

COMPONENT SPECIFICATIONS (Continued)

REMOTE CONTROL MASTER CYLINDER

Type	Positive Displacement
No. Pistons	One
Displacement Per Stroke	1.2 Cu. In.
Port, Outlet	7/16 - 24 Inverted Flare Tap
Weight	5 Lbs.

FILTER

Type	Sediment Bowl - Stacked Disc
Degree of Filtration	50 Microns
Ports, Inlets	1/8 NPTF
Outlets	1/8 NPTF

PERFORMANCE

The following figures give pertinent information on the performance of component items of the Hydrostarter system.

The accumulator fluid stored vs. nitrogen precharge pressure is indicated in Figure 11. With an initial nitrogen precharge pressure of 1250 psi, and the 1-1/2 gallon accumulator, 100 cubic inches of fluid is stored at 1800 psi pressure and 185 cubic inches is stored at 3000 psi pressure.

The effect of ambient temperature on nitrogen precharge pressure is indicated in Figure 12. An original nitrogen precharge pressure of 1500 psi at plus 70° F will decrease to 1300 psi at zero degrees F.

The starter torque vs. rpm is indicated in Figure 13 for the "20" and "35" series Hydrostarters where they are run as motors only with a constant input potential. The "35" series starter develops 80 ft. lbs. of torque at 1750 rpm and an input potential of 2000 psi.

The starter torque vs. peak starter speed for both the "20" and "35" series starters is indicated in Figure 14.

The estimated percent of engine cranking torque vs. ambient temperature for various weights of engine oil is indicated in Figure 15. Note that at plus 10° F less torque is required when using SAE 10W oil than when using SAE 20 oil. It is advisable, therefore, to use the lightest weight oil recommended by the engine manufacturer for the specific engine and application in order to achieve the fastest start.

Cranking Curves

Figures 16 through 22 indicate cranking speed versus time for typical 2, 3, 4, 6-71 inline, 6V, 8V, 12V-71, 6-110 and 4-53 engines with the accumulator and conditions noted.

Typical Cold Weather Starting Curves

Figures 23 through 28 indicate typical cold weather starting of the various engines noted using an ether starting aid.

Engine Driven Charging Pump

The upper portion of Figure 29 indicates the efficiency versus the pressure of the pump. The lower portion of Figure 29 indicates the horsepower versus the pressure of the pump.

Technical drawing of a pump assembly, showing a front view and a side view. The drawing includes the following dimensions and annotations:

- Dimensions:**
 - Top view (front view):
 - Overall width: $3\frac{13}{16}$ MAX.
 - Overall height: $2\frac{1}{16}$
 - Mounting hole spacing (center-to-center): $2\frac{1}{16}$
 - Mounting hole diameter: $\frac{1}{4}$
 - Flange thickness: $\frac{1}{2}$
 - Drain hole diameter: $\frac{1}{8}$
 - Side view:
 - Overall width: $2\frac{1}{16}$
 - Overall height: $2\frac{1}{16}$
 - Mounting hole spacing (center-to-center): $2\frac{1}{16}$
 - Mounting hole diameter: $\frac{1}{4}$
 - Flange thickness: $\frac{1}{2}$
 - Drain hole diameter: $\frac{1}{8}$
- Annotations:**
 - "HANDLE MAY BE POSITIONED AS SHOWN TO SUIT INSTALLATION" (with a 20° angle indicated).
 - "ALTERNATE DRAIN POSITION" (pointing to a hole on the side view).
 - "TO REDUCE DIA OF MOUNTING HOLES FROM $\frac{21}{32}$ TO $\frac{13}{32}$ USE BUSHING 632597" (pointing to the mounting holes).
 - "FLANGE CAN BE ROTATED IN 30° INCREMENTS" (pointing to the flange).

3.25

3.1° MAX.

7/8

6 1/32

.520

4 1/32 MAX.

16°

4 1/32 MAX.

3 3/32

3.77

5.17

14.42

2

TO RING GEAR

ALTERNATE POSITION DRAIN FITTING

PRESSURE FITTING # 8 J.I.C. THD.

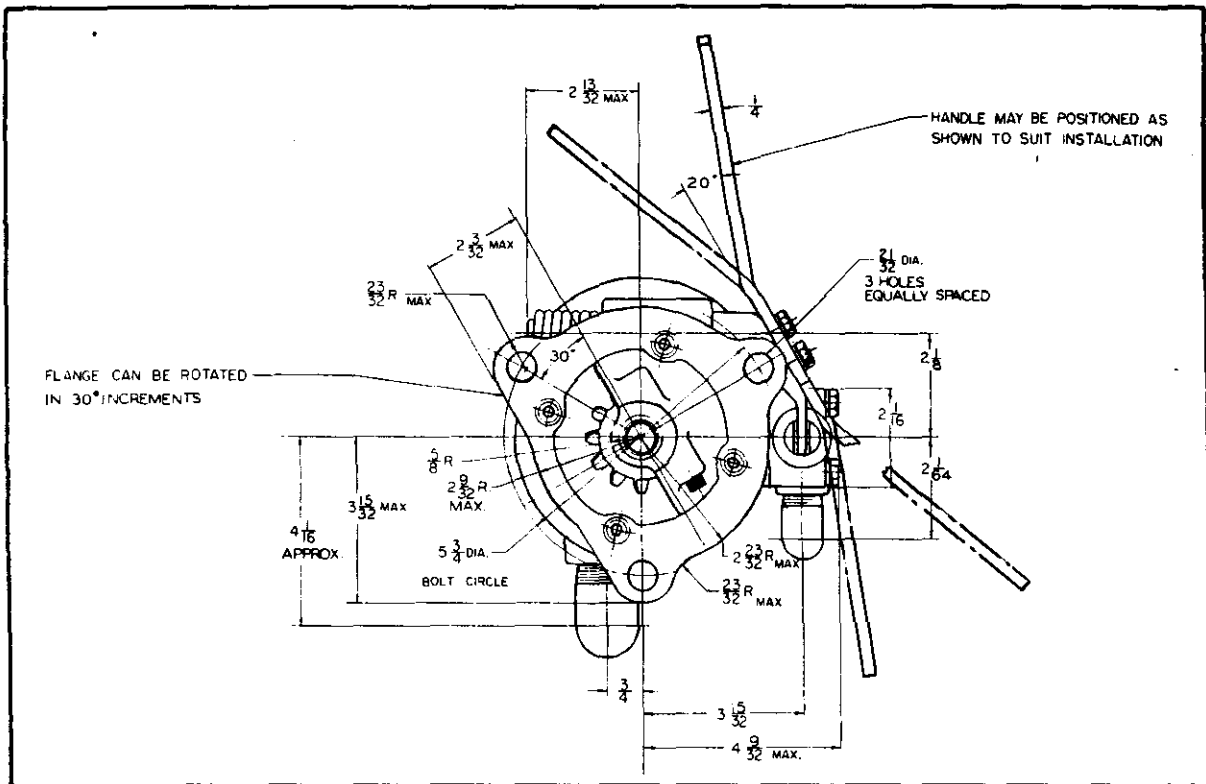
DRAIN FITTING # 10 SAE THD.

APPROX. WEIGHT 26 LBS.

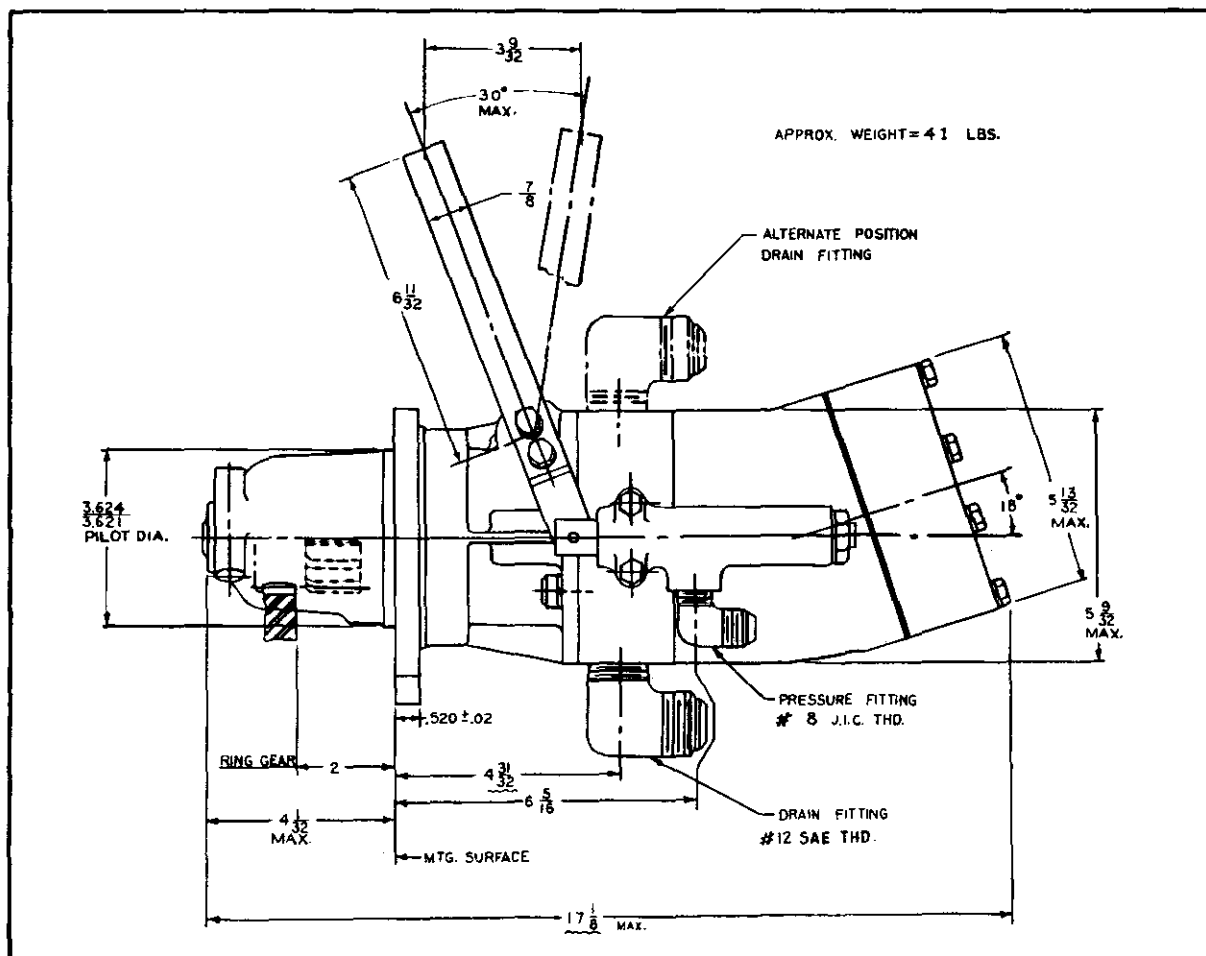
ENGINEERING - TECHNICAL DATA DEPT.

S3-59-4
8-28-59

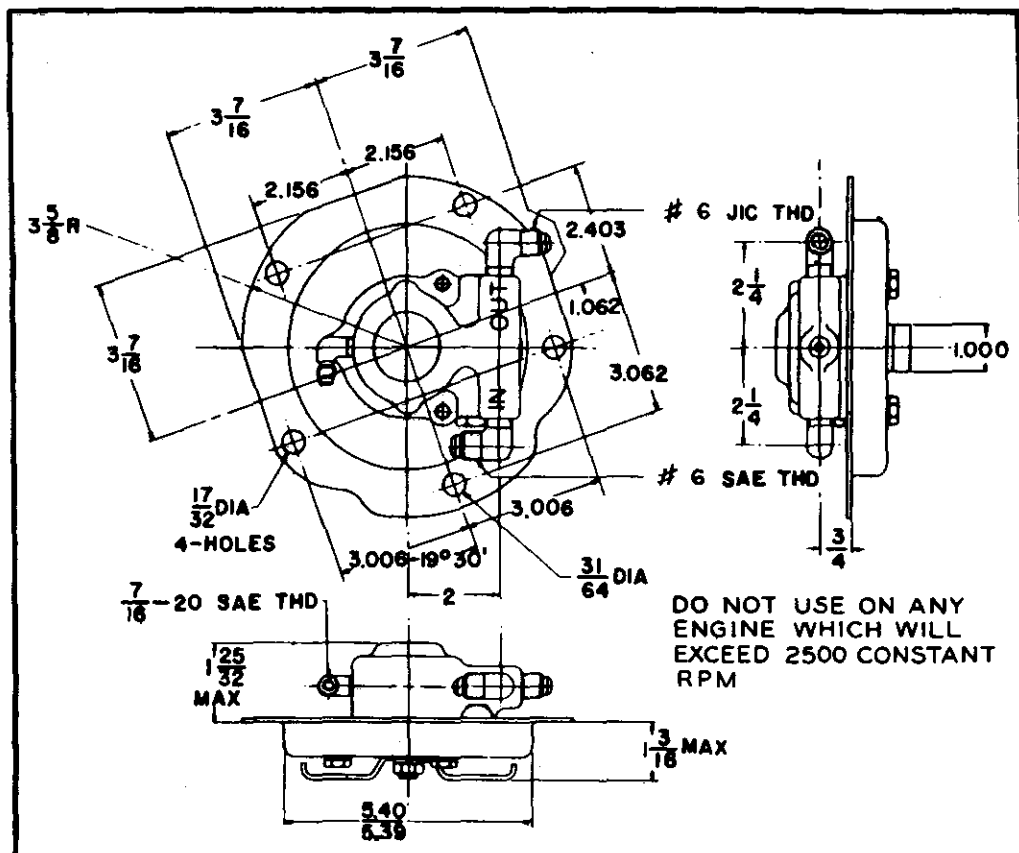
SERIES 35 STARTING MOTOR



END VIEW



SIDE VIEW



ENGINE
DRIVEN
PUMP

SHAFT
DRIVEN

PART NO.
6505004

ENGINE
DRIVEN
PUMP

BELT
DRIVEN

PART NO.
6505030

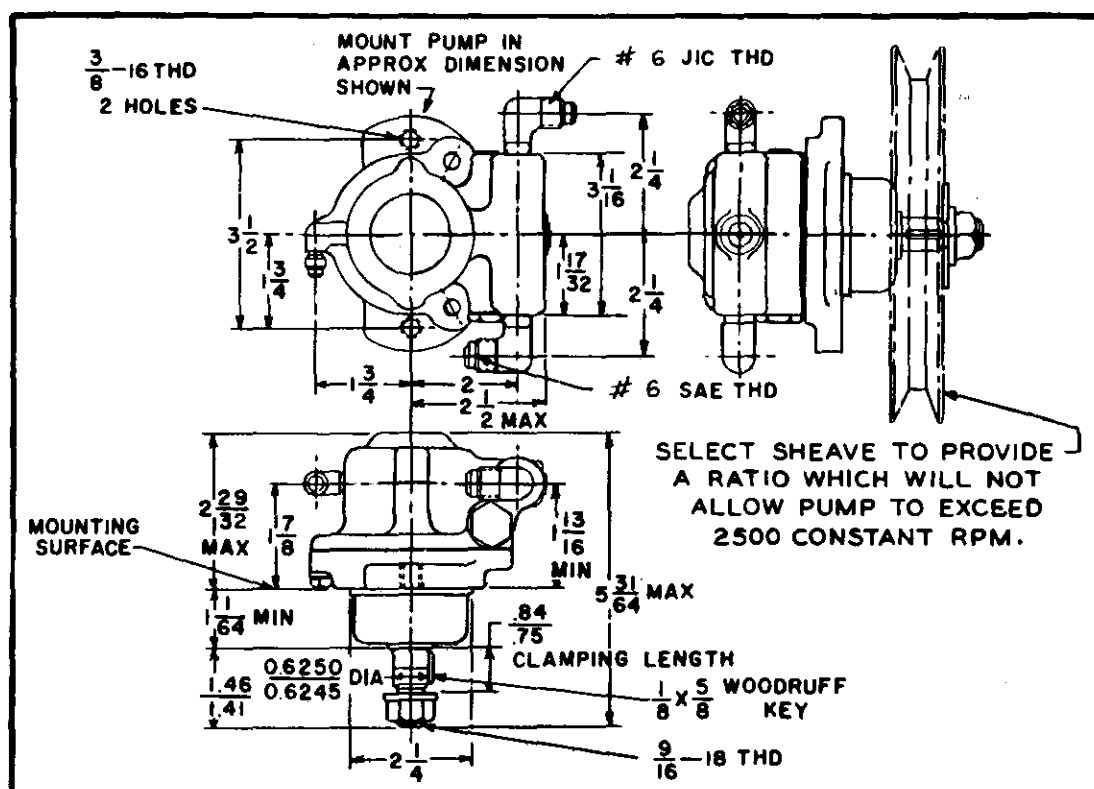
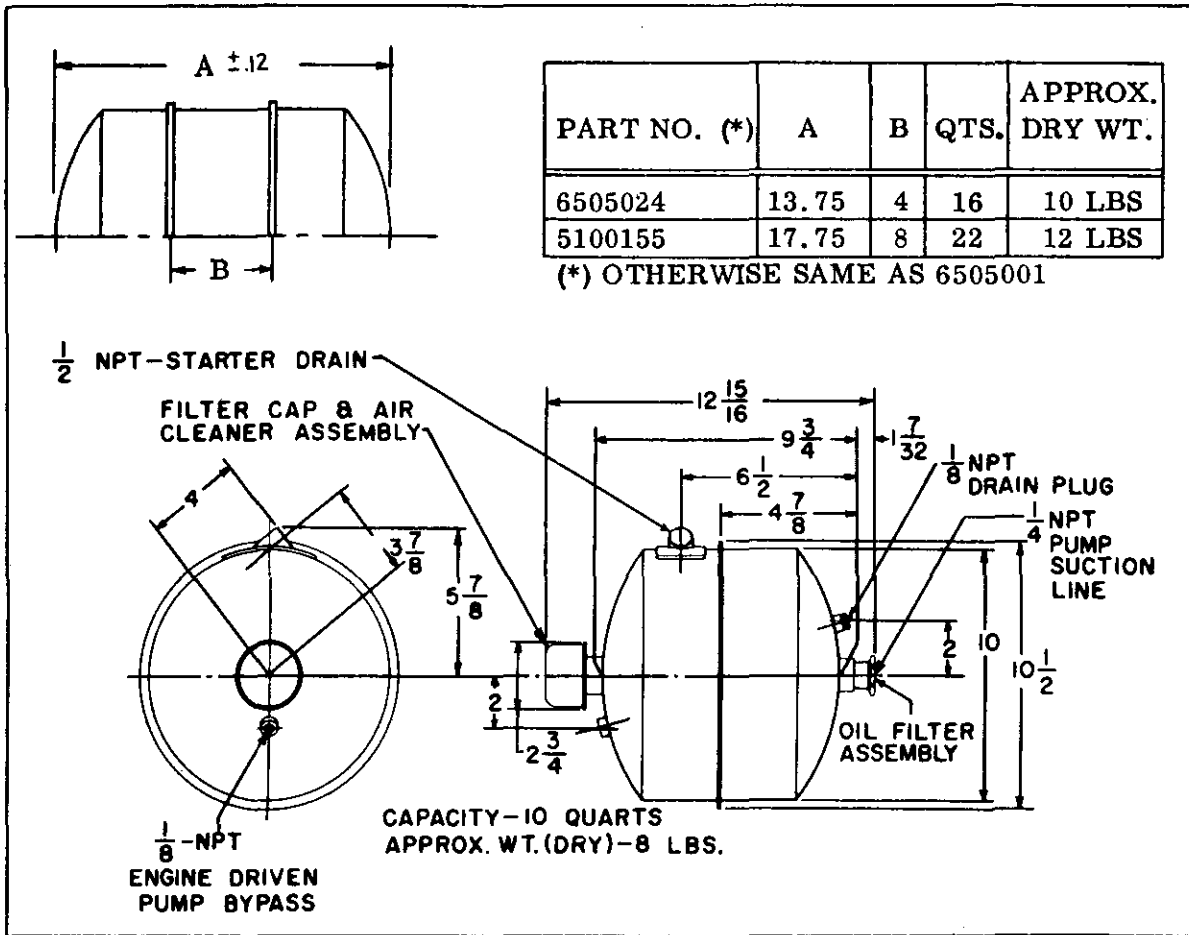
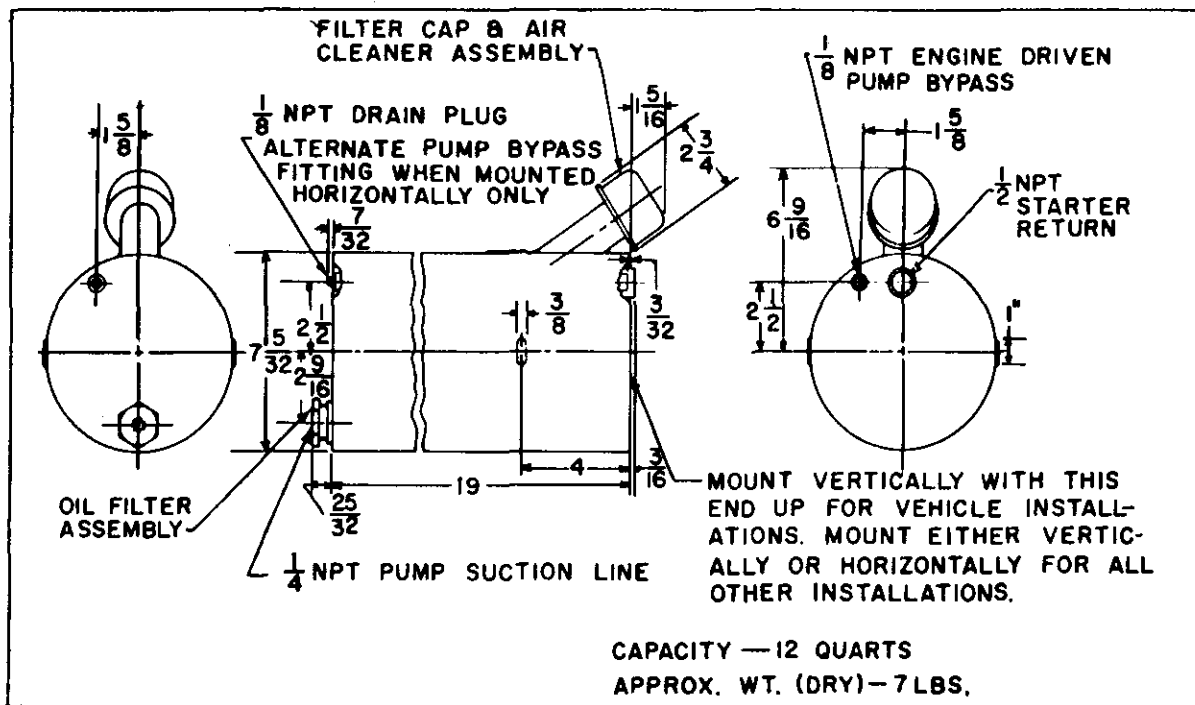


FIGURE 6

RESERVOIRS

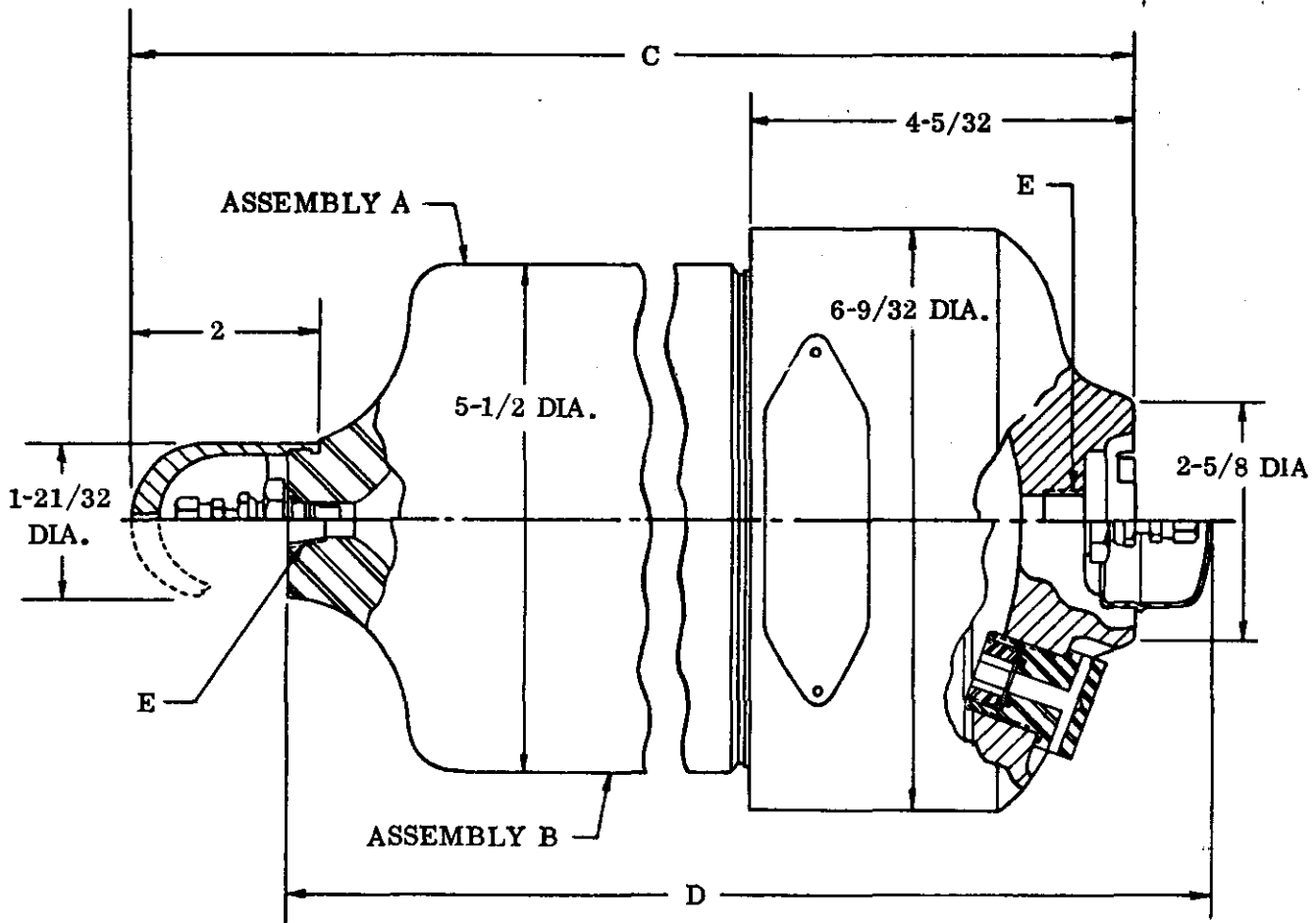


6505001



6505033

A C C U M U L A T O R A S S E M B L Y



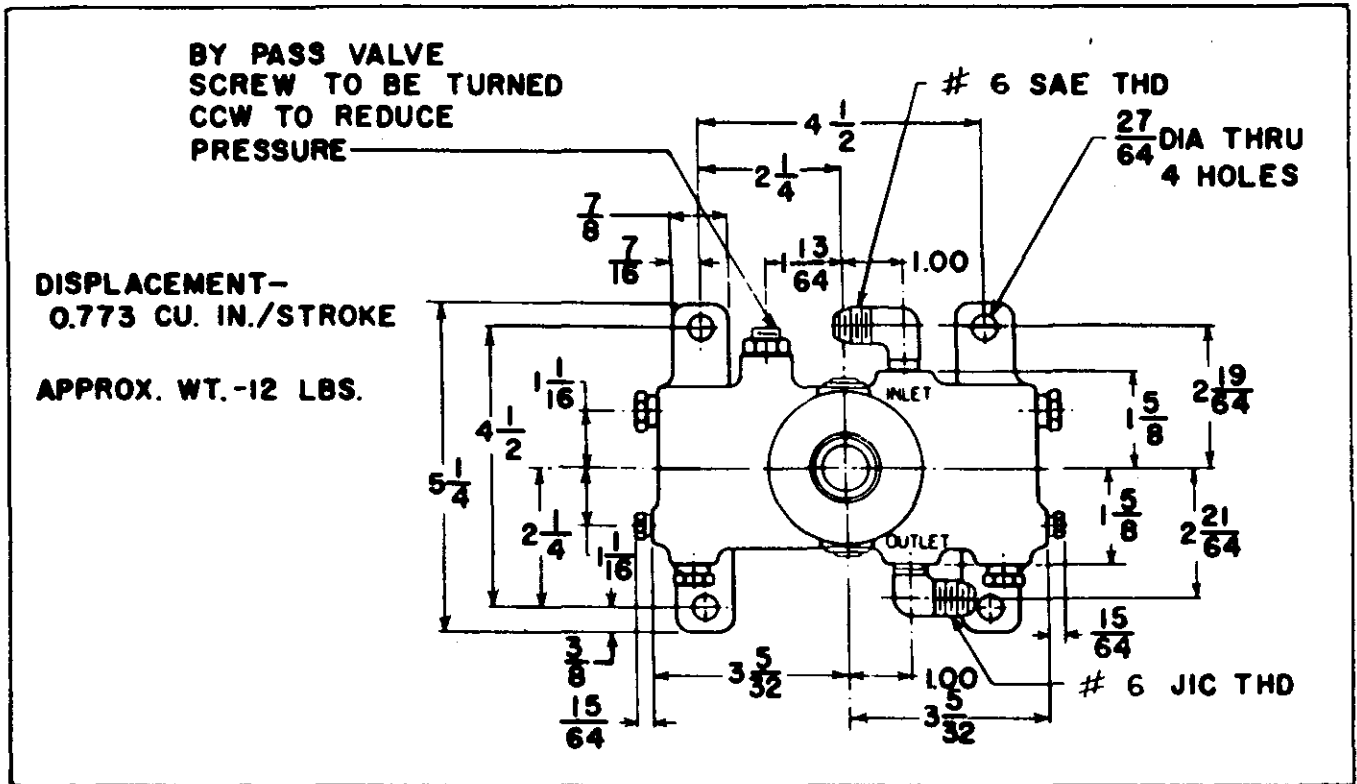
ASSEMBLY NO.		CAPACITY QTS.	DIMENSION		E DRYSEAL THD.	WEIGHT LBS.
A	5125521	1-1/2	C	26-1/4	3/8 N.P.T.F.	57
A	5125522	2-1/4	C	35-1/4	3/8 N.P.T.F.	73
A*	5128337	1-1/2	C	26-1/4	3/8 N.P.T.F.	57
A*	5128338	2-1/4	C	35-1/4	3/8 N.P.T.F.	73
B**	5127974	2-1/4	D	34-1/2	3/8 N.P.T.F.	73

* U.S. COAST GUARD APPROVED.

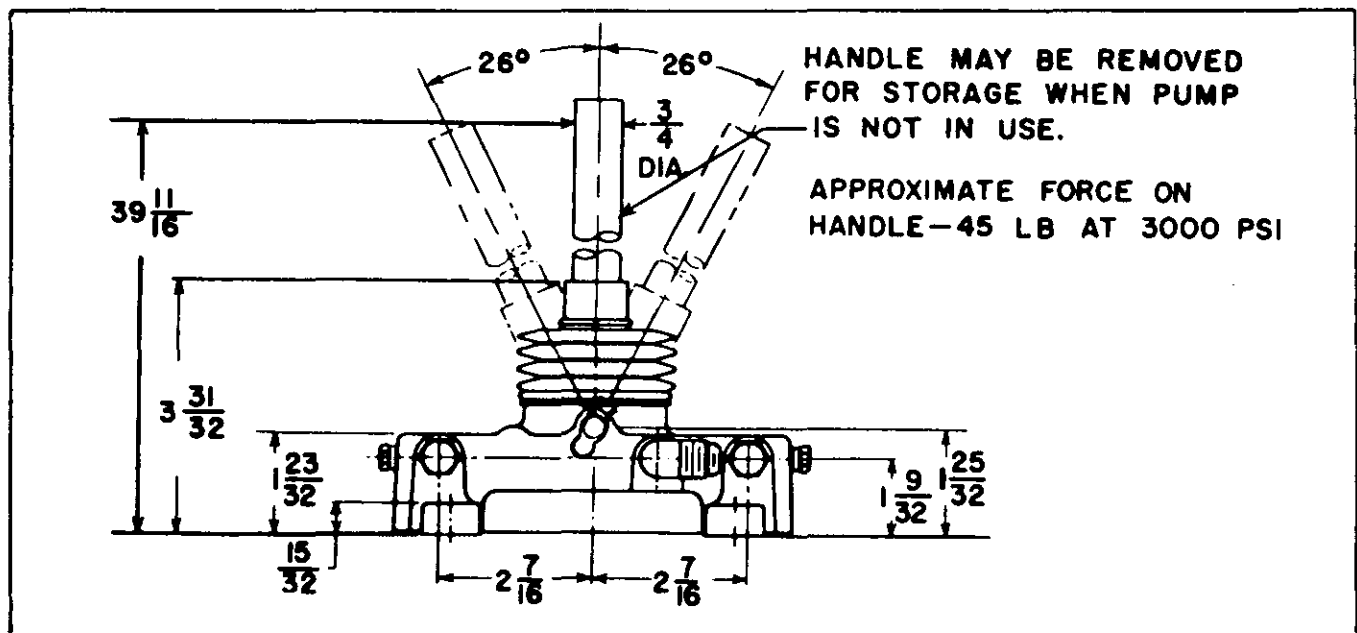
** LLOYDS OF LONDON APPROVED.

FIGURE 8

HAND PUMP



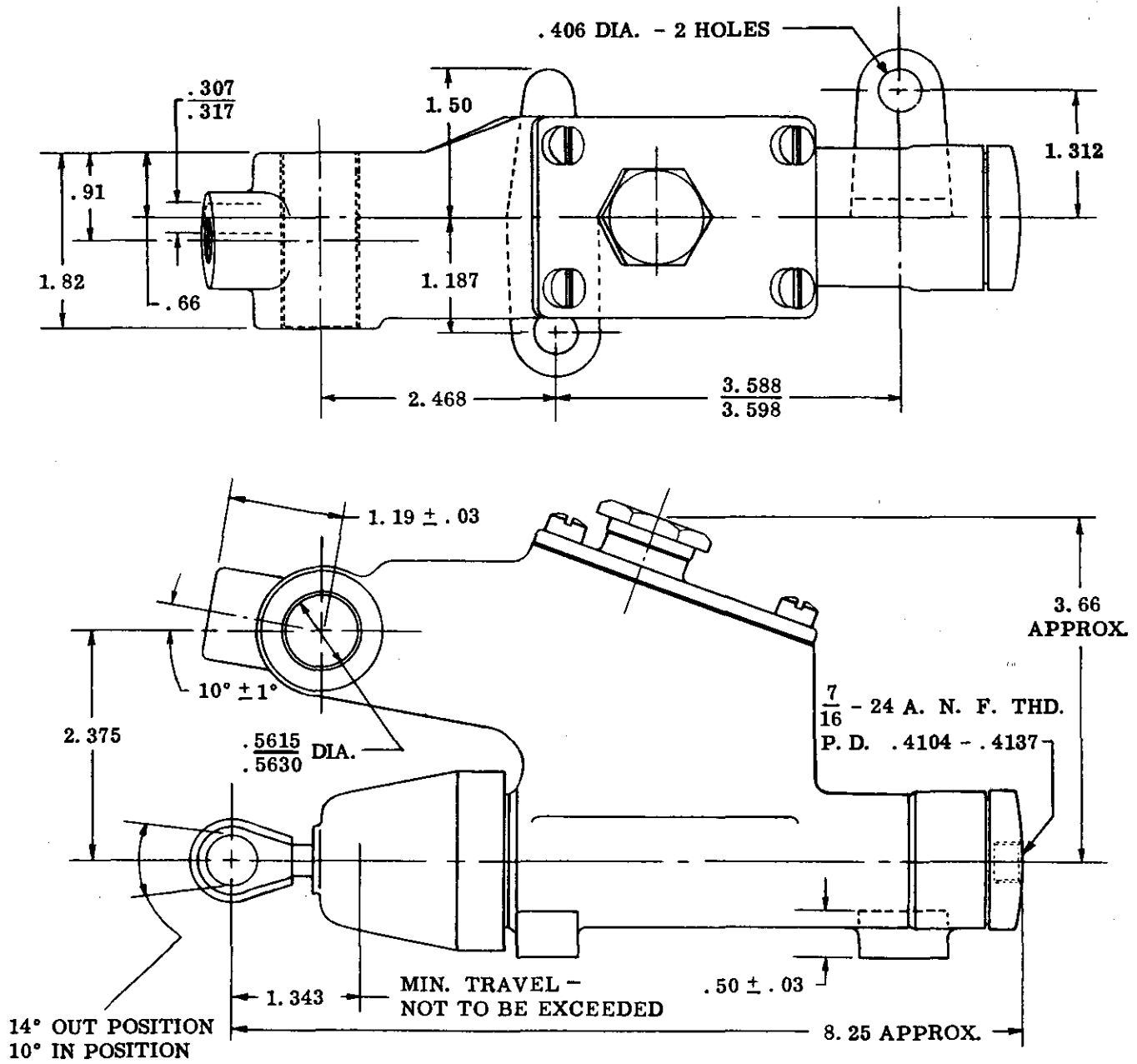
TOP VIEW



SIDE VIEW

FIGURE 9

MASTER CYLINDER





DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

ACCUMULATOR PRESSURE VS. USEFUL FLUID

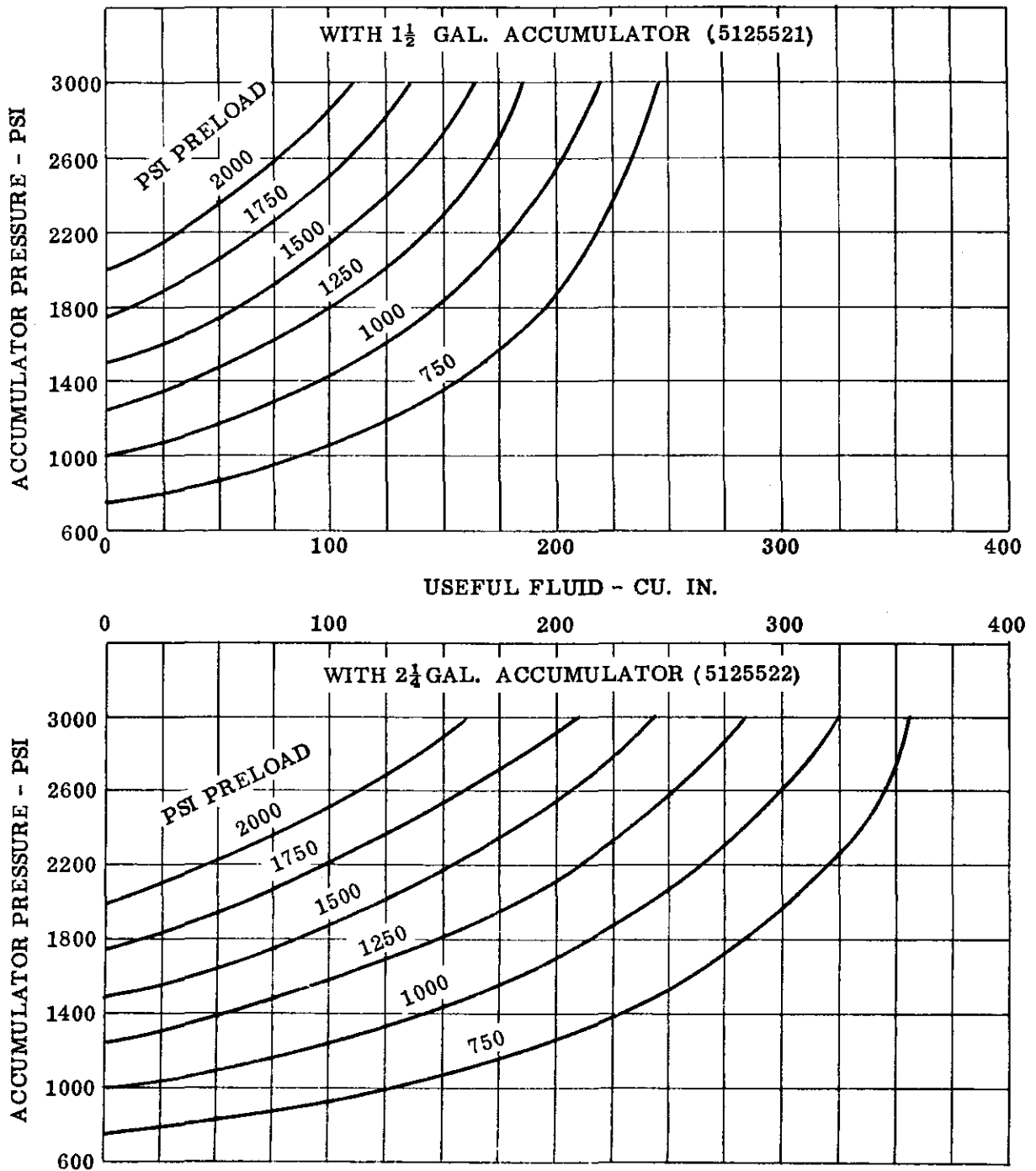


FIGURE 11



DETROIT DIESEL ENGINE DIVISION

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NITROGEN PRECHARGE PRESSURE VS. TEMPERATURE

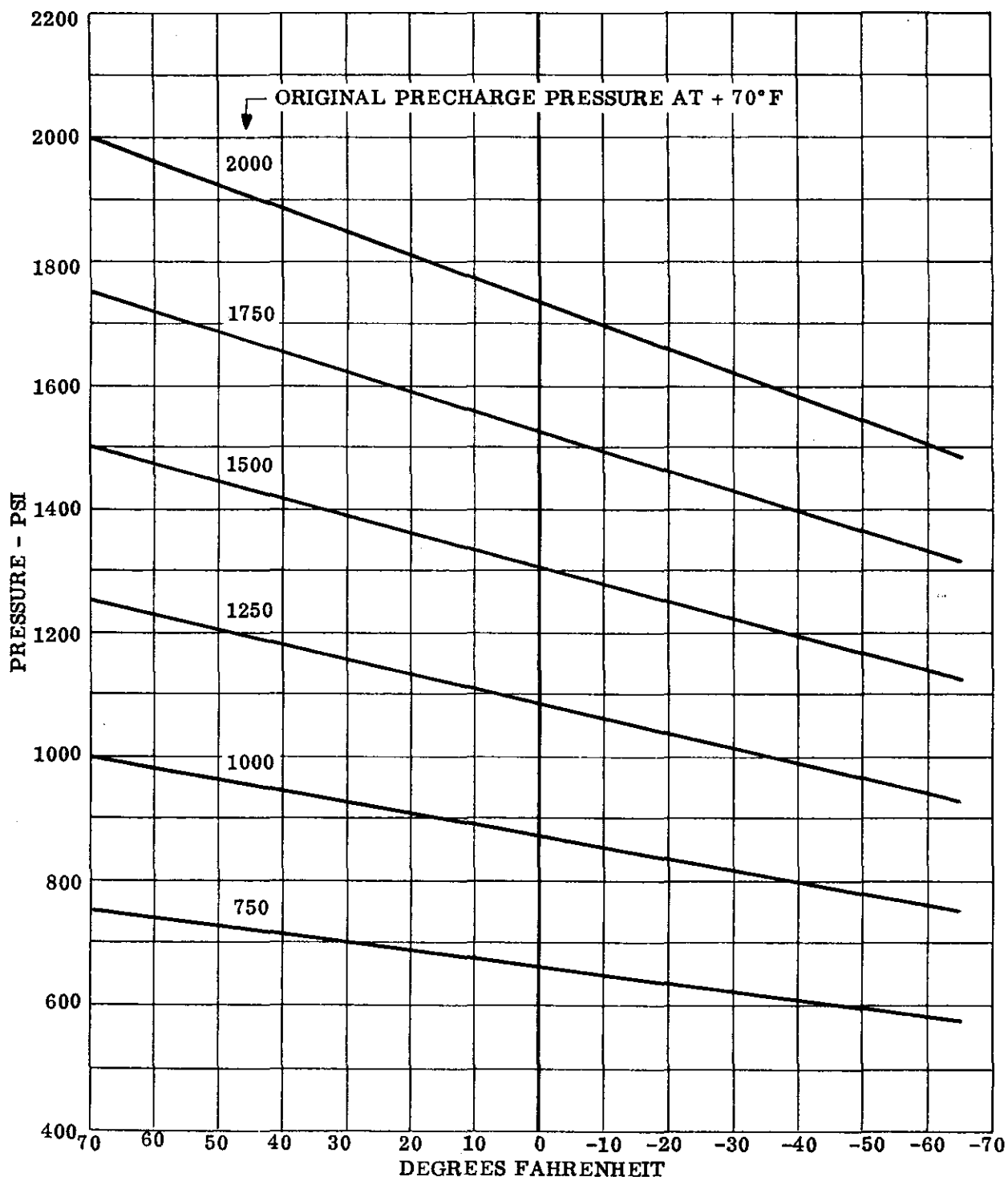


FIGURE 12



DETROIT DIESEL ENGINE DIVISION

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HYDROSTARTER MOTOR PERFORMANCE

— "35" SERIES HYDROSTARTER

- - - "20" SERIES HYDROSTARTER

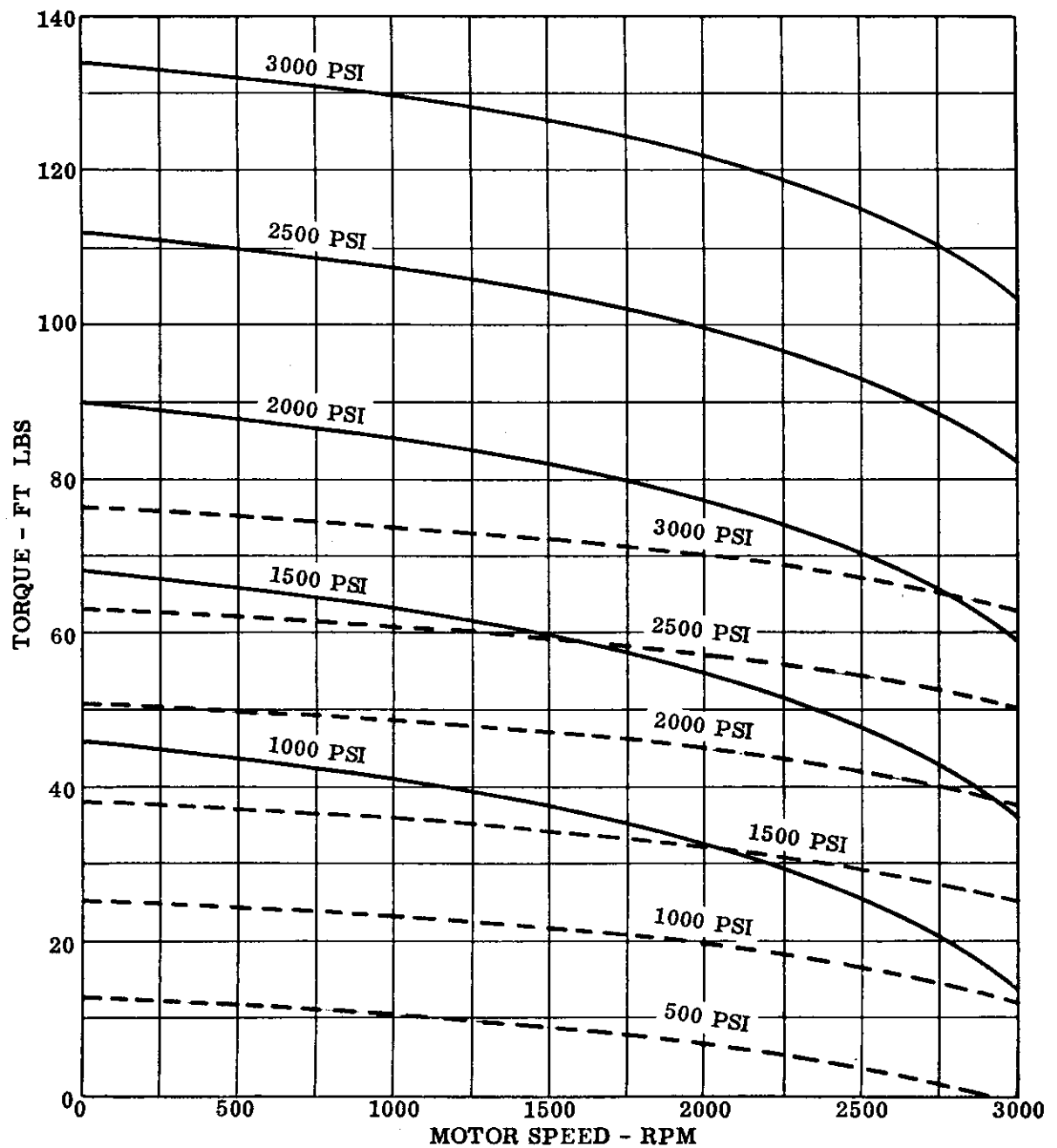


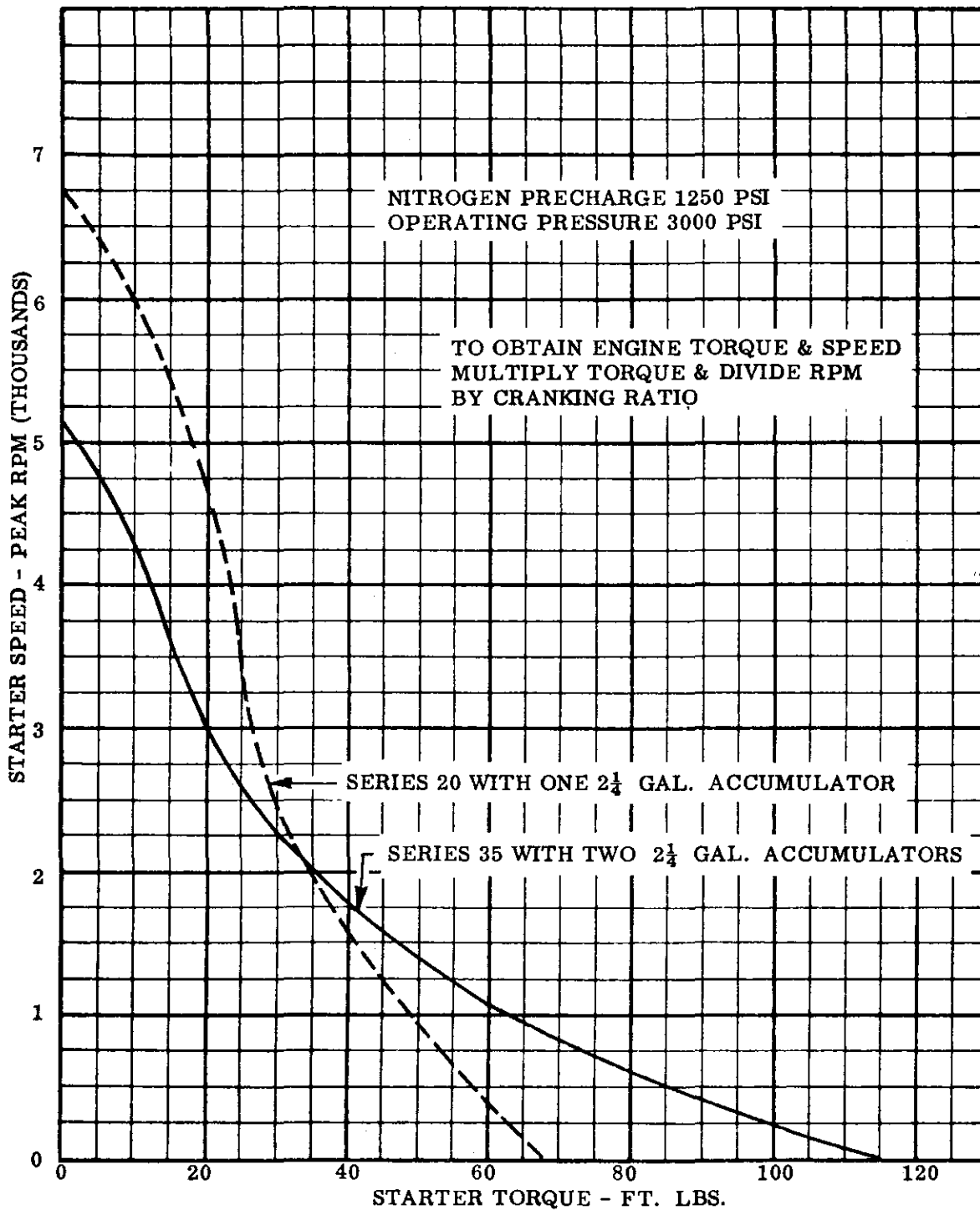
FIGURE 13



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ESTIMATED CRANKING CURVES HYDRAULIC STARTER





DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

ESTIMATED ENGINE CRANKING TORQUE VS. TEMPERATURE

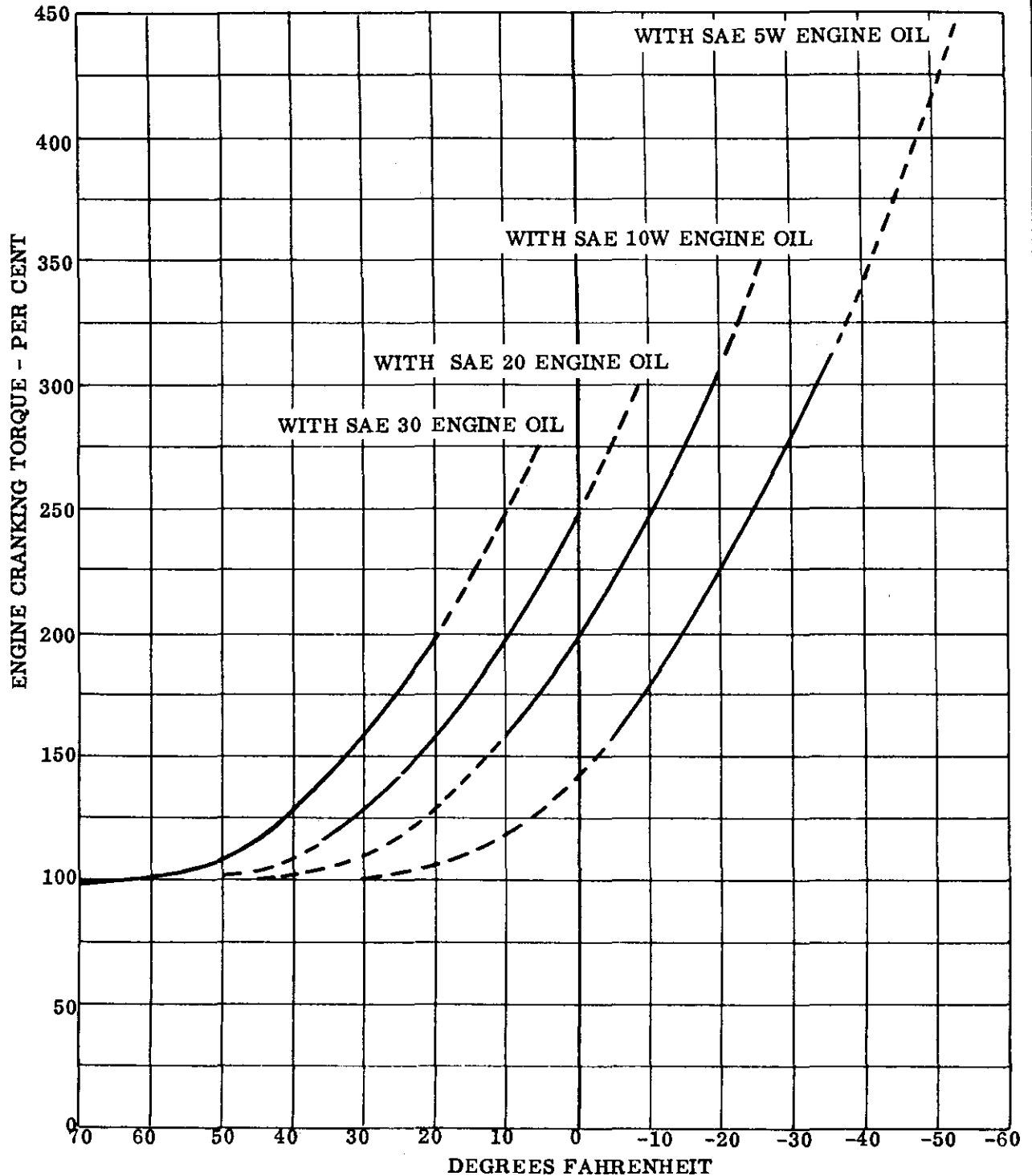


FIGURE 15



DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

2-71 ENGINE STARTING PERFORMANCE
SERIES 20 HYDROSTARTER
CRANKING RATIO 103:11
NITROGEN PRECHARGE - 1250 PSI
AMBIENT TEMPERATURE 85°F

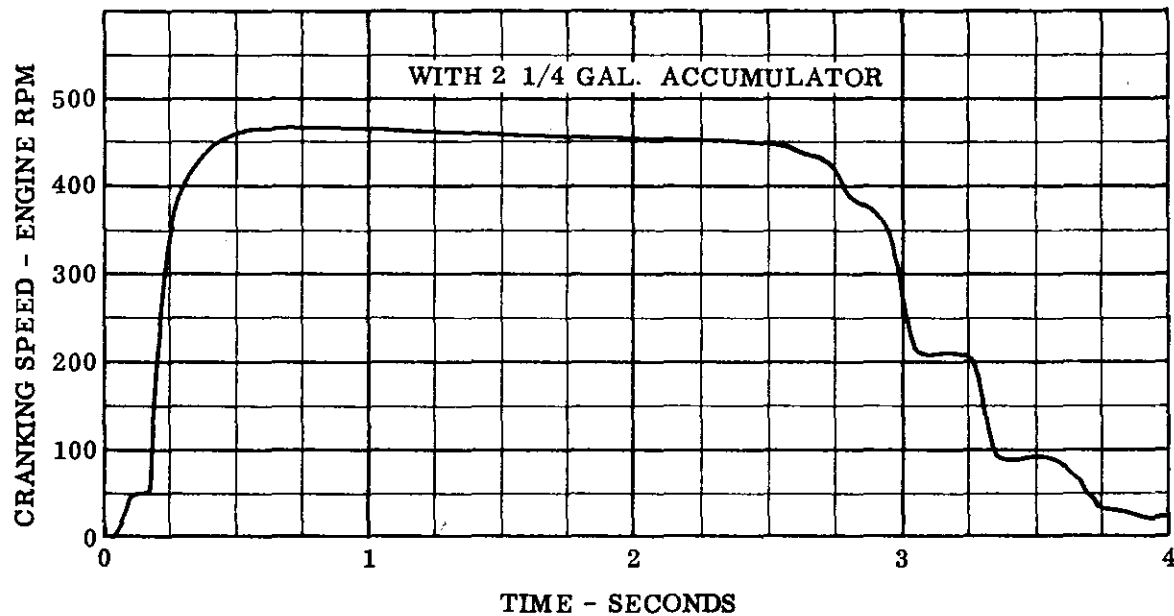
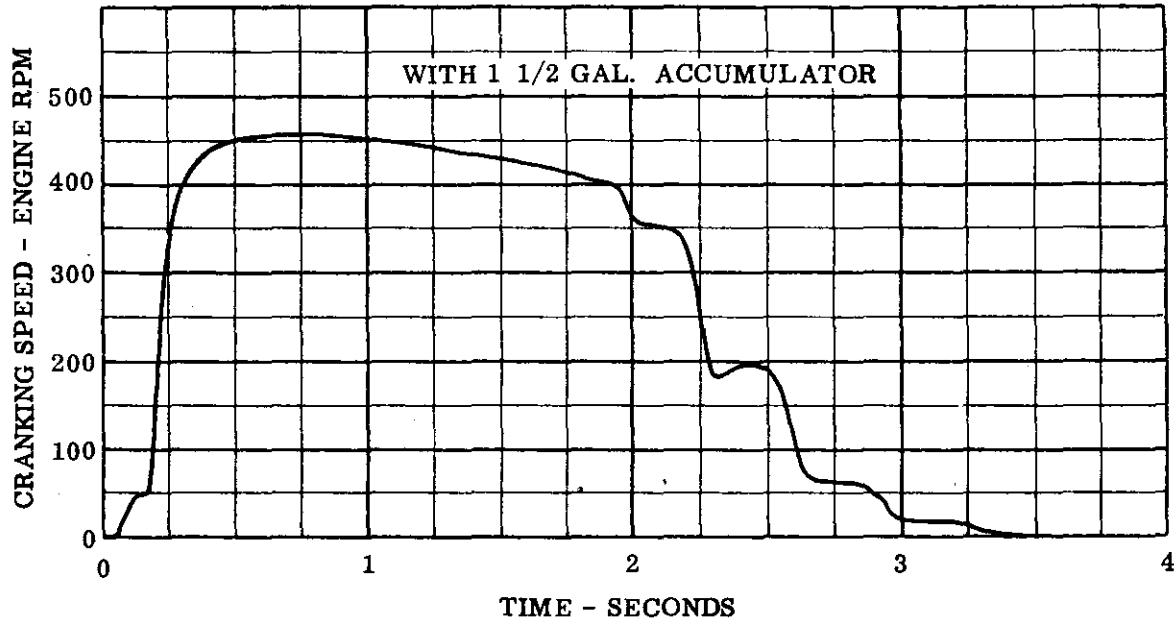


FIGURE 16

S3-59-16
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DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

3-71 ENGINE STARTING PERFORMANCE WITH SERIES 20 HYDROSTARTER
CRANKING RATIO 118:11
NITROGEN PRECHARGE 1250 PSI
AMBIENT TEMPERATURE 78°F

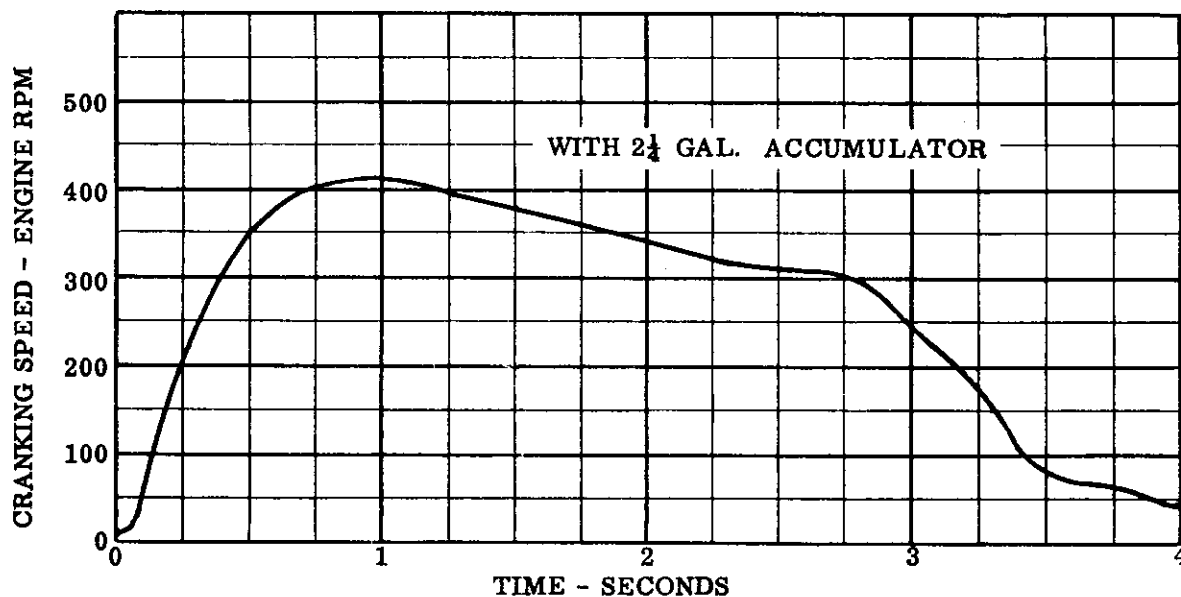
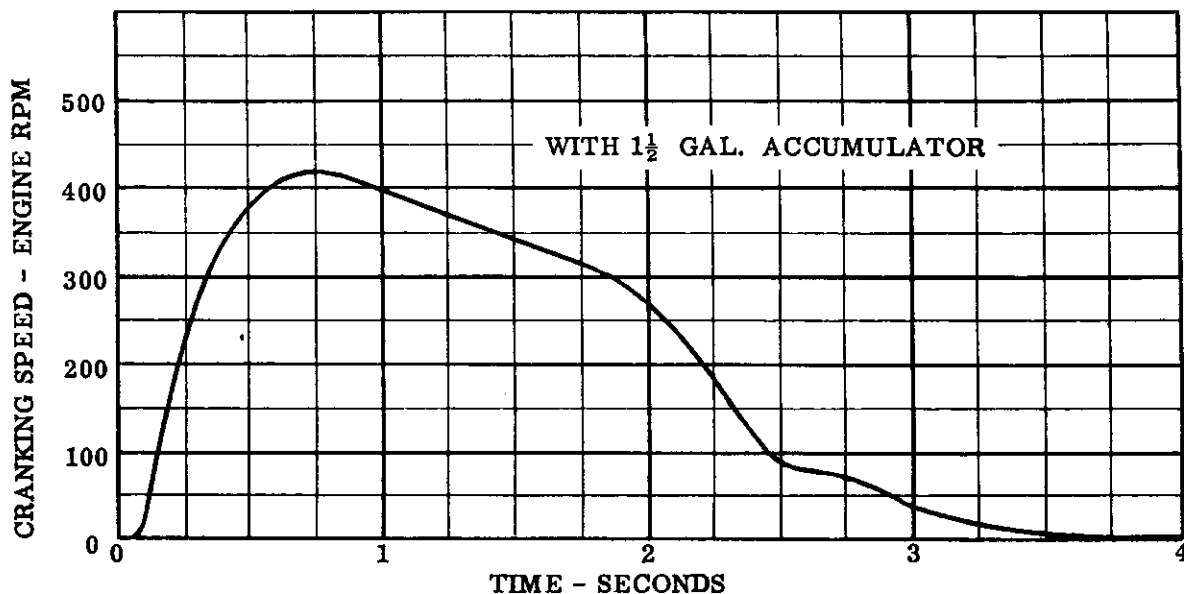


FIGURE 17



DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

4-71 ENGINE STARTING PERFORMANCE
SERIES 20 HYDROSTARTER
CRANKING RATIO 118:11
NITROGEN PRECHARGE - 1250 PSI
AMBIENT TEMPERATURE 85°F

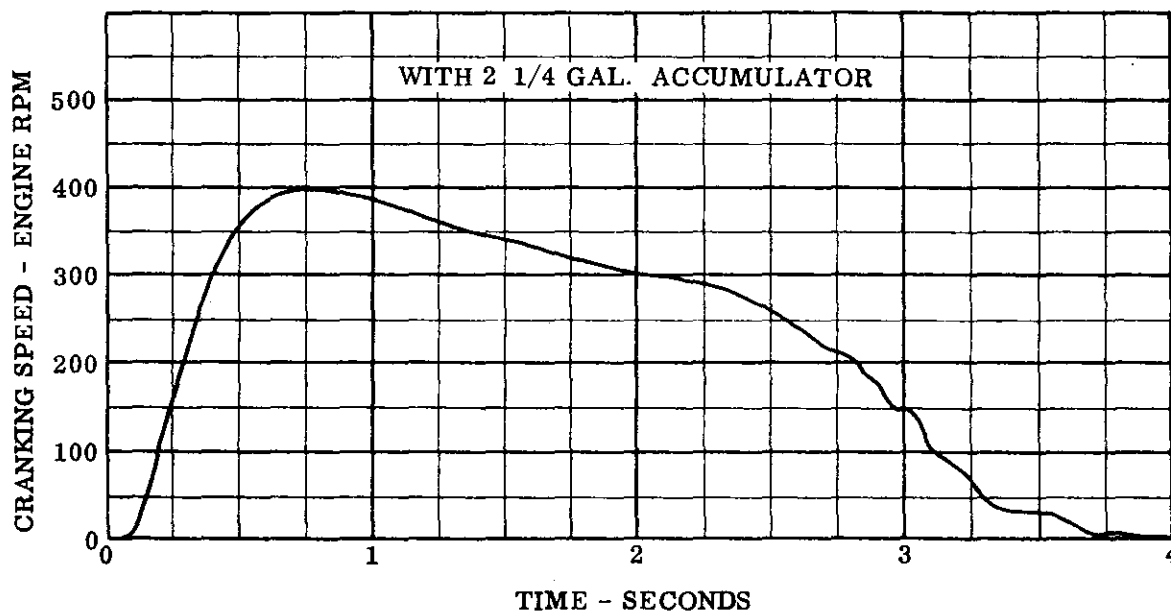
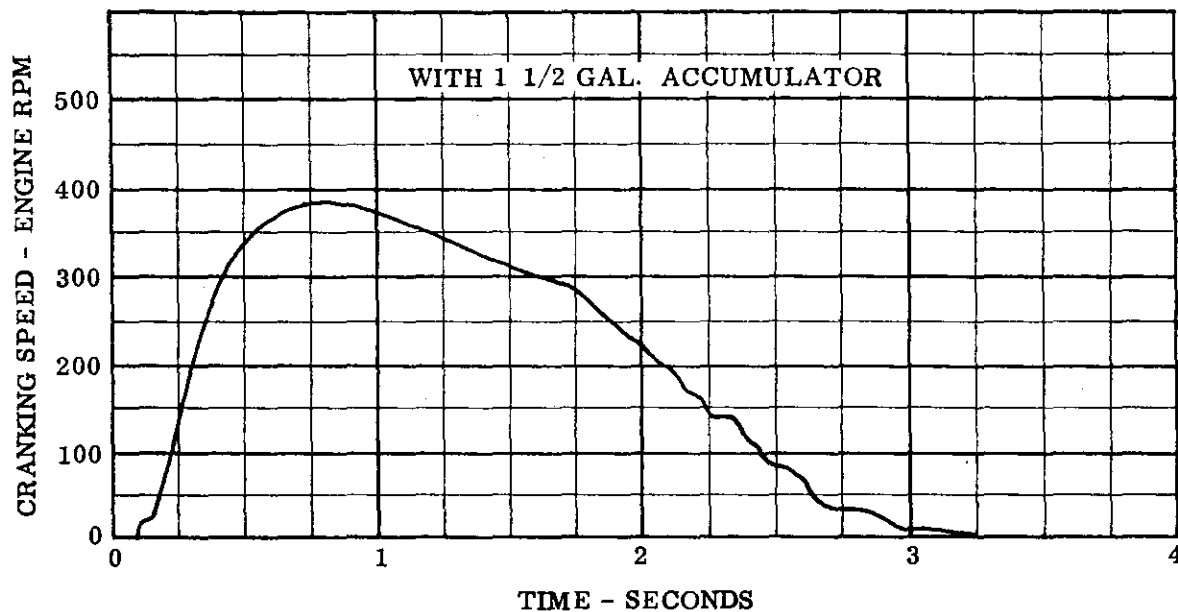


FIGURE 18



DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

6-71 ENGINE STARTING PERFORMANCE

SERIES 20 HYDROSTARTER

CRANKING RATIO 102:11

NITROGEN PRECHARGE 1175 PSI

AMBIENT TEMPERATURE 83°F

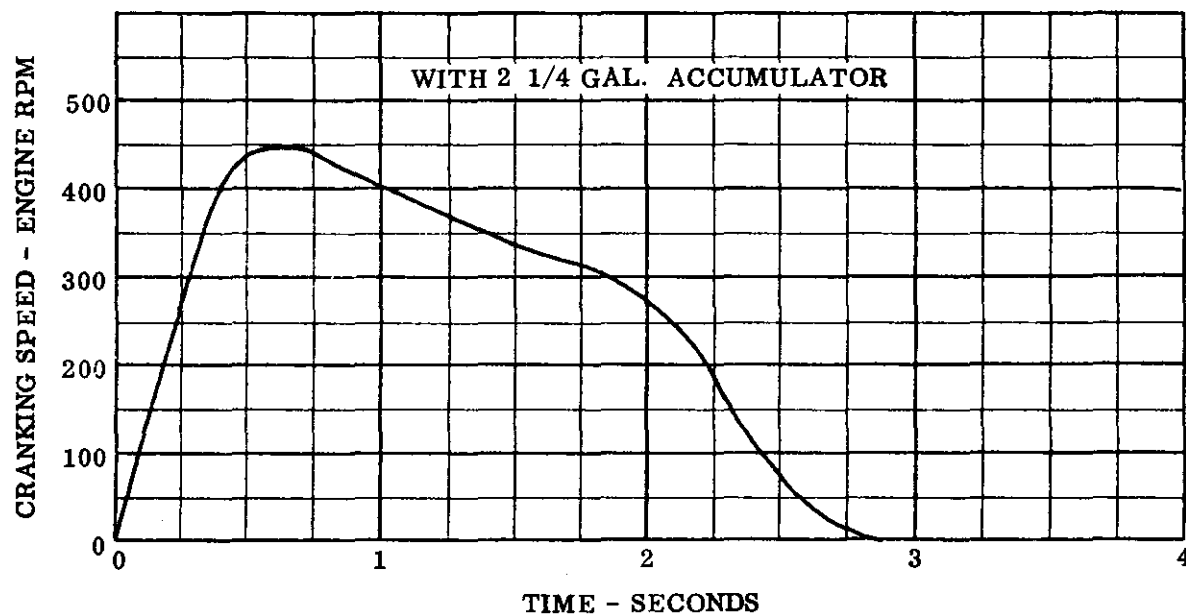
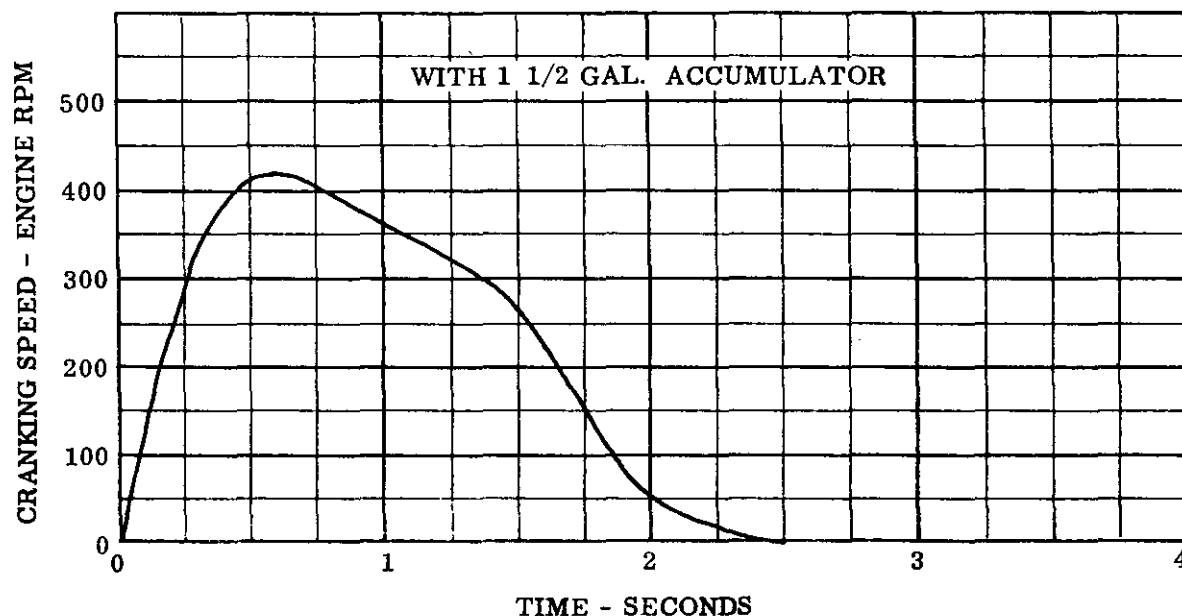


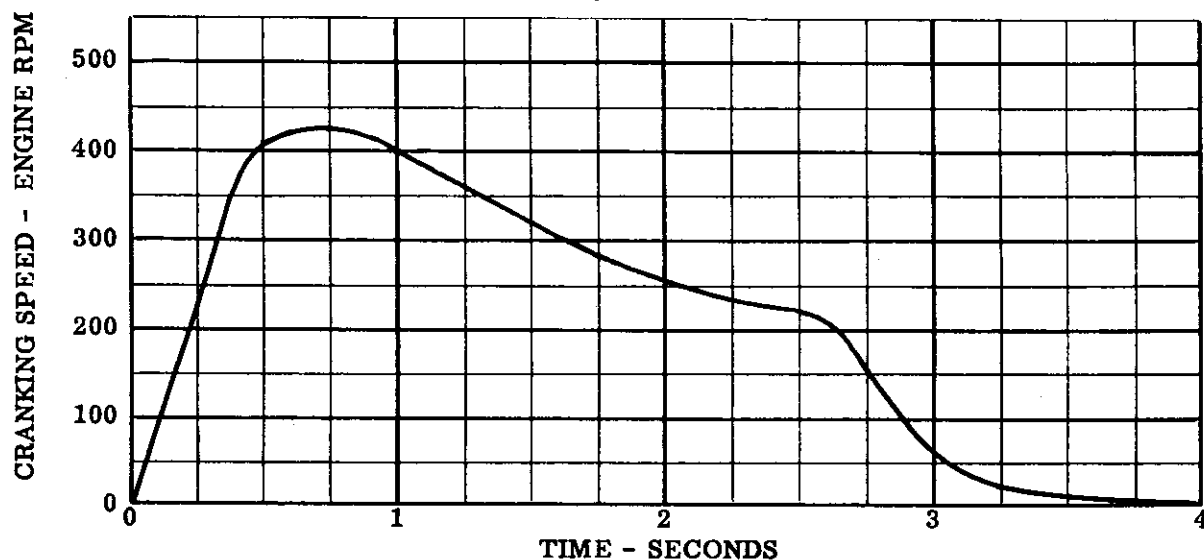
FIGURE 19



DETROIT DIESEL ENGINE DIVISION

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6V-71 ENGINE STARTING PERFORMANCE WITH SERIES 20 HYDROSTARTER
CRANKING RATIO 118:11
NITROGEN PRECHARGE 1250 PSI
AMBIENT TEMPERATURE 77°F
WITH 2½ GAL. ACCUMULATOR



8V-71 ENGINE STARTING PERFORMANCE WITH SERIES 20 HYDROSTARTER
CRANKING RATIO 118:11
NITROGEN PRECHARGE 1250 PSI
AMBIENT TEMPERATURE 77°F
WITH 2½ GAL. ACCUMULATOR

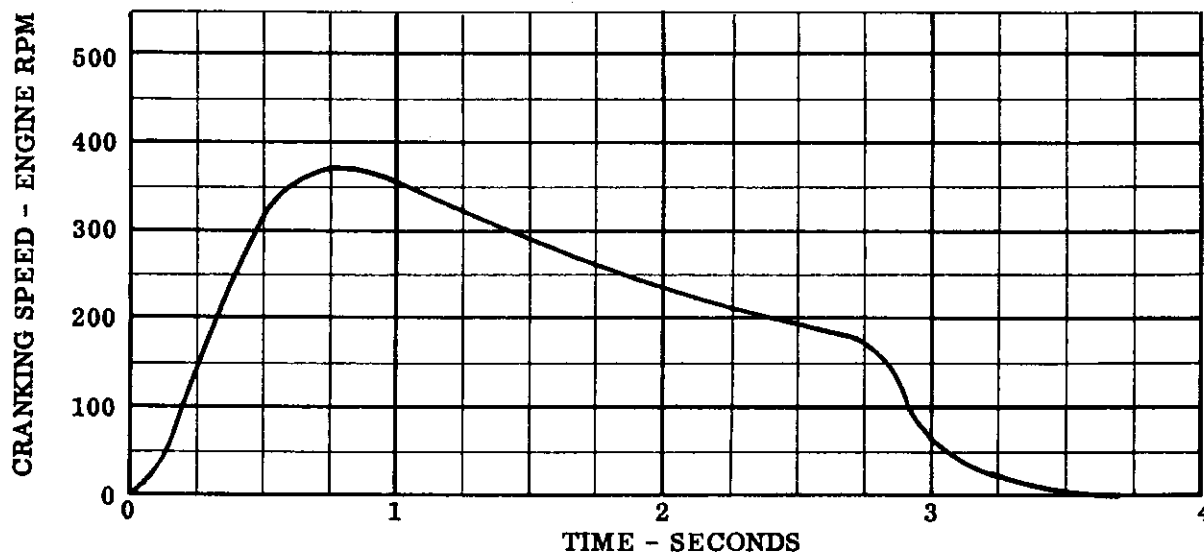


FIGURE 20

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DETROIT DIESEL ENGINE DIVISION

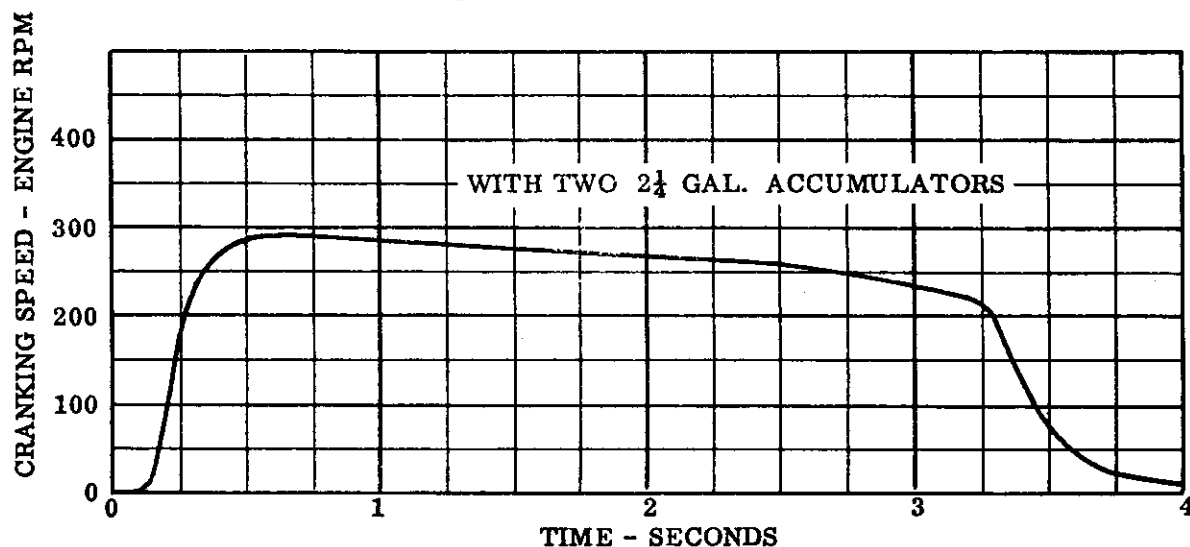
GENERAL MOTORS CORPORATION

12V-71 ENGINE STARTING PERFORMANCE WITH SERIES 35 HYDROSTARTER

CRANKING RATIO 118:11

NITROGEN PRECHARGE 1250 PSI

AMBIENT TEMPERATURE 85°F



6-110 ENGINE STARTING PERFORMANCE WITH SERIES 20 HYDROSTARTER

CRANKING RATIO 118:11

NITROGEN PRECHARGE 1500 PSI

AMBIENT TEMPERATURE 77°F

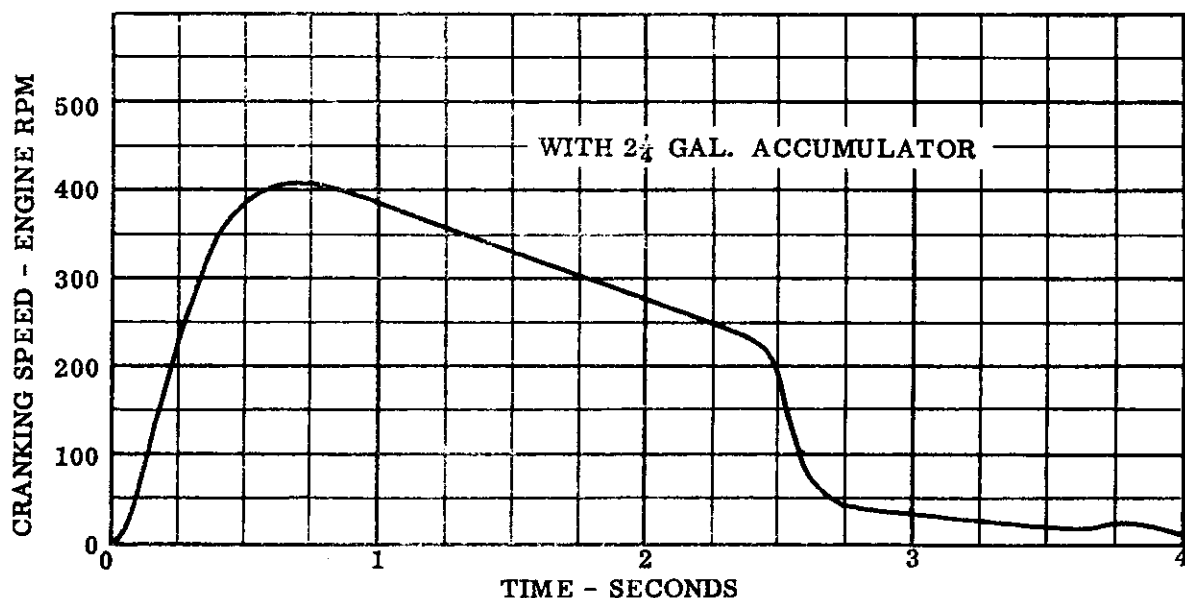


FIGURE 21



DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

4-53 ENGINE STARTING PERFORMANCE WITH SERIES 20 HYDROSTARTER
CRANKING RATIO 126:11
NITROGEN PRECHARGE 1250 PSI
AMBIENT TEMPERATURE 85°F

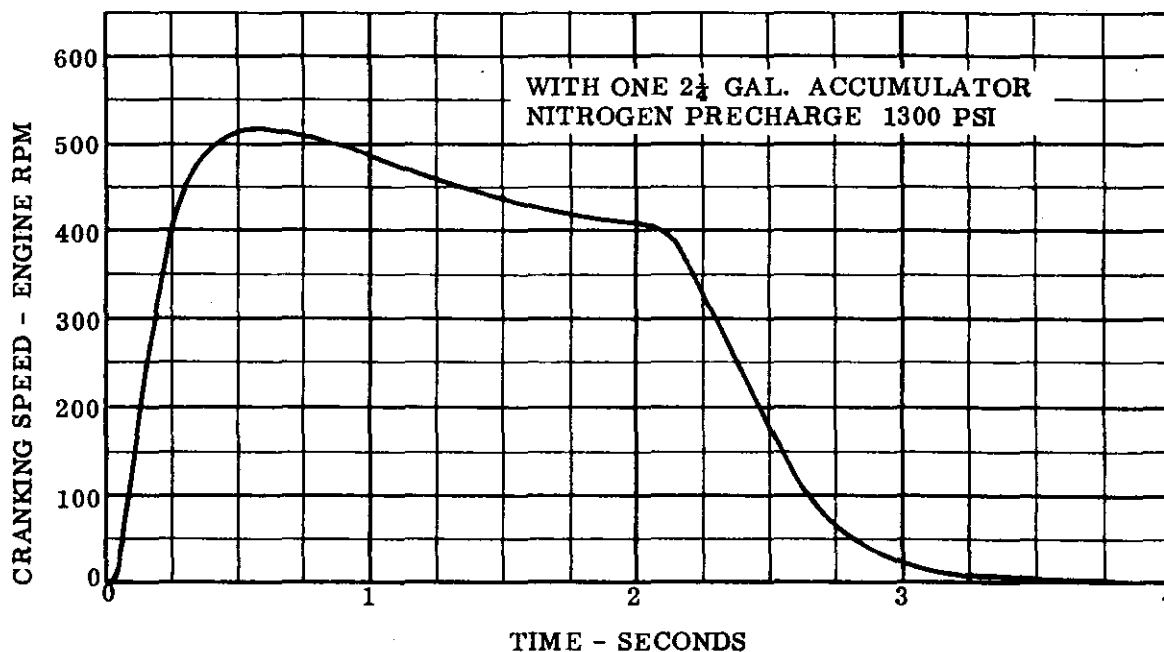
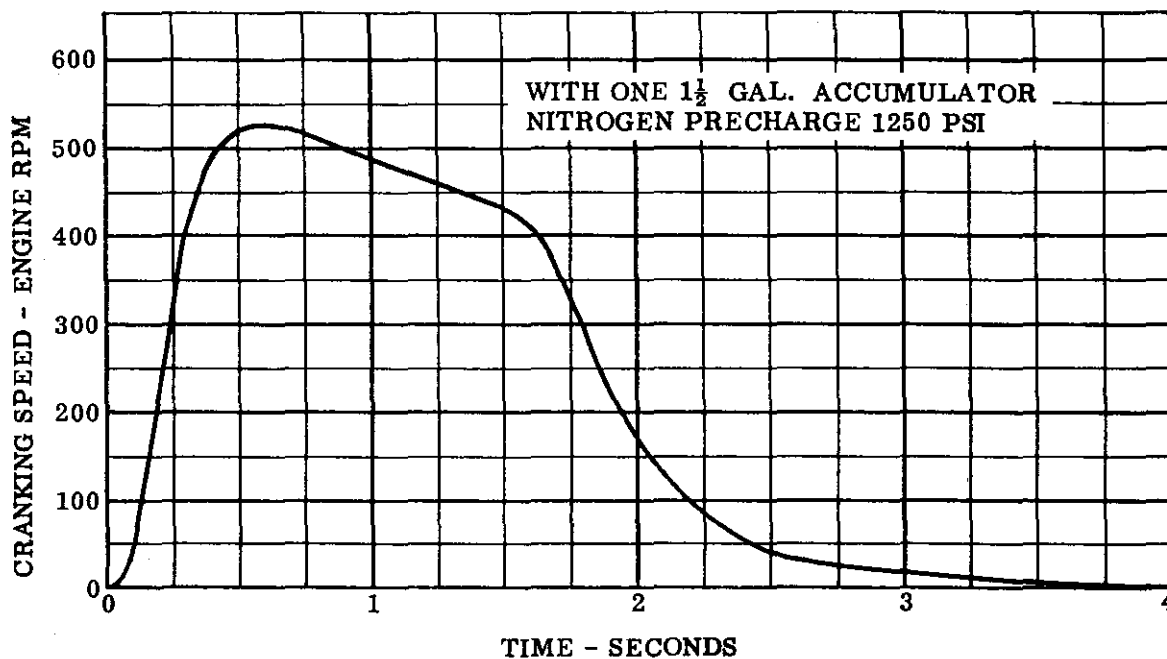


FIGURE 22



DETROIT DIESEL ENGINE DIVISION

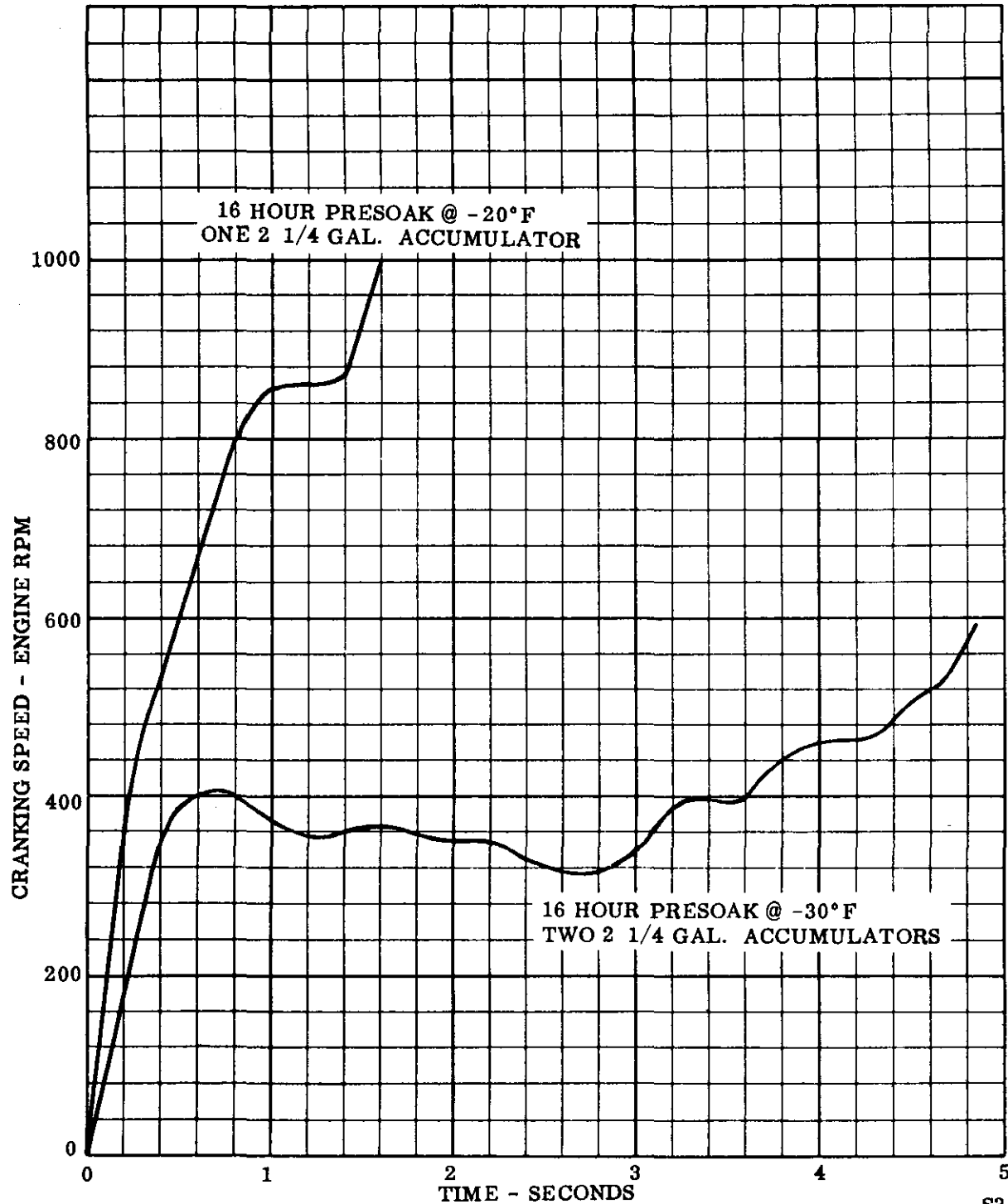
GENERAL MOTORS CORPORATION

PERKINS 259 CU. IN. DIESEL STARTING PERFORMANCE WITH SERIES 20
HYDROSTARTER

CRANKING RATIO 122:11

NITROGEN PRECHARGE 860 PSI AT 80°F

SAE 5W OIL ETHER AID





DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

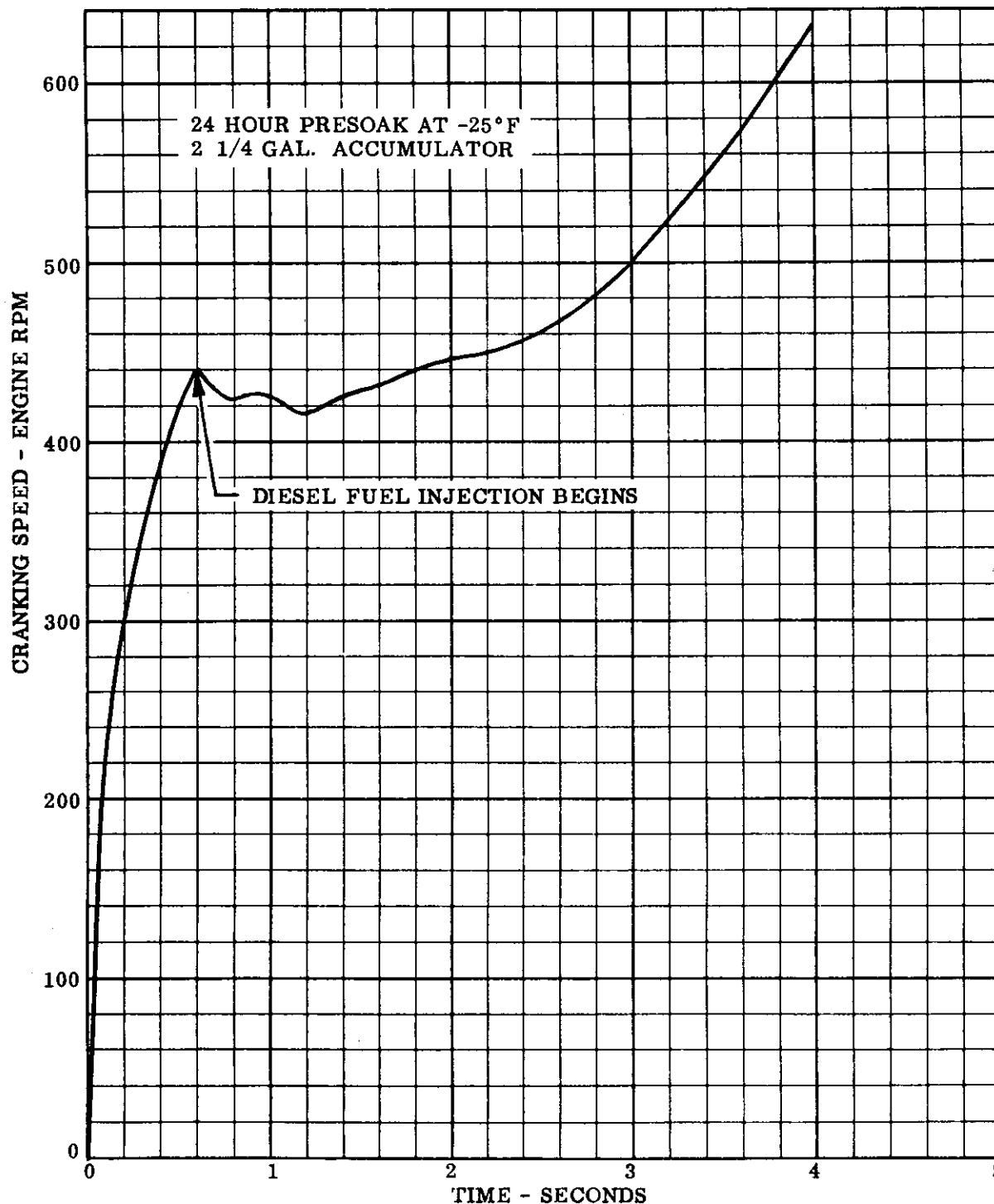
2-71 STARTING PERFORMANCE WITH SERIES 20 HYDROSTARTER

CRANKING RATIO 103:11

NITROGEN PRECHARGE 1100 PSI

MIL-0-10295 OIL

ETHER AID

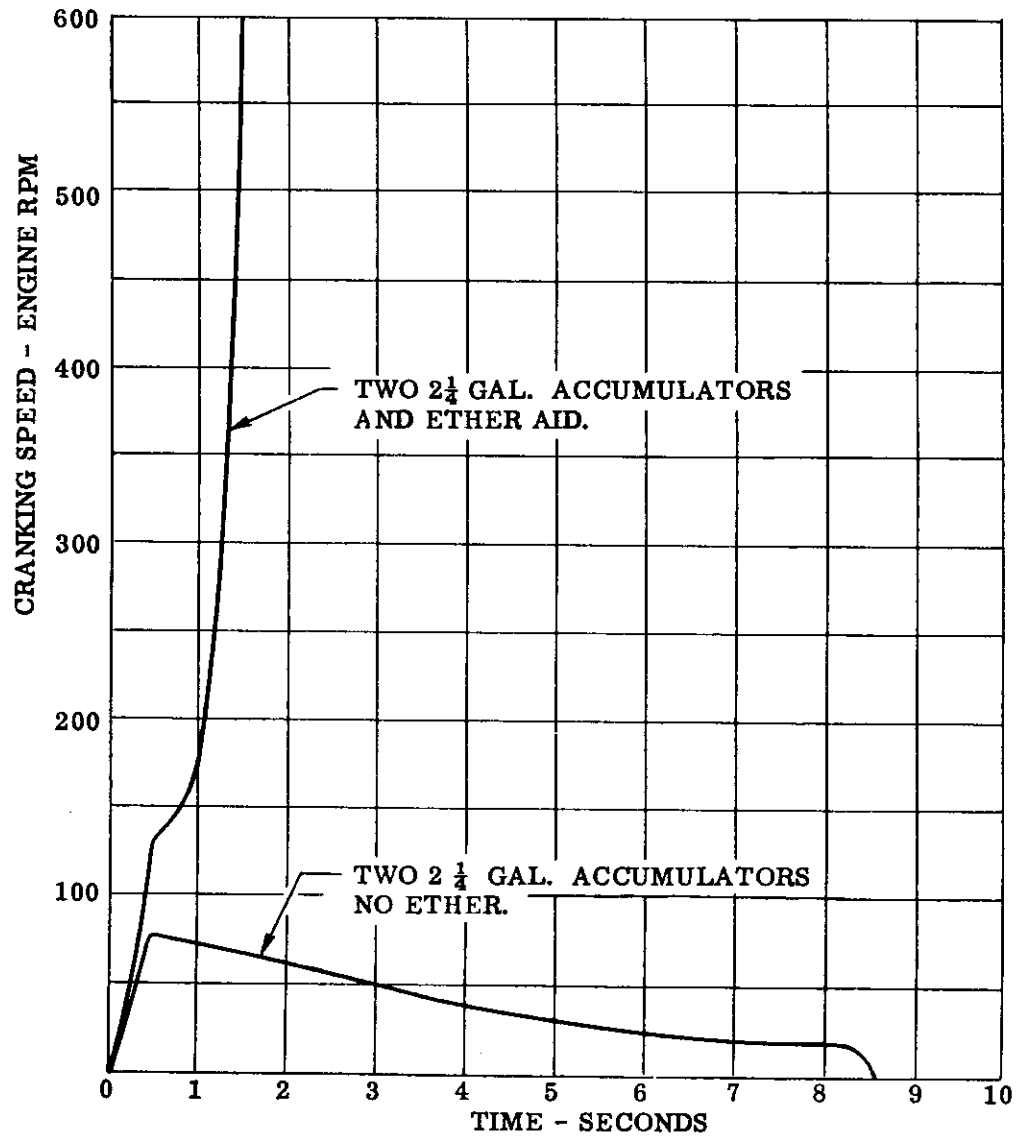




DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

6-110 ENGINE STARTING PERFORMANCE
SERIES 20 HYDROSTARTER
CRANKING RATIO 113:11
NITROGEN PRECHARGE 1200 PSI
AMBIENT TEMPERATURE - 25°F
MIL-0-10295 OIL

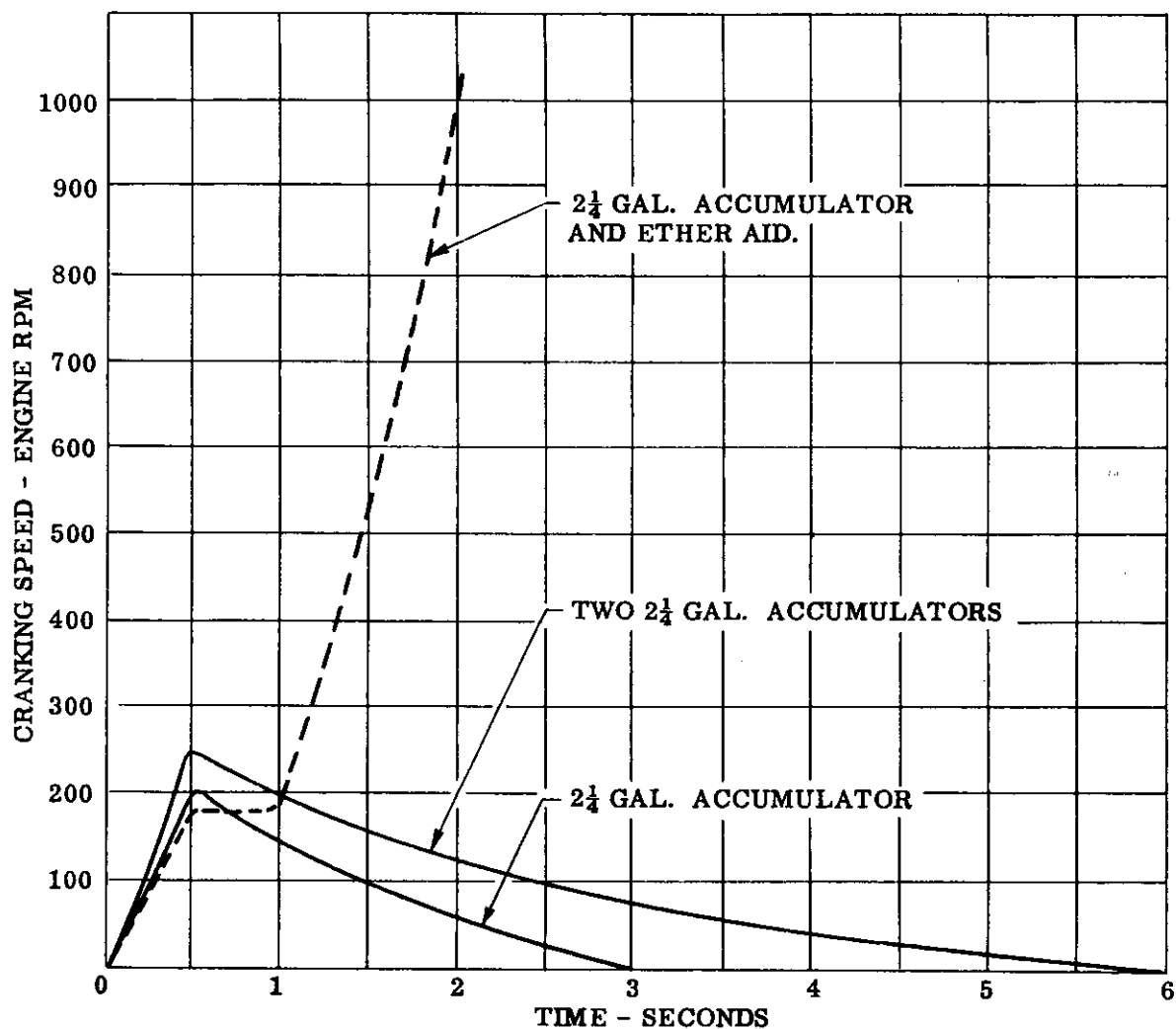




DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

8V-71 ENGINE STARTING PERFORMANCE
SERIES 20 HYDROSTARTER
CRANKING RATIO 113:11
NITROGEN PRECHARGE 1200 PSI
AMBIENT TEMPERATURE - 25°F
MIL-0-10295 OIL





DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

12V-71 STARTING PERFORMANCE WITH SERIES 35 HYDROSTARTER

CRANKING RATIO 118:11

NITROGEN PRECHARGE 1400 PSI

SAE 5W OIL

THREE 2 1/4 GAL. ACCUMULATORS

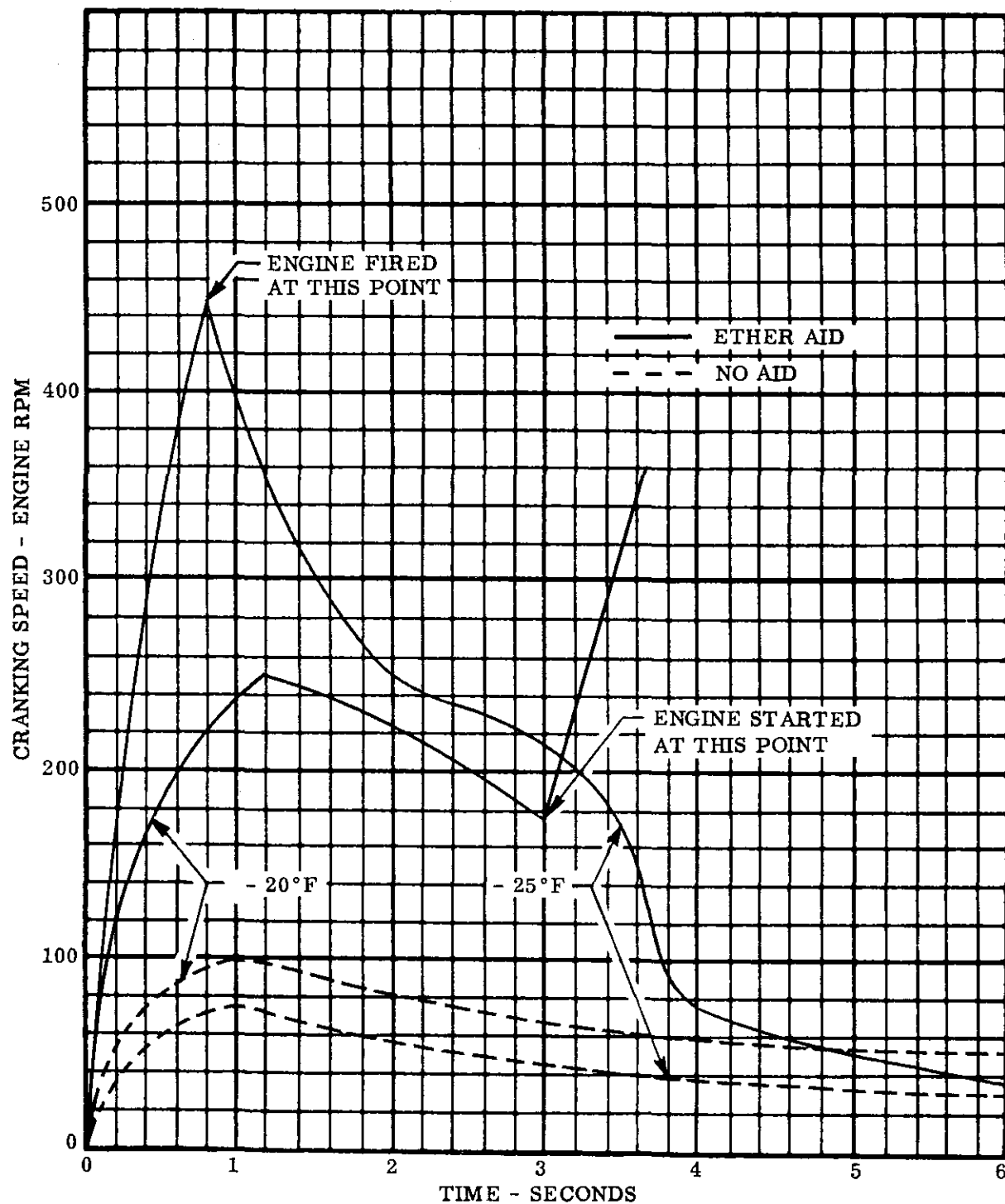


FIGURE 27



DETROIT DIESEL ENGINE DIVISION

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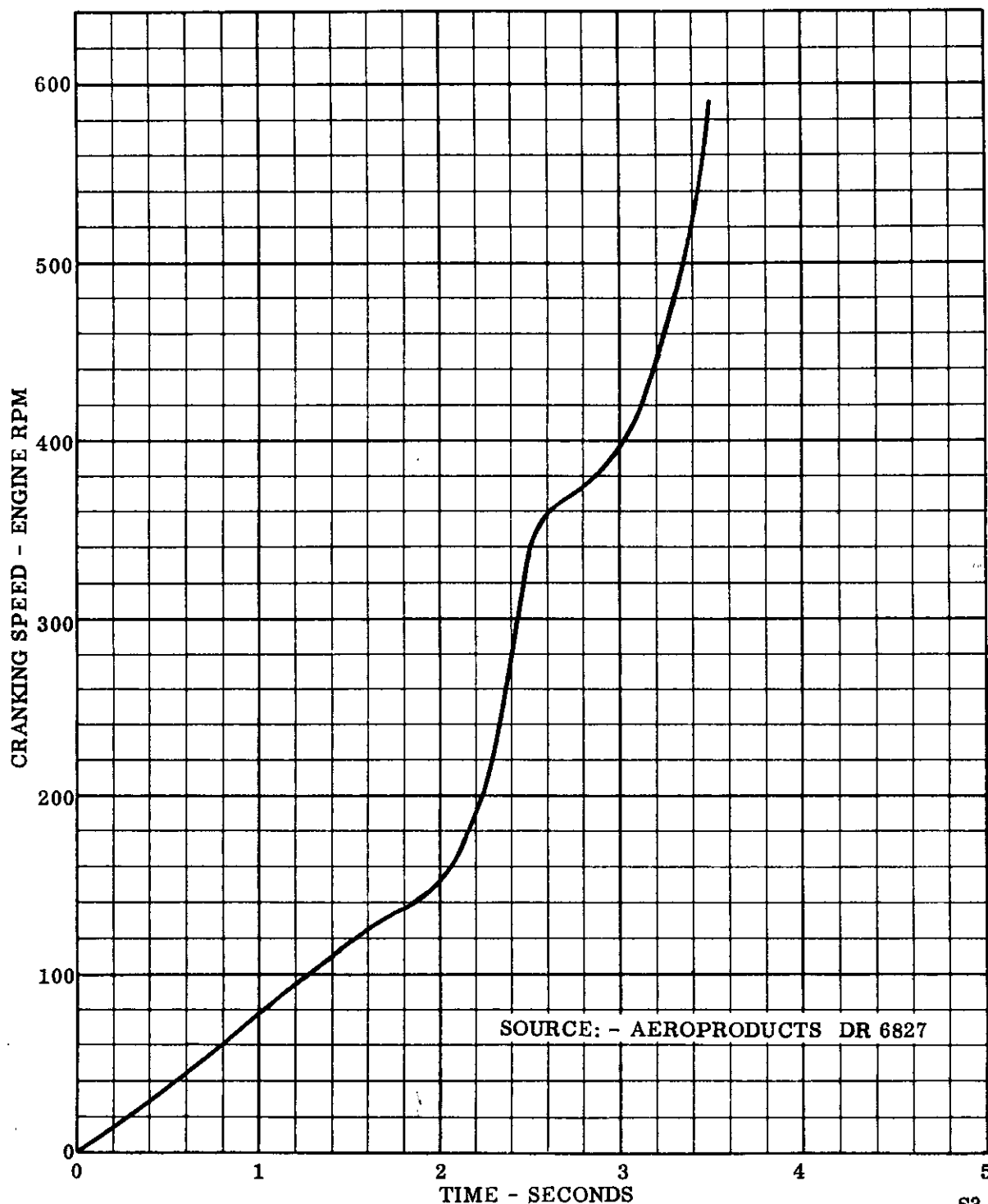
6-71 STARTING PERFORMANCE (-10°F) WITH SERIES 20 HYDROSTARTER

CRANKING RATIO 102:11

NITROGEN PRECHARGE 800 PSI AT -10°F

SAE 10W OIL

ETHER AID



SOURCE: - AEROPRODUCTS DR 6827



DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

HYDROSTARTER ACCUMULATOR CHARGING PUMP
PERFORMANCE AT 1750 RPM
(SOURCE - AEROPRODUCTS EMR-1288)

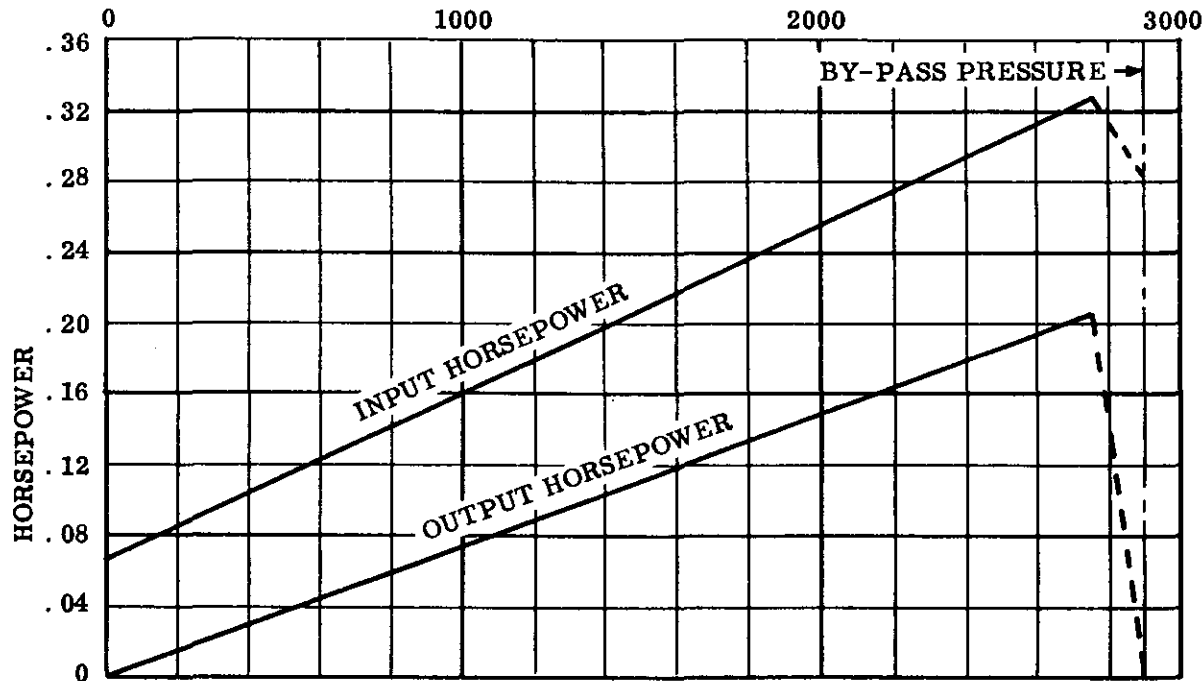
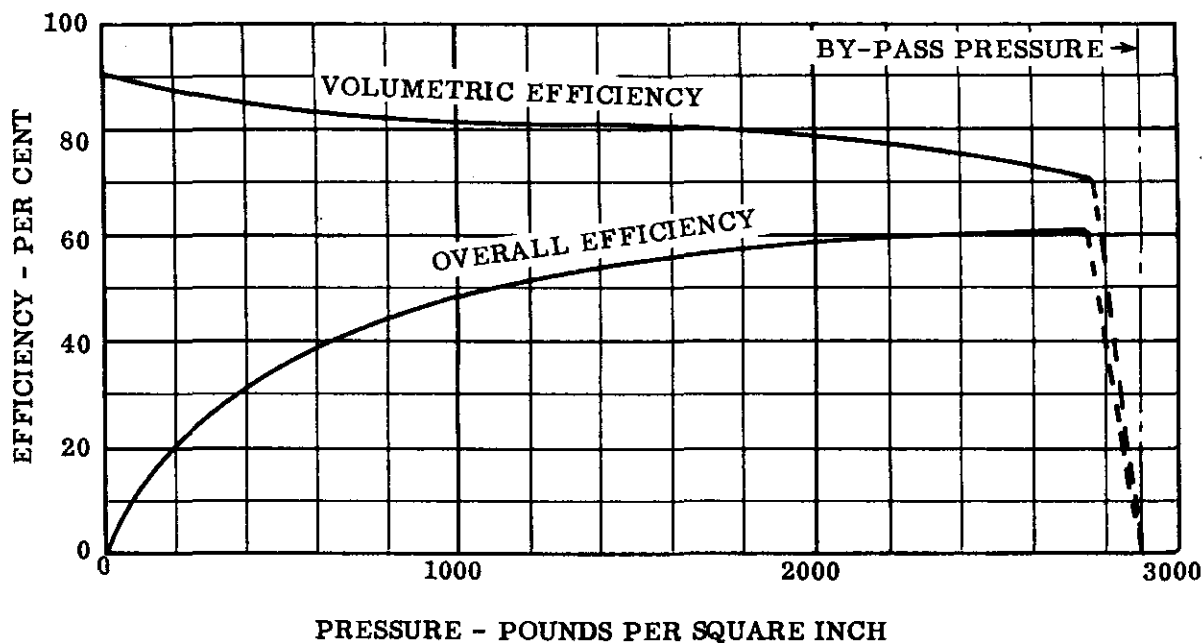


FIGURE 29



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REQUIREMENTS

For

**TORSIONAL VIBRATION
ANALYSIS**

And

VIBRATION DAMPERS

by

D. E. Miller

Rev., January, 1963

Engineering Technical Data Dept.

**ENGINEERING
BULLETIN
NO. 34**

18SA0207

REQUIREMENTS
FOR
TORSIONAL VIBRATION ANALYSIS
AND
VIBRATION DAMPERS

I. TORSIONAL FATIGUE

To avoid crankshaft breakage from torsionals (see Fig. 1) or damage to engine gear trains, couplings and driven component elements such as drive shafts, gear boxes and alignment couplings, means for properly controlling vibratory amplitudes and stress must be taken.

To protect the crankshaft against abnormal vibration stresses, an isolation bushing in the crankshaft pulley and/or vibration dampers are specified. These can be determined from the attached charts:

Even though the proper pulley or damper is selected, torsional difficulties may be encountered when additional masses are driven from either the front or rear of the engine. To avoid engine or equipment damage, a "Torsional Analysis" should be considered if the following types of masses are driven by the engine:

1. Any mass driven from the front end of the crankshaft except equipment which is belt driven from the crankshaft pulley supplied with the unit.
2. Power generators driven from rear of engine.
3. Equipment driven through shafts or couplings.
4. All reciprocating types of pumps or compressors.
5. In general, any mass driven from the flywheel end which is not bolted directly to the flywheel or attached through a torsionally rigid coupling, such as a clutch, drive disc, or very short stiff shafts.

When it is required that a "Torsional Analysis" be made, the following data must be supplied with the request.

- a. Speed range of operation .
- b. Horsepower requirements including engine driven accessories plus equipment and/or Torque Fluctuation curves, such as for reciprocating compressors.
- c. Make and model of engine driven accessories used.
- d. Layout of drive and detail prints showing size or WR^2 of all rotating parts such as shafts, couplings, gears, pulley, etc.
- e. Make and model number of power generator when used, also WR^2 plus details of shafting and coupling.
- f. Make and model of alignment or flexible coupling and/or "Rigidity factor" which is the torsional spring rate.

II. BENDING FATIGUE

After giving due consideration to the foregoing instructions, the crankshaft may still be damaged by excessive bending loads. Four factors which contribute to crankshaft bending failures (see Fig. 2) are: (1) excessive side load from drives at the front or rear of the crankshaft, (2) unbalanced rotating masses such as sheaves or flywheels, (3) shock loads from driven equipment and (4) "overhang" of pulley or gear load.

To avoid these failures, precautions should be taken so that belt drives have only enough tension to prevent slippage and load centerlines are within recommendations for the pitch diameter of the pulley or gears used. Misalignment and movement between engine and driven member should be avoided where the center distance may be changed due to this movement, such as occurs in belt drives.

To prevent unbalance stresses, all sheaves mounted on the crankshaft or to the flywheel should be balanced within $\frac{1}{2}$ in. oz. and flywheel assemblies with ring gears installed should be balanced within 1 in. oz. and bolted securely to the crankshaft by tightening the bolts to the recommended torque (foot pounds). If the preceding recommendations are followed, damage to crankshafts or driven equipment will be minimized.

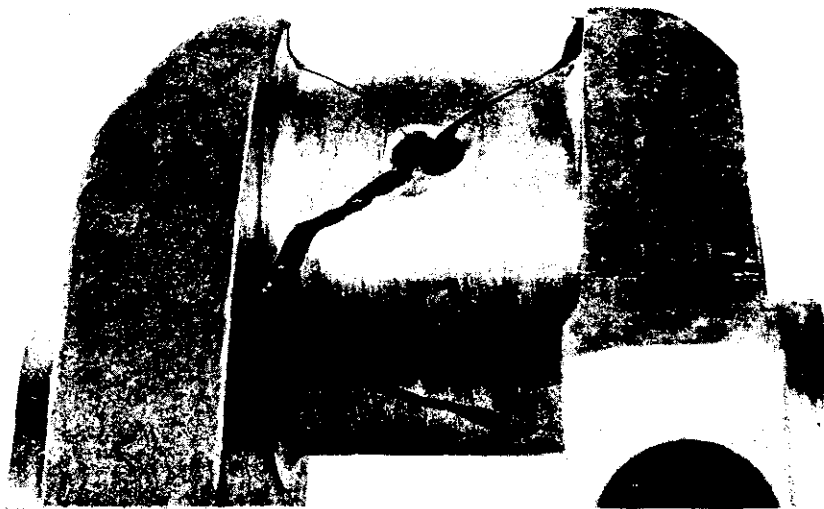


FIG. 1
CRANKSHAFT TORSIONAL FRACTURE



FIG. 2
CRANKSHAFT BENDING FAILURE



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CHART I
SUPPLEMENTARY TABLE FOR ESTIMATING PULLEY WR^2
LB. IN.² PER GROOVE OF PULLEY
CAST IRON - MODERATELY HEAVY DESIGN

Outside Dia. of Pulley	1 Groove	2 Grooves	3 or More Grooves
5.00	14	10	9
5.25	15	11	10
5.50	17	12	11
5.75	19	14	13
6.00	21	15	14
6.25	23	18	16
6.50	26	20	18
6.75	30	23	20
7.00	35	27	23
7.25	41	31	27
7.50	48	36	31
7.75	55	42	36
8.00	64	49	42
8.25	73	56	48
8.50	84	64	55
8.75	95	72	62
9.00	107	83	71
9.25	121	93	80
9.50	135	105	89
9.75	151	118	99
10.00	169	131	111
10.25	187	147	123
10.50	210	162	137
10.75	238	180	152
11.00	256	200	168
11.25	277	210	187
11.50	315	240	206

NOTE (1) In certain pulley designs, the mass of the pulley may be isolated from the hub by a flexible medium such as rubber. The WR^2 of such a pulley is taken to be zero regardless of diameter or number of grooves.



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VIBRATION DAMPER REQUIREMENTS

These damper specifications apply only to the protection of the engine crankshaft against failure by torsional fatigue. Assurance of safe operation of the entire system consisting of engine and attached driven members can be obtained only by a torsional vibration analysis of the particular case under consideration.

IN ANY CASE WHEN HEAVY MASSES OR SPECIAL EQUIPMENT ARE DRIVEN FROM EITHER END OF THE CRANKSHAFT TORSIONAL ANALYSIS IS REQUIRED TO DETERMINE THE NECESSITY OF FLEXIBLE COUPLINGS OR SPECIAL DAMPER REQUIREMENTS.

- 6V-71 No damper required. Solid crankshaft pulley up to 300lbs. in. ² can be used. Beyond this mass use rubber bushed pulley.
- 8V-71 No vibration damper is required. For pulley masses greater than 300 lb. in. ² rubber bushed pulleys are required for crankshaft protection.
For Generator Sets see C6-7085-12-1, showing Crankshaft Pulley Recommendations for optimum control of torsional vibration on constant speed generator sets.
- 12V-71 Use viscous damper (heavy) for all applications and speeds.
- 53 Series No damper required unless otherwise specified, for all applications and speeds with production crankshaft pulley. See C6-5060-12-1 for 6V-53, and C6-5040-10-1 for 4-53 Pulley Recommendations.

FOR OTHER ENGINES, SEE THE FOLLOWING CHARTS:

ENGINE	RATING	Max. F. L. Gov. RPM	CHART NO.	Type Of DAMPER
4-71	Continuous	2000	C6-1040-11-1	Rubber
	Intermittent	2300	C6-1040-11-1A	Viscous
6-71	Gen. Sets	1800	C6-1065-11-1	Rubber-Viscous*
	Continuous	2000	C6-1060-11-1	Rubber-Viscous*
	Intermittent	2100	C6-1063-11-1A	Rubber-Viscous*
	Continuous	2300	C6-1060-11-1A	Viscous
	Intermittent	2300	C6-1063-11-1	Viscous

* OPTIONAL.

C6-0000-10-1
Rev. 6-6-61



Detroit Diesel Allison

Division of General Motors Corporation

CHART II SELECTION OF RUBBER VIBRATION DAMPERS FOR CONTINUOUS DUTY INDUSTRIAL ENGINES, MARINE ENGINES, AND GENERATOR SETS 4-71 ENGINE

Houde Viscous Dampers Optional See Chart III

Full Load Governed Speed of Engine - RPM	WR ² of Pulley - Lb. In. ²					
	0-50	51-100	101-150	151-200	201-250	251-300
1000 - 1400	None	None	None	None	None	None
1401 - 1500	None	None	None	None	Light † *	Light †
1501 - 1600	None	None	None	Light † *	Light †	Light †
1601 - 1700	None	None	Light † *	Light †	Light †	Light †
1701 - 1800	None	Light † *	Light †	Light †	Light †	Light †
1801 - 1900	Light *	Light	Light	Light	Light	Light
1901 - 2000	Light	Light	Light	Light	Light	Light
2001 - 2100	Light	Light	#	#	#	#

Houde Viscous Dampers Required See Chart III

† A rubber mounted pulley may be used to reduce the damper requirements where indicated.

* When light flywheel (7500 lb. in.² or less) is used the damper requirement may be reduced where indicated.

NOTE (1) Specifications in above table are based upon use of a "heavy" flywheel (WR² = 12,000 lb. in.²). Damper selection is based upon the maximum WR² and speed of each bracket. Where the flywheel is lighter than the above or where speed or pulley WR² fall near the bottom of the bracketed values, damper equipment determined by these tables will be in excess of that actually required.

NOTE (2) It is permissible to use a Light Damper where None is specified.

NOTE (3) Pulley WR² in excess of 300 lb. in.² is not recommended because of danger of failure of the driving keys.

SEE C6-0000-10-1

For Conditions Governing These Recommendations

C6-1040-11-1

Rev. 6-6-61



Detroit Diesel Allison

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CHART III

SELECTION OF HOUE VISCOS DAMPERS FOR INTERMITTENT, DUTY INDUSTRIAL ENGINES, MARINE ENGINES, AND GENERATOR SETS 4-71 ENGINE

Full Load Governed Speed of Engine - RPM	WR ² of Pulley on Crankshaft - Lb. in. ²					
	0 - 50	51 - 100	101 - 150	151 - 200	201 - 250	251 - 300
1000 - 1400	None	None	None	None	None	None
1401 - 1500	None	None	None	None	Light †	Light †
1501 - 1600	None	None	None	Light †	Light †	Light †
1601 - 1700	None	None	Light †	Light †	Light †	Light †
1701 - 1800	None	Light †	Light †	Light †	Light †	Light †
1801 - 2000	Light	Light	Light	Light	Light	Light
2001 - 2100	Light	Light	Light	Light	Light	Light
2101 - 2300	Light	Light	Light	Light	XXX	XXX

Rubbers Dampers Optional See Chart II

† A rubber mounted pulley may be used to reduce the damper requirement where indicated.

NOTE (1) Specifications in above table are based upon use of a "heavy" flywheel (WR² = 12,000 lb. in. ²). Damper selection is based upon the maximum WR² and speed of each bracket. Where the flywheel is lighter than the above or where speed or pulley WR² fall near the bottom of the bracketed values, damper equipment determined by these tables will be in excess of that actually required.

NOTE (2) It is permissible to use a Light Damper where None is specified.

NOTE (3) Pulley WR² in excess of 300 lb. in. ² is not recommended because of danger of failure of the driving keys.

SEE C6-0000-10-1

For Conditions Governing These Recommendations

XXX Signifies operation not recommended with solid pulleys

C6-1040-11-1A

Rev. 6-6-61



Detroit Diesel Allison

Division of General Motors Corporation

CHART V SELECTION OF RUBBER VIBRATION DAMPERS FOR CONTINUOUS DUTY INDUSTRIAL AND MARINE ENGINES 6-71 ENGINE

Full Load Governed Speed - RPM	WR ² of Pulley on Crankshaft - Lb. In. ²						
	0	1 - 50	51 - 100	101 - 150	151 - 200	201 - 250	251 - 300
Up to 1400	None	None	None	None	None	None	None
1401 - 1500	None	None	None	None	None	Heavy†*	Heavy†
1501 - 1600	None	None	None	Heavy†*	Heavy†	Heavy†	Heavy†
1601 - 1700	None	None	Heavy†	Heavy†	Heavy†	Heavy†	Double†*
1701 - 1800	None	Heavy†	Heavy†	Heavy†	Double†*	Double†	Double†
1801 - 1900	Heavy	Heavy	Heavy	Double†*	Double†	Double†	Double†
1901 - 2000	Heavy	Double*	Double	Double	Double	Double	Double
2001 - 2100	Double	Double	Double	#	#	#	#

Houde Viscous Dampers Optional See Chart VII

Houde Viscous Dampers Required

† A rubber mounted pulley may be used to reduce the damper requirements where indicated.

* When light flywheel (7500 lb. -in. ² or less) is used the damper requirement may be reduced where indicated.

NOTE (1) Specifications in above table are based upon use of a "heavy" flywheel (WR² 12,000 lb. -in. ²). Damper selection is based upon the maximum WR² and speed of each bracket. Where the flywheel is lighter than the above or where speed or pulley WR² fall near the bottom of the bracketed values, damper equipment determined by these tables will be in excess of that actually required.

NOTE (2) It is permissible to use a Heavy Damper where None is specified, or a Double Damper where Heavy or None is specified.

NOTE (3) Pulley WR² in excess of 300 lb. -in. ² is not recommended because of danger of failure of the driving keys.

SEE C6-0000-10-1

For Conditions Governing These Recommendations.

C6-1060-11-1

Rev. 6-6-61



Detroit Diesel Allison

Division of General Motors Corporation

CHART VII SELECTIONS OF HOUE VISCOUS DAMPERS FOR CONTINUOUS DUTY INDUSTRIAL AND MARINE ENGINES 6-71 ENGINE

Full Load Governed Speed - RPM	WR ² of Pulley on Crankshaft - Lb. In. ²						
	0	1 - 50	51 - 100	101 - 150	151 - 200	201 - 250	251 - 300
Up to 1400	None	None	None	None	None	None	None
1401 - 1500	None	None	None	None	None	† Heavy*	Heavy †
1501 - 1600	None	None	None	† Heavy*	Heavy †	Heavy †	Heavy †
1601 - 1700	None	None	Heavy †	Heavy †	Heavy †	Heavy †	Heavy †
1701 - 1800	None	Heavy †	Heavy †	Heavy †	Heavy †	Heavy †	Heavy †
1801 - 2000	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
2001 - 2100	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
2101 - 2300	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy

Rubber Dampers Optional See Chart V

† A rubber mounted pulley may be used to reduce the damper requirements where indicated.

* When light flywheel (7500 lb. - in. ² or less) is used the damper requirement may be reduced where indicated.

NOTE (1) Specifications in above table are based upon use of a "heavy" flywheel (WR² 12,000 lb. - in. ²). Damper selection is based upon the maximum WR² and speed of each bracket. Where the flywheel is lighter than the above or where speed or pulley WR² fall near the bottom of the bracketed values, damper equipment determined by these tables will be in excess of that actually required.

NOTE (2) It is permissible to use a Heavy Damper where None is specified, or a Double Damper where Heavy or None is specified.

NOTE (3) Pulley WR² in excess of 300 lb. - in. ² is not recommended because of danger of failure of the driving keys.

SEE C6-0000-10-1

For Conditions Governing These Recommendations.

C6-1060-11-1A
Rev. 6-6-61



Detroit Diesel Allison

Division of General Motors Corporation

CHART VI

SELECTION OF RUBBER VIBRATION DAMPERS FOR INTERMITTENT DUTY
AUTOMOTIVE ENGINES

6-71 ENGINE

Full Load Governed Speed of Engine - RPM	WR ² of Pulley on Crankshaft - Lb. In. ²					
	0-25	26-50	51-75	76-100	101-125	126-150
1500 - 1700	None	None	None	None	None	None
1701 - 1750	None	None	None	None	Heavy †	Heavy †
1751 - 1800	None	None	None	Heavy †	Heavy †	Heavy †
1801 - 1850	None	None	Heavy †	Heavy †	Heavy †	Heavy †
1851 - 1900	None	Heavy †	Heavy †	Heavy †	Heavy †	Heavy †
1901 - 1950	Heavy	Heavy	Heavy	Heavy	Double †	Double †
1951 - 2000	Heavy	Heavy	Heavy	Double †	Double †	Double †
2001 - 2050	Heavy	Heavy	Double †	Double †	Double †	Double †
2051 - 2100	Double	Double	Double	Double	#	#

Houde Viscous Dampers Optional See Chart VIII

Houde Viscous Dampers Required

† A rubber mounted pulley may be used to reduce the damper requirements where indicated.

NOTE: Above schedule is made on the allowance of an occasional overrun in speed of 150 rpm to no load under control of the governor. This speed limitation must be strictly observed.

In the case of any installation where the top speed may exceed this permissible overrun, additional damper capacity is required.

(Refer to Specification Table V for Industrial Engines.)

SEE C6-0000-10-1

For Conditions Governing These Recommendations



Detroit Diesel Allison

Division of General Motors Corporation

CHART VIII
SELECTION OF HOUE VISCOUS DAMPERS FOR INTERMITTENT DUTY
AUTOMOTIVE ENGINES
6-71 ENGINE

Full Load Governed Speed of Engine - RPM	WR ² of Pulley on Crankshaft - WR ²					
	0-25	26-50	51-75	76-100	101-125	126-150
1500 - 1700	None	None	None	None	None	None
1701 - 1750	None	None	None	None	Heavy †	Heavy †
1751 - 1800	None	None	None	Heavy †	Heavy †	Heavy †
1801 - 1850	None	None	Heavy †	Heavy †	Heavy †	Heavy †
1851 - 1900	None	Heavy †	Heavy †	Heavy †	Heavy †	Heavy †
1901 - 2050	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
2051 - 2100	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
2101 - 2300	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy

Rubber Dampers Optional See Chart VI

† A rubber mounted pulley may be used to reduce the damper requirements where indicated.

NOTE: Above schedule is made on the allowance of an occasional overrun in speed of 150 rpm to no load under control of the governor. This speed limitation must be strictly observed.

In the case of any installation where the top speed may exceed this permissible overrun, additional damper capacity is required.

(Refer to Specification Table V for Industrial Engines.)

SEE C6-0000-10-1

For Conditions Governing These Recommendations

C6-1063-11-1A

3-2-61



Detroit Diesel Allison

Division of General Motors Corporation

CRANKSHAFT PULLEY RECOMMENDATIONS 4-53 AUTOMOTIVE, INDUSTRIAL, & MARINE APPLICATIONS

Full Load Governed Speed of Engine - RPM	WR ² of Pulley - Lb. In. ²				
	0 - 100	101 - 150	151 - 200	201 - 250	251 - 300
0 - 2100	Solid	Solid	Solid	Solid	Solid
2101 - 2300	Solid	Solid	Solid	Solid	Bushed
2301 - 2500	Solid	Solid	Solid	Bushed	Bushed
2501 - 2800	Solid	Solid	Bushed	Bushed	Bushed

Rubber bushed pulley recommendations are designed to avoid operation in 4th and 5th order critical speeds. These recommendations are based on the use of a light flywheel 3000 lb. in.². Rubber bushed pulleys may be used where solid pulleys are specified if desired.

Pulley WR² in excess of 300 lb. in.² is not recommended because of relatively high vibratory torques imposed on the front end of the crankshaft.

SEE C6-0000-10-1

For Conditions Governing These Recommendations

C6-5040-10-1
3-2-61



Detroit Diesel Allison

Division of General Motors Corporation

CHART IV SELECTION OF DAMPERS FOR GENERATOR SETS 6-71 ENGINE

HOUDE VISCOUS DAMPERS						
Engine Speed RPM	WR ² of Pulley on Crankshaft - Lb. In. ²					
	0-50	51-100	101-150	151-200	201-250	251-300
1000	XXX	None	None	None	None	None
1200	None	None	None	XXX †	XXX †	None
1500	None	None	Heavy †	Heavy †	Heavy †	Heavy †
1800	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
RUBBER VIBRATION DAMPERS						
1000	XXX	None	None	None	None	None
1200	None	None	None	XXX †	XXX †	None
1500	None	None	Heavy †	Heavy †	Heavy †	Heavy †
1800	Heavy	Heavy	Double †	Double †	Double †	Double †
Houde Viscous Dampers Optional See Above						
† A rubber mounted pulley may be used to reduce the damper requirements where indicated, or when operation is not recommended.						
XXX Signifies operation not recommended with solid pulley.						
NOTE (1) Generator Sets represent a special application requiring Engineering approval of entire vibratory system in all cases where there is a departure from standard generator equipment.						
SEE C6-0000-10-1 For Conditions Governing These Recommendations						

C6-1065-11-1

Rev. 6-6-61



Detroit Diesel Allison

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CRANKSHAFT PULLEY RECOMMENDATIONS 6V-53 ENGINE - ALL APPLICATIONS

Full Load Governed Speed of Engine - RPM	WR ² of Pulley - Lb. In. ²				
	0 - 50	51 - 100	101 - 150	151 - 200	200 - 250
0 - 2000	Solid	Solid	Solid	Solid	Solid
2000 - 2300	Solid	Solid	Solid	Solid	Bushed
2300 - 2550	Solid	Solid	Solid	Bushed	Bushed
2550 - 2800	Solid	Solid	Bushed	Bushed	Bushed

Rubber bushed crankshaft pulley recommendations are designed to avoid any engine operation in a dangerous 6th order critical speed. These recommendations are based on the use of a 3700 Lb. In.² flywheel. Rubber bushed pulleys may be used in place of solid pulleys if desired.

SEE C6-0000-10-1

For Conditions Governing These Recommendations

C6-5060-12-1

3-2-61



Detroit Diesel Allison

Division of General Motors Corporation

CRANKSHAFT PULLEY RECOMMENDATIONS 8V-71 GENERATOR APPLICATIONS

Full Load Governed Speed of Engine - RPM	WR ² of Pulley - Lb. In. ²					
	0 - 50	51 - 100	101 - 150	151 - 200	201 - 250	251 - 300
1000	Solid	Solid	Solid	Solid	Bushed	Bushed
1200	Solid	Bushed	Bushed	Bushed	Bushed	Bushed
1500	Solid	Solid	Solid	Solid	Bushed	Bushed
1800	Solid	Bushed	Bushed	Bushed	Bushed	Bushed

Rubber bushed crankshaft pulley recommendations for constant speed generator sets are designed to avoid continuous operation in minor 8th and 12th order critical speeds.

These recommendations are based on the use of a heavy 12700 Lb. In.² flywheel. Additional flywheel inertia or generator inertia will have little effect on these recommendations.

Rubber bushed pulleys may be used where solid pulleys are shown if desired.

Pulley WR² in excess of 300 Lb. In.² is not recommended because of danger of failures of the driving keys.

SEE C6-0000-10-1

For Conditions Governing These Recommendations

C6-7085-12-1
3-2-61



Detroit Diesel Allison

Division of General Motors Corporation

NOISE

MEASUREMENT AND CONTROL FOR DETROIT DIESEL ENGINE APPLICATIONS

Revised October 1973

Engineering Technical Data Dept.

**ENGINEERING
BULLETIN
No. 36**

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NOISE REDUCTION OF DIESEL ENGINE APP1

DATE REVISED	PAGE REVISED	GENERAL DESCRIPTI
July 1968	22	Table III updated.
June 1972	All	Complete rewrite of bulletin
Dec. 1972	20	Instruments updated.
	24	Component manufacturers u
	26	References updated.
	38	Octave band data sheet modi
	40	Legislation, regulations, an
Oct. 1973	7	Paragraph three added.
	8	Paragraph four added.
	19	Added list of related SAE T
	22 - 23	New list of Acoustical Mate:
		Companies.
	24 - 25A	New list of Component Manu
	26	New references added.
	40 - 40 A	Legislation, Regulations, an
	43	Appendix updated.

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PURPOSE OF THIS BULLETIN

The purpose of this bulletin is to provide guidance to users of Detroit Diesel Allison engines in their definition, measurement and reduction of noise produced by diesel engine applications.

All internal combustion engines produce noise. The diesel engine has many noise sources due to the inherent combustion process and its mechanical construction. The two-cycle diesel engine noise is similar to the four-cycle diesel combustion or firing noise although the frequencies are higher due to the greater number of firing impulses per revolution. The higher frequencies of the two-cycle engine will require different exhaust mufflers and air intake silencers for optimum noise reduction than four-cycle engines, although the higher frequencies of the two-cycle are easier to attenuate or reduce than lower frequencies. Many two-cycle engines are quieter than four-cycle engines.

Detroit Diesel Allison has a broad and active program of basic engine noise reduction. This program must be compatible with other design parameters; such as exhaust emissions, performance, reliability, serviceability and costs. Present knowledge does not indicate a great break-through in the reduction of the basic diesel mechanical noise, therefore, attention should be directed toward proper installation noise reduction techniques.

In most diesel engine applications, the basic engine mechanical noise is not the most predominant noise source. Since there is little that the user can do to reduce the basic engine noise, this bulletin is directed towards reducing the engine related noise sources by design and treatment of the application.

INTRODUCTION

Definition of Noise: For the intent of this bulletin, noise may be defined as unwanted sound. Noise requires a source, a path(s) and a receiver (your ears). The source can be a moving physical surface (fan blades, oil pan vibration) or a pulsating air stream (engine exhaust). The noise path can be both structural or airborne. Frequently it is both. The receiver is usually the operator of the machine or people in its immediate vicinity. To measure noise properly, we must substitute the subjective response of human hearing for the objective measurement of sound with a meter.

Definition of a Decibel: The unit of measurement of sound that is most commonly accepted in the industry and the only one that will be considered in this bulletin is the decibel (dB). The decibel is a convenient number of a logarithmic scale expressing the ratio of two sound pressures as measured in microbars. A microbar is .0001 dyne per square centimeter pressure. These terms are more fully defined in the Reference, page 27. The important thing about decibels (like electricity) is that you do not have to completely understand them to use them but should be acquainted with their sound measurement parameters. The addition and subtraction of decibels, which are not added like ordinary numbers, is discussed in the Appendix on page 29.

Definition of Frequency: Sound frequency is the number of pressure variations per unit of time and is written as Hertz (Hz) (cycles per second). Audible frequencies range from 20 to 20,000 Hz, although the average person may only "hear" a range of 40 to 16,000 Hz. For purposes of analysis, this range is divided into 10 divisions called octave bands.

Sound Measurement Instruments: Sound amplitudes or pressure levels are measured with a sound level meter. An analogy exists between a sound level meter and a pressure gauge. The sound level meter measures the amplitude variations of air pressures due to the air pulsations, whereas a pressure gauge measures the static or constant part of the air pressure. A sound level meter contains a pressure sensing element or receiver called a microphone, an electrical attenuator, an electrical amplifier, and a readable meter which has a scale in decibels.

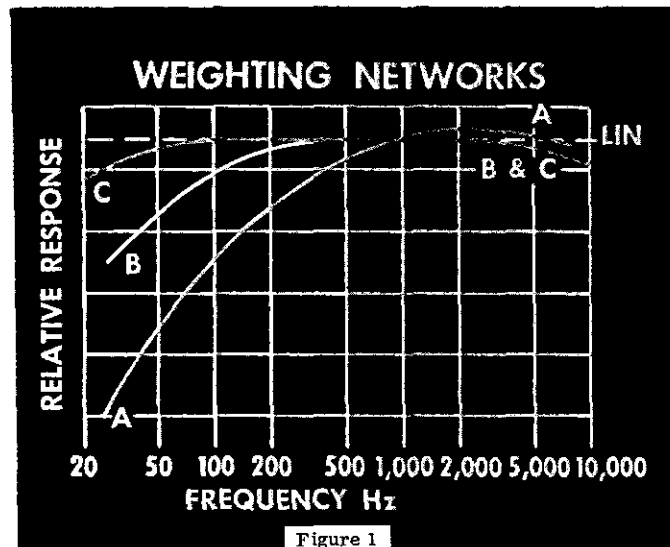
A damping circuit is usually added to achieve two desired response rates, i.e., "slow" or "fast". The "slow" setting is used for continuous or slowly varying sounds such as that generated by an engine running at constant speed, whereas the "fast" rate is used for sounds of short durations, such as the sound of a truck passing on a highway. Most specifications or test procedures specify the meter setting that should be used.

A calibrator should always be used with a sound level meter. This is an external sound generator that applies a known sound level to the meter's microphone. The meter is then adjusted (calibrated) to this known value. Some sound level meters have an internal calibrator but this is only an electrical calibration of the circuits after the microphone. This can be used as an indicator of proper electrical circuit operations, but does not take in the response of the microphone. An external sound calibration should be used for all tests. A sound level meter will "drift" and using one without calibrating it first is like measuring something with a rubber yardstick.

Most meters have weighting networks called A, B, and C weighting (scales). These networks attempt to produce an indicated sound level which corresponds to what the human ear "hears". Due to the nonlinear response of the human ear to varying loudness at various frequencies, these three networks were devised. It is now common practice however to use only the "A" weighting which is generally agreed to most closely approximate the human ear. Most meters have a Linear scale which is a flat response at all frequencies. Figure 1, page 4 shows the degree of attenuation for the various weight networks. Figure 2, page 4 shows relative values of familiar noises on the "A" weighting.

In some cases it may be found that a sound level meter does not provide enough information to completely describe the noise. In that case, an octave band analyzer may be used. This is an instrument that consists of ten electrical band filters spanning the audio frequencies (about 20 - 20,000 Hz). The term "octave-band" means that the upper frequency limit of a filter pass-band is at a frequency twice that of the lower limit of the band. The band limits normally are the frequencies where the response is three decibels below the average response within the band, see Figure 3, page 4. Octave-band filter sets are arranged so that the upper limit of, say, band one is identical with the lower limit of band two and so forth... Using octave band data, the entire audio spectrum can be represented by ten numbers corresponding to the ten continuous bands. Such a breakdown gives more information than the Linear, C-, B-, or A-weighted readings since it describes the noise by sound pressure level versus frequency bands.

There are even more sophisticated instruments available for the analysis of sound; 1/3 octave band analyzers, constant percentage narrow band, constant frequency narrow band, tape recorders, etc. A description of these items is felt to be beyond the scope of this bulletin since rarely will they be required in general noise measurements to solve a noise problem. The simple sound pressure level meter or perhaps an octave band analyzer combined with common sense and good engineering methods will suffice in most of the cases.



TYPICAL SOUND LEVELS

	140*	JET AIRCRAFT
JACKHAMMER	120	
	110	DISCOTHEQUE
PUNCH PRESS	100	
	90	CONCERT
TABULATING OFFICE	80	
	70	CITY TRAFFIC

* dB(A)

Figure 2

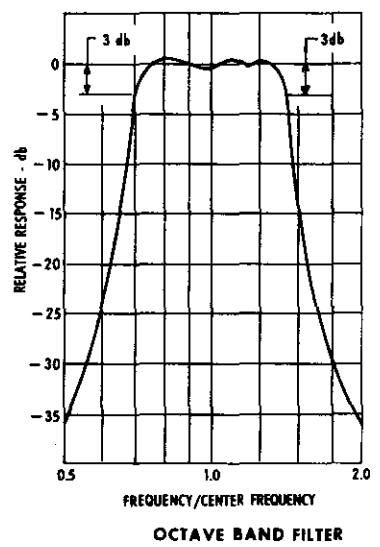


Figure 3

TOTAL NOISE SPECTRUM

The total noise spectrum emitted by an application using a diesel engine as the power source will consist of engine related noise (exhaust, fan, intake and mechanical) and application related noise (transmissions and tires, crawler-tracks, hydraulic pumps, etc.). The application related noise should be recognized as part of the total noise although it usually becomes a factor only after engine related noise is sufficiently reduced. When conducting a noise test, it is important that this relationship be kept in mind. This is because once engine noise level is reduced below application noise, further work on the engine would be fruitless in reducing the overall noise.

Engine Related Noise

With this basic distinction of noise sources in mind, it is useful to divide engine related noise into four categories:

1. Exhaust
2. Air Intake
3. Cooling Fan
4. Mechanical Radiation

Each category is treated in depth in the following pages although for purposes of clarification each category is broadly defined as follows:

1. Exhaust noise includes the various noise sources of the exhaust system. Besides the noise of the exhaust gases at the tail pipe exit, the muffler and piping shell noise, vibration and leakage of the exhaust system components (muffler, exhaust pipe, and tail pipe) must be considered.
2. Air intake noise includes the various noise sources of the air intake system. Besides the noise at the air inlet, the air cleaner and ducting shell noise, vibration and leakage of the air intake system components (air cleaner, silencer, and piping) must be considered. The blower and turbocharger noise are considered as portions of the engine mechanical noise.
3. Cooling fan noise includes the various noise sources of the cooling system. Although the predominant noise source is the fan noise, the noise of the shrouds, radiators, shutters, and grills should be considered.

4. Mechanical radiation includes the various noise sources of the engine not related to the previous three categories. These noise sources are associated with the combustion process and the mechanical components of the engine. These noises are the result of acoustical radiation or vibration of the engine structure, cover and accessories.

Application Related Noise: Reduction of application related noise is a very large subject and is not the responsibility of the engine manufacturer. These noises result from sources other than the diesel engine. Example of these noise sources are:

1. Transmission and drives
2. Tires or tracks
3. Hydraulic, electric, pneumatic and other devices

CONTROL OF EXHAUST NOISE

Mufflers: The exhaust system noise is usually the predominant noise in most diesel engine applications and is one of the more easily reduced. Present exhaust mufflers are usually inadequate and need to be replaced by the best quality muffler available within the reasonable limits of space and cost. A list of the various manufacturers is tabulated on page 24 in the Appendix. If maximum quieting is desired, use a double wall or wrapped muffler to reduce shell noise radiated from the muffler's outer surfaces.

Exhaust Pipes and Tail Pipes: Placement of the muffler within the system also has an effect on the overall system noise reduction. The exhaust pipe length (s) should be less than five feet to minimize radiation and to obtain optimum muffler quieting. The tail pipe length can also be a critical factor in the exhaust system noise. Excessive tail pipe lengths result in the "barking" or organ pipe tuning at certain engine speeds, especially during deceleration. A special resonator near the end of the tail pipe has to be included in some systems to compensate for long tail pipes. The tail pipe diameter should be large to minimize back pressure and exit gas velocities. The placement of the end of the tail pipe and the direction of the opening are critical factors on the measured noise of the exhaust system since the pipe will emit noise in a cone type pattern. If the cone pattern is directed at the microphone, the noise level will be higher. Tail pipes should, therefore, be directed away from the operator or extended vertically as high as practical to reduce operator and spectator noise levels. Additional silencing can be obtained by wrapping the tail pipe with insulation.

The leakage of the exhaust system pipes and joints are obvious noise sources. The leakage generally increases during the life of the exhaust system due to wear, misalignment, or improper repair of the exhaust system.

Mounting the Exhaust System: The mechanical vibration of the exhaust system components can result in acoustical energy. These vibrations are different than those classified as shell noise of the component, caused by the exhaust gas pulses. Most of these mechanical vibrations originate at the connection to the engine exhaust manifold (s). The normal engine vibrations excite the exhaust system components and cause them to vibrate, therefore producing noise. Sometimes the exhaust system components have their own vibration resonance which could amplify the engines vibrations. The vibrating exhaust system components can excite other components of the application, such as the cab. An ideal manifold to exhaust pipe joint will not leak and will not transmit the engine vibrations to the exhaust system. For maximum quieting, mount the muffler and exhaust pipe on isolation type mounts.

Many current exhaust systems for the more common diesel engines were evaluated and the noise levels at 50 ft. are reported in References No. 13 and 14, page 26.

CONTROL OF AIR INTAKE NOISE

Air Cleaner and/or Silencer: Air intake noise is the easiest of the engine related noise sources to reduce. The noise from the air intake system is attributed to the rush of air through the system and the blower. The major objective is to reduce the noise at the air intake inlet. Good air cleaners with built-in silencing elements or separate silencers can effectively reduce the air intake noise.

Heavy duty oil bath cleaners are good noise suppressors, but lack the cleaning efficiency which is the prime purpose of an air cleaner. Heavy duty two stage dry type cleaners can be selected that will give optimum air filtration and still provide acceptable noise attenuation. For maximum quieting, an additional intake silencer can be installed between the air cleaner and the engine inlet. These devices are not particularly expensive, are easy to install and will do a good job of absorbing the high frequency noises associated with the intake system. The silencer should be installed as close to the engine inlet as possible.

Marine engines used in yachts are seldom equipped with anything more than a direct mounted silencer having minimum air filtration characteristics. These silencers will be satisfactory provided the complete engine is totally enclosed, which is common practice in pleasure boat installations.

Avoid the use of cleaners that have large, flat sections of sheet metal. These can be effective noise broadcasters.

Air Intake Piping: Due to the high frequencies of the air intake system noise and the need for an airtight system, special attention should be made towards the air intake piping. Use heavy wall, round (instead of oval or square) piping with as few rubber sections as possible. Most rubber sections, such as elbows tubes or connectors, are not good acoustical barriers, and their use should be minimized or restricted. Use of rubber section between the air cleaner or silencer and the engine air inlet can result in high levels of air intake noise.

Mounting of the Air Intake System: Locate the air intake system components, especially the inlet, as far away from the operator as possible. Similar to the exhaust tail pipe, the location of the air inlet can influence the measured noise of the application. To reduce spectator noise, the inlet should be pointed up or directed to the front or rear of the application.

Mechanical vibration of the air intake system should be reduced to a minimum, especially if any of the components are directly connected to other parts of the machine. Attachment of the air cleaner to the cab or operator's enclosure can result in high noise levels due to the mechanical vibrations of the air intake system components being transmitted to the cab.

Many current air intake systems for the more common diesel engines were evaluated and the noise levels at 50 ft. are reported in References No. 13 and 14, page 26.

CONTROL OF COOLING FAN NOISE

Fan Noise: After the exhaust and intake noises have been reduced, the cooling fan noise will usually become predominant. Occasionally fan noise, due to a very poor consideration of this component initially, will be found to be the prime offender. To determine if fan noise is a major consideration, operate the unit with the fan or belt removed. This can usually be done with minimum danger of overheating the engine. If the fan is indeed a major noise contributor, the following items should be considered to reduce this noise.

Fan noise output consists of many harmonics of the fan rotational speed. For a four-bladed fan with equal angular spacing of the blades, the fundamental frequency would be four times rotational frequency. It would be expected that the noise due to this component of fan noise would be at that frequency. Noise peaks from an equally-spaced four-blade fan would occur not only at 4th order but also at 8th order, 12th order, 16th order, etc.; the higher order peaks are called harmonics. Similarly, an equally-spaced six-blade fan would produce components at 6th, 12th, 18th, 24th, etc. orders. If blade spacing is not equal, however, other harmonics are introduced into the spectrum and, in turn, the fundamental harmonics and integral multiples of the fundamental are reduced in amplitude. With a four-bladed fan, as the two pair of blades are each kept diametrically opposite and one set is skewed with respect to the other to form

an "X", the second harmonic is introduced, but the fourth order harmonic is reduced. Similarly, 2nd, 6th, and other even harmonics are added, but the original harmonics are reduced in level somewhat. Thus, one technique used in noise reduction of a fan is to vary blade angular spacing.

A method for reducing the loudness and annoyance of fan noise is to use a larger diameter, slower-turning fan. This shifts the most intense fan noise to a lower frequencies where a person's hearing is less sensitive. Although the energy radiated by the slower turning fan is not less than that for the higher speed fan, the annoyance as well as the loudness is reduced by the shift to lower frequencies.

Placement of objects near the fan blades can result in reduced air flow and pressure pulses or noises. The fan discharge areas should be free of engine or engine mounted accessories. Sufficient clearance should be provided for all hoses and cables. All loose items should be fixed to prevent vibration.

In summary, the best known techniques for reducing fan noise are:

1. Use as large a fan as possible turning as slowly as possible to keep tip speed down. Tip speed should not exceed 20,000 feet per minute. Tip speed is equal to $3.14 \times \text{diameter in inches} \times \text{fan rpm}$ divided by 12. Example: A 40 inch fan at .66 ratio on a 2100 rpm engine has a tip speed of:

$$\frac{3.14 \times 40 \times .66 \times 2100}{12} = 14,600 \text{ fpm}$$

2. Use a tight fitting venturi type shroud to increase efficiency. This lowers both fan horsepower and radiated sound power (noise).
3. Operate fans near maximum efficiency for minimum noise and power requirements.
4. Vary the number and spacing of blades, their pitch and the fan speed to move noise peaks to the least objectionable frequencies.

Fan Shroud: In general, a fan system which is efficient in moving air will be relatively quiet. A well-designed venturi close fitting shroud increases the efficiency of a fan. The result is that as more air flow is developed per input horsepower supplied, less noise will then be produced by the fan since the power input to it has been reduced. For a given air flow, a minimum noise operating condition exists near the maximum efficiency point of the fan system.

Other sources of noise in connection with fans may be due to mechanical vibrations of the fan blades or shrouds. Fan blades themselves sometimes become resonant in their operating range. Such resonances may be moved to an engine speed out of normal range by changing the size of the fan or its drive ratio.

Radiator, Shutters, Grills, and Baffles: These components of the overall cooling system can have a significant effect on the airflow to the fan and the overall efficiency of the cooling system. Besides affecting the cooling system efficiency, these components can have their own mechanical vibration which can contribute to the cooling system noise. When the shutters are closed to restrict the airflow, most fan systems go into a stall condition which result in greater fan noise. Radiators, grills and baffles direct the pattern of the airflow into the fan; therefore, affecting the resulting noise level of the fan.

CONTROL OF ENGINE MECHANICAL NOISE

The engine related mechanical noise as stated previously is the engine noise, and does not include the exhaust, air intake and cooling fan noises. This noise is attributed to the combustion and the rotating and reciprocating mechanical components of the basic engine and is radiating from the vibrating surfaces of the engine. Anything attached to the engine such as accessory transmissions and drives, or application structural frame and components become radiating surfaces due to the mechanical vibration transmitted from the engine. Since the engine manufacturers are active and responsible for basic engine design and modification or acoustical treatment of the engine to reduce the noise levels, the application manufacturer should concentrate on engine installation or application noise reduction. Present knowledge indicates the most significant and most economical engine mechanical noise reduction will be by acoustical treatment of the engine compartment or the use of total enclosures. Acoustical treatment of the engine compartment and use of resilient engine mounts can satisfactorily reduce the engine related mechanical noise for most applications for current noise legislation. Some applications and future legislation will need acoustically treated complete engine enclosures. A discussion of acoustical and vibration control materials, resilient mounts, and engine compartment treatments will follow.

Acoustical and Vibration Control Materials: Acoustical materials are the various types of materials used in the treatment or reduction of sound. The materials can be divided into three basic categories and are rated as to the following characteristics: sound absorption, sound barrier and damping.

Most acoustical materials have a combination of these characteristics although most are made to have one characteristic better than the others. Fabricated panels consisting of several types of acoustical materials are designed to achieve a greater overall sound reduction, Figures 4, 5, and 6 shown below:

NOISE REDUCTION WITH ABSORPTION MATERIAL

NOISE REDUCTION WITH ABSORPTION MATERIALS

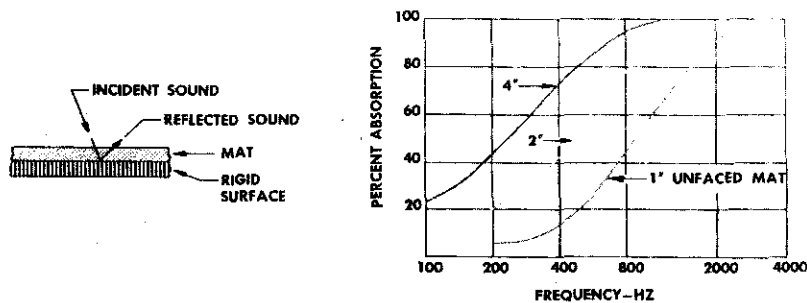


Figure 4

NOISE REDUCTION WITH ABSORPTION MATERIALS

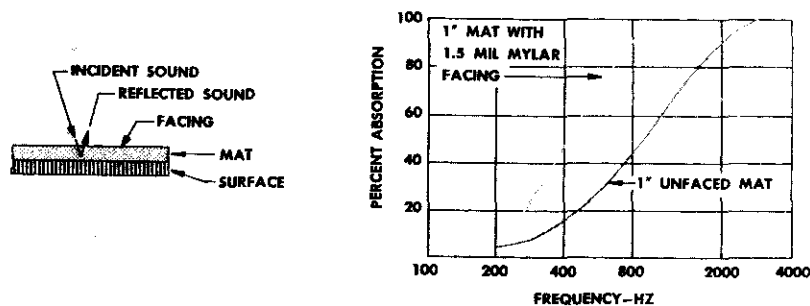


Figure 5

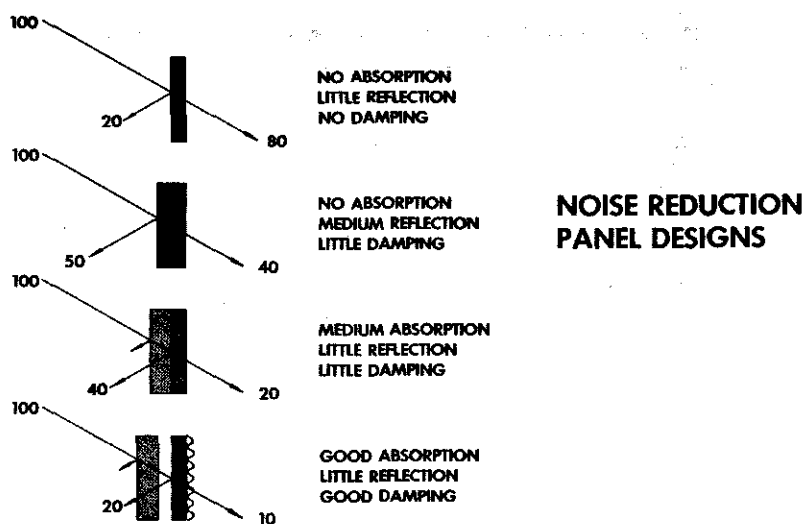


Figure 6

Absorption Materials: A sound absorption material changes the acoustical energy into some other form of energy, usually heat, as the sound strikes or passes through this material. Materials with many fine pores are good absorption materials. Some of these materials are fiberglass, woven or non-woven felt or cloth, and plastic open cell foams. Absorption materials are usually used in conjunction with a rigid surface, such as on the inside of hoods or cab. The following factors affect how much sound absorption and in which frequency range that the absorption occurs:

1. Thickness of absorption material
2. Pore size
3. Thickness and stiffness of the protective skin of the material
4. Spacing of the material from the backing or rigid surface

Since installation space may limit the use of thick materials and since lower frequencies are carried mechanically through the structure, most use of absorption materials is limited to reduction of sound with frequencies above 300 Hz. Absorption materials will reduce noise effectively when applied to "wall" surfaces of a room or compartment in which a noise source exists, particularly if the "room" has hard reflecting walls. Absorption material will reduce the noise level within an engine enclosure and within the cab of a truck. Most highly porous materials, while very effective in absorbing sound, are not good as a sound barrier or a damping material.

Barrier Materials: A sound barrier material reflects or impedes the transmission of sound energy through the material. A good sound barrier material needs:

1. Weight
2. Non-porous or good sealing
3. Multiple layers

Heavy, limp, non-porous materials like lead, sheet steel, asphalt composition and hard rubber are good barrier materials. The sound transmission is directly related to the density of the barrier material, or the "mass law". Doubling the weight will decrease the sound transmission by 6 dB (half the sound pressure transmitted).

A good barrier must be properly sealed, otherwise sound transmission will increase. An "airtight" seal of a heavy material is necessary for a good sound barrier. Heavy pliable putty-like materials make good seals around holes or seams in an enclosure. Thin rubber, pliable plastic or canvas boots around enclosure openings may be airtight seals but are not good sound barriers.

A double wall or "sandwich" type construction makes a better sound barrier than a single layer construction. The two impervious barrier layers should be separated by a compliant material. Sandwich type barriers are superior to single barriers of the same weight especially for the middle and high frequency sounds.

Damping: A damping material is not generally used to reduce sound but is used to absorb vibratory energy or restrain the vibratory motion of mechanical structures. Reducing the motion of these structures as used in "sandwich" construction of acoustical materials does result in a reduction of the sound transmission. Damping is beneficial in reducing the vibration of panels or other materials in two ways:

1. Damping is most effective in reducing the amplitude of motion when the panel or material is vibrating at its resonant frequency.
2. Damping can reduce the vibration amplitude and frequency of materials due to the additional mass of the damping material.

Resilient Mounts: One of the most effective ways of reducing the transmission of engine mechanical vibration to other components of the application is to mount the engine or engine/transmission package on resilient mounts. Engine vibration is frequently amplified and/or transmitted through surrounding sheet metal and frame rails which results in greater operator and spectator noise. The use of correctly sized rubber or spring type mounts can substantially reduce this noise. A list of manufacturers who can supply these mounts is in the Appendix. Allowance for engine movement on these style mounts must be considered in the installation. The engineering and installation problems involved in replacing solid mounts with resilient mounts are relatively simple and straightforward.

Engine Compartment Treatment: The acoustical treatment of engine compartment includes the closing of the sides and holes with covers, side shields, or panels. The covers and panels should be rigid to prevent excessive mechanical vibrations with all holes or cracks eliminated. After the mechanical covers and panels are installed to enclose the engine compartment, acoustical materials should be added to provide absorption, barrier, and damping characteristics.

The maximum effective application of Absorption, Barriers and Damping Materials is much more complex. The sketches and graphs in Figure 3 and 4 show the effect of various materials and where they are applied. The dB values are actually not meaningful as presented, but indicate that absorption in the engine compartment reduces noise in the engine and passenger compartments as well as outside the vehicle. Treatment of the passenger compartment, with or without treatment in the engine compartment, will reduce noise only in the passenger compartment, for example, treatment of the passenger compartment will not reduce noise radiated out through the radiator.

In general, the degree of engine compartment and/or cab treatment will depend on the amount of noise attenuation required and the economic realities involved. As stricter noise control laws are passed, the increased costs necessary to meet these regulations will become less prohibitive since all members of a given industry will be faced with the same problem.

PLANNING A NOISE REDUCTION PROGRAM

Selection of Objectives and Procedures: It is assumed that anyone using this bulletin has a noise problem or is interested in reducing the noise of an application powered by a Detroit Diesel Allison engine. The first step in establishing such a program is, of course, to define the goals or objectives to be attained. This will require answers to the following questions.

1. Is the machine to be made quieter for the operator, the spectator or both?
2. What requirements, such as Walsh Healey (for operator noise), or various vehicle traffic codes are to be met?
3. Is certification necessary?
4. Have test procedures and/or industry standards been established for this type machine?

After the objectives have been resolved there are two basic ways or test procedures to obtain the objectives:

1. The "shot gun" procedure will produce the most results with least amount of experimentation. It involves using the optimum choices of all the items listed in the previous sections to attain, with one grand effort, the quietest possible application. It is effective but relegates cost to a minor consideration. When time is of the essence and research is secondary it may be the best way.
2. The components procedure consists of a careful step-by-step evaluation of the noise level of each component so that the greatest noise contributor may be first identified and then improved, the second contributor identified and then improved, etc. It is basically a component improvement subtraction technique and will be described fully in following sections.

Treatment of Individual Noise Sources: Once the objectives of the program have been resolved and a decision to use the "components" approach rather than the "shot gun" approach has been made, the program may proceed:

1. Evaluate the overall noise.
2. Identify and evaluate the individual noise sources.
3. Reduce the individual noise sources or their paths or radiating surfaces.
4. Re-evaluate the overall noise with the reduced individual noise sources.

Methods of treating or reducing the noise and evaluating each of the major noise sources are:

1. Exhaust System: Large industrial type mufflers are used in series with the stock mufflers to reduce the exhaust noise at the tail pipe exit. The exhaust pipe, connecting pipes, and both mufflers should be acoustically treated to reduce the shell, leakage, and mechanical vibration noises. High temperature, fine fibrous mat or felts with a sheet of lead are used as the thermal and sound barriers on the exhaust system components. Flat sheets of asbestos materials can be used on the silencer in place of the fibrous felts. All areas must be covered to prevent melting of the lead. The sheets of lead are held to the exhaust system components by wire or band type attachments. Piping bends and lengths should be minimized to prevent excessive exhaust back pressure. Precaution should be made to prevent fuel, lube oil or exhaust "wet stacking" soaking into the acoustical wrapping of the exhaust system to eliminate the possibility of a fire hazard.

For vehicles which can be evaluated in a stationary position, the exhaust systems can be attenuated by a long pipe between the silencer and the engine. The pipe should be solid steel heavy wall type of 50-foot length with a short flexible section at the exhaust manifold. At least the first half of the pipe starting at the exhaust manifold should be wrapped with thermal insulation and then a barrier material to eliminate the shell noise of the pipe. At the end of the pipe a large industrial type muffler should be installed behind a barrier or be acoustically treated to eliminate shell noise. The exhaust noise should not be detectable at the microphone locations.

2. Air Intake System: Large industrial type air silencers are used in series with the stock air intake system to reduce the air intake noise at the air cleaner inlet.

The air inlet pipe, connecting pipes, and air silencers are acoustically treated to reduce the air intake system shell, noise, leakage, and mechanical noise sources. A good barrier material such as sheet lead or lead vinyl materials is used to wrap the air intake system. Piping bends and lengths should be minimized to prevent excessive air intake restrictions.

For vehicles which can be evaluated in a stationary position, the air intake system can be attenuated by a long pipe between the silencer and the engine. The pipe should be solid steel piping of 50-foot length with a short flexible section at the blower air inlet. At least the first half of the piping starting at the blower air inlet should be wrapped with a barrier material to eliminate the shell noise of the pipe. At the end of the pipe a large industrial type silencer should be installed behind a barrier or be acoustically treated to eliminate the shell noise of the silencer. The air intake noise should not be detectable at the microphone locations.

3. Fan Noise: The fan noise can be eliminated by removing the fan belt or the fan. Most equipment can be operated for short periods of time with the fan disconnected. Caution should be exercised to prevent any engine overheating and to assure that the tests are run at or near the normal temperature conditions.
4. Mechanical Noise: The engine mechanical noise can be reduced by acoustical treatment of the engine, similar to that used for the exhaust system. Caution should be exercised that the acoustical material does not become soaked with fuel or lube oil thereby presenting a serious fire hazard. The basic engine noise in many applications can be reduced by proper isolation mountings, either on the engine or the operator's cab. Proper isolation of engine noise and vibration will be necessary in many types of equipment to achieve satisfactory operator noise levels and to evaluate the individual noise sources.
5. Application Related Noise Source: The various application related noise sources can be acoustically treated similar to the engine related noise sources or disengaged or made inoperative.

Evaluation of Individual Noise Sources: The various noise sources under stock operating condition can be obtained by individually returning to stock condition each noise source and measuring the increase in noise over the reduced noise condition or the original engine noise condition. Each individual noise source should then be retreated to the initial attenuated condition before another individual noise source is exposed. Since this procedure is a difference or subtraction type method of determining the individual noise sources, it is imperative that the test conditions, procedures, etc., be controlled in the best manner possible. See the Appendix for addition and subtraction of dB sound levels.

Contributions of application treatment of engine mechanical noise are obtained by removing appropriate hoods, side panels, fire wall treatment, mounts, etc.

As stated previously, this is a subtraction method, the purpose of which is to identify and evaluate the major noise contributors so that noise reduction may be done on each of them. As an example, if the fan is reinstalled and the overall noise level does not increase then the fan is obviously not a major noise contributor and can be left alone.

By obtaining the values of the individual noise sources, the overall sound levels can be calculated by proper dB addition techniques. If the calculated overall noise does not agree with the previously measured overall noise level, it indicates the test techniques may not have been done properly. A calculated value less than the measured value could indicate a noise source which was not evaluated.

TEST PROCEDURES AND DATA SHEETS

Test Procedures: Various legislative and industrial codes are quite specific in the methods of sound tests as well as the instrumentation that is to be used. Copies of some of these codes are included in this bulletin. The techniques described should certainly be used where applicable, but other techniques of an investigative nature will be required to locate, identify and suppress individual noise sources. The human ear is a good instrument to begin with. Walk around, crawl under, get on top of the machine you are trying to quiet. LISTEN to it! Your ear can tell you where the noise is coming from. Then use your sound level meter. Is the noise directional or omni-directed? Try the meter on "Fast" and "Slow" response. Try the various weighting networks to determine the amount of low frequency noises, experiment with it.

Most of the noise test procedures are self-explanatory as to their objectives and procedures. Many of the test procedures are being updated or their format is being changed. Revised versions will be added to the Appendix periodically. The SAE procedures are being updated to be compatible with other SAE procedures and the format is being changed to be compatible with a new set of procedures being developed by the American National Standards Institute (ANSI). The metric units are also being incorporated into these standards. The SAE test procedures are generally used in North America, whereas the ISO tests are generally used in the rest of the world. The basic difference is in use of 7 1/2 meter (approximately 25 feet) instead of 50 feet as the distance between the application and the microphone. The CAGI-PNEUROP code is a procedure used with pneumatic equipment and is generally used all over the world.

The Idle-Maximum Governed Speed-Idle test (I-M-I) is a stationary, rapid acceleration and deceleration test procedure being developed by SAE as a simple test procedure to measure the noise on a stationary application for comparison with the other more detailed SAE test procedures. This test procedure would be useful for enforcement purposes.

Test Data Sheets: A sample of noise test data sheets is provided in the Appendix. Use of these forms usually results in a more complete test information and data. Some of the information may seem irrelevant at the time of the test, but it will generally be needed for complete description of the application, test equipment, test location, test condition, and test data. Experience in noise reduction programs will confirm the need for use of detailed noise test data sheets.

SUMMARY

Each diesel engine user must plan his own noise reduction program according to his application or industry requirements. To assist the engine user in his noise reduction program, the Appendix contains additional information on instruments for sound measurement, acoustical and vibration control materials, component suppliers, test procedures, data sheets, and other reference materials. The techniques of noise reduction are not difficult, the modifications are not dramatic, the costs are not prohibitive and the results of a well planned and executed noise reduction program can result in an acceptable quiet diesel engine application.

APPENDIX

Instruments for Sound Measurement

Acoustical and Vibration Control Materials

Component Manufacturers

Exhaust Mufflers

Air Cleaners and Silencers

Cooling Fans and Shrouds

Isolation Mounts

References

Bibliography

Glossary of Noise Control Terminology

Combining Noise Levels

Handy Numbers

Test Procedures

SAE Recommended Practices

SAE J-336 (6-68) Sound Level for Truck Cab Interior

J-366a (6-71) Exterior Sound Levels for Heavy Trucks
and Buses

J-952b (1-69) Sound Levels for Engine Powered Equipment

J-919a (4-71) Sound Level Measurements at the Operator
Station for Agricultural and Construction
Equipment

List of other related SAE Test Procedures.

Idle-Maximum Governed Speed-Idle Noise Test

Data Sheets

Legislation, Regulations, and Specifications

INSTRUMENTS FOR SOUND MEASUREMENT

Sound Level Meters:

Precision ¹	Manufacturer's Model B & K Model 2203 B & K Model 2204 B & K Model 2206 GR Model 1561 GR Model 1933
General Purpose ²	B & K Model 2205 GR Model 1551C GR Model 1565B
Calibrators for Sound Level Meters	B & K Model 4220 B & K Model 4230 GR Model 1562A GR Model 1567
Octave Band Analyzers ³	B & K Model 1613 GR Model 1933

1. Meets the requirements of the ANSI S1.4-1971 Type 1, Specifications for Precision Sound Level Meters, IEC Recommendation Publication - 179 and DIN-45633 pt. 1 for Precision Sound Level Meters.
2. Meets the requirements of the ANSI S1.4-1972 Type 2, Specifications for General Purpose Sound Level Meters and IEC Recommendation R-123.
3. Meets the requirements of the ANSI S1.11-1966 Class II Filters and IEC Recommendations 225-1966.

B & K Instruments, Inc.
5111 West 164th Street
Cleveland, Ohio 44142

Telephone 216/267-4800

General Radio Company
300 Baker Avenue
Concord, Massachusetts 01742

Telephone 617/369-8770

ACOUSTICAL AND VIBRATION CONTROL MATERIALS

***A Buyer's Guide to Manufacturers and Suppliers of Sound Absorption, Sound Barrier, Vibration & Shock Isolation, and Vibration Damping Materials.** The Buyer's Guide lists manufacturers and suppliers of materials for the control of noise, vibration, and mechanical shock. Refer to the following table and preceding each of the four major categories for the various classifications by material type.

1. Sound absorption materials are porous or fibrous materials which absorb sound energy -- they do not block the transmission of sound.
2. Sound barrier materials are dense, impervious materials which block the transmission of sound energy -- they generally reflect rather than absorb sound.
3. Vibration and shock isolation materials are resilient materials that isolate mechanical structures from forced vibration or shock energy sources.
4. Vibration damping materials are viscoelastic materials that absorb vibrational energy or restrain the vibratory motion of mechanical structures.

For easy reference to the company or product wanted, find the appropriate category in the table. Then locate the manufacturer by referring to the company listings and product sub-classifications. See pages 22 and 23.

***Courtesy of SOUND AND VIBRATION Magazine, Acoustical Publication, Inc.**

*Acoustical Material Manufacturing Companies:

I. Sound Absorption Materials

1. Formboard
 2. Glass Fiber & Foam
 3. Metal Felt & Porous Metals
 4. Mineral Wool
 5. Perforated Ceramic Tile
 6. Perforated Sheet Metal
 7. Plastic Foam Sheet
 8. Slotted Masonry Units
 9. Spray-on Absorptive Coatings
 10. Wood Fiber & Fiberboard
 11. Woven & Nonwoven Felt & Cloth
- Accessible Products Co., 1350 E. 8th St., Tempe, AZ 85281 (7)
- ACS Industries, Inc., 71 Villanova St., Woonsocket, RI 02895 (4)
- Advanced Acoustical Research Corp., 2259 Sawmill River Rd., Elmsford, NY 10523 (2,4,6,7,9)
- Air-O-Plastik Corp., Asia Place, Carlstadt, NJ 07072 (2,7)
- Airtex Industries, Inc., Flexible Products Div., 3558 2nd St. N., Minneapolis, MN 55412 (7)
- Alpro Acoustics Div., P.O. Box 30460, New Orleans, LA 70190 (6)
- American Acoustical Products, 9 Cochituate St., Natick, MA 01760 (2,4,7)
- Architectural Products Div., Erdle Perforating Co., Inc., P.O. Box 1568, Rochester, NY 14603 (6)
- Arrow Sintered Products Co., 7650 Industrial Dr., Forest Park, IL 60130 (3)
- Barry Div./Barry Wright Corp., 700 Pleasant St., Watertown, MA 02172 (3)
- H. L. Blachford, Inc., 1855 Stephenson Hwy., Troy, MI 48084 (2,7)
- Brunswick Corp., Technical Products Div., One Brunswick Plaza, Skokie, IL 60076 (3,6)
- The Celotex Corp., P.O. Box 22622, Tampa, FL 33602 (7,10)
- Chemical Coatings & Engineering Co., Inc., 221 Brook St., Media, PA 19063 (9)
- Consolidated Kinetics Corp., 249 Fornof Lane, Columbus, OH 43207 (2,7)
- Conwed Corp., 2200 Highcrest Rd., St. Paul, MN 55113 (10)
- Diamond Perforated Metals Co., A Div. of Whittaker Corp., 17915 S. Figueroa St., Gardena, CA 90248 (6)
- Donn Products, Inc., 1000 Crocker Rd., Westlake, OH 44145 (6)
- Duracote Corp., 350 N. Diamond St., Ravenna, OH 44266 (7)
- Eckoustic Div., Eckel Industries, 155 Fawcett St., Cambridge, MA 02138 (2)
- Electro-Ionic Systems, Inc., 1085 Memorex Dr., Santa Clara, CA 95050 (7)
- Environmental Services and Products, Inc., P.O. Box 1281, OH 45401 (7)
- Fansteel/Reflective Laminates, 851 Lawrence Dr., Newbury Park, CA 91320 (2,4,6)
- Ferguson Perforating & Wire Co., Inc., 133 Ernest St., Providence, RI 02905 (6)
- Ferro Corp., Composites Div., 34 Smith St., Norwalk, CT 06852 (7)
- GAF Corp., Industrial Products Div., Glenville Station, Greenwich, CT 06830 (11)
- Gaska-Tape, Inc., 1801 Minnie St., Elkhart, IN 46514 (7)
- General Noisecontrol Corp., 101 E. Main St., Little Falls, NJ 07424 (2,4)
- Globe Industries, Inc., Acousti-Pad Div., 2638 E. 126th St., Chicago, IL 60633 (11)
- The Harrington & King Perforating Co., Inc., 5655 Fillmore St., Chicago, IL 60644 (6)
- Hecht Rubber Co., 484 Riverside Ave., Jacksonville, FL 32202 (7)
- Industrial Acoustics Co., Inc., 380 Southern Blvd., Bronx, NY 10454 (2,4,6)
- Ineson, Inc., 5235 Darrow Rd., Hudson, OH 44236 (2,7)
- Insul-Coustic/Birma Corp., Jernee Mill Rd., Sayreville, NJ 08872 (2,11)

- Johns-Manville, Greenwood Plaza, Denver, CO 80217 (2)
- Korfund Dynamics Corp., Cantiague Rd., Westbury, NY 11590 (2,7)
- MBI Products Co., 1176 E. 38th St., Cleveland, OH 44114 (2,11)
- National Cellulose Corp., 12315 Robin Blvd., Houston, TX 77045 (9)
- National Gypsum Co., Gold Bond Building Products Div., 325 Delaware Ave., Buffalo, NY 14202 (1,4)
- National Perforating Corp., Parker St., Clinton, MA 01510 (6)
- Nichols Dynamics, Inc., 740 Main St., Waltham, MA 02154 (2,7,9)
- Noise Measurement & Control Div., National Research Corp., 322 E. Lancaster Ave., Wayne, PA 19087 (2,6,7,10)
- Norton Co., Sealant Operations, 12 Bennett Dr., Granville, NY 12832 (7)
- Owens-Corning Fiberglas Corp., 1 Fiberglas Tower, Toledo, OH 43659 (1,2)
- Pittsburgh Corning Corp., Three Gateway Center, Pittsburgh, PA 15222 (2)
- The Proudfoot Co., Inc., P.O. Box 9, Greenwich, CT 06830 (8)
- Ray Proof Corp., 50 Keeler Ave., Norwalk, CT 06856 (6)
- Scason, Inc., 112 Main St., Norwalk, CT 06430 (7)
- Scason Canada, Ltd., 2220 Midland Ave., 31 Administration Park, Scarborough, Ontario M1P 3E6, Canada (7)
- Scott Paper Co., Foam Div., 1500 E. Second St., Chester, PA 19013 (7)
- Sound/Eaze Products-John Schneller and Assoc., P.O. Box 386, Kent, OH 44240 (7)
- Singer Partitions, Inc., 444 N. Lake Shore Dr., Chicago, IL 60611 (7)
- The Soundcoat Co., Inc., 175 Pearl St., Brooklyn, NY 11201 (7)
- Sound Solutions Corp., 601 Washington St., Lynn, MA 01901 (2,6,7,9)
- Specialty Composites Corp., Delaware Industrial Park, Newark, DE 19711 (7)
- Standard Felt Co., 115 S. Palm Ave., Alhambra, CA 91802 (11)
- Stark Ceramics, Inc., P.O. Box 8880, Canton, OH 44711 (5)
- Steel-Fab, Inc., 430 Crawford St., Fitchburg, MA 01420 (2)
- Tull Environmental Systems, Div. J. M. Tull Industries, Inc., 285 Marietta St., NW, Atlanta, GA 30302 (2,6,7)
- United States Gypsum Co., 101 S. Wacker Dr., Chicago, IL 60606 (4,10)
- Veneered Metals, Inc., Woodbridge Ave. at Main St., Edison, NJ 08817 (6)
- Vibration Mountings & Controls Inc., Post Office Box 776SV, Butler, NJ 07405 (9)
- Webster Products Co., 1261 W. Wright St., Santa Ana, CA 92705 (7)
- Wilshire Foam Products, Inc., 2665 Columbia St., Torrance, CA 90503 (7)

II. Sound Barrier Materials

1. Asphalted Felt & Fiberboard
2. Constrained Sheet Metal Composites
3. Gypsum Board
4. Insulation Board
5. Lead Sheet
6. Loaded Plastic Sheet
7. Loaded Plastic/Plastic Foam Composites
8. Loaded Rubber Sheet
9. Mastic/Celulose Composites
10. Particle Board
11. Sealants & Sealing Tapes
12. Semi-Liquid Compounds
13. Sheet Metal/Mineral Wool Composites
14. Sheet Metal/Plastic Foam Composites

- Accessible Products Co., 1350 E. 8th St., Tempe, AZ 85281 (5-7,11)
- ACS Industries, Inc., 71 Villanova St., Woonsocket, RI 02895 (13)
- Advanced Acoustical Research Corp., 2259 Sawmill River Rd., Elmsford, NY 10523 (2,5,6,13)
- The Aeroacoustic Corp., P.O. Box 65, Amityville, NY 11701 (13,14)
- Aeronca, Inc./Environmental Control Group, P.O. Box 688, Pineville, NC 28134 (13,14)
- Air-O-Plastik Corp., Asia Place, Carlstadt, NJ 07072 (7,11,14)
- Airtex Industries, Inc., Flexible Products Div., 3558 2nd St. N., Minneapolis, MN 55412 (5,7,8)
- Alpro Acoustics Div., P.O. Box 30460, New Orleans, LA 70190 (13)
- American Acoustical Products, 9 Cochituate St., Natick, MA 01760 (5-7,13,14)
- American Smelting & Refining Co./Federated Metals Div., 150 St. Charles St., Newark, NJ 07105 (5)
- Architectural Products Div., Erdle Perforating Co., Inc., P.O. Box 1568, Rochester, NY 14603 (13,14)
- Barley-Earhart Co., 233 Divine Hwy., Portland, MI 48875 (1,9)
- Bar-Ray Products, Inc., 209 25th St., Brooklyn, NY 11232 (5-8)
- Barry Div./Barry Wright Corp., 700 Pleasant St., Watertown, MA 02172 (2,8)
- H. L. Blachford, Inc., 1855 Stephenson Hwy., Troy, MI 48084 (5-7)
- Canada Metal Co., Noise Control Div., 721 Eastern Ave., Toronto, Ontario M4M 1E6, Canada (5)
- The Celotex Corp., P.O. Box 22622, Tampa, FL 33602 (1,3,4)
- Certain-Teed Products Corp., CSG Group, P.O. Box 860, Valley Forge, PA 19482 (4)
- Chemical Coatings & Engineering Co., Inc., 221 Brook St., Media, PA 19063 (6-8,11)
- Chemprene, Inc., 579 South Ave., Beacon, NY 12508 (6-8)
- Consolidated Kinetics Corp., 249 Fornof Lane, Columbus, OH 43207 (6,7,11)
- Conwed Corp., 2200 Highcrest Rd., St. Paul, MN 55113 (4)
- Cowl Div. of James B. Carter, 88 Fennel St., Winnipeg, Manitoba, Canada (12)
- Dow Corning Corp., Midland, MI 48640 (11)
- Duracote Corp., 350 N. Diamond St., Ravenna, OH 44266 (6,7)
- Eckoustic Div., Eckel Industries, 155 Fawcett St., Cambridge, MA 02138 (7)
- Electro-Ionic Systems, Inc., 1085 Memorex Dr., Santa Clara, CA 95050 (14)
- Environmental Services and Products, Inc., P.O. Box 1281, Dayton, OH 45401 (6-8)
- Fansteel/Reflective Laminates, 851 Lawrence Dr., Newbury Park, CA 91320 (13)
- Ferro Corp., Composites Div., 34 Smith St., Norwalk, CT 06852 (6,7)
- GAF Corp., Industrial Products Div., Glenville Station, Greenwich, CT 06830 (1,9)
- Gaska-Tape, Inc., 1801 Minnie St., Elkhart, IN 46514 (11)
- General Electric Co., Silicone Products Dept., Waterford, NY 12188 (11)
- General Noisecontrol Corp., 101 E. Main St., Little Falls, NJ 07424 (5,13)
- Globe Industries, Inc., Acousti-Pad Div., 2638 E. 126th St., Chicago, IL 60633 (1,9,12)
- Hecht Rubber Co., 484 Riverside Ave., Jacksonville, FL 32202 (8,11)
- Industrial Acoustics Co., Inc., 380 Southern Blvd., Bronx, NY 10454 (13)
- Ineson, Inc., 5235 Darrow Rd., Hudson, OH 44236 (5-7,14)
- Insul-Coustic/Birma Corp., Jernee Mill Rd., Sayreville, NJ 08872 (4-7,11)
- Johns-Manville, Greenwood Plaza, Denver, CO 80217 (3)
- Korfund Dynamics Corp., Cantiague Rd., Westbury, NY 11590 (6,7)

*Courtesy of SOUND AND VIBRATION Magazine, Acoustical Publication, Inc., July 1973

*Acoustical Materials Manufacturing Companies:

Lambda Corp., Box 181, Whippany, NJ 07981 (12)
 MBI Products Co., 1176 E. 38th St., Cleveland, OH 44114 (4)
 National Gypsum Co., Gold Bond Building Products Div., 325 Delaware Ave., Buffalo, NY 14202 (3,4,10)
 National Research Corp., Concord Rd., Billerica, MA 01821 (6)
 Nichols Dynamics, Inc., 740 Main St., Waltham, MA 02154 (5-8)
 Noise Control Products, Inc., 969 Lakeville Rd., New Hyde Park, NY 11040 (13)
 Noise Measurement & Control Div., National Research Corp., 322 E. Lancaster Ave., Wayne, PA 19087 (1,2,4-7,13)
 Norton Co., Sealant Operations, 12 Bennett Dr., Granville, NY 12832 (11)
 Owens-Corning Fiberglas Corp., 1 Fiberglas Tower, Toledo, OH 43659 (4)
 Quaker, State Oil Refining Corp., P.O. Box 989, Oil City, PA 16323 (9,12)
 Ray Proof Corp., 50 Keeler Ave., Norwalk, CT 06856 (5,13)
 Scason, Inc., 112 Main St., Norwalk, CT 06430 (2,6)
 Scason Canada, Ltd., 2220 Midland Ave., 31 Administration Park, Scarborough, Ontario M1P 3E6, Canada (2,6)
 Scott Paper Co., Foam Div., 1500 E. Second St., Chester, PA 19013 (7)
 Sound/Eaze Products-John Schneller and Assoc., P.O. Box 386, Kent, OH 44240 (6,7)
 Singer Partitions, Inc., 444 N. Lake Shore Dr., Chicago, IL 60611 (6,7,9)
 The Soundcoat Co., Inc., 175 Pearl St., Brooklyn, NY 11201 (2,5-7,14)
 Sound Solutions Corp., 601 Washington St., Lynn, MA 01901 (5-8,11)
 Specialty Composites Corp., Delaware Industrial Park, Newark, DE 19711 (6,7)
 Tull Environmental Systems, Div. J. M. Tull Industries, Inc., 285 Marietta St., NW, Atlanta, GA 30302 (2,5-7,14)
 United States Gypsum Co., 101 S. Wacker Dr., Chicago, IL 60606 (3,4,11)
 Veneered Metals, Inc., Woodbridge Ave. at Main St., Edison, NJ 08817 (2)
 Webster Products Co., 1261 W. Wright St., Santa Ana, CA 92705 (7,9)
 Wilshire Foam Products, Inc., 2665 Columbia St., Torrance, CA 90503 (14)

III. Vibration/Shock Isolation Materials

1. Elastomeric Pads & Foams
2. Elastomers
3. Fibrous Blankets & Boards

Aeroflex Laboratories, Inc., Isolator Products Div., 35 South Service Rd., Plainview, NY 11803 (1)
 Air-Loc Products, Fisher St., Franklin, MA 02038 (1)
 Amber/Booth Co., 7914 Westglen, Houston, TX 77042 (1-3)
 American Acoustical Products, 9 Cochituate St., Natick, MA 01760 (1)
 Barley-Earhart Co., 233 Divine Hwy., Portland, MI 48875 (1)
 Louis P. Batson Co., P.O. Box 3978, Greenville, SC 29608 (1)
 Barry Div./Barry Wright Corp., 700 Pleasant St., Watertown, MA 02172 (1,2)
 Beltran Associates, Inc., 1133 E. 35th St., Brooklyn, NY 11210 (1)
 Chemical Coatings & Engineering Co., Inc., 221 Brook St., Media, PA 19063 (2)
 Consolidated Kinetics Corp., 249 Forno Lane, Columbus, OH 43207 (1,3)
 Conwed Corp., 2200 Highcrest Rd., St. Paul, MN 55113 (3)
 Dow Corning Corp., Midland, MI 48640 (2)
 Environmental Services and Products, Inc., P.O. Box 1281, Dayton, OH 45401 (1)
 Fabreeka Products Co., 1190 Adams St., Boston, MA 02124 (1)
 GAF Corp., Industrial Products Div., Glenville Station, Greenwich, CT 06830 (3)

General Electric Co., Silicone Products Dept., Waterford, NY 12188 (1,2)
 Gilmore Industries, Inc., 3355 Richmond Rd., Cleveland, OH 44122 (1)
 Hecht Rubber Co., 484 Riverside Ave., Jacksonville, FL 32202 (1,2)
 Industrial Acoustics Co., Inc., 380 Southern Blvd., Bronx, NY 10454 (1,2)
 Insul-Coustic/Birma Corp., Jernee Mill Rd., Sayreville, NJ 08872 (3)
 Korfund Dynamics Corp., Cantigue Rd., Westbury, NY 11590 (1,2)
 H. F. Livermore Corp., 20 Linden St., Boston, MA 02134 (1)
 Lord Kinematics, 1635 W. 12th St., Erie, PA 16512 (1)
 Machinery Mountings, Inc., 41 Sarah Dr., Farmingdale, NY 11735 (1-3)
 Martec Acoustical Products Co., Div. of Martec Associates, Inc., 1645 Oakton St., Des Plaines, IL 60018 (1)
 Mason Industries, Inc., 92-10 182 Place, Hollis, NY 11423 (2)
 MBI Products Co., 1176 E. 38th St., Cleveland, OH 44114 (3)
 National Research Corp., Concord Rd., Billerica, MA 01821 (1)
 Nichols Dynamics, Inc., 740 Main St., Waltham, MA 02154 (1)
 Norton Co., Sealant Operations, 12 Bennett Dr., Granville, NY 12832 (1)
 Scott Paper Co., Foam Div., 1500 E. Second St., Chester, PA 19013 (1)
 Sound Solutions Corp., 601 Washington St., Lynn, MA 01901 (1,2)
 Specialty Composites Corp., Delaware Industrial Park, Newark, DE 19711 (1,2)
 Standard Felt Co., 115 S. Palm Ave., Alhambra, CA 91802 (3)
 Tull Environmental Systems, Div. J. M. Tull Industries, Inc., 285 Marietta St., NW, Atlanta, GA 30302 (1)
 Unisorb Machinery Installation Systems, 22 West St., Millbury, MA 01527 (1)
 VibraSonics, P.O. Box 14098, Fort Worth, TX 76117 (1,2)
 Vibration Mountings & Controls Inc., Post Office Box 776SV, Butler, NJ 07405 (1,2)

IV. Vibration Damping Materials

1. Adhesives
2. Elastomers
3. Mastic Sheet & Tile
4. Plastic Sheet & Tile
5. Semi-Liquid Compounds, Mastic Based
6. Semi-Liquid Compounds, Plastic Based
7. Tapes

Air-O-Plastik Corp., Asia Place, Carlstadt, NJ 07072 (7)
 Airtex Industries, Inc., Flexible Products Div., 3558 2nd St. N., Minneapolis, MN 55412 (4,7)
 American Acoustical Products, 9 Cochituate St., Natick, MA 01760 (2,4)
 Barley-Earhart Co., 233 Divine Hwy., Portland, MI 48875 (7)
 Barry Div./Barry Wright Corp., 700 Pleasant St., Watertown, MA 02172 (1,2,4)
 H. L. Blackford, Inc., 1855 Stephenson Hwy., Troy, MI 48064 (4,6)
 Chemical Coatings & Engineering Co., Inc., 221 Brook St., Media, PA 19063 (1-6)
 Consolidated Kinetics Corp., 249 Forno Lane, Columbus, OH 43207 (1,4,6,7)
 Dow Corning Corp., Midland, MI 48640 (1,6)
 Duracote Corp., 350 N. Diamond St., Ravenna, OH 44266 (4)
 Electro-Ionic Systems, Inc., 1085 Memorex Dr., Santa Clara, CA 95050 (6)
 Environmental Services and Products, Inc., P.O. Box 1281, Dayton, OH 45401 (4)
 Fabreeka Products Co., 1190 Adams St., Boston, MA 02124 (2)
 Ferro Corp., Composites Div., 34 Smith St., Norwalk, CT 06852 (6)
 GAF Corp., Industrial Products Div., Glenville Station, Greenwich, CT 06830 (3)
 Gaska-Tape, Inc., 1801 Minnie St., Elkhart, IN 46514 (7)

General Electric Co., Silicone Products Dept., Waterford, NY 12188 (1,2)
 General Rubber Corp., 9 Empire Blvd., South Hackensack, NJ 07606 (2)
 Gilmore Industries, Inc., 3355 Richmond Rd., Cleveland, OH 44122 (2)
 Globe Industries, Inc., Acousti-Pad Div., 2638 E. 126th St., Chicago, IL 60633 (3,5)
 Hecht Rubber Co., 484 Riverside Ave., Jacksonville, FL 32202 (1,2,7)
 IMS Co., 24050 Commerce Park Rd., Cleveland, OH 44122 (4)
 Insul-Coustic/Birma Corp., Jernee Mill Rd., Sayreville, NJ 08872 (1,5)
 Korfund Dynamics Corp., Cantigue Rd., Westbury, NY 11590 (6)
 Lambda Corp., Box 181, Whippany, NJ 07981 (6)
 Lord Kinematics, 1635 W. 12th St., Erie, PA 16512 (2)
 Mason Industries, Inc., 92-10 182 Place, Hollis, NY 11423 (2)
 3M Co., Industrial Specialties Div., 3M Center, St. Paul, MN 55101 (7)
 National Research Corp., Concord Rd., Billerica, MA 01821 (2,4)
 Nichols Dynamics, Inc., 740 Main St., Waltham, MA 02154 (1,5-7)
 Noise Measurement & Control Div., National Research Corp., 322 E. Lancaster Ave., Wayne, PA 19087 (3,4)
 Norton Co., Sealant Operations, 12 Bennett Dr., Granville, NY 12832 (7)
 Philadelphia Resins Corp., P.O. Box 454, Montgomery, PA 18936 (1,4-6)
 Quaker State Oil Refining Corp., P.O. Box 989, Oil City, PA 16323 (5)
 Scason, Inc., 112 Main St., Norwalk, CT 06430 (4,6)
 Scason Canada, Ltd., 2220 Midland Ave., 31 Administration Park, Scarborough, Ontario M1P 3E6, Canada (4,6)
 Singer Partitions, Inc., 444 N. Lake Shore Dr., Chicago, IL 60611 (1,3)
 The Soundcoat Co., Inc., 175 Pearl St., Brooklyn, NY 11201 (2,4,6)
 Sound Solutions Corp., 601 Washington St., Lynn, MA 01901 (3,5)
 Specialty Composites Corp., Delaware Industrial Park, Newark, DE 19711 (4)
 Tull Environmental Systems, Div. J. M. Tull Industries, Inc., 285 Marietta St., NW, Atlanta, GA 30301 (1,2,4)
 United States Gypsum Co., 101 S. Wacker Dr., Chicago, IL 60606 (1)
 VibraSonics, P.O. Box 14098, Fort Worth, TX 76117 (2)
 Vibration Mountings & Controls Inc., Post Office Box 776SV, Butler, NJ 07405 (1,2,5,6)
 Webster Products Co., 1261 W. Wright St., Santa Ana, CA 92705 (3)
 Wilshire Foam Products, Inc., 2665 Columbia St., Torrance, CA 90503 (7)

* Courtesy of SOUND AND VIBRATION Magazine, Acoustical Publication, Inc., July 1973

COMPONENT MANUFACTURERS

Exhaust Mufflers:

Burgess-Manning Division 8101 Carpenter Freeway Dallas, Texas 75257	Telephone (214)631-1410
Cowl Industries, Limited 88 Fennel St. Winnipeg, Manitoba, Canada	Telephone (204)452-2516
Donaldson Company, Inc. 1400 West 94th Street Minneapolis, Minnesota 55431	Telephone (612)888-7981
Kittell Muffler & Engineering 1977 Blade Avenue Los Angeles, California 90039	Telephone (213)662-8177
Nelson Muffler Company Highway 51 Stoughton, Wisconsin	Telephone (608)873-6641
Riker Manufacturing Company 4901 Stickney Avenue Toledo, Ohio 43612	Telephone (419)729-1626
Riley-Beaird, Inc. Maxim Products Group P.O. Box 1115 Shreveport, Louisiana 71102	Telephone (318)868-4441
Stemco Manufacturing Company P. O. Box 1989 Longview, Texas 75601	Telephone (214)758-3383
Universal Silencer Corp. P. O. Box 268 Libertyville, Illinois 60048	Telephone (312)542-8720

Air Cleaners and Silencers:

Air Maze Corporation 25000 Miles Road Cleveland, Ohio 44128	Telephone (216)292-6800
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Air Cleaners and Silencers- continued

Donaldson Company, Inc.
1400 West 94th Street
Minneapolis, Minnesota 55431 Telephone (612)888-7981

Farr Filter Company
P. O. Box 92187
Air Port Station
Los Angeles, California 90009 Telephone (213)772-5221

Vortox Company
P. O. Box 70
Claremont, California 91711 Telephone (714)621-3843

Cooling Fans and Shrouds:

Fans:

Air Turbine Propeller Company
Box 218
Zelienople, Pennsylvania 16063 Telephone (412)452-9540

Brookside Corporation
McCordsville, Indiana 46055 Telephone (317)335-2101

Engineered Cooling Systems, Inc.
201 W. Carmel Drive
Carmel, Indiana 46032 Telephone (317)846-3438

Hayes-Albion Corporation
437 Fern Avenue
Jackson, Michigan 49202 Telephone (517)782-9421

Schwitzer Division
Wallace-Murray Corporation
1125 Brookside Avenue
Indianapolis, Indiana 46206 Telephone (317)436-3311

Shrouds:

Memphis Metal Manufacturing Co. Inc.
795 Tanglewood Street
Memphis, Tennessee Telephone (901)276-6363

Isolation Mounts:

Lord Manufacturing Company
1635 W. 12th Street
Erie, Pennsylvania 16512

Telephone 814/456-8511

The Korfund Dynamic Company, Inc.
Cantigaue Road
Westbury, New York

Telephone 212/353-8188

REFERENCES

Bibliography:

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2. Beranek, L. L.: Noise Reduction, McGraw-Hill Book Company, Inc., New York 1960
3. Beranek, L. L.: Acoustics, McGraw-Hill Book Company, Inc., New York, 1954
4. Peterson, A. P. G. and E. E. Gross, Jr.: Handbook of Noise Measurement, General Radio Company, West Concord, Massachusetts, 1972
5. Harris, C. M.: Shock and Vibration Handbook, Vol. 3, McGraw-Hill Book Company, Inc., New York, 1961
6. Crede, C. E.: Vibration and Shock Isolation, John Wiley and Sons, New York, 1951
7. Industrial Noise Manual, American Industrial Hygiene Association, Detroit, Michigan
8. American National Standards Institute: Acoustical Terminology (including mechanical shock and vibration) 5-25-60
9. American National Standards Institute: Method for the Physical Measurement of Sound, 8-20-62
10. Sound and Vibration Magazine: Periodical, Acoustical Publications, Inc.
11. Noise Control and Vibration Reduction: Periodical, Trade & Technical Press Ltd., Morden, Surrey, England
12. Noise Control Engineering: Periodical, P.O. Box 2167, Morristown, New Jersey 07960
13. Technical Report for DOT, Contract DOT-TSC-533 by Donaldson Company: A Baseline Study of the Parameters Affecting Diesel Engine Intake and Exhaust Silencer Design; July, 1973
Available from National Technical Information Service, Springfield, Va. 22151
14. Technical Report No. DOT-TSC-057-73-12 for DOT Contract DOT-TSC-533 by Stemco Manufacturing Co.: Diesel Exhaust and Air Intake Noise, July 1973; National Technical Information Service, Springfield, Va. 22131



glossary of noise control terminology

... a guide to better understanding

A-scale

A filtering system that has characteristics which roughly match the response characteristics of the human ear at low sound levels (below 55 dB SPL, but frequently used to gauge levels to 85 dB). A-scale measurements are often referred to as dB (A).

Absorption Coefficient (α)

The absorption coefficient of a material or sound-absorbing device is the ratio of the sound absorbed to the sound incident on the material or device. The sound absorbed by a material or device is usually taken as the sound energy incident on the surface minus the sound energy reflected.

Acoustical Material

Any material considered in terms of its acoustical properties. *Commonly and especially*, a material designed to absorb sound.

Airborne Noise

A condition when sound waves are being carried by the atmosphere.

Ambient Noise

Ambient noise is the characteristic (or background noise) of a given environment.

Anechoic Room

An anechoic room provides a free-field acoustic testing environment like the out-of-doors. All of the sound emanating from a source is essentially absorbed at the walls of the anechoic room. Hence, there are no reflections and the spatial sound radiation pattern of a source may be determined. An anechoic room may be described as "echoless" or acoustically "dead"

B-scale

A filtering system that has characteristics which roughly match the response characteristics of the human ear at sound levels between 55 and 85 dB. B-scale measurements are often referred to as dB (B).

Bending Wave

A wave that travels in a structure by de-

forming the structure in bending. Bending waves may also be called flexural waves or transverse waves because their displacement is transverse to their direction of travel.

C-scale

A filtering system that has characteristics which roughly match the response characteristics of the human ear at sound levels above 85 dB. The filtering system in this case is flat with frequency. C-scale readings may be referred to as dB (C).

Critical Frequency

The lowest frequency at which the wavelength of a bending wave traveling in a structure is the same as the wavelength in air at that frequency. Coupling between the air and the structure is very good at this point, and sound waves may move from the structure to the air and vice-versa with ease.

Damping

Dissipation of *structure-borne noise* (usually traveling bending waves) by conversion to some other form of energy, usually heat. For the most part, this is accomplished by using a material with a high internal energy-absorbing capacity (i.e. high internal damping).

Diffuse Sound Field

A diffuse sound field is one in which the sound field at any given point is made up of sound waves of all angles of incidence.

Direct Field

The sound in a region in which all or most of the sound arrives directly from the source without reflection.

Dissipative Muffler

This is a muffler which has wide band noise-reduction characteristics. Most of the noise reduction is accomplished by the use of a sound-absorbing material.

Flanking Transmission

The reduction in apparent transmission loss of a wall caused by sound being carried around the wall by other paths. (Structure-borne, leaks, etc.)

Free Sound Field (Free Field)

A free sound field is a field in a homogeneous, isotropic medium free from boundaries. In practice, it is a field in which the effects of the boundaries are negligible over the region of interest. In the free field, the sound pressure level decreases 6 dB for a doubling of distance from a point source.

Frequency Spectrum

Usually a visual representation of a complex sound or noise which has been resolved into frequency components. The detailed nature of a complex sound may be studied by obtaining its frequency spectrum. Frequency spectra are commonly obtained in octave bands, $\frac{1}{2}$ -octave bands, and various narrow bands.

Insertion Loss

The insertion loss of an element of an acoustic transmission system is the positive or negative change in acoustic power transmission that results when the element is introduced.

Intensity Level (LI) (IL)

A measure of the acoustic power passing through a unit area expressed on a decibel scale referenced to some standard (usually 10^{-12} watt per square meter).

Longitudinal Wave

A longitudinal wave is a wave in which the direction of displacement at each point of the medium is normal to the wave front. Sound in air propagates as a longitudinal wave.

Loudness

Loudness is the subjective human definition of the intensity of a sound. Human reaction to sound is highly dependent on the sound pressure and frequency.

Loudness Level

A subjective method for rating loudness in which a 1000-Hz tone is varied in intensity until it is judged by listeners to be equally as loud as a given sound sample. The loudness level in phons is taken as the sound pressure level, in decibels, of the 1000-Hz tone.

continued...

*Courtesy Lord Manufacturing Company, Division of Lord Corporation, Erie, Pa.

Glossary of Noise Control Terminology* - Continued

Mass Law

The law relating to the transmission loss of walls which says that in a part of frequency range, the magnitude of the loss is controlled entirely by the mass per unit area of the panel. The law also says that the transmission loss increases 6 decibels for each doubling of frequency or each doubling of the panel mass per unit area.

Noise

Any undesired sounds usually of different frequencies resulting in an objectionable or irritating sensation.

Noise Reduction (NR)

- 1) The reduction in sound pressure level caused by making some alteration to a sound source.
- 2) The difference in SPL measured between two adjacent rooms caused by the transmission loss of the intervening wall.

Octave Band (O.B.)

A range of frequency where the highest frequency of the band is double the lowest frequency of the band. The band is usually specified by the center frequency.

Pitch

The pitch of a sound depends primarily on its frequency. In music, sounds of higher frequency are referred to as treble notes, while those of lower frequency are referred to as bass notes.

Pure Tone

A pure tone has a unique pitch and is characterized by a sinusoidal variation in sound pressure with time. The frequency spectrum of a pure tone shows a single line at a discrete frequency.

Radiation

The process of turning structure-borne noise into airborne (or some other fluid-borne) noise.

Random Noise

Random noise is a complex vibration made up of frequencies and amplitudes that vary with time in a random or statistical fashion.

Reactive Muffler

A muffler which is characterized by sharp peaks and valleys in its noise-reduction curves. It accomplishes most of its reduction by wave interference effects. The wave interference is often obtained by resonating air-filled cavities in a manner similar to blowing over a soda bottle.

Reverberation

Reverberation is the persistence or echoing of previously generated sound caused by reflection of acoustic waves from the surfaces of enclosed spaces.

Reverberation Room

Reverberation rooms are specially designed rooms in which the reverberation time is long (several seconds). When the reverberation room is properly designed, the sound field within the room is diffuse; and the sound pressure of an acoustic source is not a function of position within the room.

Sabin

The unit of acoustic absorption. One sabin is one square foot of perfect sound-absorbing material.

Shear Wave

A shear wave is an elastic disturbance within a medium in which the shape of the medium changes without a change in the volume of the medium. The speed of a shear wave is governed by the shear modulus and the shear mass.

Sone

A unit used in judging the loudness of sound. One sone is defined as the level, at 1000 Hz, that is 40 dB above the subject's threshold of hearing. The loudness of a given sound is rated by the listener as some multiple of the sone.

Sound

Deformation waves that are traveling in the air or other elastic materials. It should be noted that sound can be defined as the disturbances themselves or the sensations they produce.

Sound Absorption

- 1) The process of dissipating or removing sound energy.
- 2) The property possessed by materials, objects, and structures such as rooms, of absorbing sound energy.
- 3) The measure of the magnitude of the absorptive property of a material, an object, or a structure such as a room.

Sound-Level Meter

An instrument for the direct measurement of sound pressure level. Sound-level meters often are made with various filtering networks that measure the sound directly on A, B, C, etc. scales. Sound-level meters may also incorporate octave-band filters for measuring sound directly in octave bands.

Sound Power Level (Lw) (PWL)

A measure of the total airborne acoustic power generated by a noise source, expressed on a decibel scale referenced to some standard (usually 10^{-12} watt).

Sound Pressure

A fluctuating pressure superimposed on the static atmospheric pressure in the presence of sound. In analogy with alternating voltage, its magnitude can be expressed in

several ways such as instantaneous sound pressure or peak sound pressure; but the unqualified term means root-mean-square (rms) sound pressure.

Sound Pressure Level (Lp) (SPL)

A measure of the air pressure change caused by a sound wave. Expressed on a decibel scale referenced to some standard (usually $.0002 \mu\text{bar}$).

Standing Wave

The interference pattern formed by two waves of the same wavelength traveling in opposite directions. The result is a wave pattern which does not move. A standing wave is a resonance within a medium as influenced by the boundaries of the medium (e.g. a standing wave in the air column enclosed within an organ pipe one end of which may be either open or closed). All standing waves are resonances. All resonances are not standing waves. For example, a rigid mass supported by a spring has a resonant frequency $\omega = \sqrt{\frac{k}{m}}$. This resonance

does not represent a standing wave in the spring.

Structure-Borne Noise

A condition when the sound waves are being carried by a solid material. Sound waves in this state are inaudible to the human ear, since they cannot carry energy to it. Airborne noise can be created from the radiation of structure-borne noise into the air. Structure-borne noise may be propagated by shear waves, tension-compression waves, bending waves, or complicated combinations of waves.

Transmission Loss (TL)

The reduction of airborne sound power that is caused by placing a wall or barrier between the reverberant sound field of a source and its receiver. Transmission loss is a property of the wall or barrier.

Wavelength (λ)

The wavelength of a sound is the distance between a point of a given phase of one wave and a point of the same phase of an adjacent wave.

Wave Motion

A wave involves some physical quantity that is a function of both position and time and that (a) changes in magnitude more or less regularly with time at a given location, and (b) at a fixed time changes from place to place in a more or less regular manner.

White Noise

White noise is noise of wide frequency range in which the amplitude of the noise is essentially the same in all frequency bands.

*Courtesy Lord Manufacturing Company, Division of Lord Corporation, Erie, Pa.

Combining of Noise Levels: Combining noise or sound levels from different sources can be done and is used in many noise reduction programs. The addition and subtraction of sound sources of various dB levels can be done by using a table or a curve. An example of the use of each is illustrated. Another table presents the relationship between dB and relative sound pressure levels. This table also includes the percentage increase or decrease in relative sound pressure levels for various dB differences.

Combining Noise Levels from Different Sources *

The following table is to be used in determining the cumulative noise level produced by two or more sources. In combining more than two sound pressure levels (stated in decibels) by this method, the two highest sound pressure levels should be first combined. The total thus determined is next combined with the highest remaining level, with the method being followed until all levels are combined.

<u>Difference Between Levels in dB</u>	<u>Number of dB to be Added to Higher Level</u>
0	3.0
1	2.6
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
12	0.3
14	0.2
16	0.1

Example: If it were desired to determine the overall sound pressure level a truck with an exhaust noise of 85 dB, fan noise of 84 dB, intake noise 82 dB, and tire noise of 74 dB, the result would be:

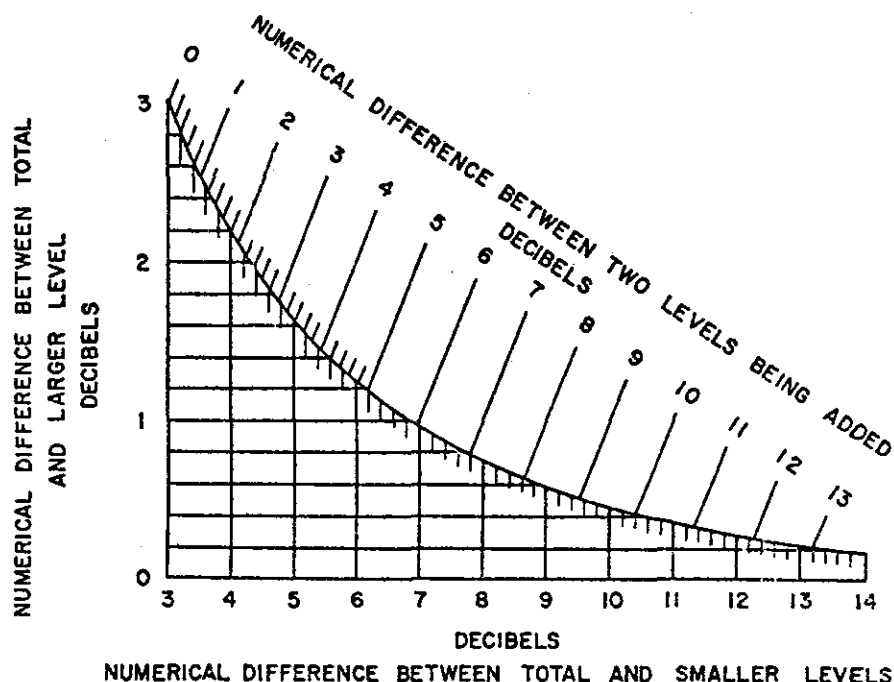
(Difference of 1) $85 \text{ dB} + 84 \text{ dB} = 85 + 2.6 = 87.6 \text{ dB}$ (exhaust and fan noise)

(Difference of 5.7) $87.6 \text{ dB} + 82 \text{ dB} = 87.6 + 1.1 = 88.7 \text{ dB}$ (exhaust, fan and intake noises)

(Difference of 14.7) $88.7 \text{ dB} + 74 \text{ dB} = 88.7 + 0.2 = 88.9$ (total noise)

*Courtesy of Western Highway Institute, "Fundamentals of Noise and Vehicle Exterior Noise Levels".

Chart for Combining or Subtracting Decibels*



To Combine Decibels: Enter the chart with the **NUMERICAL DIFFERENCE BETWEEN TWO LEVELS BEING ADDED**. Follow the line corresponding to this value to its intersection with the curved line then left to read the **NUMERICAL DIFFERENCE BETWEEN TOTAL AND LARGER LEVEL**. Add this value to the larger level to determine the total.

Example: Combine 75 dB and 80 dB. The difference is 5 dB. The 5-dB line intersects the curved line at 1.2 dB on the vertical scale. Thus the total value is $80 + 1.2$ or 81.2 dB.

To Subtract Decibels: Enter the chart with the **NUMERICAL DIFFERENCE BETWEEN TOTAL AND LARGER LEVELS** if this value is less than 3 dB. Enter the chart with the **NUMERICAL DIFFERENCE BETWEEN TOTAL AND SMALLER LEVELS** if this value is between 3 and 14 dB. Follow the line corresponding to this value to its intersection with the curved line, then either left or down to read the **NUMERICAL DIFFERENCE BETWEEN TOTAL AND LARGER (SMALLER) LEVELS**. Subtract this value from the total level to determine the unknown level.

Example: Subtract 81 dB from 90 dB. The difference is 9 dB. The 9-dB vertical line intersects the curved line at 0.6 dB on the vertical scale. Thus the unknown level is $90 - 0.6$ or 89.4 dB.

*Courtesy of the General Radio Company, Handbook of Noise Measurement. This chart is based on one developed by R. Musa.

Sound Pressure Levels*

<u>Decibels</u>	<u>Relative Sound Pressure Levels</u>	<u>% of Relative Sound Pressure Level</u>	
		<u>Increase</u>	<u>Decrease</u>
0	1.000	0.0	0.0
1	1.122	12.2	10.8
2	1.259	25.9	20.6
3	1.413	41.3	29.2
4	1.585	58.5	36.9
5	1.778	77.8	43.8
6	1.995	99.5	49.9
7	2.239	123.9	55.3
8	2.512	151.2	60.2
9	2.818	181.8	64.5
10	3.162	216.2	68.4
11	3.548	254.8	71.8
12	3.981	298.1	74.9
13	4.467	346.7	77.6
14	5.012	401.2	80.0
15	5.623	462.3	82.2
16	6.310	531.0	84.2
17	7.079	607.9	85.9
18	7.943	694.3	87.4
19	8.913	791.3	88.8
20	10.000	900.0	90.0

*Courtesy of Western Highway Institute, "Fundamentals of Noise and Vehicle Exterior Noise Levels".

Handy Numbers: These numbers show relationship of increasing decibels interpreted in terms of percentage.

Plus .1 dB = 1% increase in sound pressure
 Plus 1.0 dB = 10% increase in sound pressure
 Plus 6.0 dB = 2 x sound pressure
 Plus 10.0 dB = 3 x sound pressure
 Plus 20.0 dB = 10 x sound pressure