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SELECT THERMAL AND PHYSICAL PROPERTY DATA FOR LEAD CARBONATE (U)

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Introduction

The 9975 shipping package has been used for shipping and storing radioactive materials. Field surveillance activities of 9975 shipping packages following storage in the K Area Material Storage (KAMS) facility have identified that a lead carbonate layer forms on the shield of these packages after a period of time. Analysis of this corrosion product has identified the presence of lead carbonate ($PbCO_3$) and/or basic lead carbonate ($2PbCO_3$ $Pb(OH)_2$). In order to update calculations of the performance of the package in service, Materials Science & Technology was requested to compile thermal and physical properties of lead carbonate. This report transmits the information which was located.

The requested properties include thermal conductivity, specific heat capacity, density and emissivity. Several of the identified properties were found in the literature, and others were not. For the properties that were not located for lead carbonate, the same properties were located for other compounds which might behave similar to lead carbonate. Some general guidance as to the applicability of these data to lead carbonate is provided in lieu of actual lead carbonate properties. Where data were provided for both lead carbonate and basic lead carbonate, the values for each are reported. However, in most cases basic lead carbonate was not included in the references.

Data

Several references were located which contain the identified properties for lead carbonate in particular, or for a number of compounds in general. Thermal conductivity data for lead carbonate was not found in any of the listed references. In this case, thermal conductivity data for a variety of other compounds is identified, and used to provide a potential range for lead carbonate. While specific heat capacity data for lead carbonate was identified, a comparison to other compounds was made prior to locating that data. This comparison is included for completeness. Data for density and emissivity of lead carbonate were located, and are reported. Should additional information be required, further searches might focus on information from the paint/pigment industry.

Thermal Conductivity

Thermal conductivity data for lead carbonate was not found. However, Reference 1 compiles thermal conductivity data for a number of other compounds. Data for several compounds which might be similar to lead carbonate are listed in Table 1.

Table 1. Thermal conductivity for compounds which might behave similar to lead carbonate. Data are for 300K unless otherwise noted.

Compound	Thermal Conductivity (w/cm-K)
$MgCO_3$	0.0465
$CaCO_3$ (marble powder)	0.005 - 0.006
PbO + SiO2	0.0053
SiO_2 crystalline	0.06 – 0.12
SiO_2 fused	0.01 – 0.02
$PbTiO_3$	~0.04, ~0.03 (~580K)
$PbZrO_3$	0.0136 (345K), 0.0150 (530K)
KNO_3	0.0090 (353K), 0.0045 (573K)
$AgNO_3$	0.00447 (469K)
$NaNO_3$	0.00565 (582K)

The following observations are drawn from the thermal conductivity data.

- Two other carbonate compounds have values ranging from 0.005 to 0.046 w/cm-K.
- Three nitrate compounds have values from 0.004 to 0.009 w/cm-K
- The range among the three nitrate compounds is relatively small, and similar to the value for $CaCO_3$.
- Since the values for SiO_2 are much higher than those for $PbO+SiO_2$, the value for just PbO may be less than 0.005 w/cm-K
- Values for 2 other oxides are 0.014 and 0.04 w/cm-K
- Over the temperature ranges given in the reference (not included in Table 1), values for the carbonates vary more with temperature (data for ~300K and lesss) than values for the lead oxides.

There are no obvious trends among these compounds that suggest a likely thermal conductivity value for $PbCO_3$. It may be that the primary factor influencing thermal conductivity is the form of the material; a porous layer of any of these compounds will be a relatively effective thermal insulator. Reference 1 in turn lists the sources from which this data was compiled. It may be possible to track down these source references and determine which compounds were tested in a form most like the $PbCO_3$ film that forms on a 9975 lead shield. Otherwise, the limiting value listed above (0.004 or 0.046 w/cm-K, each value might be limiting for different scenarios) might be an appropriate approximation.

Specific Heat Capacity

Specific heat capacity data for lead carbonate were found in Reference 2, and are summarized in Table 2.

Table 2. Specific heat capacity for lead carbonate. Data from Reference 2 are in cal/mol-K. These values are also shown converted to cal/g-K.

T (K)	$PbCO_3$ cal/mol-K	$PbCO_3$ cal/g-K	PbO-$PbCO_3$ cal/mol-K	PbO-$PbCO_3$ cal/g-K
298	20.917	0.0783	31.875	0.0650
300	20.970	0.0785	31.940	0.0651
400	23.830	0.0892	35.440	0.0723
500	26.690	0.0999	38.940	0.0794
600	29.550	0.111	42.440	0.0865
700	32.410	0.121	45.940	0.0937
800	35.270	0.132		

Conversion from mol to g: 267.1 g/mol $PbCO_3$, 490.41 g/mol PbO-$PbCO_3$

It is possible that the carbonate layer might form along with an oxide layer, or on top of an oxide layer. If this is considered credible, the data for PbO-$PbCO_3$ might be considered. Otherwise the $PbCO_3$ data would be appropriate.

Prior to locating the above data, the specific heat capacity data for similar compounds were examined. These data are in Table 3. It is noted that the specific heat capacity generally varies with the molecular weight. A consistent trend was observed between the weight of the metal atom and the specific heat capacity of the carbonate compound for those compounds with a single metal atom. The data for these compounds at 300K are plotted in Figure 1. A curve fit for these data identified by Excel spreadsheet is extrapolated to the atomic weight of lead. It is noted from Figure 1 that this gives very close agreement to the value reported in Reference 2. This relationship is shown primarily to suggest possible approaches in the use of the thermal conductivity data above.

Table 3. Specific heat capacity (Cp) for several carbonate compounds. Units are cal/g-K

Compound	At. Wt. of metal	Cp at 100K	Cp at 300K	Cp at 600K
$PbCO_3$	207.2			
$BaCO_3$	137.3	0.0608	0.104	0.1368
Ag_2CO_3	107.9	0.0614	0.097	
$SrCO_3$	87.6	~0.07	~0.13	
$MnCO_3$	54.9		~0.17	~0.22
$CaCO_3$	40.1	~0.09	0.2	~0.19
Li_2CO_3	6.9			0.5

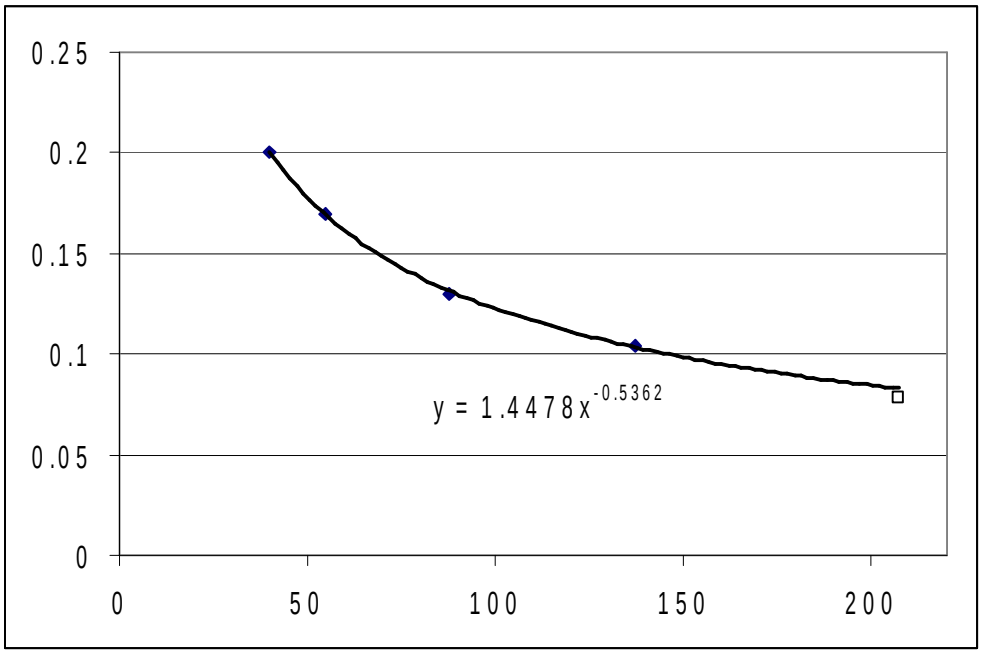

Figure 1. Specific heat capacity of carbonate vs atomic weight of metal (for compounds with a single metal atom). Curve fit by Excel spreadsheet is extrapolated to the atomic weight of lead.

Density
The following data are found in both References 4 and 5.
Lead carbonate, $PbCO_3$, 6.6 specific gravity
Basic lead carbonate, $2PbCO_3\ Pb(OH)_2$, 6.14 specific gravity

In contrast, Reference 6 identifies a slightly different value for basic lead carbonate. It gives the following data:
Lead carbonate, $PbCO_3$, 6.6 g/cc density
Basic lead carbonate, $2PbCO_3\ Pb(OH)_2$, ~6.5 g/cc density

Emissivity
Reference 7 identifies the following data for lead carbonate emissivity.

Table 4. Lead carbonate emissivity

Temperature (C)	Emissivity (%)
52	89
400	71
2750	8
solar	12

Reference 5 provides the following emissivity data.
For oxidized Pb (metal, not carbonate), emissivity (total) = 0.05 at 200C
For unoxidized Pb (metal, not carbonate), emissivity (total) = 0.63 at 200C

Two additional references for emissivity data were cited, but the references (8, 9) were not located for this review.

Summary

Specific heat capacity, density and emissivity data for lead carbonate were identified and reported. The density of basic lead carbonate was also reported. The thermal conductivity of lead carbonate was not found, but the thermal conductivity of a number of other compounds is summarized. A correlation was observed between the metal atomic weight and specific heat capacity for several carbonate compounds. While this specific relationship does not appear applicable to the thermal conductivity, it might suggest an alternate approach to estimate the thermal conductivity of lead carbonate. However, in the absence of any demonstrated relationship, it is recommended that the maximum or minimum value reported for other compounds (whichever is more limiting) be used for lead carbonate.

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