Reports

Space Charge in Exhaust of Motor Vehicles

Abstract. Exhaust gases are electrically charged, usually positively but sometimes negatively. This charge does not depend on the electric potential of the vehicle. Whether the charge is positive or negative seems to depend on whether water droplets or carbon particles predominate in the exhaust.

It has been shown (*1*) that clouds of ions whose net charge is sometimes positive and sometimes negative frequently pass overhead at altitudes as low as 10 meters or less. These ion clouds seemed to originate in motor vehicles, particularly, in heavy diesel-powered vehicles. This was confirmed by construction of a space-charge detector in the form of a cylindrical Faraday cage of window screening, 50 cm in diameter and 50 cm long. The cage was grounded. In the center of the cage was placed a polonium button which was connected directly to the input terminal of a Keithley electrometer (model 200A, zero centered) on which the cage rested. When positive (or negative) space charge enters the cage, the potential of the button may be several volts positive (or negative) with respect to ground. This cage was used to test the exhaust gases of the diesel engine of an earth-mover, and these gases were found to be strongly positively charged. The exhaust gases of passenger automobiles were less strongly charged, sometimes positively and sometimes negatively; occasionally they were uncharged. The exhaust gases of one diesel locomotive tested proved to be uncharged. It should be noted that Stimmel, Rogers, Waterfall, and Gunn (*2*) have shown that, under certain conditions, ionization of the exhaust gases plays an important role in discharging electricity from an airplane.

In order to explain why the exhaust gases of motor vehicles are charged and to account for the sign of the charge, it was originally assumed that the ions were produced in the combustion chambers of the engine and that the sign of the emitted space charge depended on whether the rubber-tired vehicle was positive or negative with respect to ground. This theory would account for the lack of space charge in the exhaust of a diesel locomotive, since it is well grounded to the rails.

To test this hypothesis further, a bunsen burner was placed about 10 cm from the Faraday cage, and an oscillating fan was used to blow the exhaust gases from the burner into the Faraday cage. When the burner was 5 volts positive with respect to the cage, the electrometer indicated a reading between + 1.5 and + 2.0 volts when the fan blew toward the cage, showing the presence of pronounced positive space charge. When the burner was 5 volts negative with respect to the cage, the electrometer indicated a reading between − 1.0 and − 1.5 volts, showing pronounced negative space charge. It is surprising that such a small potential gradient produced such marked charge separation. Apparently most of the negative ions in the flame are electrons whose mobility is high enough to account for the observed charge separation. It might be concluded from this experiment that if the chassis and exhaust pipe of an automobile were positive with respect to ground, the exhaust would contain positive space charge. Similarly, if the exhaust pipe was negative, the space charge should be negative.

The same Keithley electrometer was used to measure the potential of a moving car with respect to ground (contact with ground was obtained by dragging a brass chain). When the car was moving, whether or not the engine was running, the potential of the car was negative. Two cars tested showed the same result, which is in agreement with other tests (*3, 4*) showing that rubber-tired vehicles generally are at a negative potential with respect to ground. However, when the space charge in the exhaust of these two cars was tested (cars in motion), the space charge in each case, instead of being negative, as anticipated, was positive.

It appears that the emission of space charge by the exhaust pipe of a motor vehicle does not depend on the potential of the vehicle with respect to ground but is caused by contact potential differences between the exhaust pipe and particles in the exhaust such as water droplets or carbon particles. It is well known that wet steam in a locomotive exhaust is positive charged (*5*), and it is possible that the positive space charge in the exhaust of a motor vehicle is produced by the same mechanism.

To determine the sign of the charge on carbon particles, the following experiment was performed. The exhaust of an automobile was tested for space charge when the engine was "gunned"; generally, the needle of the electrometer would swing from full-scale negative to full-scale positive, the positive deflection gradually decreasing as the engine slowed down. However, when the engine was choked so that black smoke was produced in the exhaust, the electrometer needle swung full-scale negative and stayed there. Several cars tested performed the same way. This indicates that the carbon particles in the exhaust of a motor vehicle are negatively charged.

These results are consistent with the hypothesis that the exhaust of a motor vehicle may be positively or negatively charged, depending on whether water droplets or carbon particles predominate.

When a motor vehicle, especially a heavy truck, is driven along a highway, it may acquire a high negative potential with respect to ground. This is due to the contact potential difference between tires and pavement. Beach (*3*) has shown that a drag chain under a gasoline truck may be ineffective in discharging the truck due to possible high resistivity of the pavement. It is suggested that the discharge of negative electricity on the truck might be accomplished by the simple expedient of running the engine with choke open at the end of a trip (*6*).

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References and Notes

1. C. J. Brasefield, *J. Geophys. Research* 64, 141 (1959).
2. R. G. Stimmel, E. H. Rogers, F. F. Waterfall, R. Gunn, *Proc. Inst. Radio Engrs.* 34, 175 (1946).
3. R. Beach, *Elec. Eng.* 60, 202 (1941).
4. C. Bulgin, *Brit. J. Appl. Phys.* 4, suppl. 2, 83 (1953).
5. This was verified by blowing steam from a boiler into the Faraday cage. Only a small puff of steam caused the electrometer needle to go off scale in the positive direction.
6. It is a pleasure to acknowledge the assistance of our shop mechanic, Robert Griggs, in carrying out these experiments. Thanks are also due to Leonard B. Loeb of the University of California for helpful comments on this problem.

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Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* 125, 16 (1957)].