SURFACE VEHICLE STANDARD

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Electrical Charging Systems for Off-Road Work Machines

RATIONALE

Administrative changes to modernize language (i.e., replace references to master and slave). Grammar, capitalization, hyphenation corrections needed to be made.

1. SCOPE

This SAE Standard describes alternator physical, performance, and application requirements for heavy-duty electrical charging systems for off-road work machines, including those defined in SAE J1116.

1.1 Purpose

The purpose of this SAE Standard is to provide information on which to base machine and component design and to establish minimum requirements that will result in the most satisfactory operation of electrical charging systems for off-road work machines and other heavy-duty applications.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J56 Road Vehicles - Alternators with Regulators - Test Methods and General Requirements

SAE J537 Storage Batteries

SAE J930 Storage Batteries for Off-Road Self-Propelled Work Machines

SAE J1113-11 Immunity to Conducted Transients on Power Leads

SAE J1116 Categories of Off-Road Self-Propelled Work Machines

SAE J1416 Generator Terminal Labeling

SAE J1455 Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications

SAE J2669 Voltage Regulators for Automotive-Type Generators

3. DEFINITIONS

3.1 BATTERYLESS OPERATION

Batteryless operation occurs in a machine application whenever the battery becomes disconnected from the alternator. The electrical load of the alternator is significantly different in this situation. The disconnection may be intentional or unintentional. In some applications, machines are shipped for export without batteries. In this situation, an external battery may be used for jump-starting the machine. After the machine is started, the battery is disconnected, and the machine is moved. During movement, the alternator is operating without the battery and expected to power such items as the engine control unit, transmission control unit, and engine fuel solenoids.

Batteryless operation can also occur during operational usage whenever there is:

a. A battery open cell failure

b. The battery becomes extremely sulfated

c. The connections to the battery become loose

d. The connections to the battery become corroded

e. A master disconnect switch becomes open or its connections become open

The effect of the alternator operating in a batteryless situation is typically a wider range of voltages in output than when loaded with a battery. Some alternators do not produce output without a battery, or voltage regulation may become unstable.

3.2 LOAD DUMP

A sudden interruption of most electrical loads from the alternator during alternator operation causes a self-induced voltage surge named load dump. Load dump could be caused by such items as connections to the alternator B+ terminal becoming loose, connections to the alternator B+ terminal being corroded, defective alternator output cables, etc. The effect of a load dump is the presence of voltage spikes significantly exceeding system voltage and may exceed the voltage breakdown limits of some electrical components to cause damage.

3.3 NORMAL CHARGING SYSTEM OPERATION

Normal charging system operation includes an alternator that generates electrical energy from a mechanical source, a voltage regulator to control the alternator output voltage, and a battery that provides a standby source of electrical energy. Further information on voltage regulators is found in SAE J2669 and on battery specifications is found in SAE J537 and SAE J930.

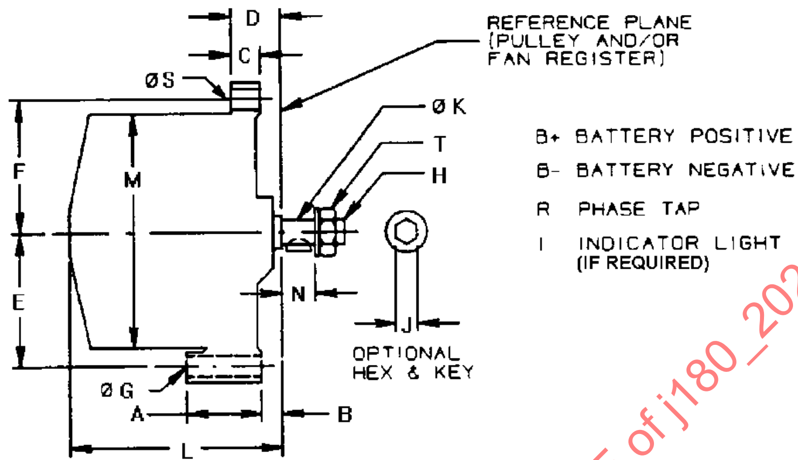
3.4 REVERSE POLARITY

Reverse polarity occurs when the battery positive and negative cables are hooked up in reverse. This condition normally results in damage to the alternator and to any other semiconductor loads that experience the reverse polarity hookup.

4. PHYSICAL REQUIREMENTS

4.1 Dimensional

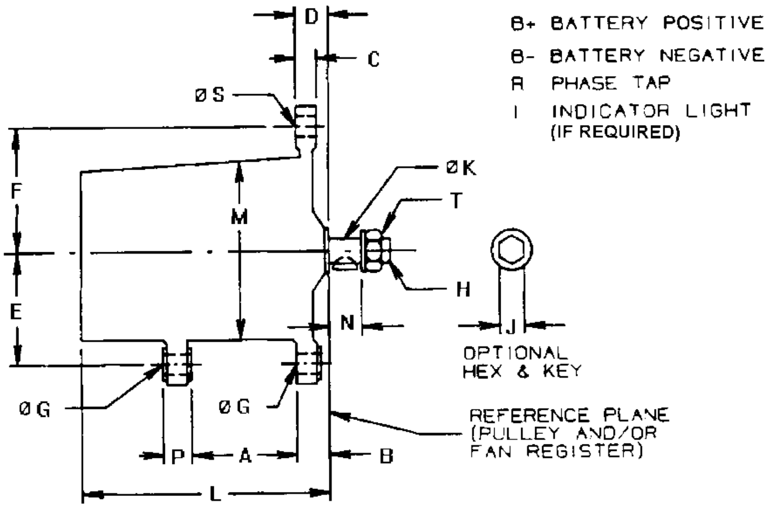
Figure 1 portrays a spool-mount alternator. Figure 2 portrays a hinge-mount alternator. Figure 3 portrays a pad-mount alternator. Included in all are alternator shaft hub dimensions.



															Terminals			
A ◊	B ◊	C	D	E Max	F Max	G	H	J	K ◊	L Max	M Max	N	S	T Torque Max	B+	B-	R	I
51	21	16	32	105	105	10	5/8 or M16	8	17 or 22.2	170	180	20	10 or M8	65 Nm	5/16 or M10	1/4 or M6	#10 or M4	#10 or M4

Note: Unless indicated all dimensions are nominal.
◊ is a critical dimension

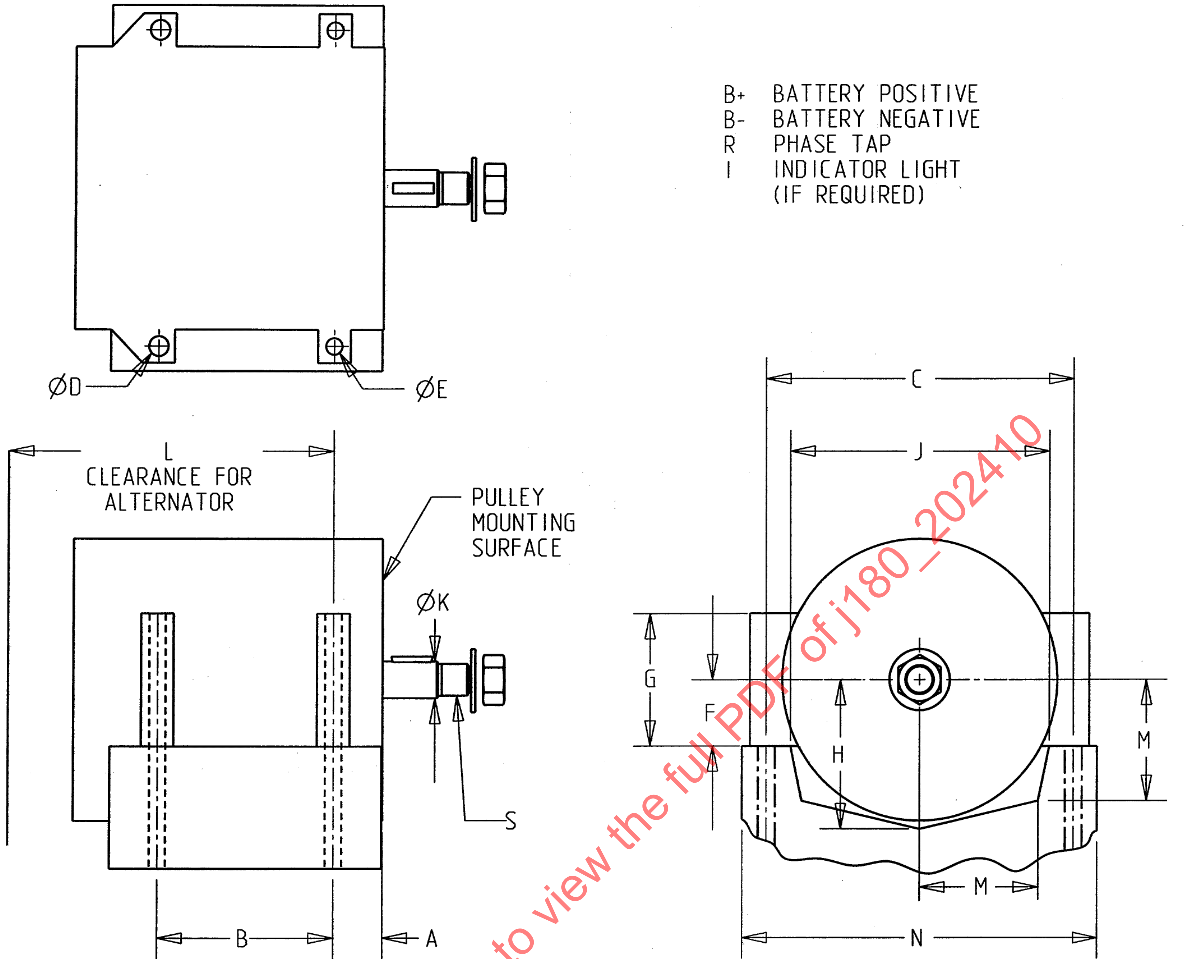
Figure 1 - Alternator dimensions for spool mounting



A ◊	B ◊	C	D	E Max	F Max	G	H	J	K ◊	L Max	M Max	N	P	S	T Torque Max	Terminals B+	Terminals B-	Terminals R	Terminals I
100	30	14.5	30	120	115	13	5/8 or M16	8	22.2	280	205	40	20	1/2 or M12	108 Nm	7/16 or M12	1/4 or M6	3 mm Dia. Pin or M4	#10 or M4

Note: Unless indicated all dimensions are nominal.
◊ is a critical dimension

Figure 2 - Alternator dimensions with hinge mounting



VERSION	A◊	B◊	C◊	D	E	F	G	H*	*J◊	K	L	M*	N*	S	TERMINALS B+	B-	R	I
190-1	30.1	108	190	12.5	10.5	40	80	90	160	22.2	200	73	220	5/8 OR M20	3/8 OR M10	5/16 OR M8	1/4 OR M6	1/4 OR M6
190-2	30.1	126.3	190	12.5	10.5	40	80	90	160	22.2	200	73	220					

NOTE: UNLESS INDICATED ALL DIMENSIONS ARE NOMINAL
◊ IS A CRITICAL DIMENSION
* BRACKET DIMENSION

Notes:

1. Four M10 bolts are recommended for mounting an alternator with 40 N•m torque.
2. Diameter D is intended for additional mounting bolt clearance.
3. Brackets may have additional holes to accommodate 190-1 and 190-2 versions on the same bracket.

Figure 3 - Alternator and bracket dimensions for pad mount

4.2 Mounting Recommendations

4.2.1 Hinge Mounting

Figure 4 shows a hardened split bushing in the alternator mounting lug opposite the drive end. The mounting bolt clamps the mounting bracket to this bushing. Tightening of the mounting bolts positions the bushing, easing strain on the bracket and lugs.

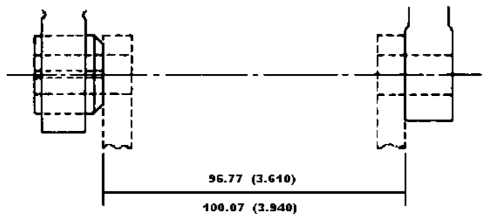


Figure 4 - Typical installation of split bushing in hinge mounting lug

4.2.2 Spool Mounting

Figure 5 shows the hardware and brackets for spool mounting. A hardened, split bushing is located in the mounting bracket.

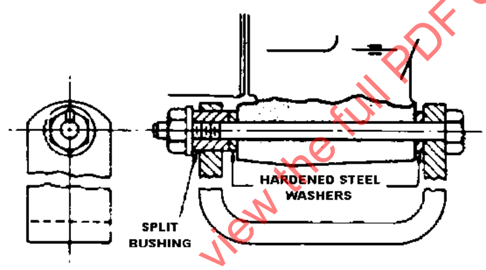


Figure 5 - Typical installation of split bushing in bracket for spool mounting

4.2.3 Pad Mounting

A single-piece pad-mount bracket is recommended over a multipiece pad-mount bracket. Hardened washers under nuts and under mounting bolts are required.

4.3 Terminals

On all alternators, provisions shall be made for a negative ground connection, either by a terminal post or a threaded hole, to ensure a sound electrical ground path from the alternator to the machine system ground.

To ensure correct electrical connection between the alternator and the mating wiring harness, and to standardize on terminals between the various alternator manufacturers, terminal sizes are recommended in Figures 1, 2, and 3. For additional guidance on terminal marking, refer to SAE J1416.

Blade-type external terminations are not recommended to be used on alternators that are covered by this SAE document.

4.4 Alternator Drive Configuration

See Figures 1, 2, and 3 for shaft sizes and drive alignment reference.

4.5 Alternator Identification

The alternator nameplate shall be visible in its normal mounting orientation. Each alternator shall be identified with the following characteristics:

Manufacturer's Identification, Part Number, Voltage Rating, Current Rating, Manufacturing Plant, and Manufacturing Date Code (and/or Serial Number).

5. PERFORMANCE REQUIREMENTS

5.1 Performance

Refer to SAE J56 for performance and test procedure.

5.2 Regulation

Refer to SAE J2669 for voltage regulator performance and battery charge voltage and temperature compensation.

5.3 Batteryless Application

The machine designer shall consider the probability of open-circuit operation and accidentally induced high transient voltage. The designer shall define the conditions (maximum speed, maximum load change, repetition rate) to the alternator manufacturer and specify the maximum voltage (peak and duration) tolerable to the load components of the electrical system.

The average steady-state alternator system output terminal voltage, with battery disconnected and a minimum resistive load of 60 Ω, shall not rise by more than 10% when compared to the allowable voltage with the battery connected.

5.4 Load Dump

The alternator system, including all associated rectifying, regulating, and filtering devices, shall withstand the self-induced voltage surge resulting from the sudden disconnection (not longer than 20 ms to complete break) from 85 to 10% of the rated output current (including battery) at 6000 rpm. This test shall be conducted a minimum of five consecutive times, or as agreed between the machine designer and alternator manufacturer. Alternator system shall limit output voltages to 60 V maximum. Refer to SAE J1113-11 for additional guidance.

5.5 Alternator Efficiency

Most engine-driven alternators have a wide operating speed range, and electrical loads may range between very low amperage to its maximum rated amperage. Over such a wide operating envelope, the alternator efficiency varies significantly between a peak efficiency and much lower efficiency. Average alternator efficiency takes into account alternator efficiency at several operating speeds at a fixed electrical load proportional to the alternator output rating.

5.5.1 Determination of Alternator Efficiency

For each operating point, i, the efficiency shall be calculated in accordance with Equation 1 for each operating point provided in Table 1.

$$\eta_i = \frac{60 \times U_i \times I_i}{2\pi \times M_i \times n_i} \times 100 \quad \text{(Eq. 1)}$$

where:

η_i = efficiency at operating point i, as a percentage

U_i = voltage at operating point i, in volts

I_i = current at operating point i, in amperes

M_i = torque at operating point i, in Newton-meters

n_i = rotational frequency at operating point i, in revolutions per minute

I_R = alternator rated current, in amperes

Table 1 - Specifications for operating points

Operating Point Step No.	Holding Time t_D seconds	Rotational Frequency n_i rpm	Alternator Current I_i A
1	1200	2000	$I_R/2$
2	1200	3000	$I_R/2$
3	600	4000	$I_R/2$
4	600	5000	$I_R/2$

At each operating point, the minimum time specified (t_D) is to allow the alternator to reach steady-state temperature.

Test current shall be defined as half the alternator rated current, I_R. If the alternator cannot deliver half the rated current ($I_R/2$ A) at 2000 min^{-1}, the efficiency value at 2000 min^{-1} shall be measured at full load with a specified voltage of 13.5 V ± 0.2 V for 12-V systems and 27 V ± 0.2 V for 24-V systems.

5.5.2 Determination of Average Efficiency

Weighted alternator efficiency is based on application duty cycles that identify the most common alternator operating speed and electric load range. The test measurements for average alternator efficiency can then be modified with weighting coefficients to derive a weighted efficiency that is useful for calculating engine fuel used to power electrical loads.

Average efficiency shall be calculated in accordance with Equation 2.

$$\eta_w = \sum_{i=1}^{4} \eta_i \times h_i \quad \text{(Eq. 2)}$$

where:

η_w = average efficiency, as a percentage

η_i = efficiency at operating point i, as a percentage

h_i = weighting coefficient of operating points i, as per Table 2