "generator" are used interchangeably.

Generators are manufactured in a variety of nominal sizes and ratings suited to a wide range of voltages and loads. A generator can be built to match the exact requirements of an application, including different voltages, both single-phase and polyphase, all drawn off one generator. Complex loads can be connected to a generator in different ways such as line-to-line, line-to-neutral, half line-to-line; etc., or transformers can be employed, so that each load is served with its proper voltage and phase. Voltage can be regulated so that the sensitive loads are not affected by other loads served by the same generator.

If the public utility power adequately serves all loads by furnishing certain minimum voltages at the load bus, then a properly regulated standby generator should serve these loads adequately by furnishing the same voltages at the same point. Most generators have a range of voltage adjustment so that voltage at the generator can be adjusted to compensate for voltage drop in the leads from the electric set to the load circuit breaker. Thus the desired voltage at the load bus can be furnished, provided the maximum voltage capability of the generator is sufficient.

It should be remembered that an engine-driven generator is not an infinite bus. It has a maximum KVA capacity. It will exhibit voltage and frequency deviations during load transients. But its performance can be made suitable for any application. You can get the performance you require by specifying performance. Knowing voltage requirements of electrical

equipment and the line drops, the voltages required at the generator can be specified along with limits on voltage dip and recovery time. This information plus peak load and motor sizes will enable the electric-set manufacturer to recommend a generator and voltage regulator that will meet the load and transient performance requirements.

Desired performance can be achieved without excessive generator cost by avoiding load conditions that burden the system unnecessarily. For example, performance can be improved or size and cost reduced by avoiding across-the-line starting of large motors or by avoiding simultaneous starting of several motors.

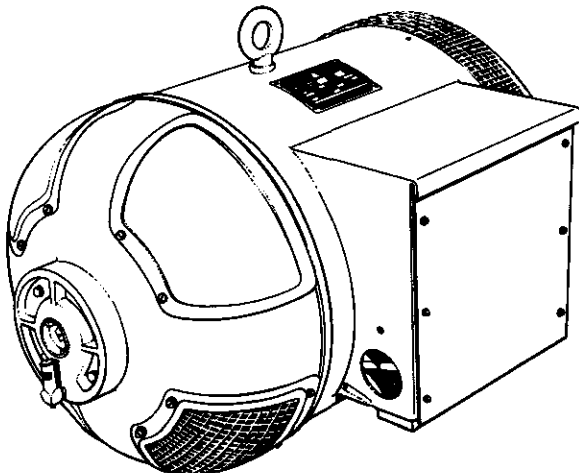
Alternator Configuration

For reasons of efficiency and economy, the typical modern alternator has a rotating field, and the power-generating coils are stationary. Thus the field is

Table 3-2 Synchronous Speeds of Alternators

No. of Poles	60 Hertz RPM	50 Hertz RPM	400 Hertz RPM
2	3600	3000	24,000
4	1800	1500	12,000
6	1200	1000	8000
8	900	750	6000
10	720	600	4800
12	600	500	4000
14	514	429	3429
16	450	375	3000
18	400	333	2667
20	360	300	2400
22	327	273	2182
24	300	250	2000
26	277	231	1846
28	257	214	1714
30	240	200	1600
32	225	188	1500
34	212	176	1412
36	200	167	1333
38	190	158	1264
40	180	150	1200

Figure 3-1. Typical Alternator



$$\text{Synchronous Speed} = \frac{120 \times \text{Frequency}}{\text{No. of Poles}}$$

$$\text{One Hertz Equivalent RPM} = \frac{\text{Full-Load RPM}}{\text{Full-Load Frequency}}$$

EXAMPLE:

$$\text{One Hertz Equivalent RPM} = \frac{1800 \text{ RPM}}{60 \text{ Hertz}} = 30 \text{ RPM/Hertz}$$

If the frequency-control governor is the droop type, the droop adjustment should be set so that the No-Load Speed is in the range of 3—5% above the Full-Load Operating Speed. This range provides satisfactory governor stability.

referred to as the rotor, and the armature is the stator. Rotation of field flux past the stationary armature coils generates a voltage in the power leads from the armature. To supply rated voltage under all operating loads, there must be adequate flux and this is maintained by supplying direct current to the field coils by means of an exciter. The exciter may be static, or it may be a small rotating generator.

Alternator Speed and Frequency

An alternator operates at a single "synchronous" speed to produce a specified alternating current frequency. The unit of frequency is Hertz (hz), which is the same as cycles per second (cps). The universal frequency in the United States and most of Canada is 60 cycles per second (60 hz). In part of Canada and overseas, the standard frequency of A.C. service is 50 cycles per second (50 hz). For communications, radar or aircraft applications, a frequency of 400 hz is used.

The frequency of an alternator's output depends on the rotating speed and the number of poles. Table 3-2 shows synchronous speeds for 50, 60 and 400 hz frequencies related to the number of poles in the alternator. A typical aircraft ground power alternator has 24 poles and rotates at 2000 rpm to generate a frequency of 400 hz.

In standby electric sets, the usual alternator has 4 poles and rotates at 1800 rpm to generate 60-cycle current or at 1500 rpm for 50-cycle service. By using a 6-pole alternator, it is possible to generate these frequencies at 1200 and 1000 rpm, respectively. But a 6-pole alternator is larger and more complex, and the slower speed requires a larger engine, making the electric set larger and heavier. Moreover, in applications where motor starting becomes a determining factor in required generator capacity, 6-pole alternators must have greater KVA capacity than 4-pole alternators. For maximum efficiency and lower weight per KW,

Detroit Diesel-powered electric sets are designed to operate at their continuous rated speed of 1800 rpm for 60 hz and 1500 rpm for 50 hz.

Frequency deviates briefly from standard when load is applied to or removed from the generator. If the load includes computers or other critical time-oriented equipment, such frequency deviations must be limited to a fraction of a percent. Frequency control is a function of the speed-regulating governor that controls speed of the engine. The required frequency performance should be specified in terms of regulation and transient response. This is explained in a later chapter on FREQUENCY CONTROL.

Exciter

Included as part of the generator package is an exciter, which supplies direct current to the generator field windings to magnetize the rotating poles. One type of exciter is a small rotating alternator with a rotating rectifier that is direct-connected to the rotor shaft of the generator. The exciter field is stationary, and its armature rotates.

The exciter output is controlled by a voltage regulator, which diverts current from the power generator output, rectifies it and supplies it to the exciter field. When there is any variation in power generator voltage, the voltage regulator changes exciter field current, causing the exciter to increase or decrease generator field current to maintain rated voltage.

The exciter with rotating rectifier does not require brushes to connect exciter output to the generator field since the field, rectifier and exciter armature rotate together as a unit. A generator equipped with this type of exciter is referred to as a "brushless generator". This system replaces brushes, brush holders, commutators and slip rings, thus reducing maintenance and radio noise while improving reliability.

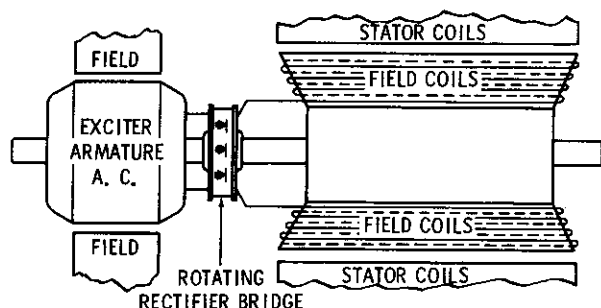


Figure 3-3. Brushless Excitation System

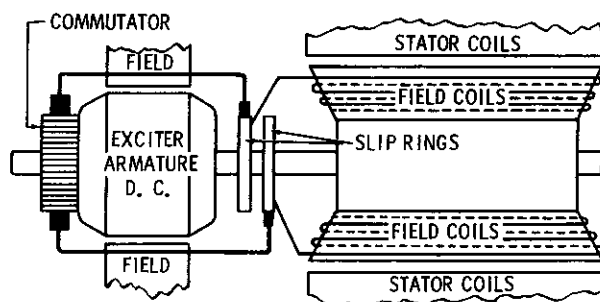


Figure 3-4. Stationary Brush-type Excitation System

Other types of exciters are static exciters and small rotating D.C. generators. Both require brushes. A static exciter incorporates a static voltage regulator and a static amplifying section and thus has no moving parts. It rectifies current drawn from the power generator output and supplies it directly to the generator field. A static exciter thus performs the function of a voltage regulator as well as an exciter and is properly called an exciter-regulator. In the past, static exciters offered performance advantages. However, with the development of new features, the performance of brushless generators is now claimed to equal or exceed that of static-excited generators.

When a generator first begins to rotate, it depends on residual magnetism in its field poles to generate enough voltage to excite the field of the exciter so the latter can generate excitation current for the field of the power generator. By this means, both fields build up until the power generator is producing its rated voltage. If there is not enough residual magnetism to get this cycle started, "field flashing" must be employed. If the exciter is the rotating type, a battery or other power source is connected to the exciter field to give it enough initial strength so the exciter can begin to build up the field strength of the power generator. If the exciter is the static type, the battery is connected to flash the field of the power generator. The flashing power source is disconnected after generator voltage rises to some predetermined percentage of rated value.

Generator Cooling and Protection

Generator copper and iron core losses are converted into heat. Copper losses are I^2R losses and vary with load. Core losses vary with voltage, but not with load. Winding temperature depends on the ambient temperature plus the temperature rise caused by the copper and core losses. To keep winding temperatures below a level that would shorten insulation life, a

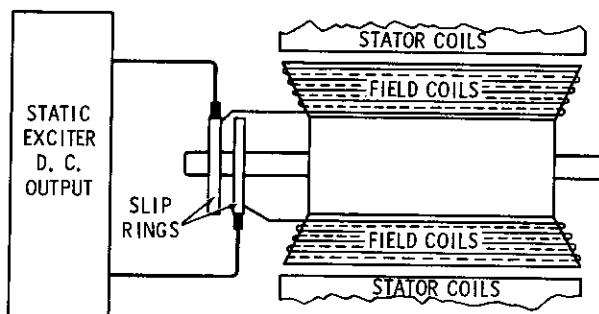


Figure 3-5. Static Excitation System

generator is equipped with a fan that draws air into the generator housing at one end and expels it at the other.

An open-ventilated generator has large air openings at each end and minimum flow restriction. In an open-guarded generator, the air openings are covered by screening. A drip-proof generator has its ventilation openings so constructed that drops of liquid falling on the generator will not enter the housing if they fall at an angle not greater than 15 degrees from vertical. A generator may be totally enclosed so that air, water or dust cannot enter. In this case, the fan draws cooling air through an enclosed space around the outside of the housing, or the generator is liquid-cooled.

The open-ventilated or open-guarded types cost less and are easiest to cool, but should only be used in a clean environment where there is little chance that dust or liquid will enter the generator. The totally enclosed type provides the most protection from water, dirt and foreign materials, but it is most expensive to cool. So it should only be specified where necessary.

Generators operating in the tropics are apt to encounter excessive moisture, high temperature, fungus, vermin, etc. Such conditions may require special tropical insulation or a preservative on the windings.

Standby generators operating in the tropics should have electrical heaters to keep windings dry.

Generator Rating

The rated capacity of a generator is stated on the nameplate in terms of KW, KVA, voltage, power factor and temperature rise. The KW rating is established by the peak demand. The KVA rating on the nameplate corresponds to the rated KW and power factor. In some cases, to meet voltage transient

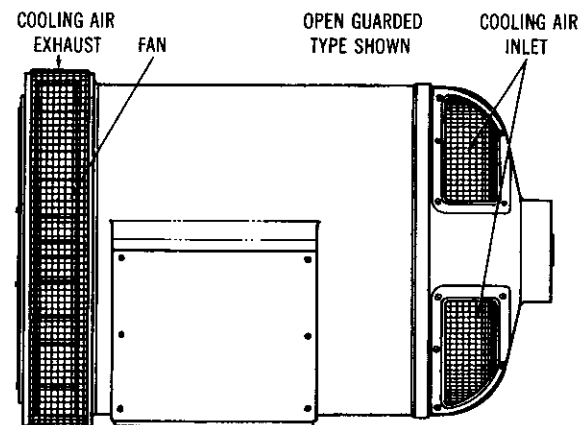


Figure 3-6. Generator Ventilation