PHYSICAL CHARACTERISTICS OF ALKALINE METALS AND BEHAVIOUR OF LIQUID METAL COOLANT DROPLETS OCCURRING IN NEAR-EARTH ORBITS

S.A. Meshcheryakov
TZNIIMASH,
141070, Kaliningrad, Moscow region, Pionerskaya,4

Abstract

This work continues the report contributed at Darmstadt conference in 1996, and concerns the problem of orbital debris sources at altitudes of 900 - 1000 km. As distinguished from the previous work, there are new results in favor of the Kessler's hypothesis [1].
The optical characteristics and the vapor pressure proved to be of first rate importance for the behaviour of the alkaline droplets, thrown into near-Earth space. If the droplets do not evaporate, there would not be millimeter alkali droplets at attitudes of 900 -1000 km [2].The atmospheric drag would have time to clean this region. Finite vaporization rate effects the situation.
The first attempt [3] to evaluate the vaporization rate failed. The value of Sun's constant was ten times as much, consequently, calculated value of lifetime was very small. Here I correct this mistake. Besides angle dependence of reflection coefficients was accounted for, optical constants for sodium were taken more accurately. The obtained evaluation shows lifetime of millimeter droplets is such that they may occur at altitudes of interest today.

1. Introduction

Strong gas flow from a disrupted reactor body should give large scattering of droplets' velocities and orbit parameters. There is a common Gabard's diagram in Figure 1. The altitude distribution curve (Figure 2) resembles the first peak in the space debris model. It is attractive to have essential part of space debris to be generated by a single source. Paradoxically, but this conclusion could facilitate the protection problem for ISS "Alfa".
Heating of the droplets by solar light is the most important factor making effect on behaviour of K-Na droplets. It is known that surface phenomena are very changeable and dependent on many reasons. Surface layer abundance and state may vary in time under space factors. These phenomena usually are studied experimentally. To make such an experiment are required applying preliminary evaluations of known theoretical and experimental data.

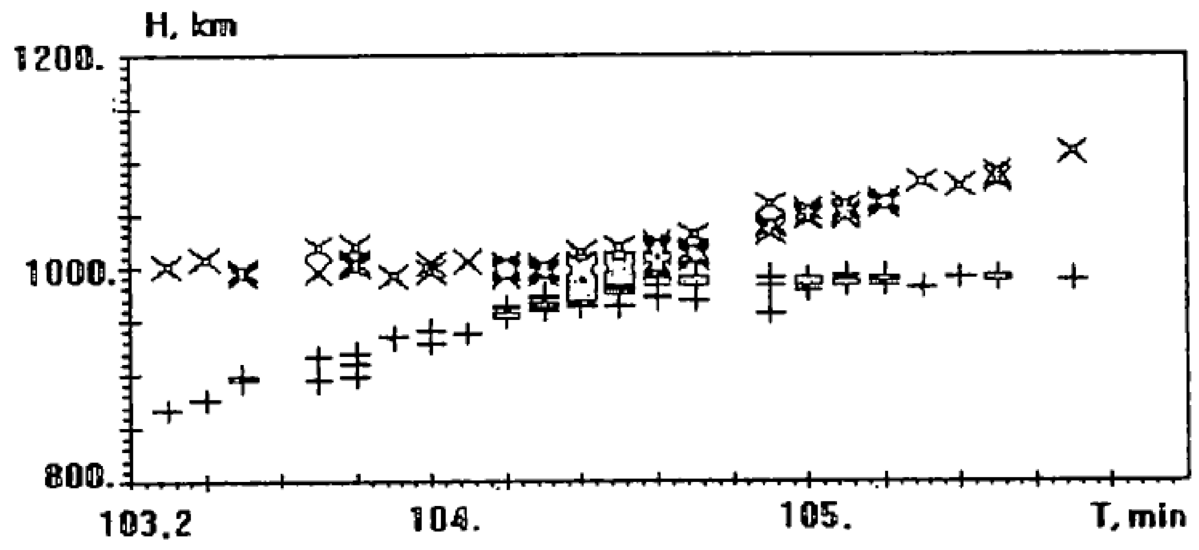

Figure 1 Common Gabard's diagram for one throwing of K-Na droplets

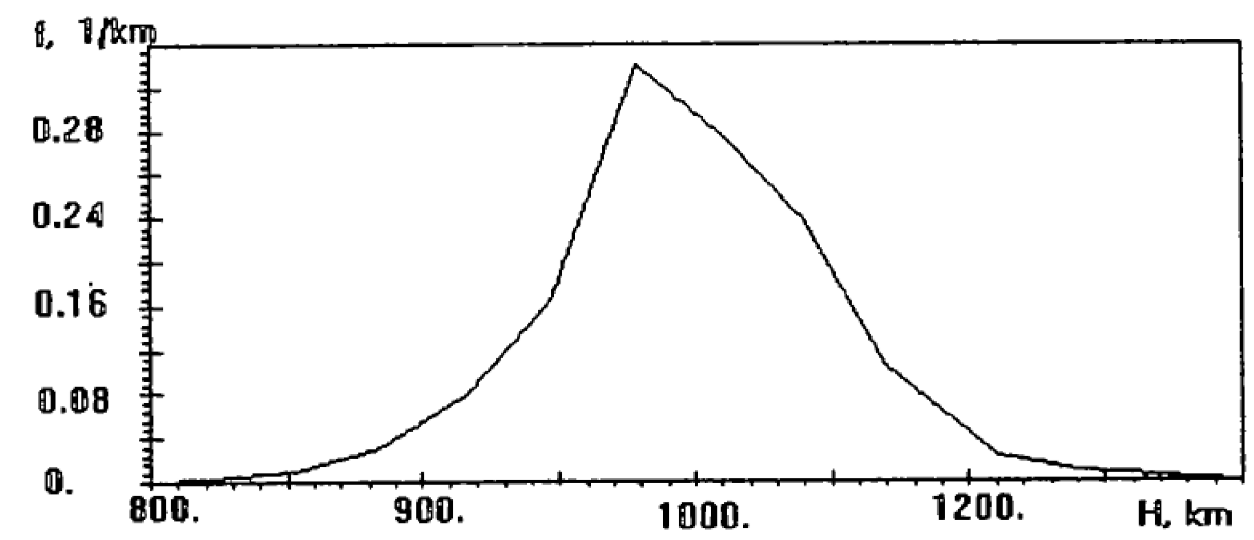

Figure 2 Common altitude distribution of one throwing of K-Na droplets

2. Optical parameters of sodium and potassium

In the work [3] theoretical results of G.P. Motulevich [4] were used. Unfortunately, they are not adequately exact. Experimental data [5] are more proper, but they do not describe the whole wave length span and temperature and angle dependence. Now I again use the Motulevich's formulae, but

Proceedings of the Second European Conference on Space Debris, ESOC, Darmstadt, Germany, 17-19 March 1997, (ESA SP-393, May 1997)

only for extending the applicability region the experimental data. There are reflection coefficients' dependencies on the wave length depicted in Figure 3 for normal incidence on sodium and potassium surfaces. The surface temperature is equal 293 °K. The used experimental data are depicted also.

For further evaluations I suppose that the surface is sodium, because potassium evaporates rather more quickly, its content in surface layer should be poor in any case. As one may see in Figure 3 potassium presence raises the equilibrium temperature, and a transfer to a stage when one has a pure sodium surface is accelerated. The solar light spectrum is given in Figure 4. Integral reflection coefficients for solar light and sodium sphere at temperature of 335 °K is depicted in Figure 5.

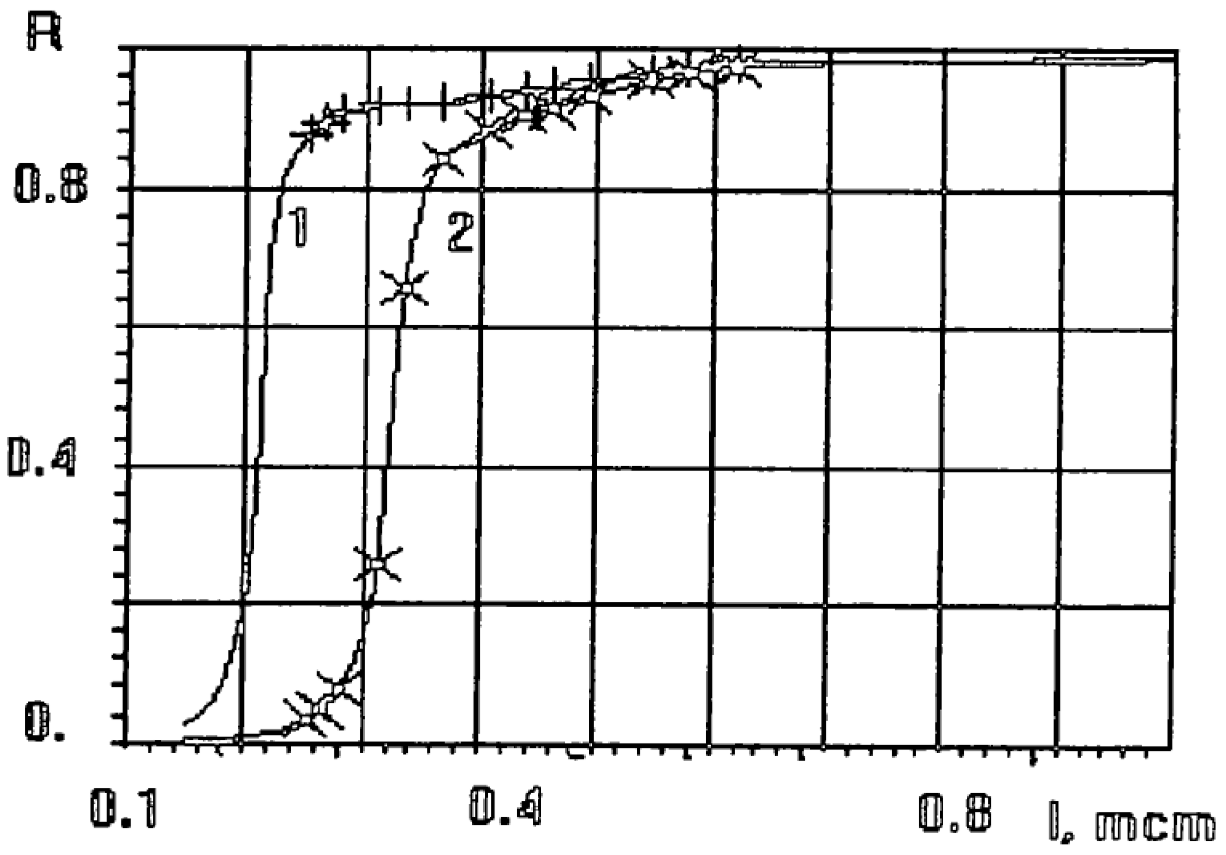

Figure 3 Reflection coefficients for normal incidence
1 -- sodium
2 - potassium

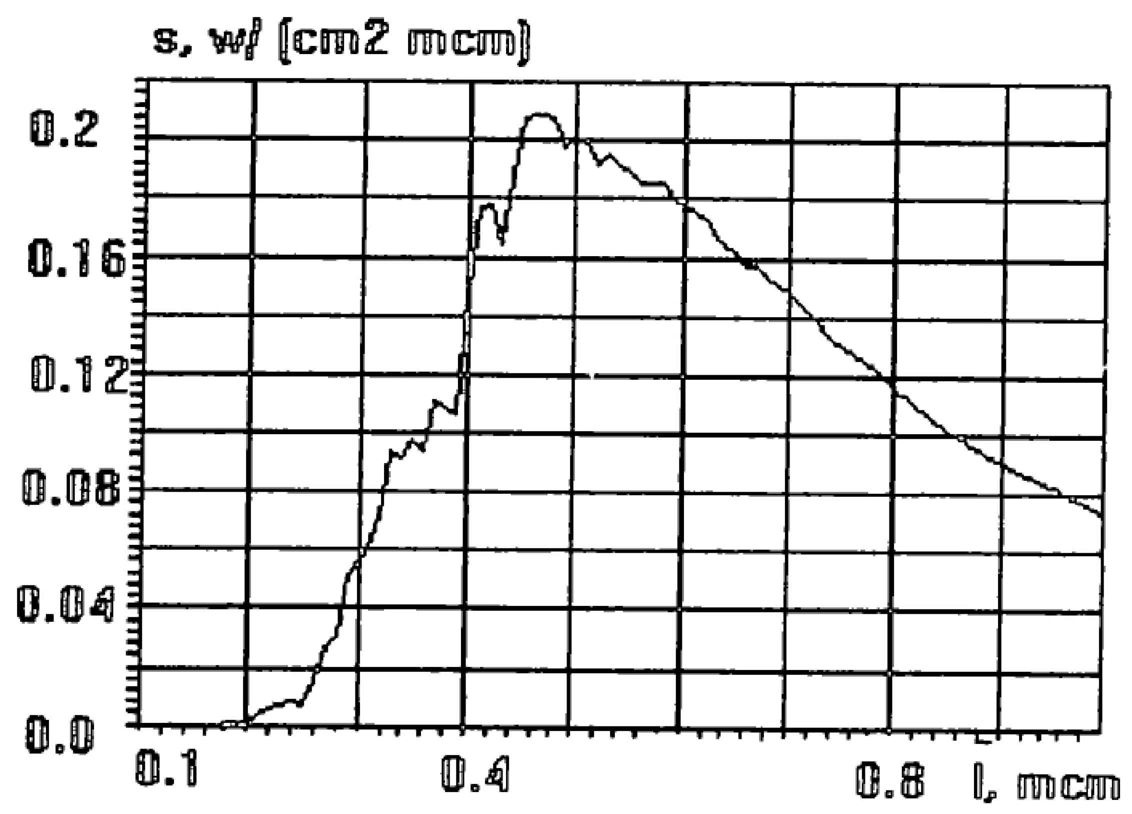

Figure. 4 Sun light spectrum

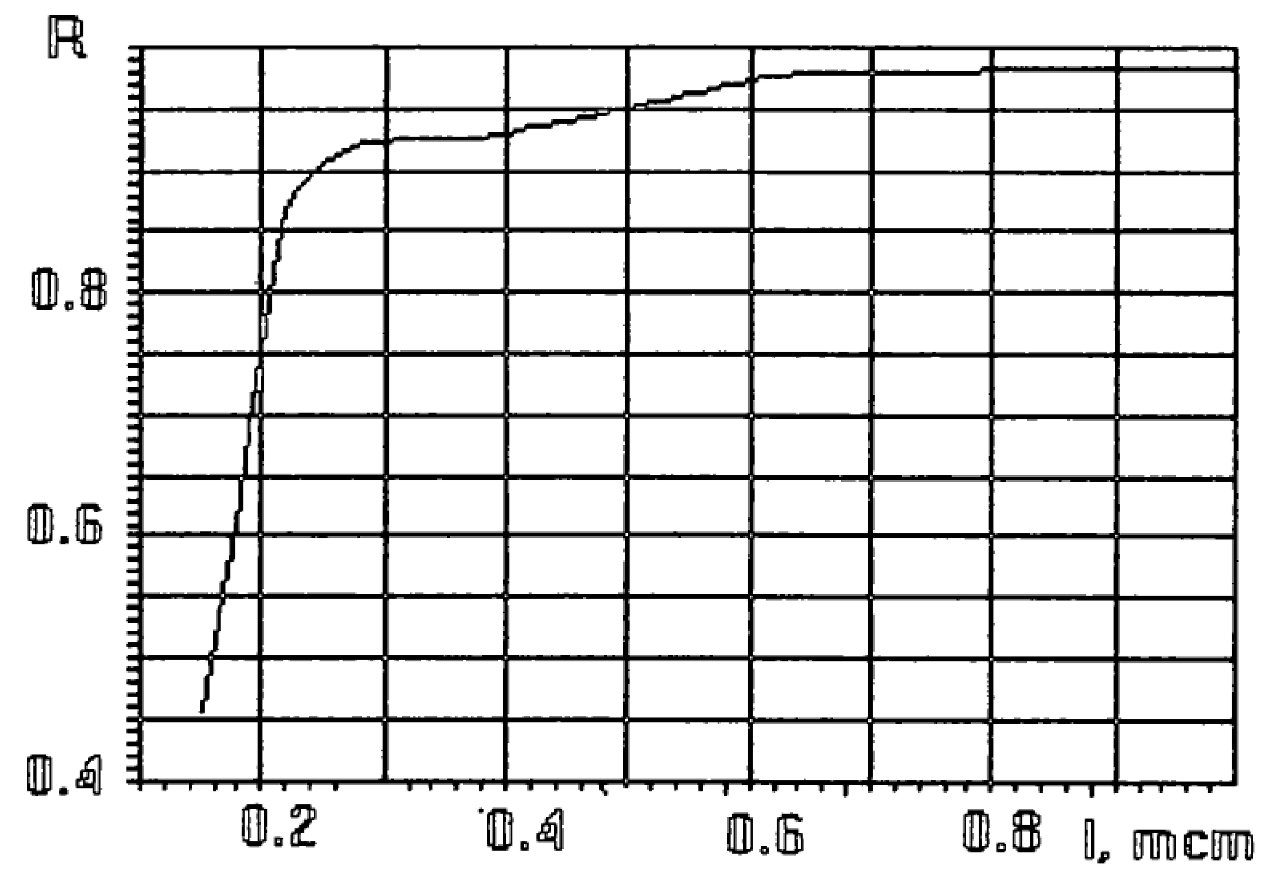

Figure 5 Integral reflection coefficients for sodium sphere at 335 °K

3. Vapor pressure of alkali metals

There are many data on alkali metal vapor pressure, but all data were obtained under rather high temperatures, that are comparative with boiling temperatures. For a lower temperature the data have large errors. Accommodation coefficient data for alkali molecules are not available. These coefficients are usually obtained equal to 1 that can cause some understating of vaporization rate.

4. Equilibrium temperature and vaporization rate of K-Na droplets

The components of thermal balance for K-Na droplets 30 mm in diameter are depicted in Figure 6. Here is a full incident solar light energy, an absorpted energy, a value of thermal radiation of the droplet, and even a sublimation energy. In this problem the balance of incoming and outcoming radiation is very unstable. It is so unstable that the sublimation energy is noticable. The main components are incident and reflected solar energy. Minor errors in reflection coefficients lead to a great change in the equilibrium temperature. It is known that vaporization rate raises rapidly with temperature. It was the main reason that the results of this work would be called as preliminary and asimilar to the previous ones.

Equilibrium temperature of the droplet is somewhat higher than 335 °K. The calculations show that because of a trifle of absorbed energy the equilibrium temperature does not be reached, and droplet temperature increases lightly all along.

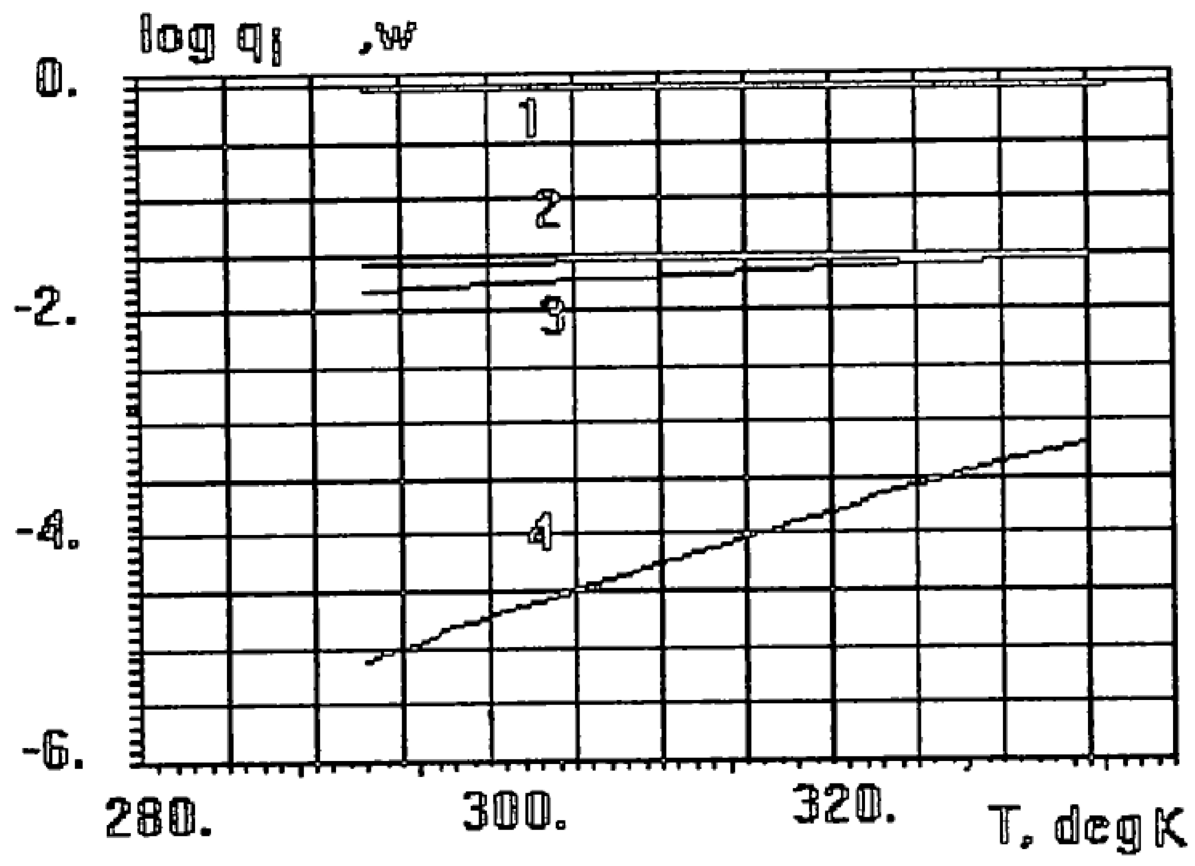

Figure 6 Components of thermal balance for a 30 mm droplet illuminated by Sun

.

1 --incident solar light energy,
2 -- absorpted energy,
3 -- value of thermal radiation of the droplet,
4 -- sublimation energy

5. Behavior of the K-Na droplets. Conclusion

1. Lifetime of K-Na droplets under vaporization with initial diameter of the order of 30 mm is greater than time past since the last deployments of the nuclear reactors. They may be at altitudes 900 - 1000 km now. their spreading region covers the first peak in minor orbital debris fragmetnts distribution.

2. Calculated rates of droplet sizes change are rather high especially at the first stage. This fact defines orbit evolution of the droplets. It is probable that one may evaluate this change rate even by ground-based tracking facilities.

3. Thermal balance of K-Na droplet in near-earth space is very unstable, and it is necessary to have very accurate spectrum-angle reflection coefficient data. Different pollution initially contained in the alloy, solved metals of a reactor body, nitrides and oxides as a result of permanent staying in space can essentially influence the state of droplet's surface and , consequently the vaporization rate.

Existence of alkali droplets is possible. On-board experiment in situ might give a final answer.

6. References

1. Donald J. Kessler. "A new source of debris: RORSAT's.",12th Inter-Agency Space Debris Coordination Meeting, Houston, TX, March 8-10,1995.

2. Meshcheryakov S.A. Analysis of one line of evidence of orbital debris population bred by RORSAT satellites. 1st workshop on space debris. Moscow, Center of Program studying, October 9 -11,. 1995.

3. Meshcheryakov S.A. Critical Time Periods for Collision Hazards of Spacecraft. 13th Inter-Agency Space Debris Coordination Meeting, ESA/ESOC, Darmstadt, Germany, 28 Feb.--01 Mar, 1996.

4. Motulevich G.P. Optical properties of nontransfer metals. In “Optical properties of nontransfer metals. Intermolecular action," Moscow, “Nauka," 1971..

5. Mayer H., Hietel B. Experimental results on the optical properties of the alkali metals. In “Optical properties and electronic structure of metals and alloys”. Ed. by F.Abeles. North Holland Publishing Company, Amsterdam, 1965.