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DRAG COEFFICIENTS FOR BURNING KEROSENE DROPS

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Foreword

This report was prepared by the Engineering Research Institute of the University of Michigan, on U. S. Air Force Contract No. AF33(616)-2436. The work was sponsored by the Wright Air Development Center, with Jack W. Fulton acting as project coordinator. The work was conducted at the University of Michigan under Projects 1988 and 2253-3.

NOMENCLATURE

A	Projected area of the drop, ft
C_D	Coefficient of drag (dimensionless)
D	Diameter of drop, ft
F	Drag force, lbs
M	Momentum of drop, mv, lb-sec
m	Mass of drop, slugs
v	Velocity of drop, ft/sec
ρ_a	Density of air, slugs/ft^3
ρ_k	Density of kerosene, slugs/ft^3

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INTRODUCTION

In accordance with the desire of the project sponsor, brief reports covering specific phases of this research investigation will be prepared as the work proceeds. It is hoped that this method will be more effective in making the information available to interested groups than the usual practice of waiting until the completion of the project to write a single large report.

SOURCE OF DATA

The data for these calculations were taken from Appendix B of the report by Bolt, Boyle, and Mirsky[1], covering the size and velocity of drops of burning kerosene thrown from a spinning disc. By photographing drops in the burning zone twice with a known interval (see Fig. 1), both the diameter and the velocity were determined. It was pointed out that an accuracy of ± 5μ in diameter and ± 0.3 ft per sec in velocity was obtained. The temperature of the atmosphere surrounding the drops was measured with an optical pyrometer and found to be 2000°F.

BASIS OF CALCULATIONS

It is assumed for these purposes that the only force resisting the motion of the drop is the drag force.

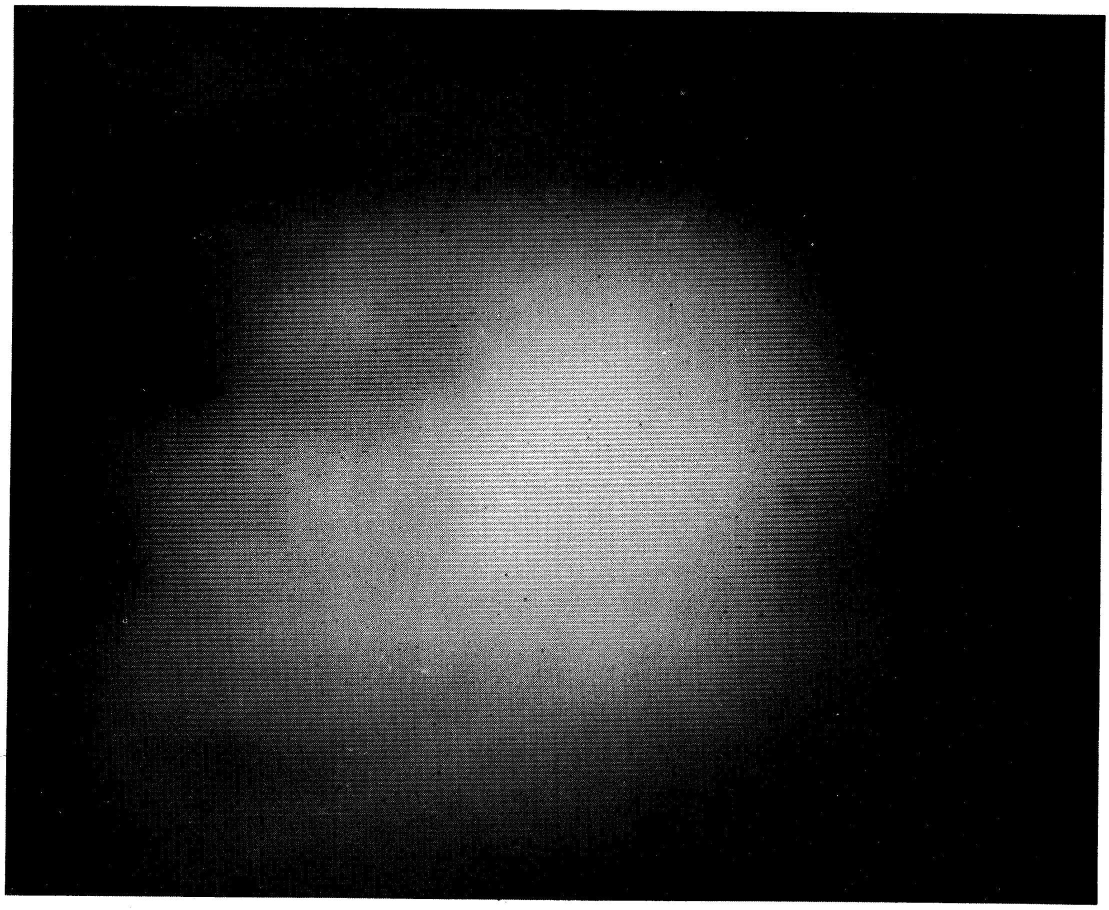


Fig. 1

$$F = \frac{dM}{dt},$$

where $$M = mv;$$

then $$F = \frac{\pi}{6} \rho_k \frac{d(D^3v)}{dt} \tag{1}$$

Drag is usually expressed in the following form:

$$F = C_D \frac{v^2 A \rho_a}{2} = C_D \frac{v^2 \pi D^2 \rho_a}{8} \tag{2}$$

When the two expressions are combined,

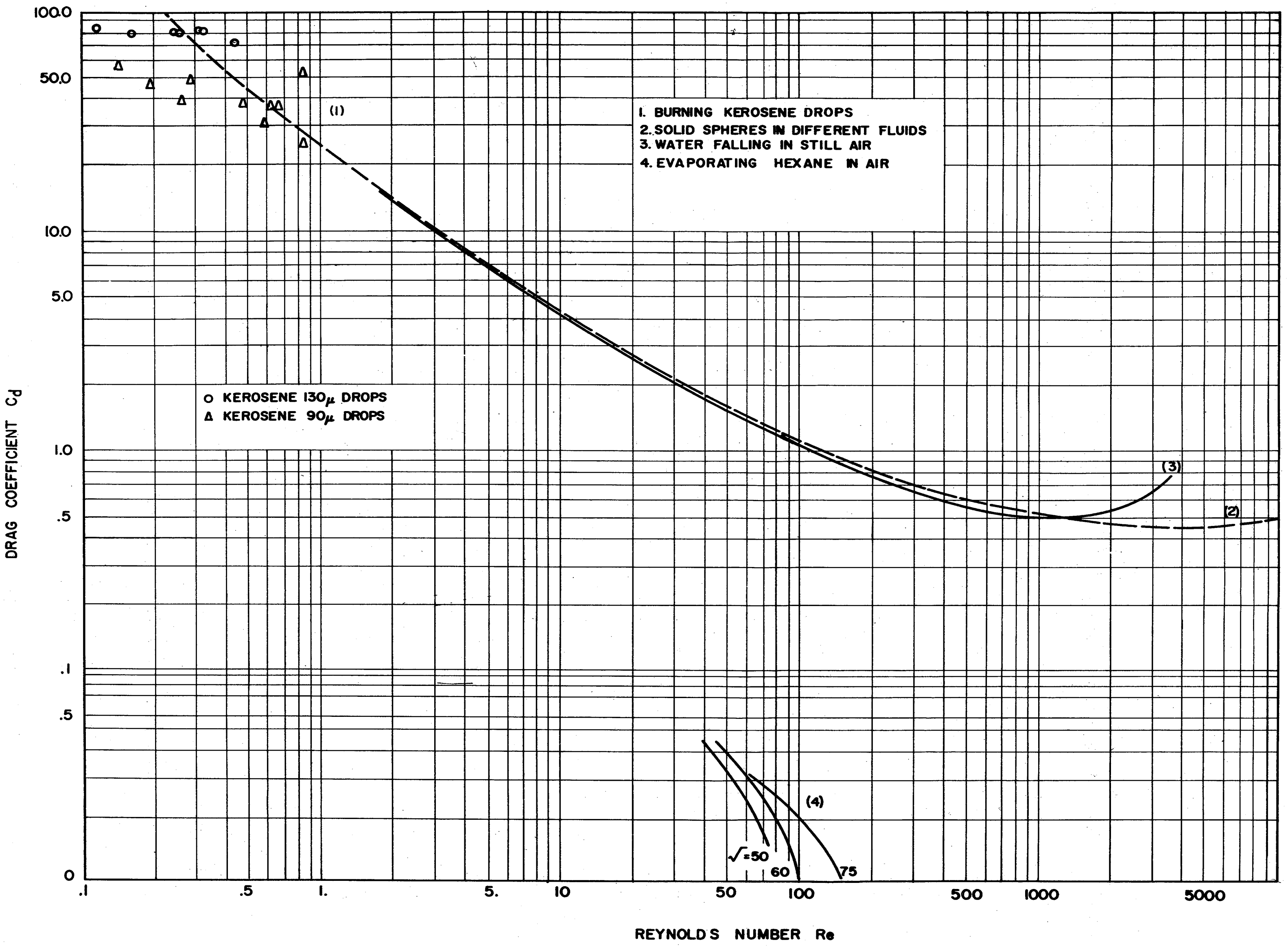
$$C_D = \frac{4}{3} \frac{\rho_k}{\rho_a} \frac{1}{v^2 D^2} \frac{d(D^3v)}{dt} \tag{3}$$

CALCULATIONS

The data from several photographs for drops 90μ and 130μ in original size were averaged. The burning time was plotted against D^3v and the derivative determined from the slope of the curve. The drag coefficient was then determined by formula 3.

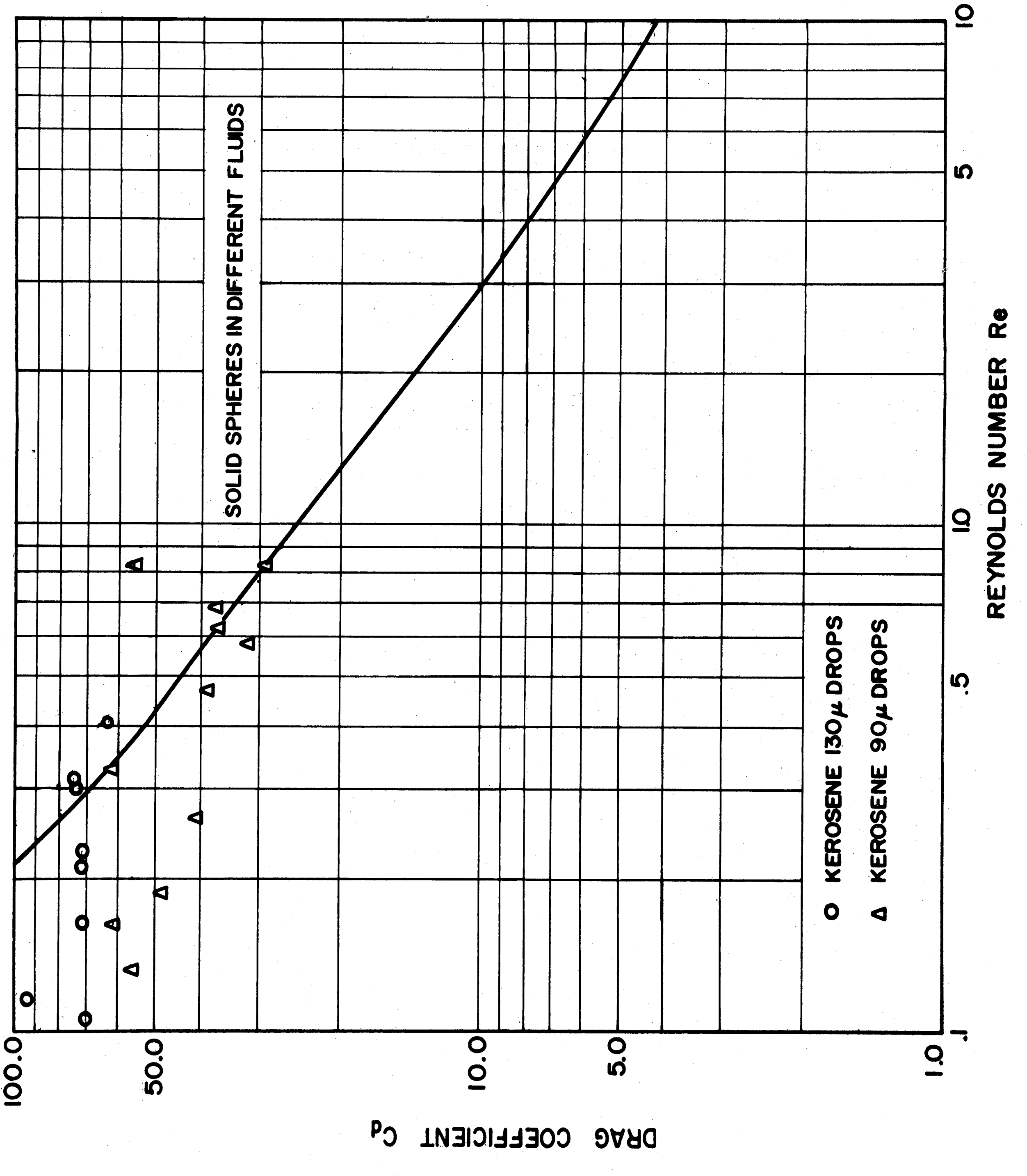
RESULTS

The results can be seen in Fig. 2 and Table 1, where the drag coefficient is plotted against Reynolds number. These data can be considered accurate to 15 per cent, but the scatter probably results from the action of combustion. Fig. 3 compares these results with data obtained for solid spheres moving in many different fluids.[2] The data of Gunn and Kinzer[3] for water drops falling in still air, and of Fledderman and Hanson[4] for the evaporation of hexane sprays, are plotted for reference.



COEFFICIENTS OF DRAG OF BURNING FUEL DROPS COMPARISION WITH NON-BURNING CONDITIONS

Fig. 2



SOLID SPHERES IN DIFFERENT FLUIDS
o KEROSENE 130μ DROPS
Δ KEROSENE 90μ DROPS
REYNOLDS NUMBER Re
.1
.5
1.0
5
10
DRAG COEFFICIENT Cd
100.0
50.0
10.0
5.0
1.0

Fig. 3

TABLE 1

DRAG COEFFICIENTS OF BURNING KEROSENE DROPS

130μ Drops		90μ Drops	
R_e	C_D	R_e	C_D
.423	73.3	.825	56.8
.332	85.6	.835	28.6
.307	85.2	.686	37.3
.255	82.2	.617	37.3
.2375	82.5	.583	32.0
.163	81.6	.467	39.1
.124	114.8	.336	62.5
.114	80.8	.282	50.2
.0712	84.5	.260	41.0
.0409	94.5	.191	49.0
		.1324	57.6

CONCLUSION

The results shown correlate reasonably well with those for solid spheres. However, work now in progress should give better results, since it will deal with data on single drops, rather than with statistically analyzed data.

BIBLIOGRAPHY

1. Bolt, J. A., Boyle, T. A., and Mirsky, W., "The Generation and Burning of Uniform-Size Liquid Fuel Drops", Univ. or Mich., Ann Arbor, Mich., Eng. Res. Inst., Project M988, May, 1953.

Uniformly sized drops (90μ and 130μ) of kerosene burning in air were were photographed at known intervals. From the photograph the size and velocity of the drops were determined.

2. Goldstein, S., Modern Developments in Fluid Dynamics, Oxford University Press, 1938, Vol. 1, 16

A graph is presented of drag coefficients for solid spheres moving in various fluids at different Reynolds numbers.

3. Gunn, Ross, and Kinser, Gilbert D., "The Terminal Velocity of Fall for Water Droplets in Stagnant Air", Journal of Meteorology, 6, No. 4, 243-248, August, 1949.

The terminal velocity and drag coefficient for distilled water droplets falling through still air are determined for drops ranging in size from 0.2 μg to 100,000 μg. The over-all accuracy of the measurements was better than 0.7 per cent.

4. Fledderman, R. G., and Hanson, A. R., "The Effects of Turbulence and Wind Speed on the Rate of Evaporation of a Fuel Spray", Univ. of Mich., Ann Arbor, Mich., Eng. Res. Inst., Project CM667, June, 1951.

From work done with fuel sprays evaporating in a wind tunnel, drag coefficients were calculated for hexane drops. The results deviated considerably from the data for solid spheres.