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LATENITE: hygrothermal material property database
Karagiozis, Achilles; Salonvaara, Mikael; Kumaran, Kumar

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LATENITE

HYGROTHERMAL

MATERIAL PROPERTY

DATABASE

by Achilles Karagiozis, Mikael Salonvaara and Kumar Kumaran

Report T1-CA-94/04
Contribution to the IEA-Annex 24 meeting

Trondheim, April 1994

Canada

Introduction

With the effort of Annex 24, better understanding of the basic principles of moisture transport is evolving among participating members. This can be confirmed with the recent additions of new analytical/numerical modeling tools for hygrothermal analysis developed by the participating countries. As these activities continue, the significance of the most critical parameters influencing the hygrothermal performance of building structures will become standard knowledge. Modeling will likely be a key tool (of high importance) in generating these extensive guidelines since it costs less and is considerably less time consuming in comparison with its experimental counterpart.

Along with having a model that can accurately predict the transport phenomena in a building envelope part, the accuracy of the material properties can be critical. The manner in which the material properties are used can be different in each model. For instance the model WUFITZ developed by Kunzel (1) assumes that the vapor permeability is constant through-out the vapor regime and has conducted tests to substantiated this effect. On the other hand, the TCCC2D model developed by Ojanen (2) uses these variable vapor permeabilites as an integral part of the material properties behavior. Examples similar to the above can be found among most of the models developed by the participating IEA countries. Indeed, most of these models either have databases or coding that is not publicly available to other models. It is most probable that a prediction of exactly the same wall structure for the same environmental conditions will give different quantitative results even if the same potential for moisture transport is used. It becomes apparent that the need for a common material property database that can be used by a majority, if not all hygrothermal models, is critical. Much of the success of our modeling activities depend on the consistency of the results among the models.

In this report several material properties that are commonly used by hygrothermal models, are compiled and presented in a graphical manner. The material property database includes experiments conducted by IEA members and others, and is still at its infancy stage. Most of the properties listed in the report have not been thoroughly tested, and thus there is a cautionary note to this effect. However the objective of this effort is to allow other model users to compare and add/share other material properties to this database. The LATENITE model uses this material property database as an integral part of the Software interface, where the user can view in a graphical display each material property. This is done prior to each simulation and the user can print out this information to any printer. This can assist the user in the interpretation of the results and thus considered an important step in the modeling effort.

LIST OF PROPERTIES

Both types of material classes, the macroporous and the capillary, are included in this preliminary database. Forty-one material properties have been compiled from several researchers; these can be found in the list of references. The following material properties are tabulated:

- Sorption Isotherms (kg/kg)
- Vapor Permeability (kg/msPa)
- Liquid Diffusivity (m^2/s)
- Thermal Conductivity (W/mK)
- Air Permeability (m^2)
- Heat Capacity (J/kgK)
- Density (kg/m^3)

MATERIAL PROPERTIES

For the first 4 material properties, graphs are presented that show the properties as a function of moisture (relative humidity or moisture content). Only for a few materials a complete set of this functional dependency is available for all four properties. A list of the forty-one materials, along with the some fundamental properties are given in Table 1. In APPENDIX 1 to 41 the material properties particulars for each material is presented. For each APPENDIX number the sorption isotherm curve is presented first followed by the vapor permeability, the moisture diffusivity and the thermal conductivity is plotted out as a function of relative humidity or moisture content.

SORPTION ISOTHERM

In the hygroscopic region a equation with the following form was used,

$$U = a\phi^b + c\phi^d. \quad (1)$$

In the capillary regime, the equation takes the form,

$$U = C_0 + C_1 \bullet \phi \quad (2)$$

In the region between hygroscopic and capillary, a blending equation was formulated that maintained the continuity in derivatives and had a form similar to equation (2), that is

$$U = U_1 + \frac{\partial U}{\partial \phi} \Big|_1 (\phi - \phi_1) + E \left(\frac{\phi - \phi_1}{\phi_2 - \phi_1} \right)^F \quad (3)$$

The above equations were employed such that a continuous function existed with the restriction of a continuous 1 st derivative.

Vapor Permeability, Liquid Diffusivity and Thermal Conductivity

The functions to describe these material properties as a function of relative humidity are not unique and for each property the one recommended by the source is used. For vapor permeability at high RH, a first order decay was assumed that allowed the vapor

permeability to gradually become zero at $rh=100\%$. A similar function was used for the liquid diffusivity at low moisture contents. These decay functions are not shown in the Figures of Appendices.

Conclusions

In this report a compilation of some important material properties for use in hygrothermal modeling is presented. This material property database will continuously be updated and verified with other experimental data. The database is expected to expand and include additional materials which will be presented at future IEA Annex 24 meetings. Additional or similar material properties from all participating members are more than welcome in this effort to compile a database for numerical modeling. This effort may move in a parallel direction as that of the Material Property Task Group effort, and could formulate the information to be directly transferable to other models. A FORTRAN version of this database (in form of subroutines) will be available in the near future for those interested.

#	MATERIAL	DENSITY, kg/m ³	HEAT CAPACITY, J/kgK	AIR PERMEABILITY, m ²
1	WOOD CHIP BOARD	700.0	2100.0	1.e-13
2	POROUS WOOD FIBRE BOARD	310.0	2100.0	1.e-13
3	GYPSUM1 BOARD	620.0	840.0	1.e-13
4	PINE WOOD	425.0	2390.0	6.e-14
5	MINERAL FIBRE	20.0	670.0	1.1-2.1e-9
6	AERATED CONCRETE	550.0	840.0	1.e-15
7	MORTAR	1800.0	840.0	1.e-16
8	CONCRETE	2200.0	840.0	1.e-16
9	EXPANDED CLAY AGGREGATE	1000.0	840.0	1.e-13
10	PLYWOOD	450.0	1880.0	1.e-16
11	EXTRUDED POLYSTYRENE	35.0	1470.0	1.e-16
12	EXPANDED POLYSTYRENE	30.0	1470.0	7.7e-8
13	WHITE BRICK	1730.0	840.0	1.e-14
14	RED BRICK	1670.0	840.0	3.e-13
15	SAND LIME STONE	1800.0	850.0	1.e-16
16	CELLULOSE1	30.0	1400.0	5.5e-7
17	POLYETHELENE SHEET 6-MIL	840.0	1256.0	1.e-20
18	AIR BARRIER	840.0	1256.0	1.e-20
19	ALUMINUM SIDING	840.0	1256.0	1.e-20
20	BRICK (REHEATED)	1800.0	800.0	3.e-13
21	BUILDING PAPER	840.0	1250.0	1.e-20
22	BUILT UP ROOFING	1120.0	1466.0	1.e-20
23	CELLULOSE2	80.0	1382.0	5.5e-7
24	CEMENT PARGE COATING	1920.0	838.0	1.e-20
25	CONCRETE BLOCK	2240.0	921.0	1.e-20
26	EXPANDED POLYSTYRENE	16.0	1214.0	7.7e-8
27	EXTERIOR GRADE PLYWOOD	510.0	1214.0	1.e-16
28	EXTRUDED PLOYSTRENE	42.0	1214.0	1.e-16
29	FIBER BOARD SHEATHING	266.0	1298.0	3.e-13
30	FOAM CORE SHEATHING	97.0	1298.0	1.e-16
31	GLASS FIBRE	11.0	712.0	1.1-2.1e-9
32	GRAVEL	1442.0	839.0	1.e-16
33	GYPSUM2 BOARD	670.0	1089.0	2.8e-11
34	KRAFT PAPER	840.0	1256.0	1.e-16
35	MICRO FINE PARTICLE	762.0	1298.0	4.8e-11

36	ORIENTED STRAND BOARD	641.0	1298.0	1.e-13
37	PERMEABLE BOARD	266.0	1298.0	3.e-13
38	ROOF SHINGLES	1121.0	1256.0	1.e-16
39	STUCCO FINISH	670.0	1089.0	2.8e-11
40	SUGAR PINE	365.0	1633.0	1.e-14
41	WAFERBOARD	706.0	1214.0	1.e-14

REFERENCES

- 1) Kunzel, H. Fraunhofer-Institut für Bauphysik 1992
- 2) Ojanen T. VTT, Finland, 1990
- 3) Catalogue of Material Properties, International Energy Agency, Report Annex XIV, Volume 3, March 1991
- 4) VTT TRATMO2 Material Property Database
- 5) IRC, Building Performance Laboratory, Database
- 6) MOIST, NIST material property database
- 7) IEA Annex 24 Common Exercises I and III

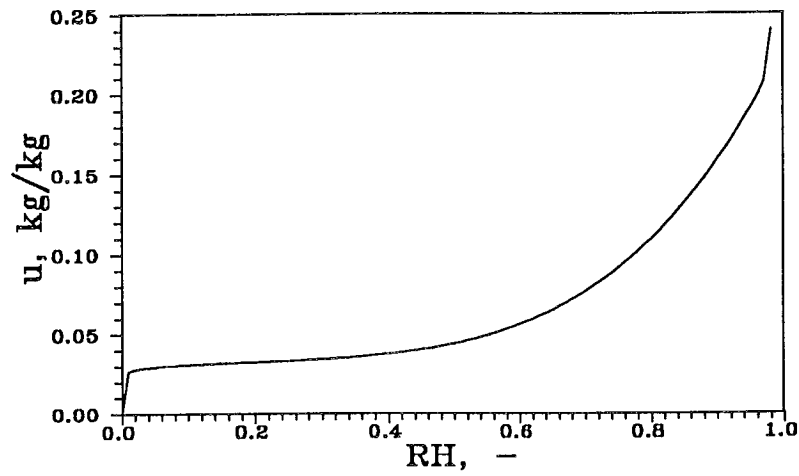


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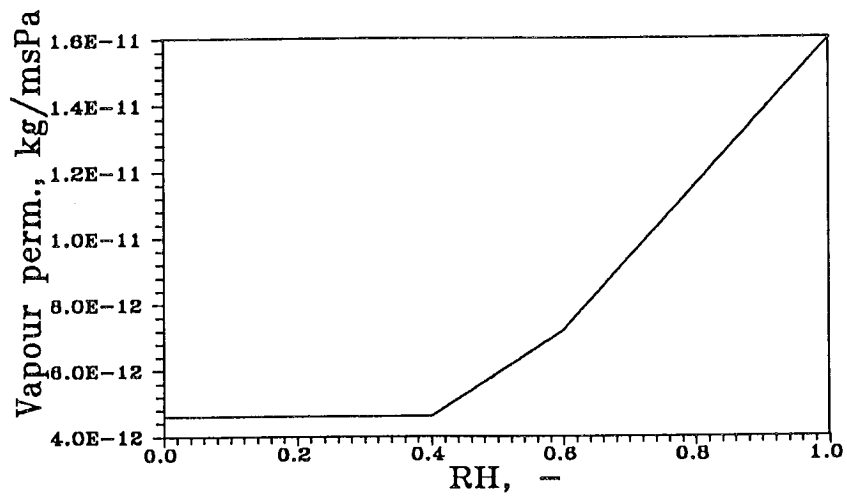


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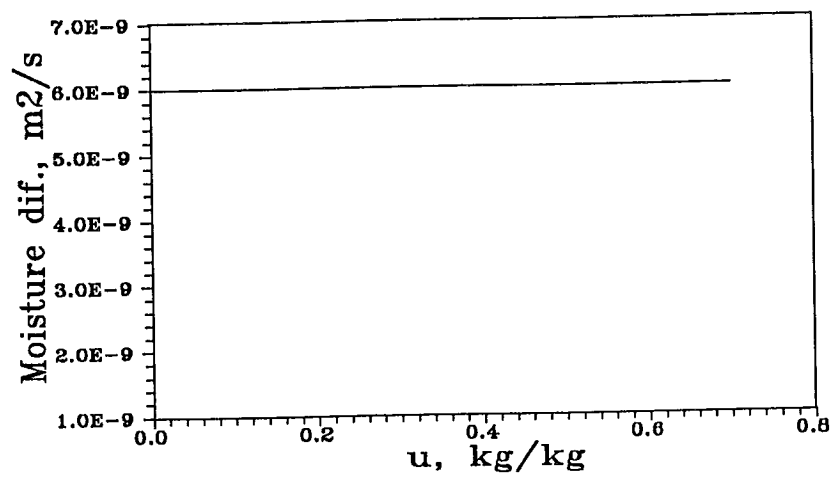


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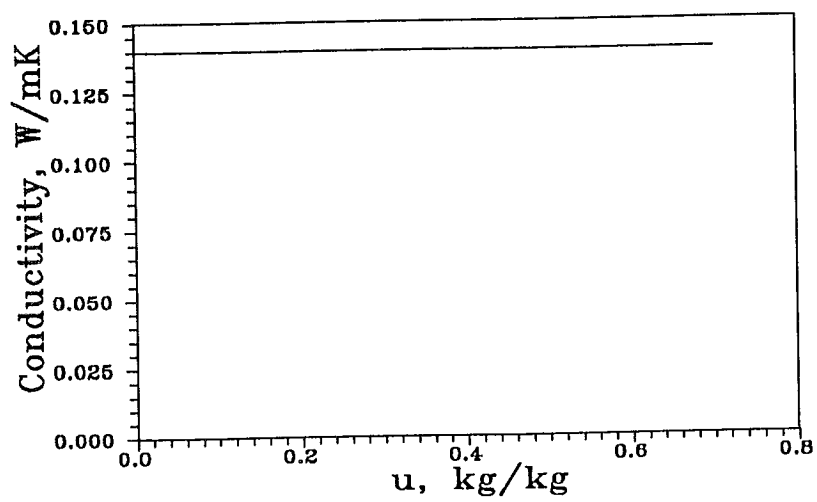


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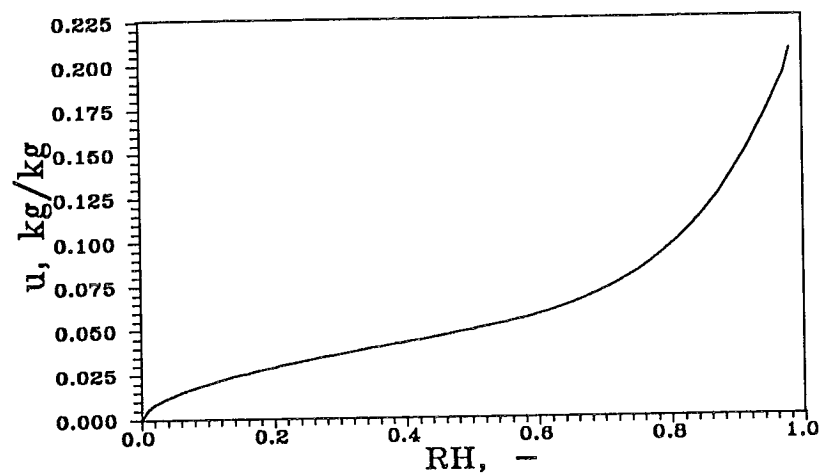


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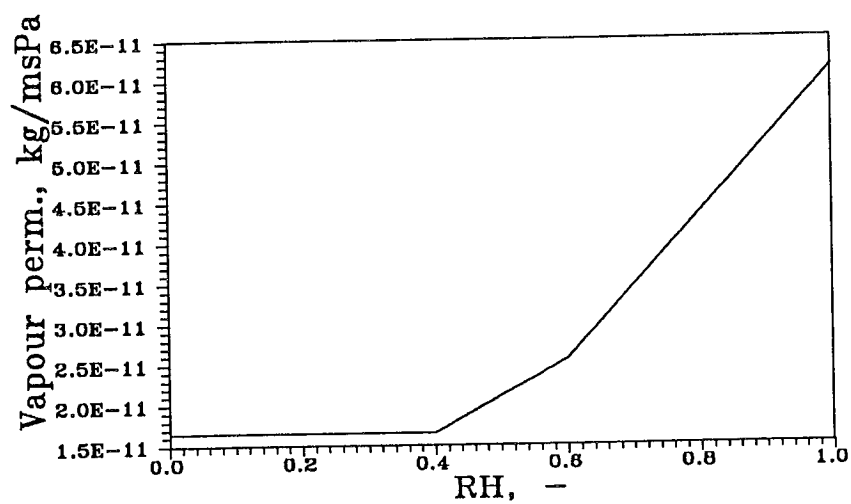


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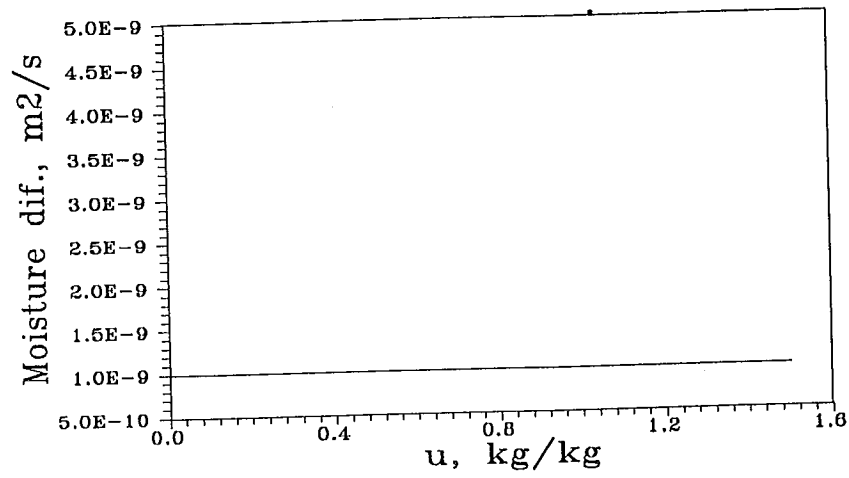


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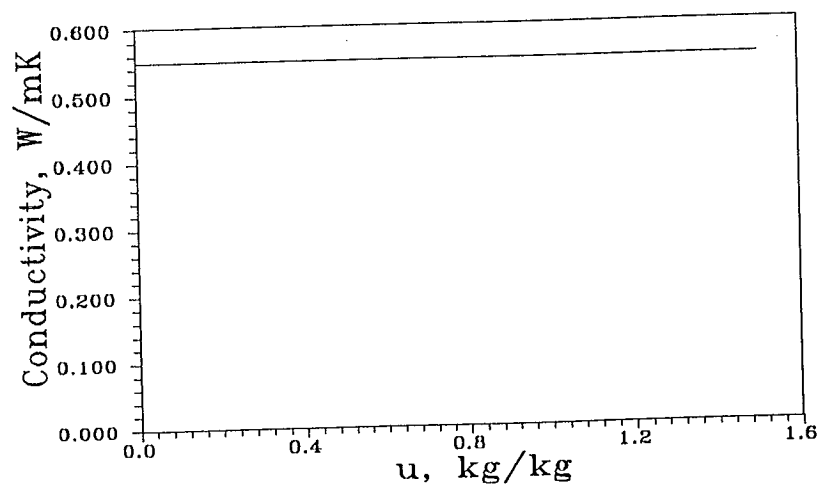


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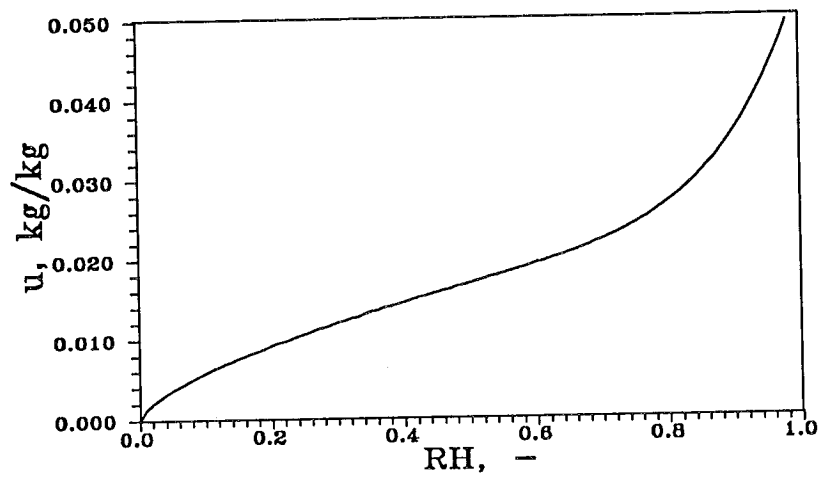


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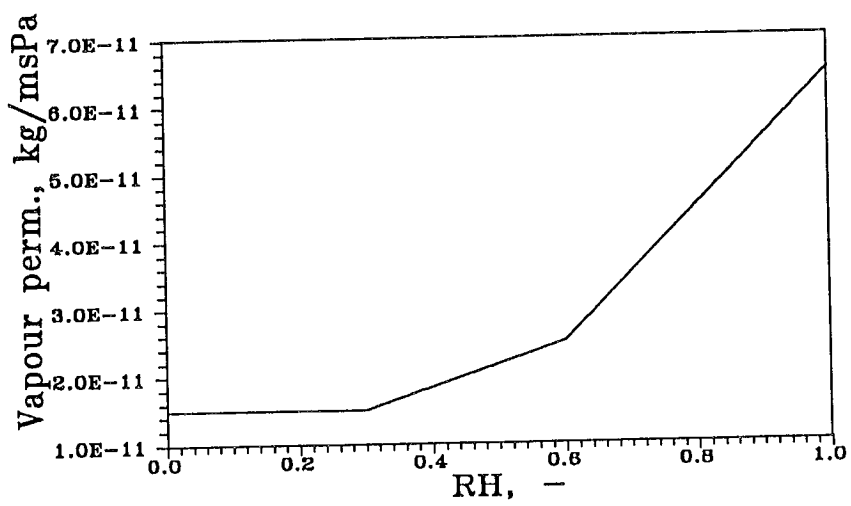


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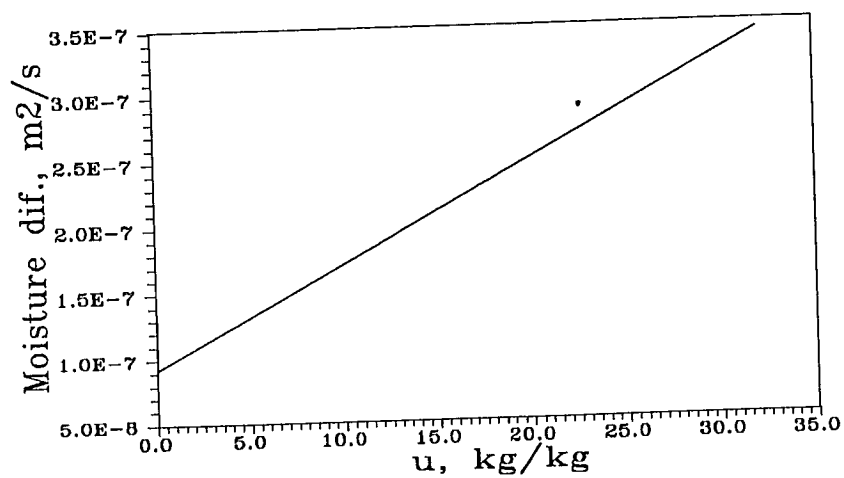


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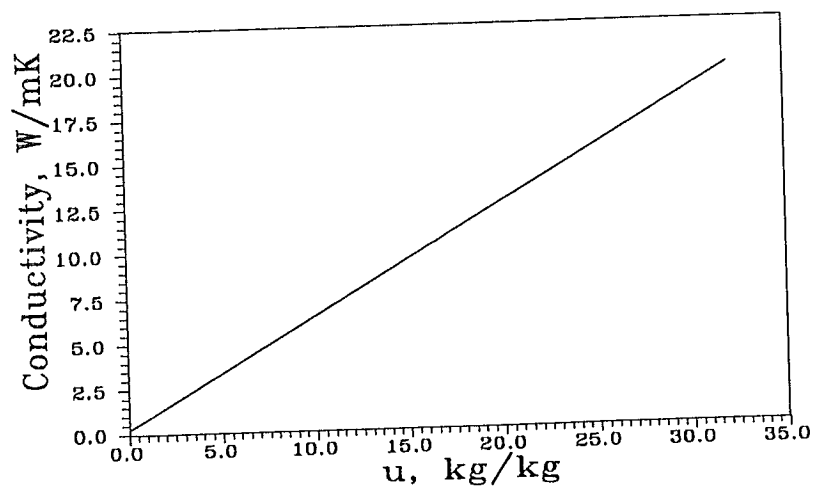


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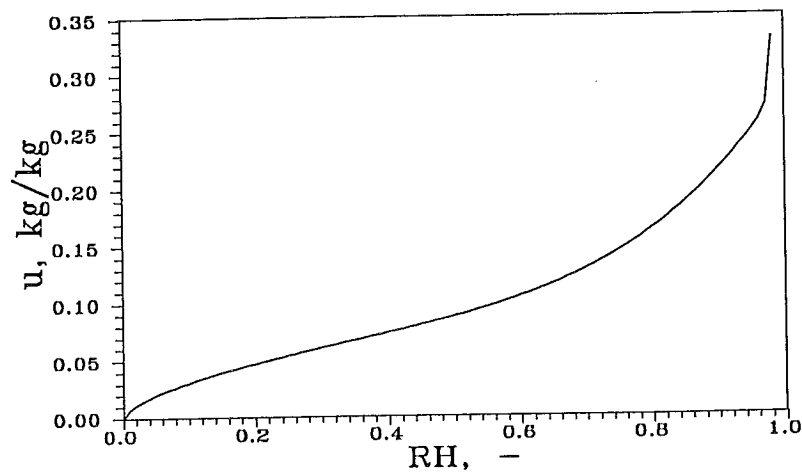


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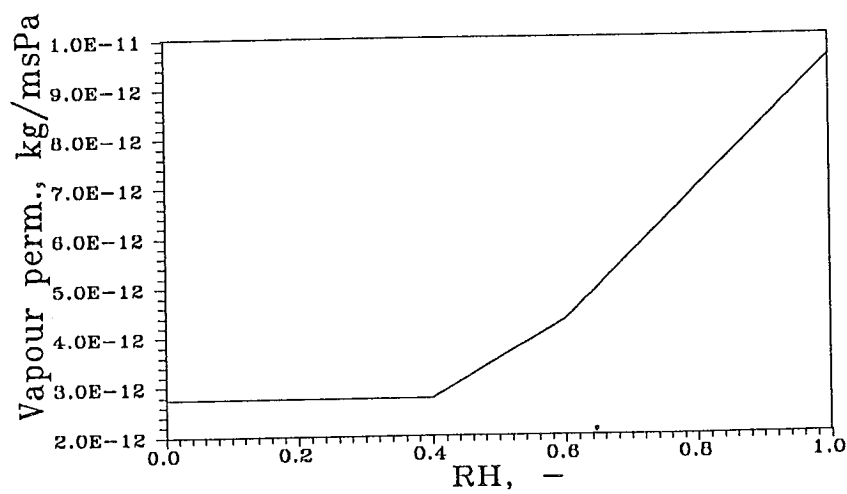


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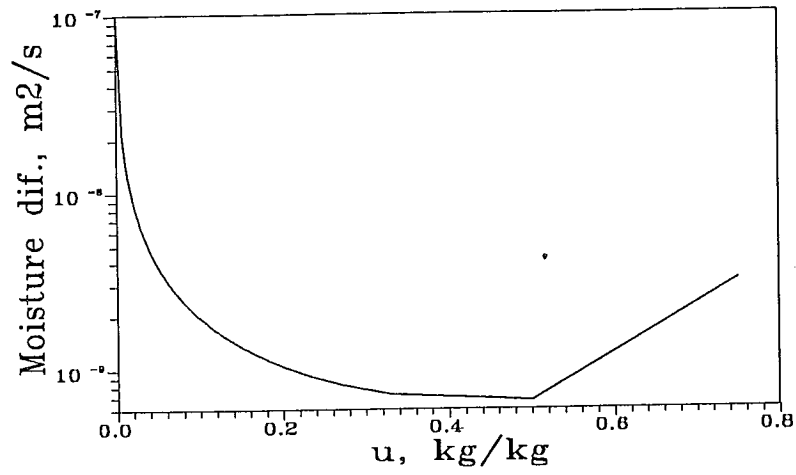


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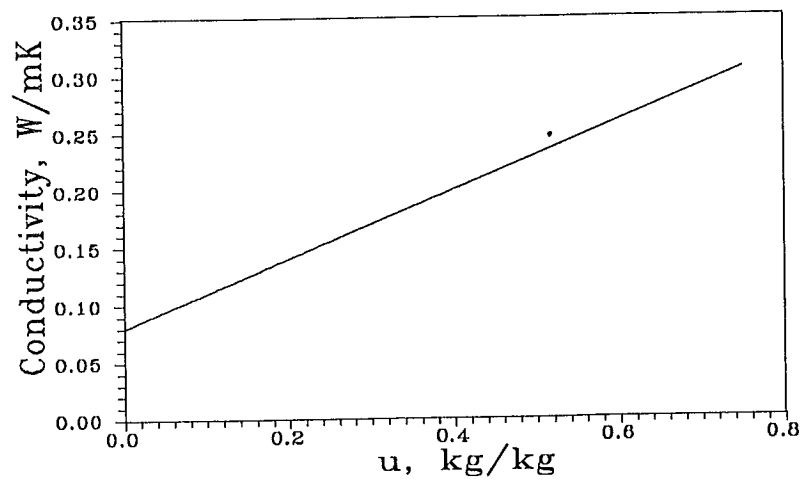


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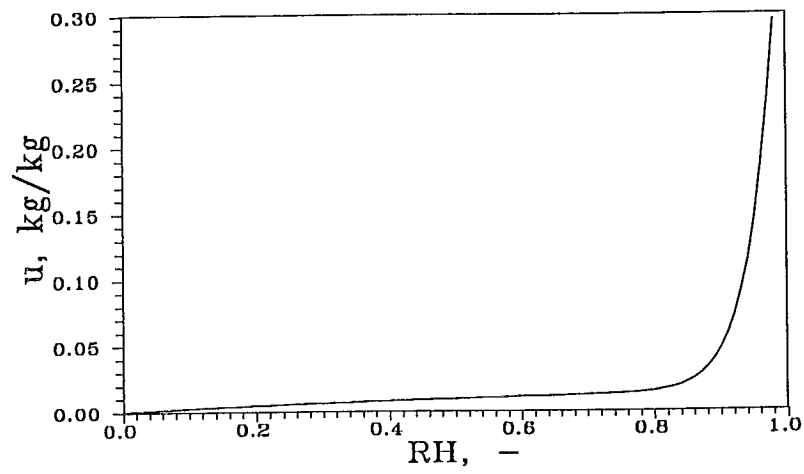


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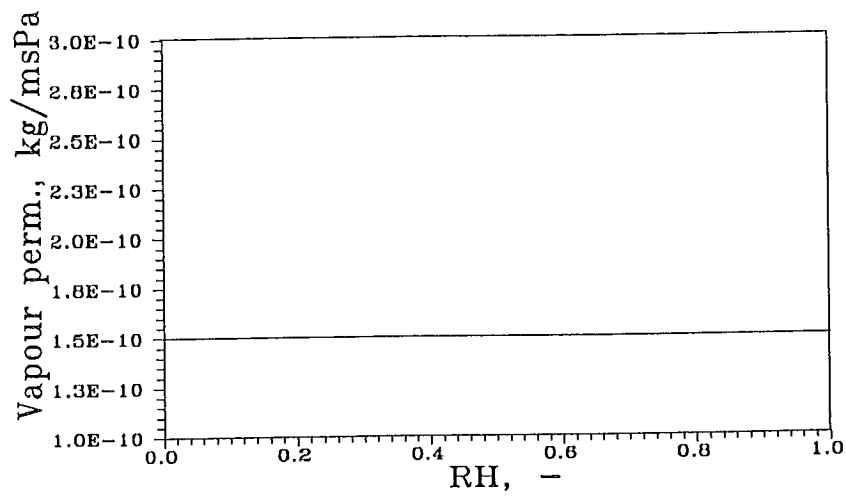


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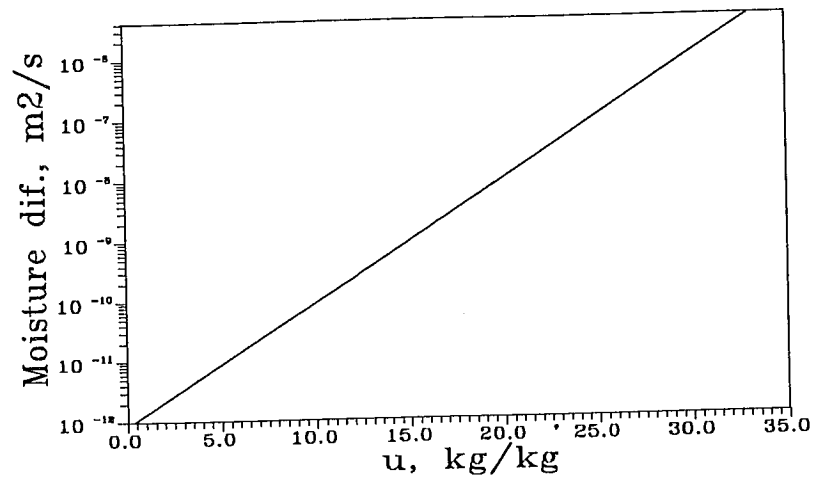


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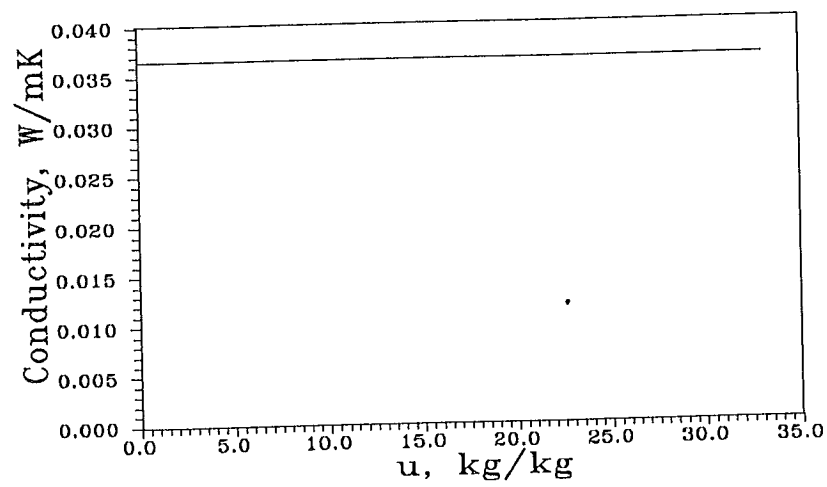


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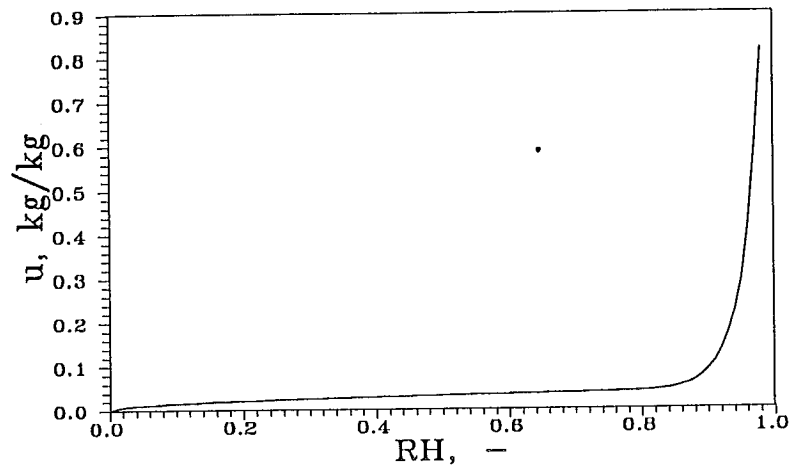


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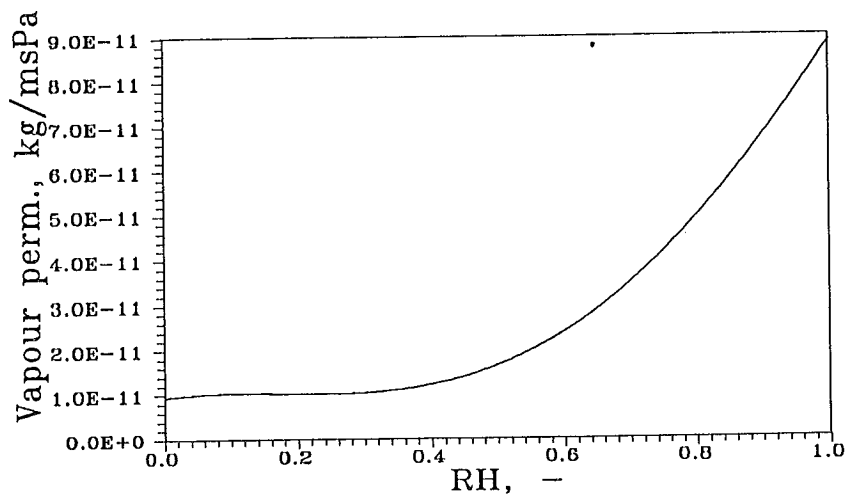


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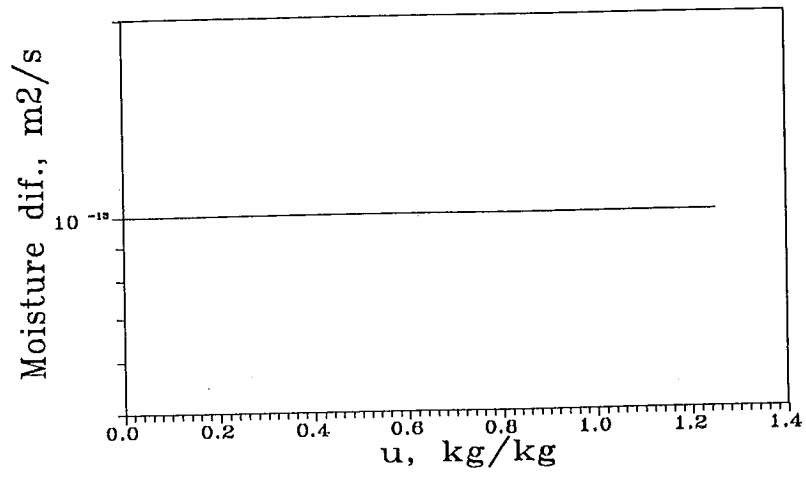


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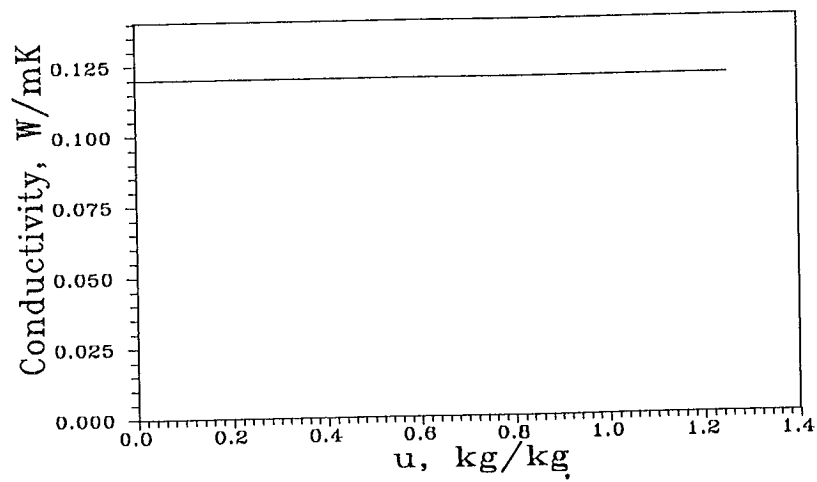


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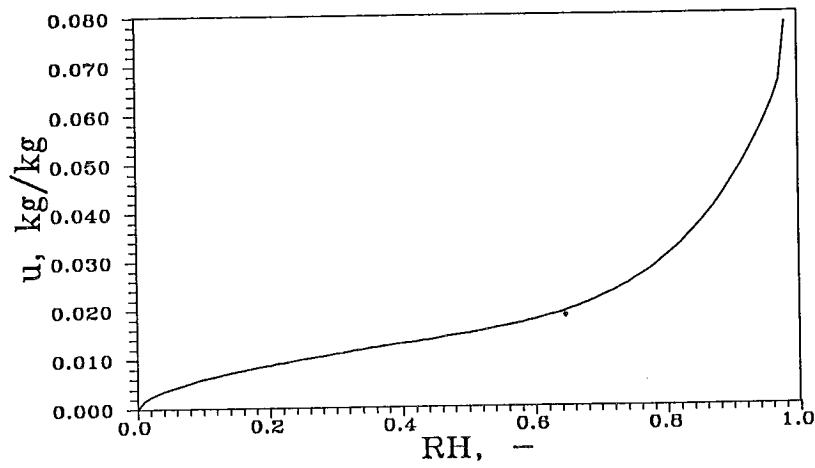


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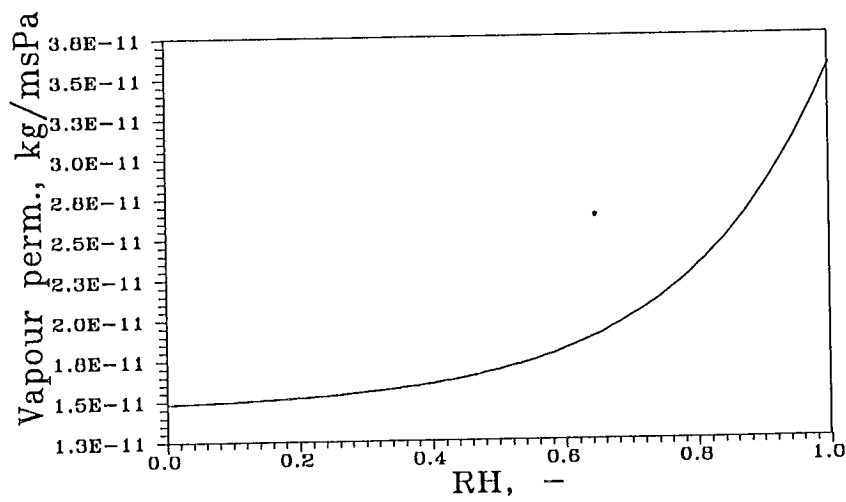


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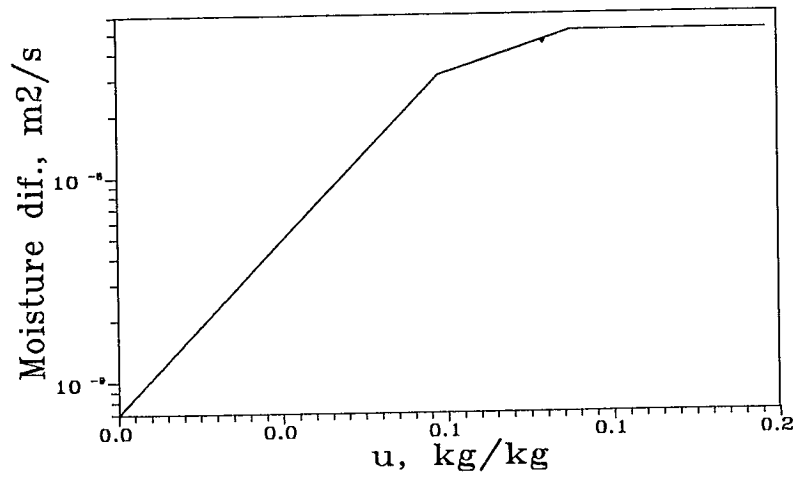


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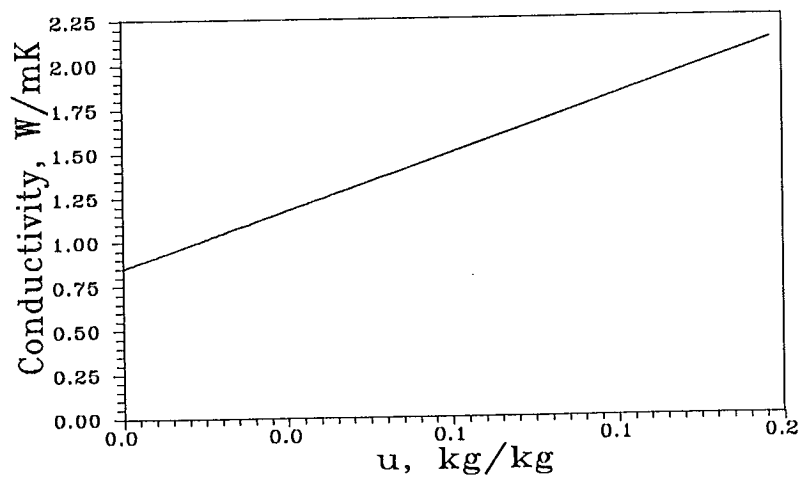


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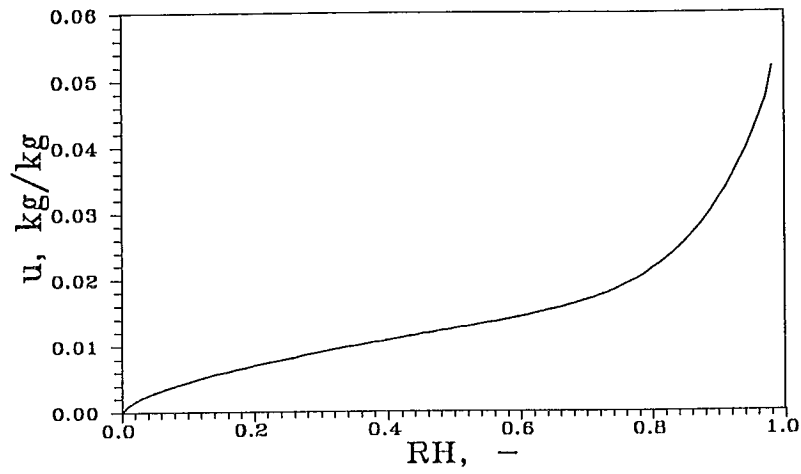


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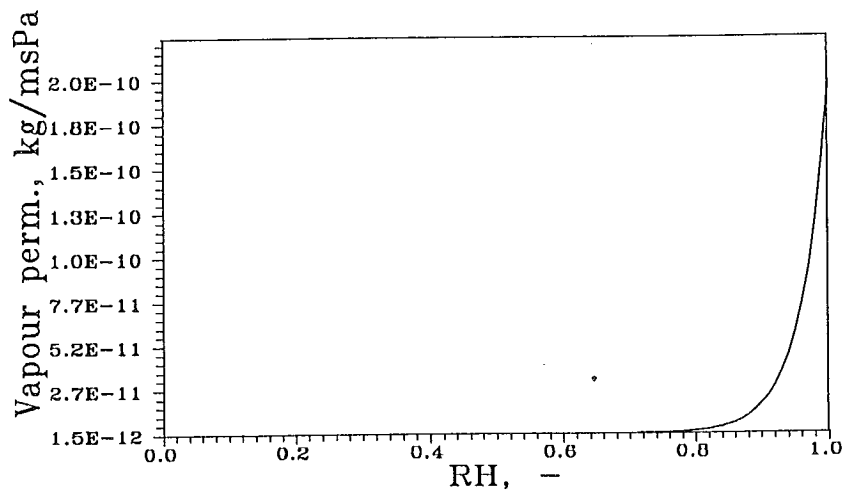


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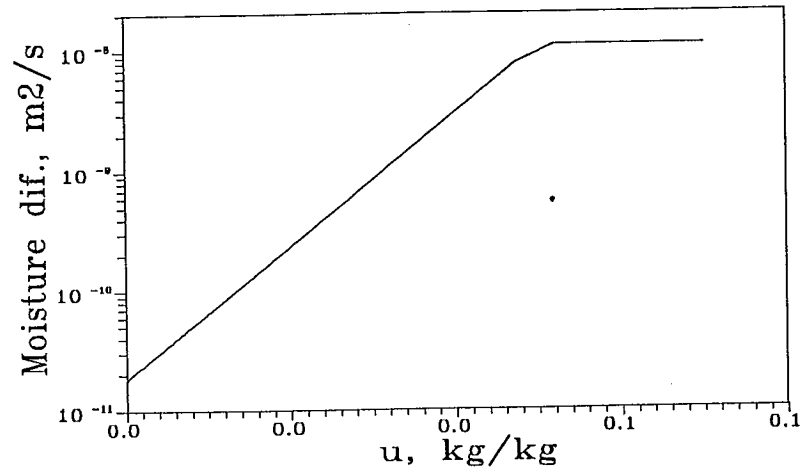


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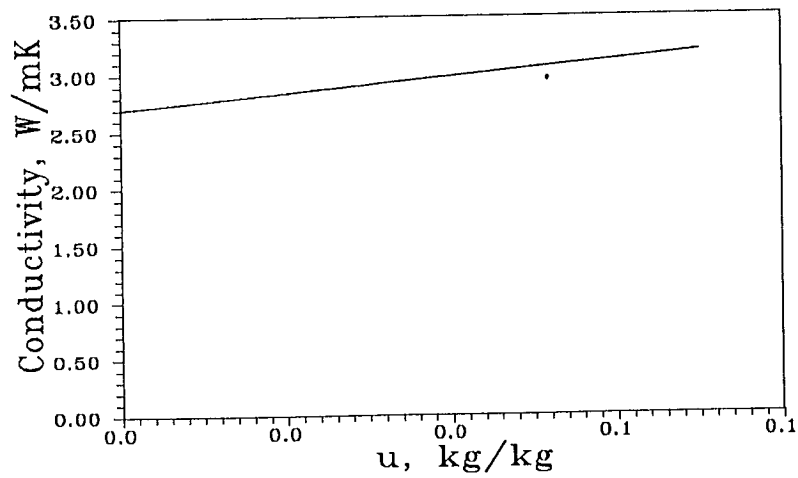


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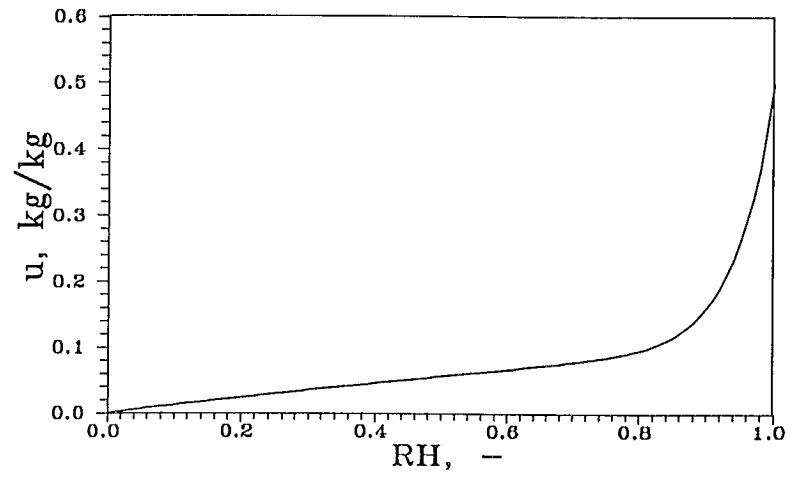


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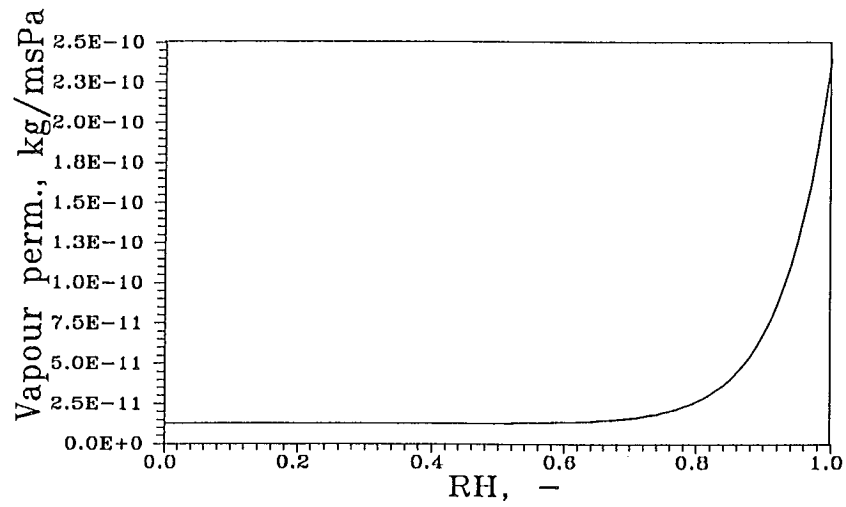


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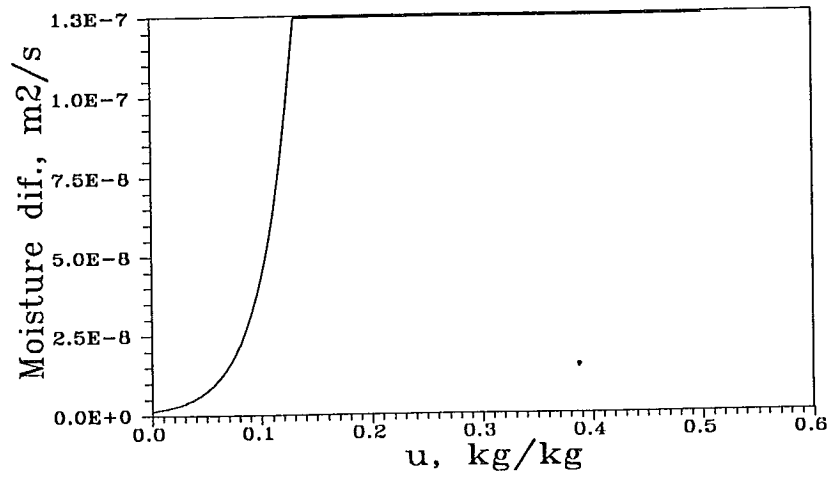


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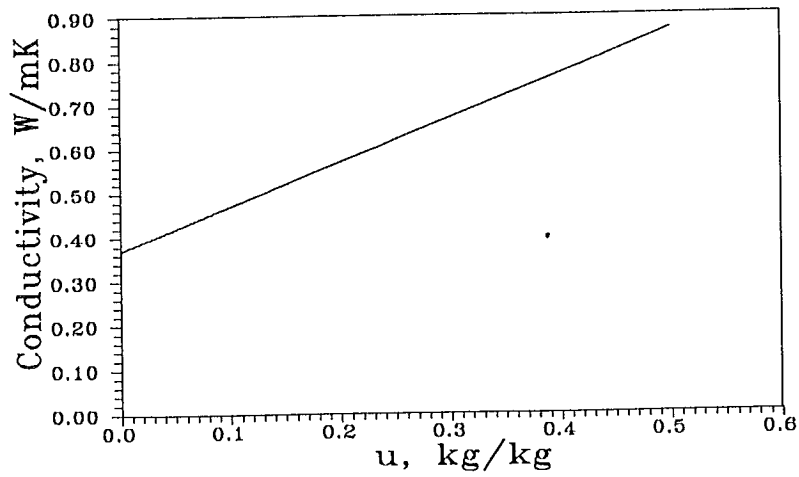


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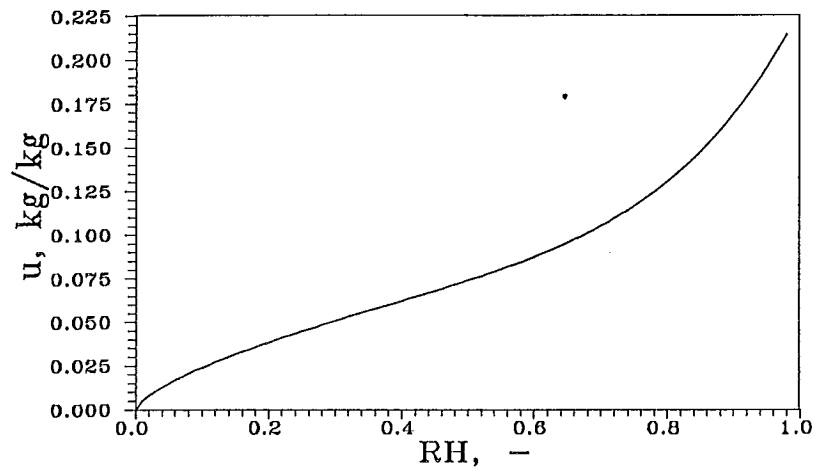


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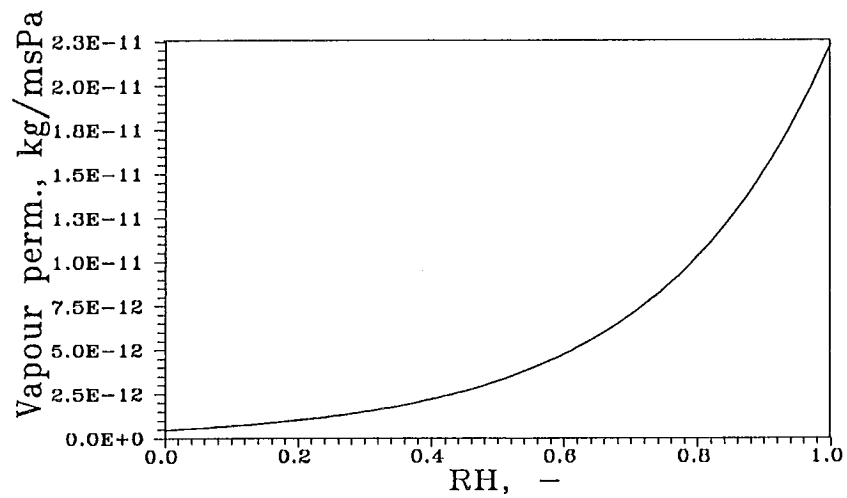


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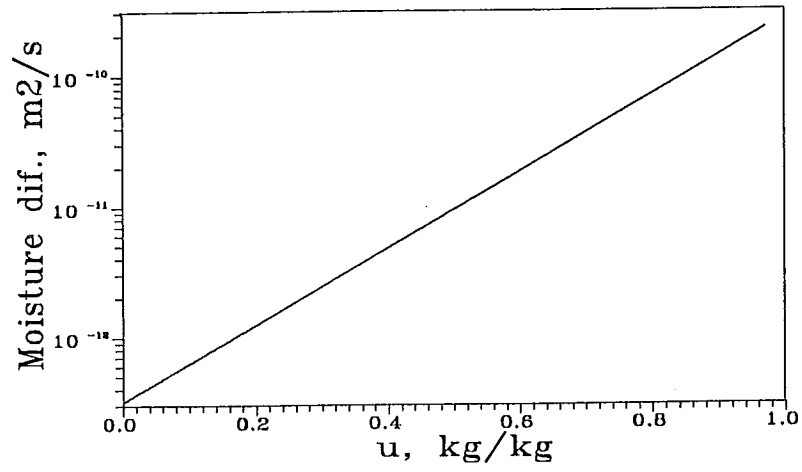


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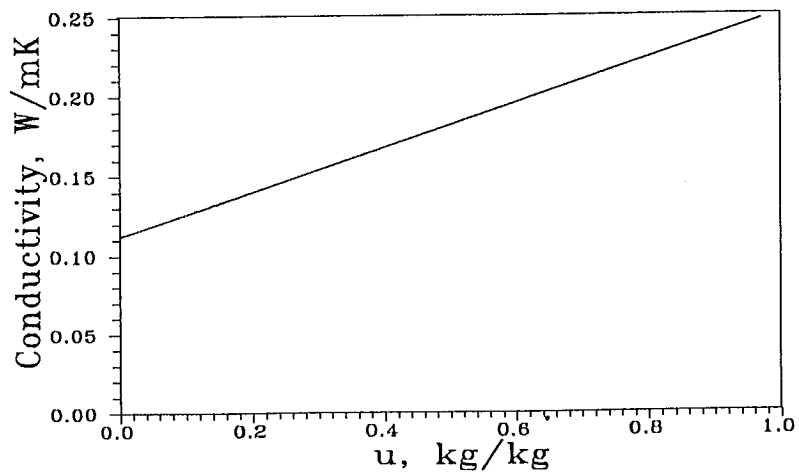


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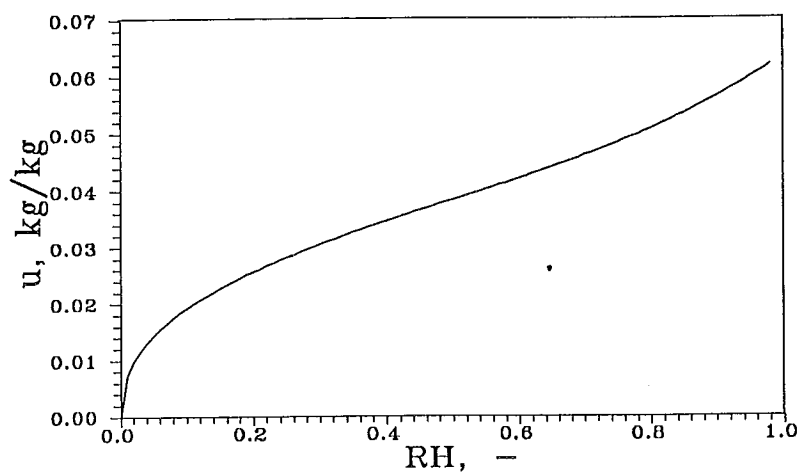


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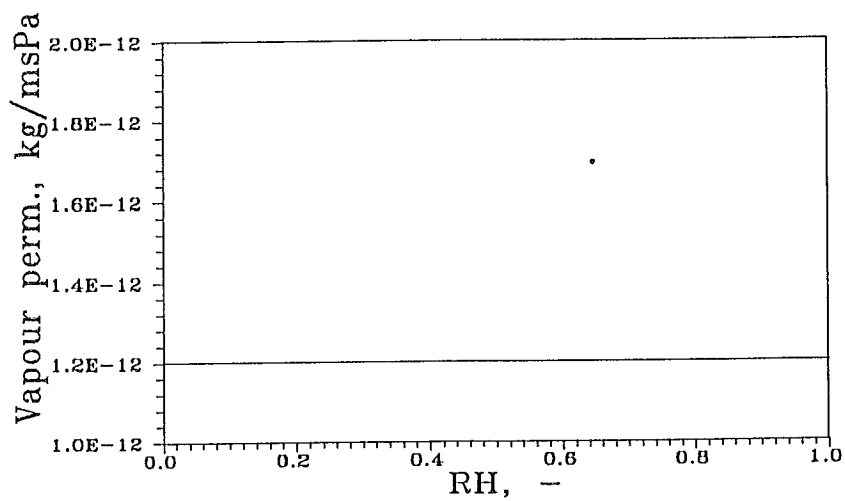


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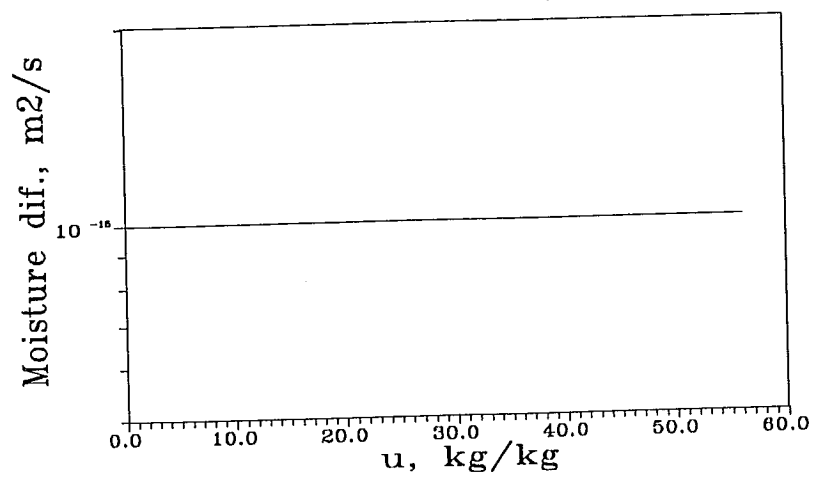


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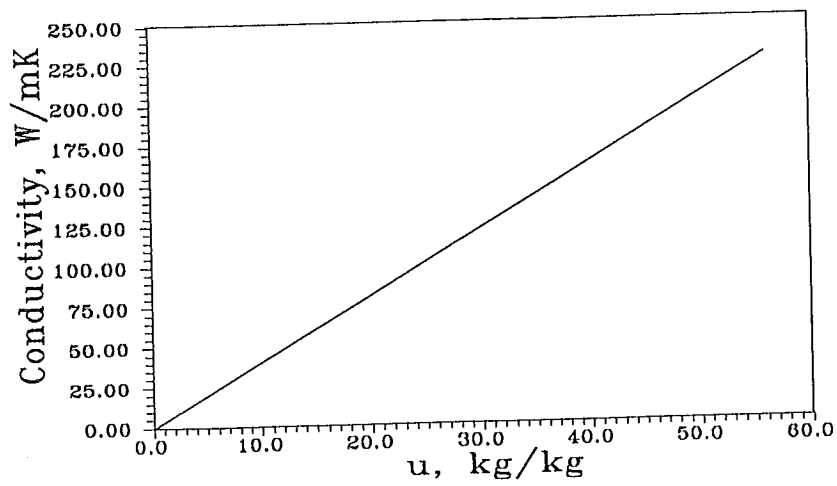


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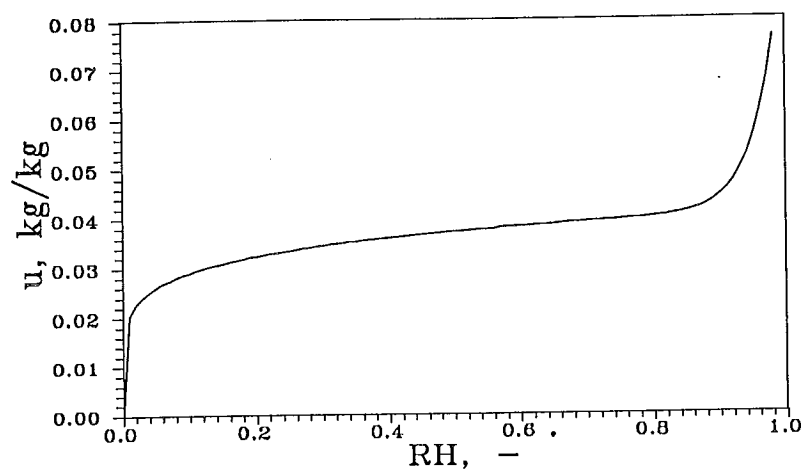


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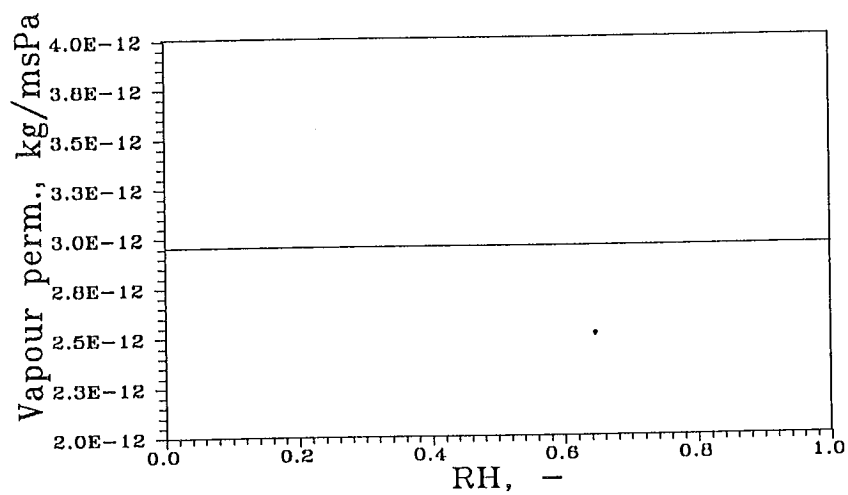


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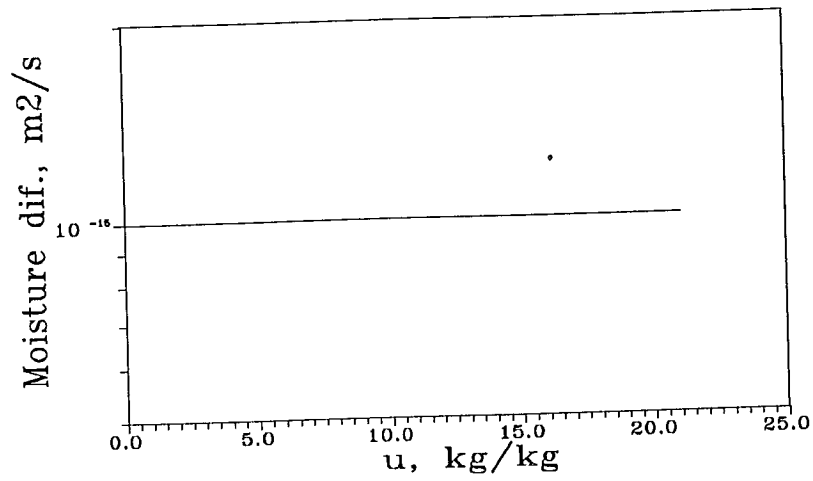


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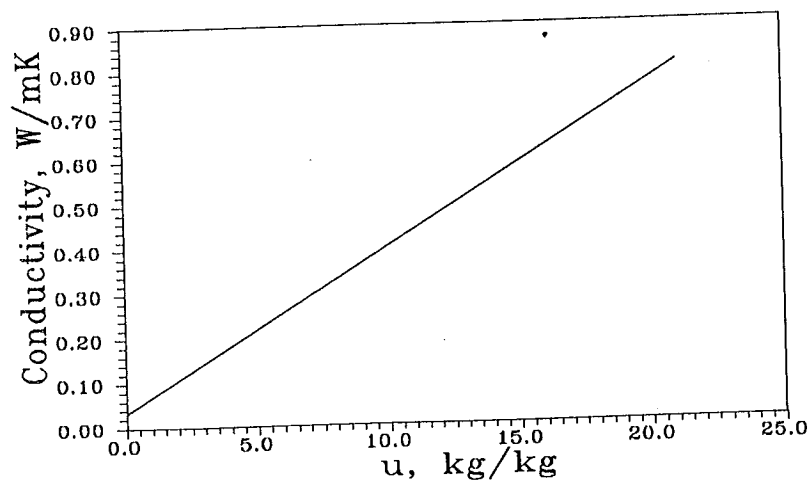


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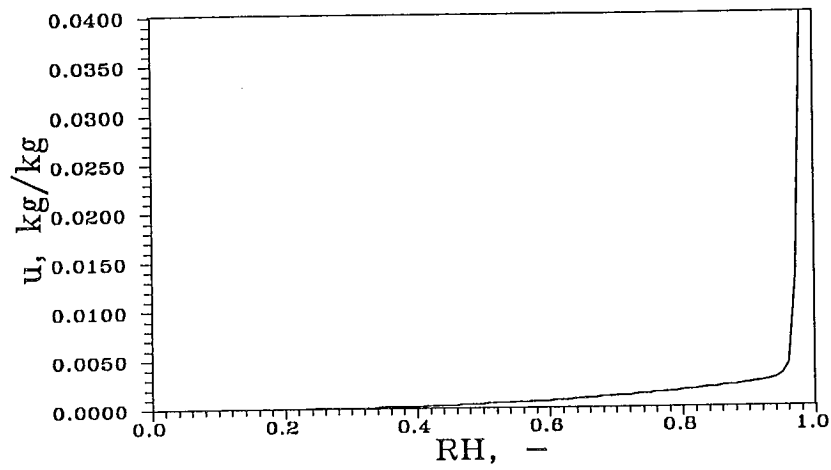


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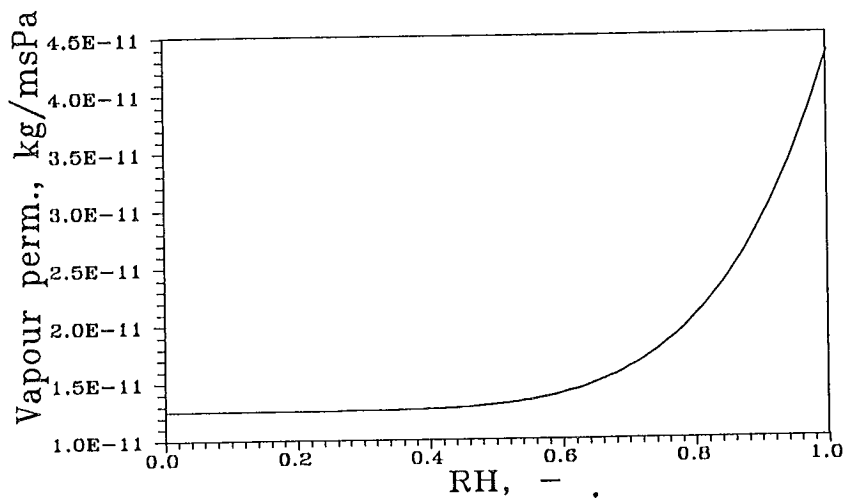


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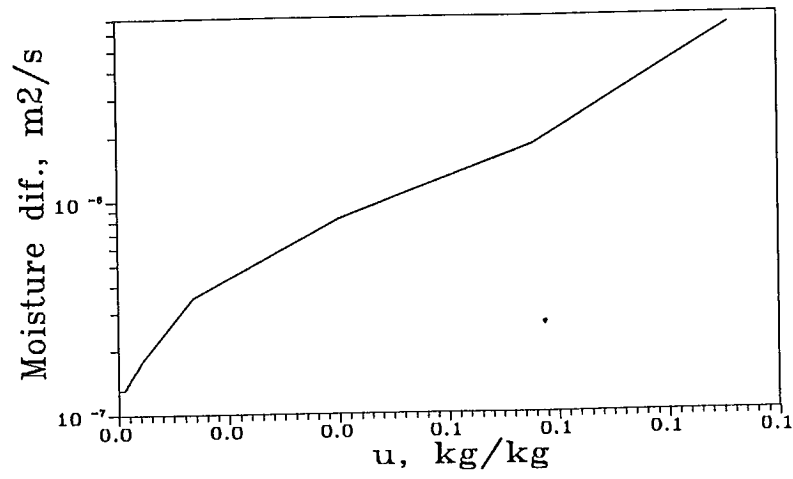


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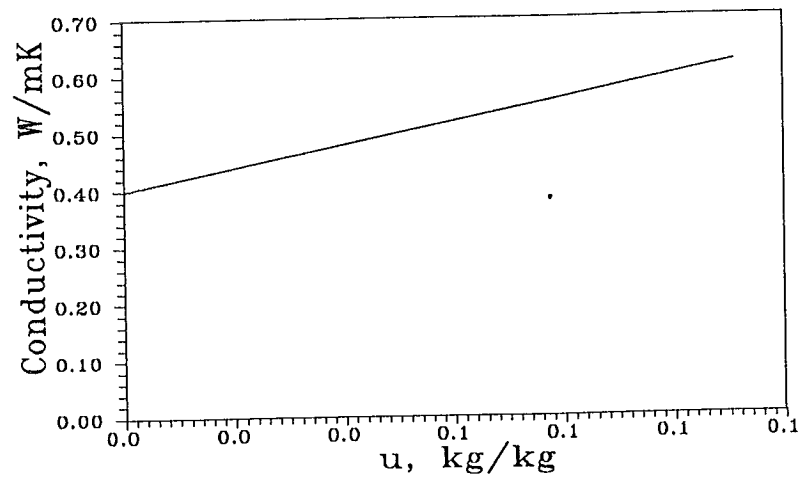


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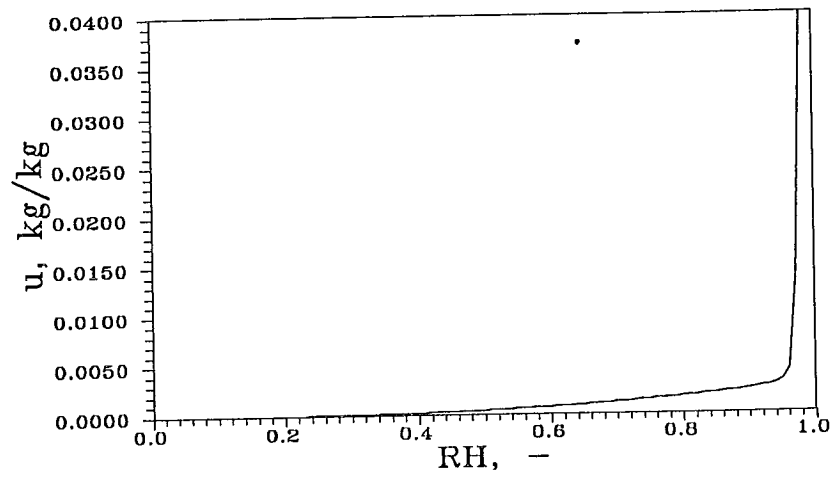


Figure 1. Sorption isotherm.

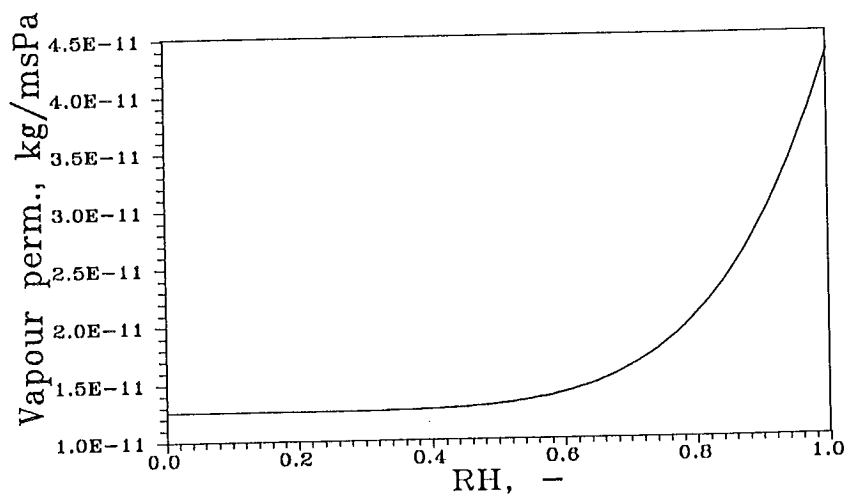


Figure 2. Vapor permeability.

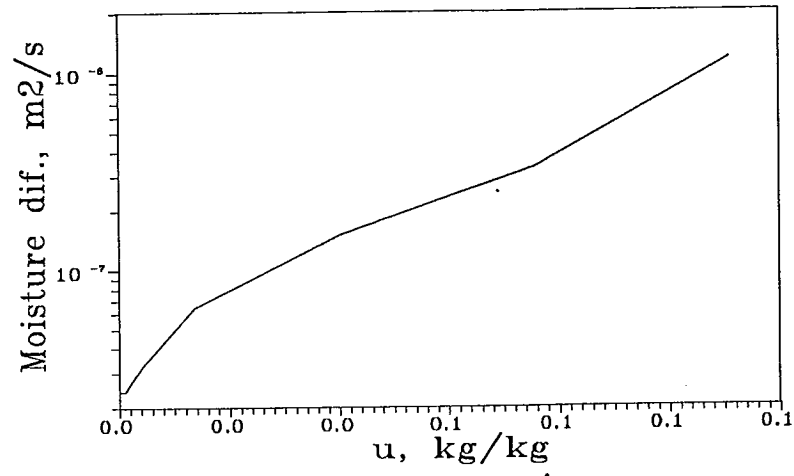


Figure 3. Moisture diffusivity.

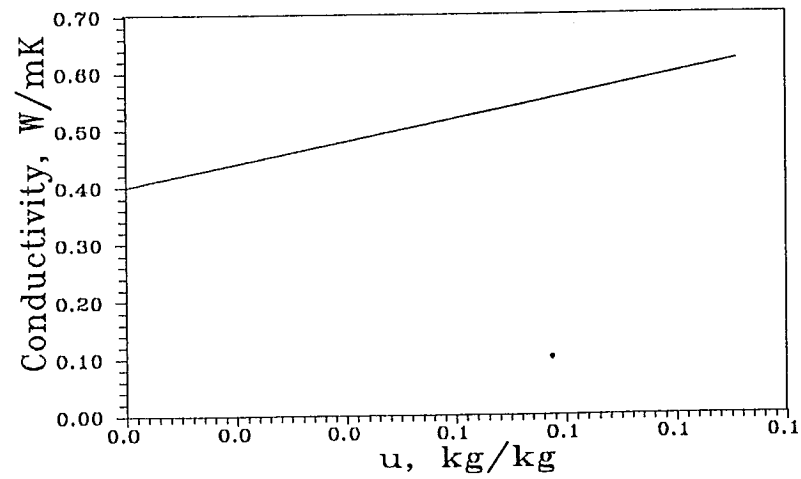


Figure 4. Thermal conductivity.

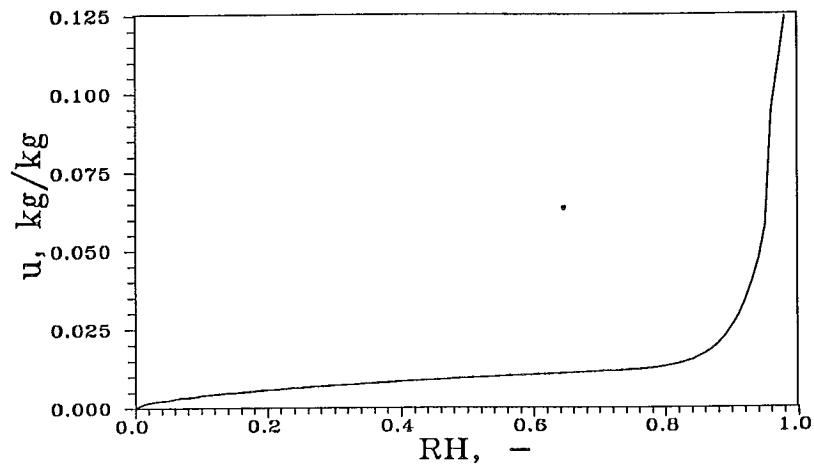


Figure 1. Sorption isotherm.

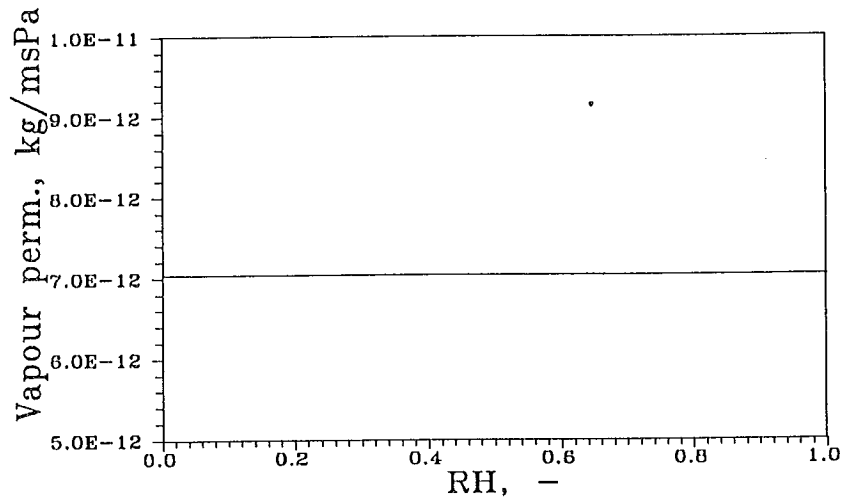


Figure 2. Vapor permeability.

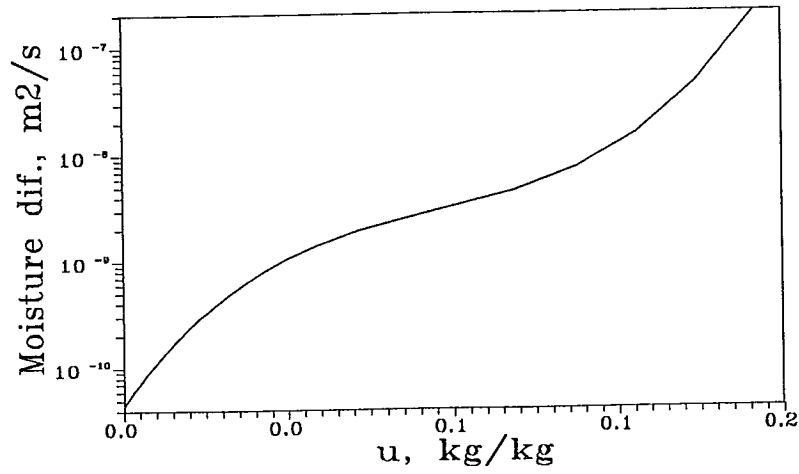


Figure 3. Moisture diffusivity.

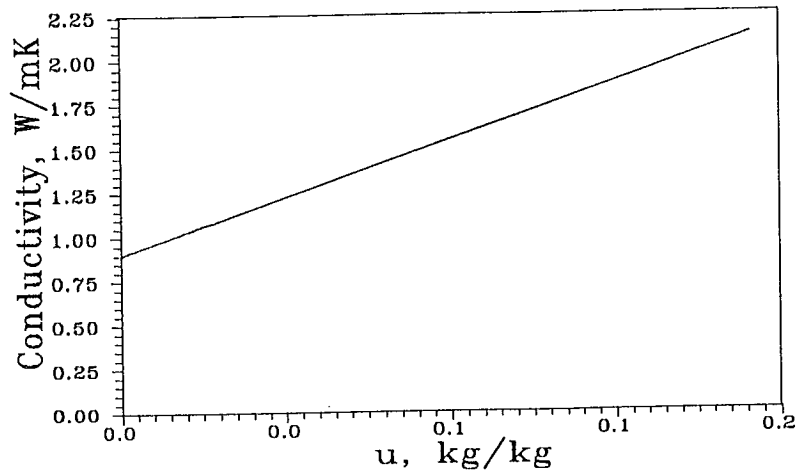


Figure 4. Thermal conductivity.

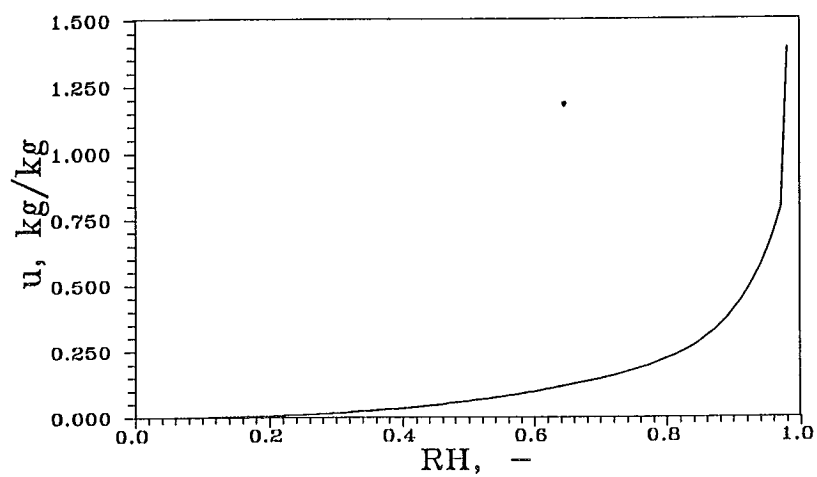


Figure 1. Sorption isotherm.

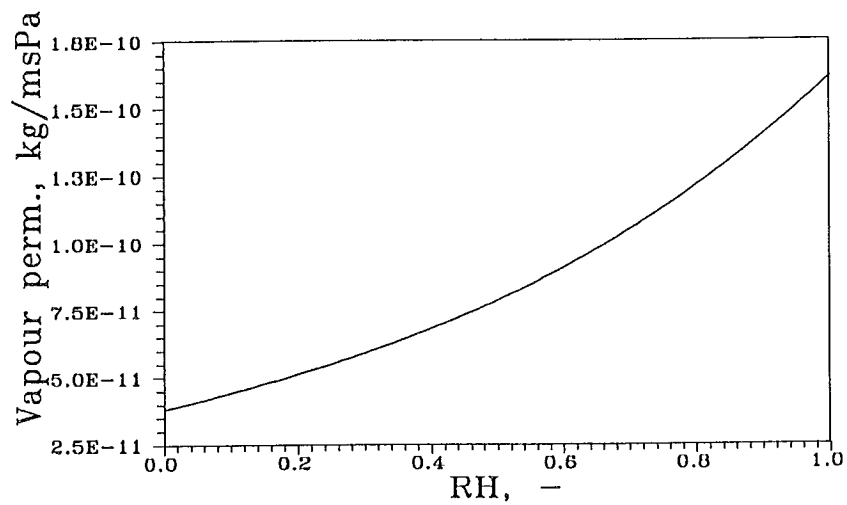


Figure 2. Vapor permeability.

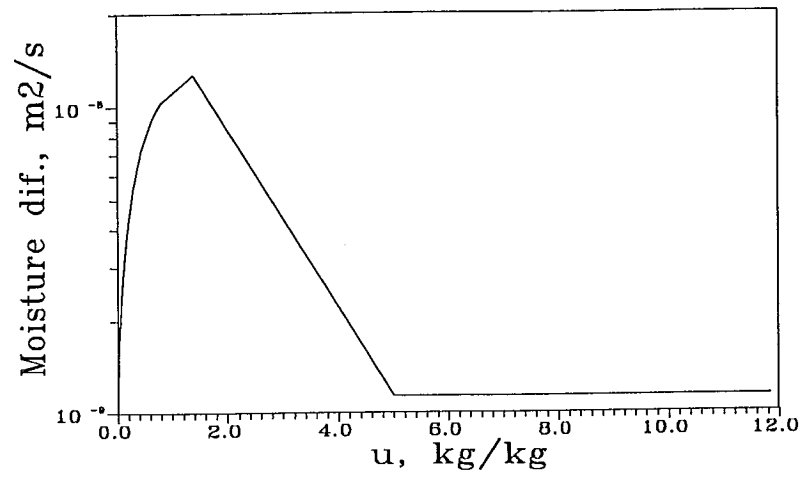


Figure 3. Moisture diffusivity.

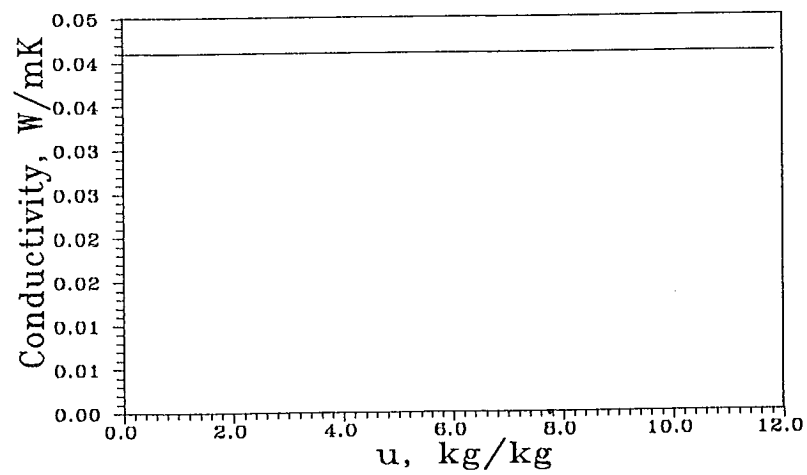


Figure 4. Thermal conductivity.

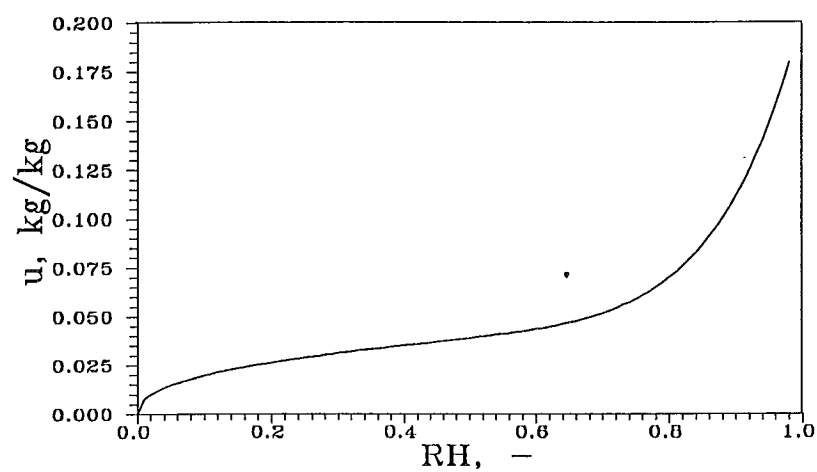


Figure 1. Sorption isotherm.

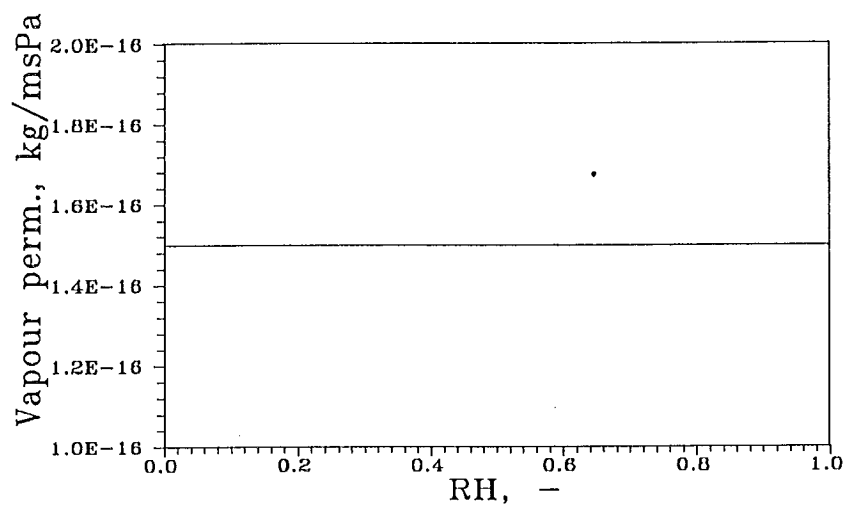


Figure 2. Vapor permeability.

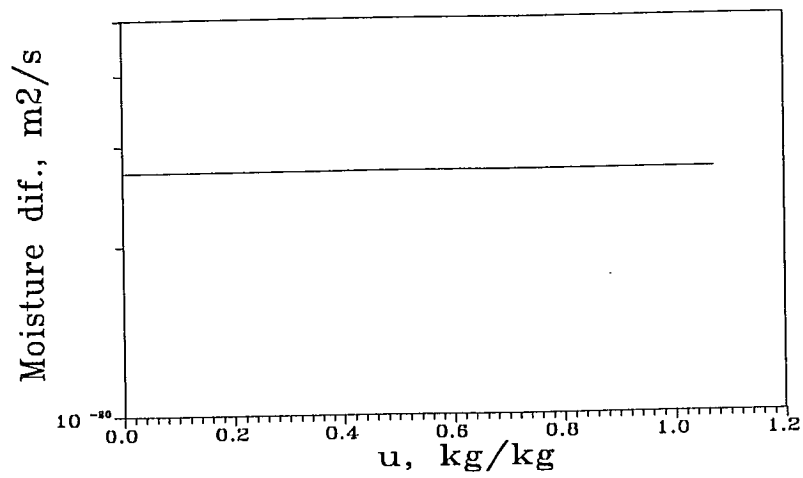


Figure 3. Moisture diffusivity.

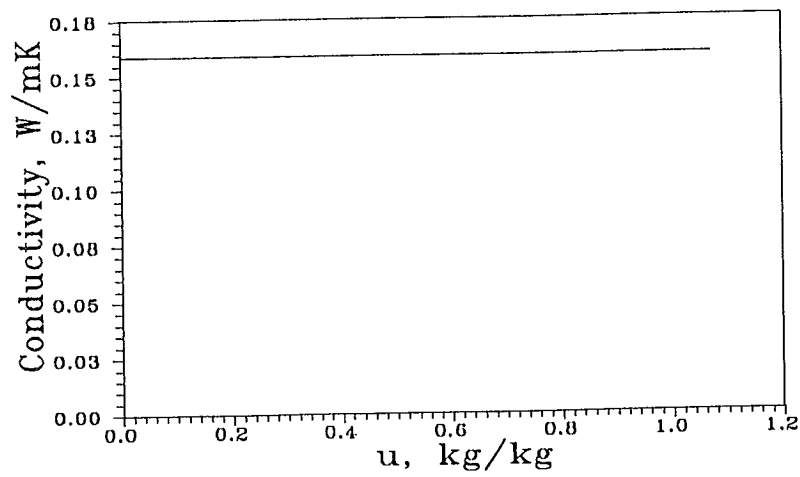


Figure 4. Thermal conductivity.

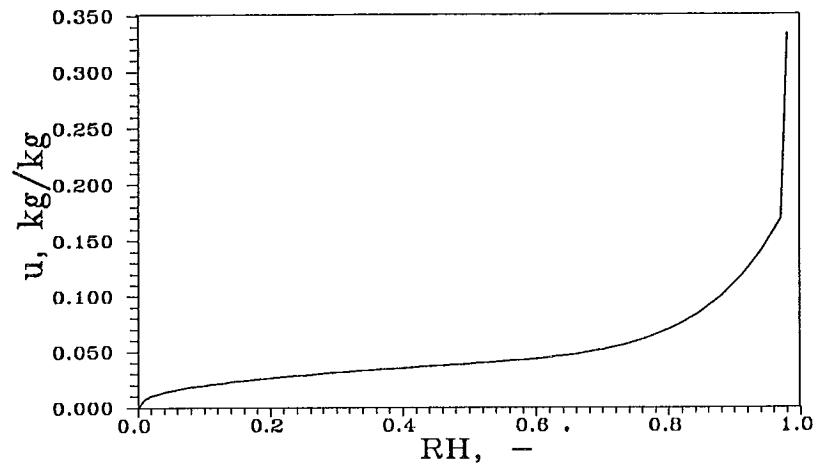


Figure 1. Sorption isotherm.

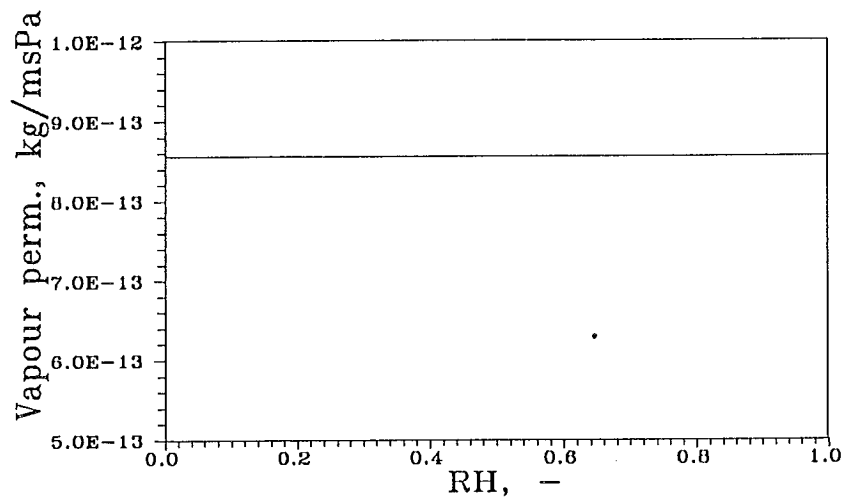


Figure 2. Vapor permeability.

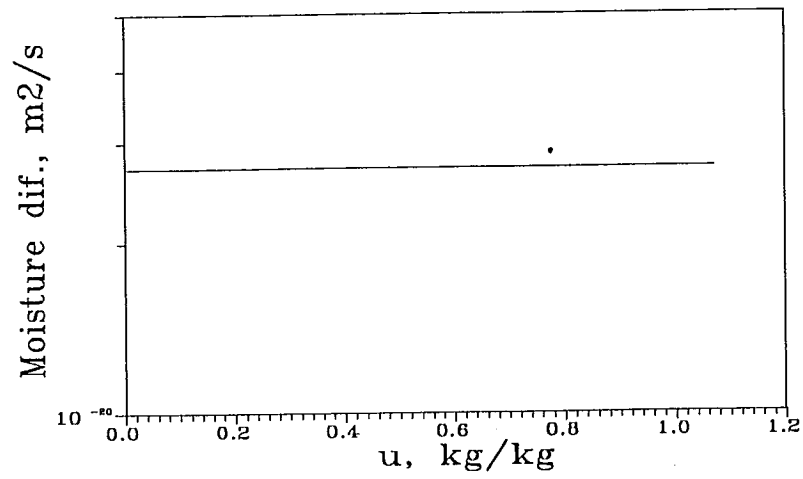


Figure 3. Moisture diffusivity.

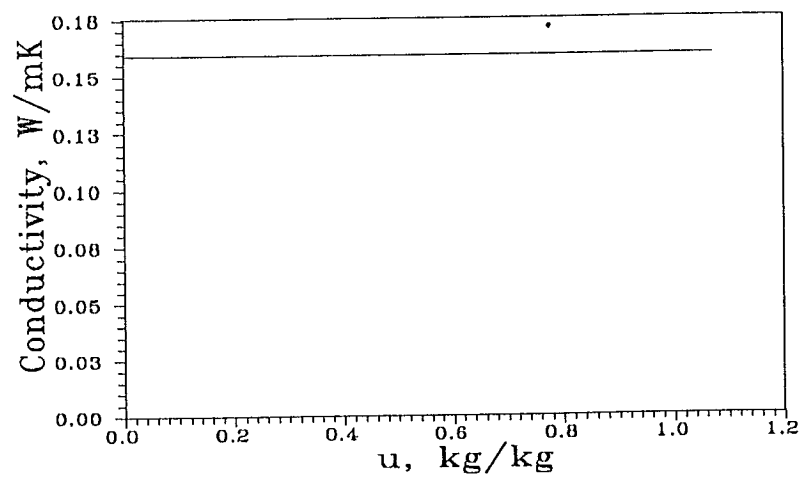


Figure 4. Thermal conductivity.

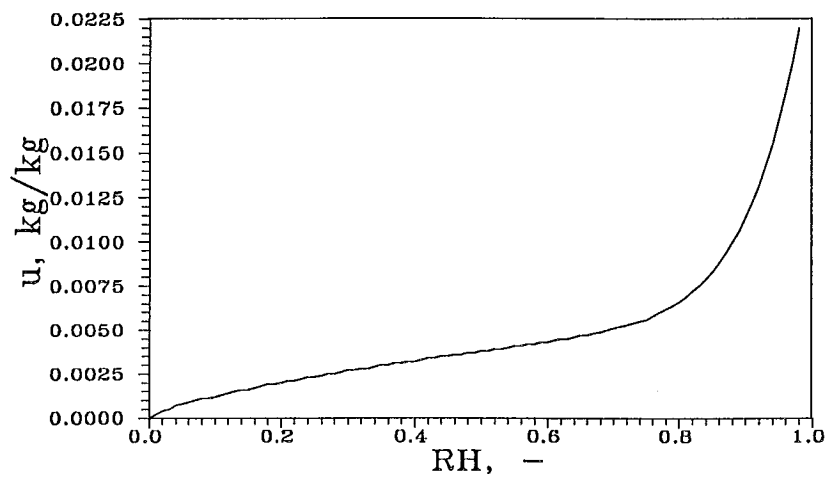


Figure 1. Sorption isotherm.

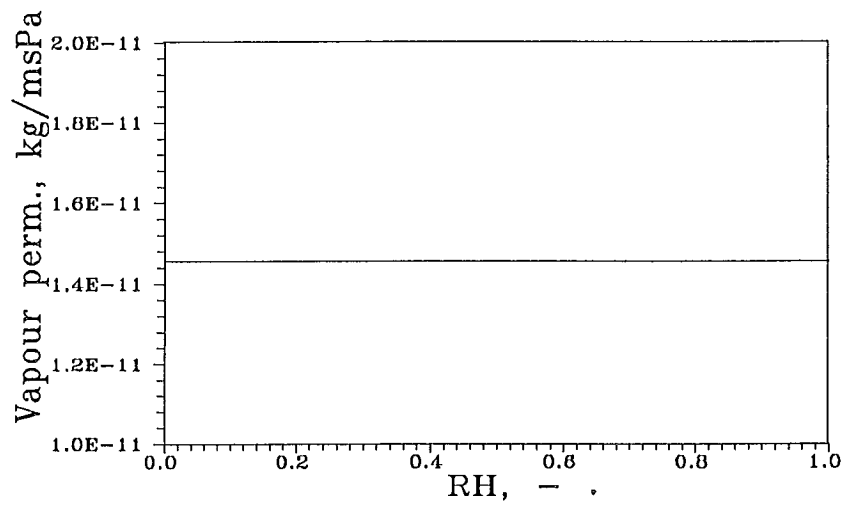


Figure 2. Vapor permeability.

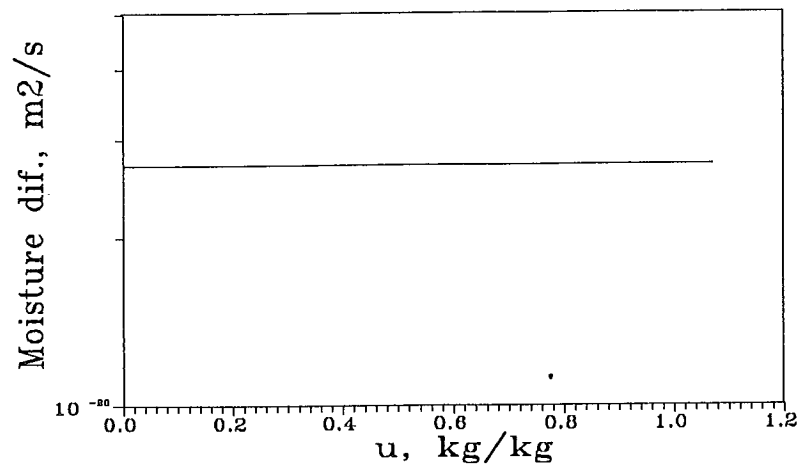


Figure 3. Moisture diffusivity.

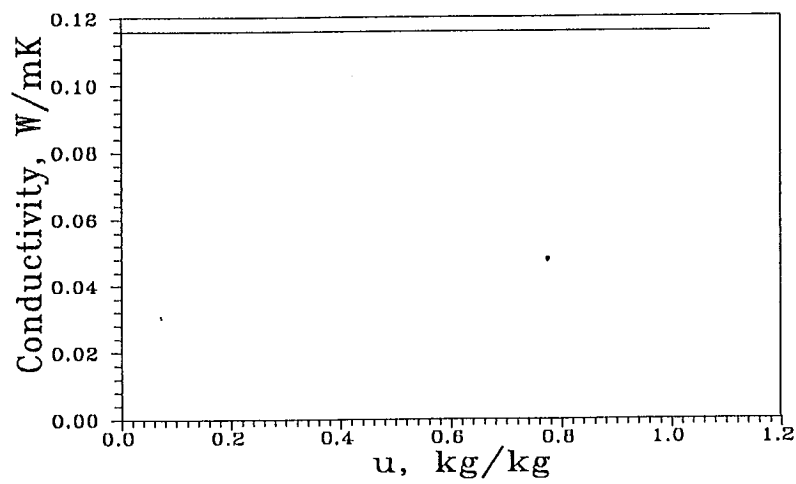


Figure 4. Thermal conductivity.

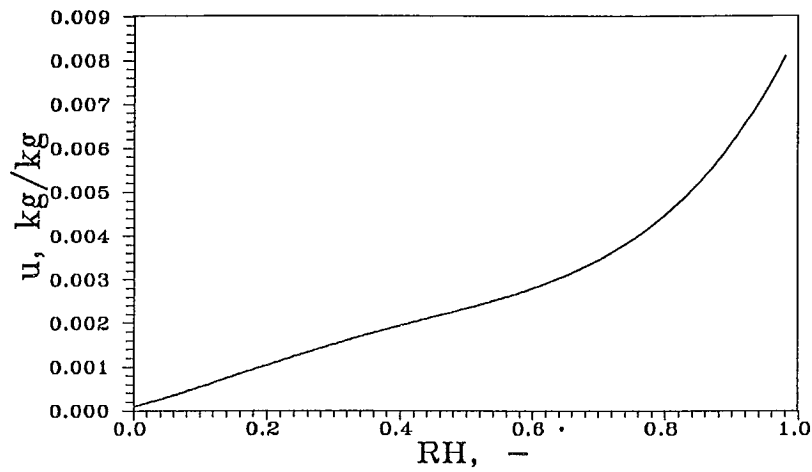


Figure 1. Sorption isotherm.

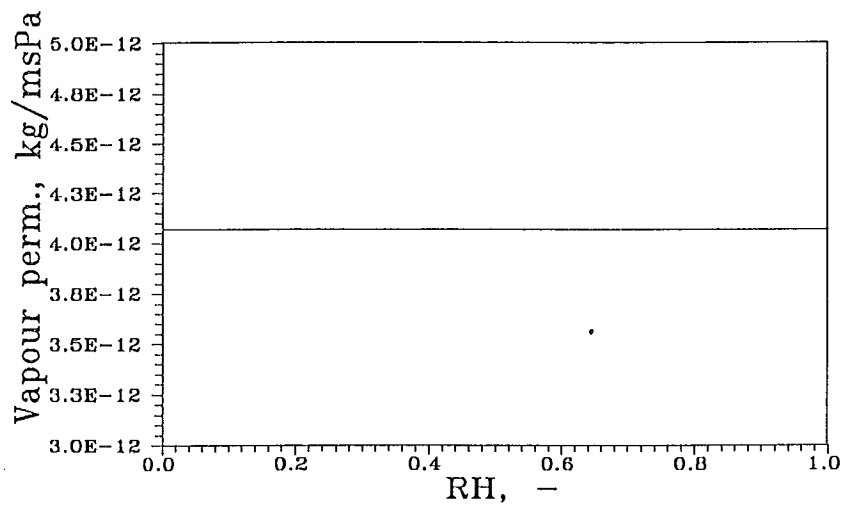


Figure 2. Vapor permeability.

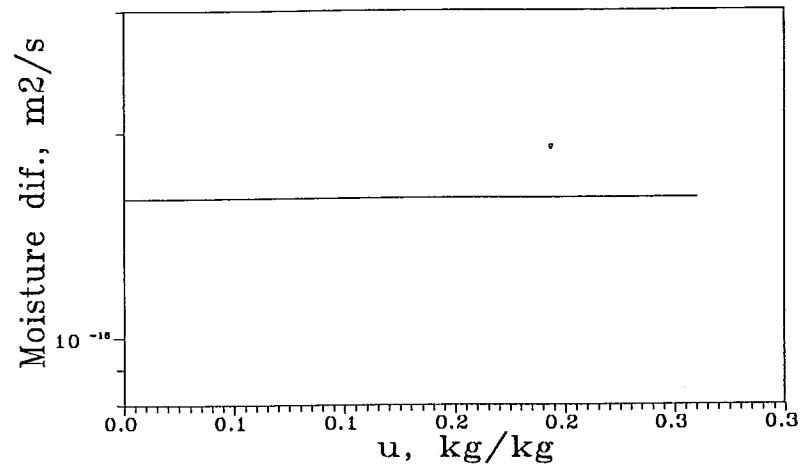


Figure 3. Moisture diffusivity.

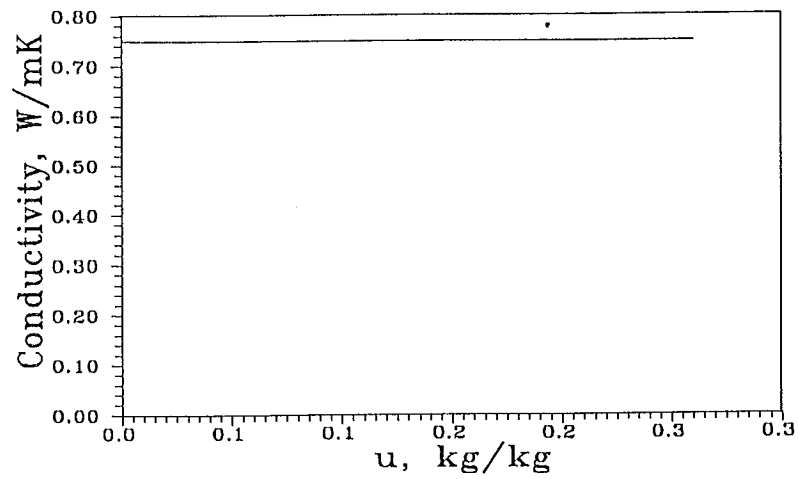


Figure 4. Thermal conductivity.

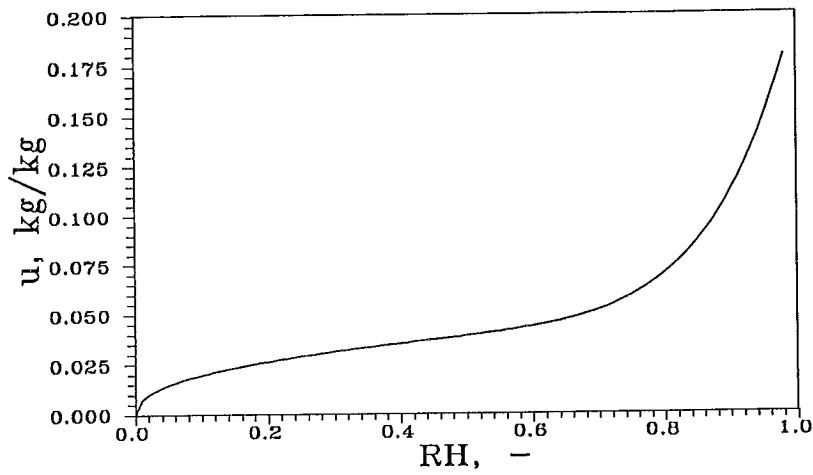


Figure 1. Sorption isotherm.

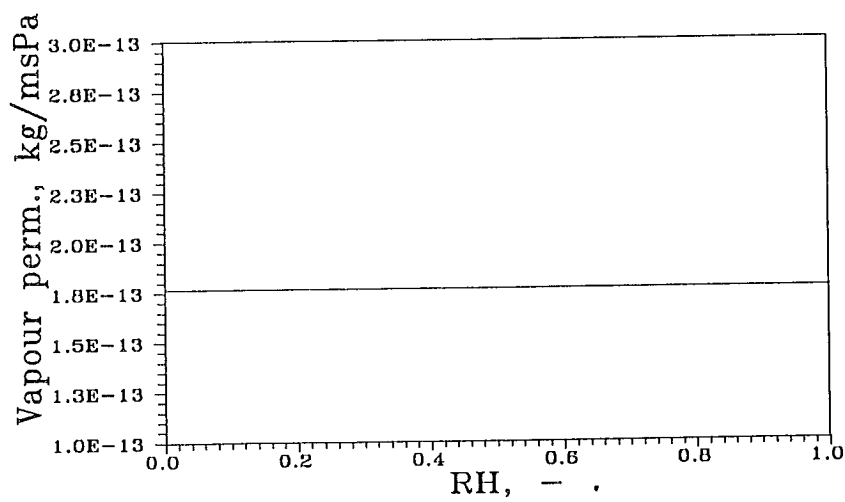


Figure 2. Vapor permeability.

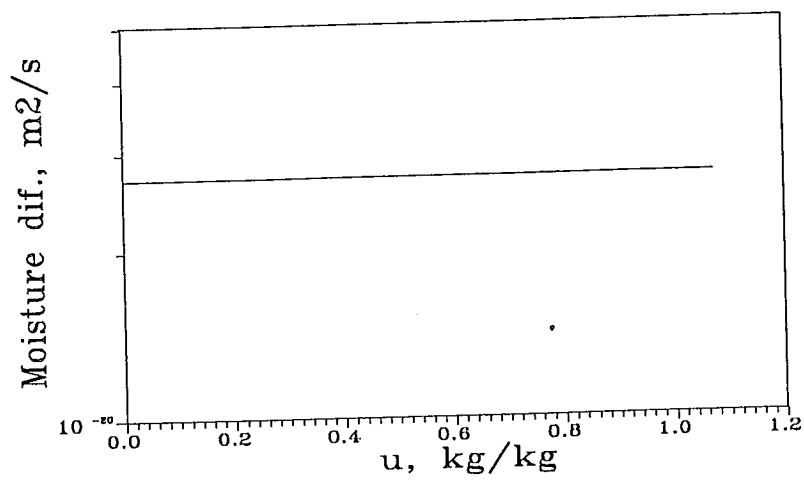


Figure 3. Moisture diffusivity.

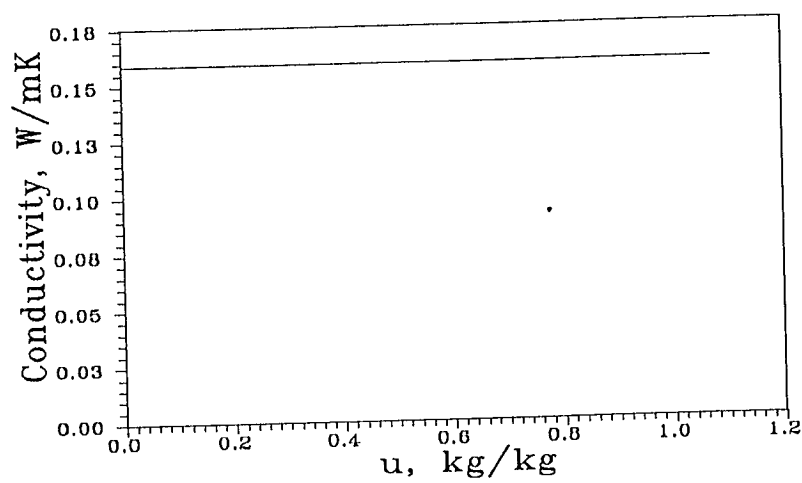


Figure 4. Thermal conductivity.

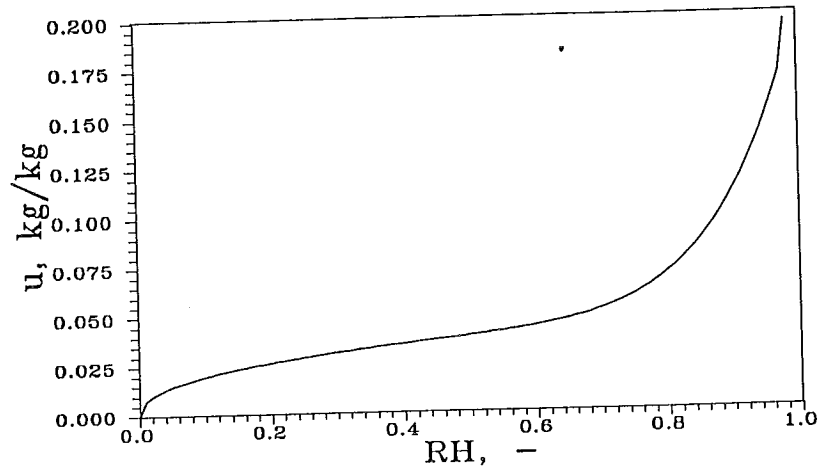


Figure 1. Sorption isotherm.

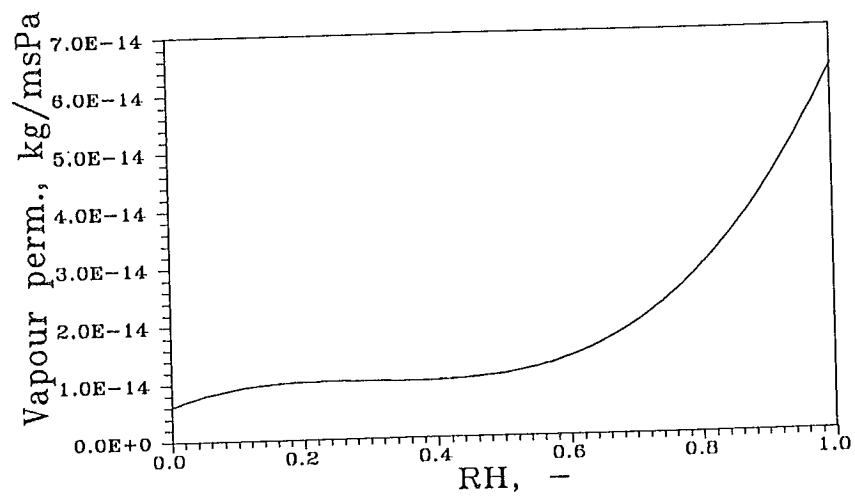


Figure 2. Vapor permeability.

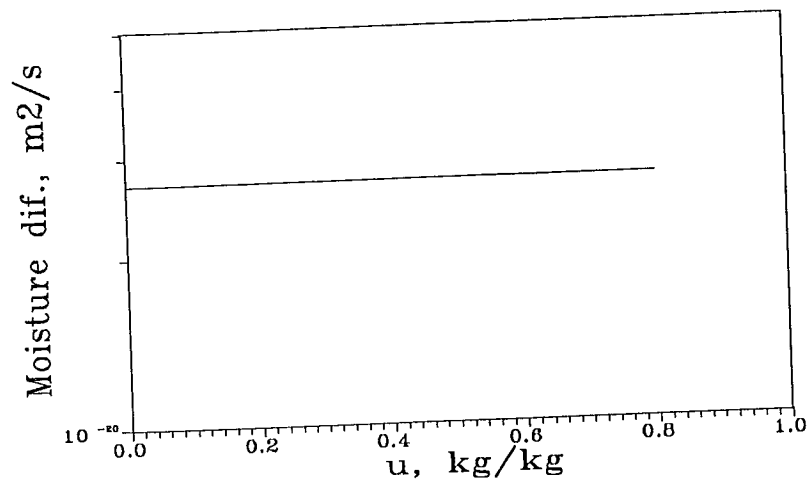


Figure 3. Moisture diffusivity.

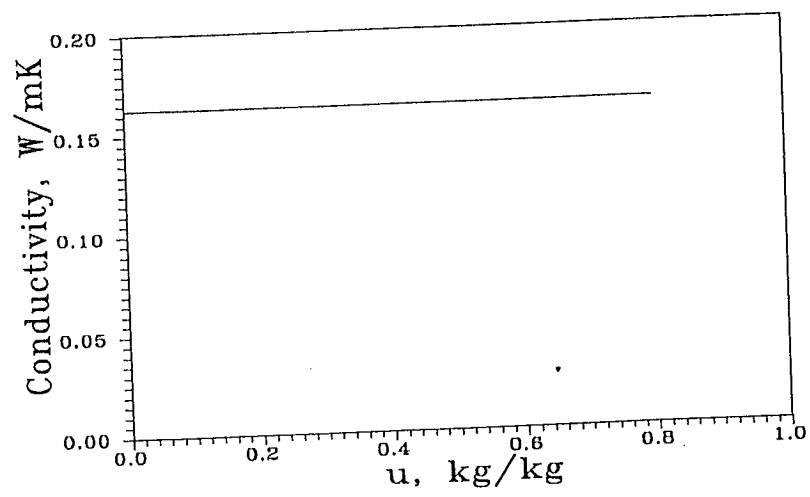


Figure 4. Thermal conductivity.

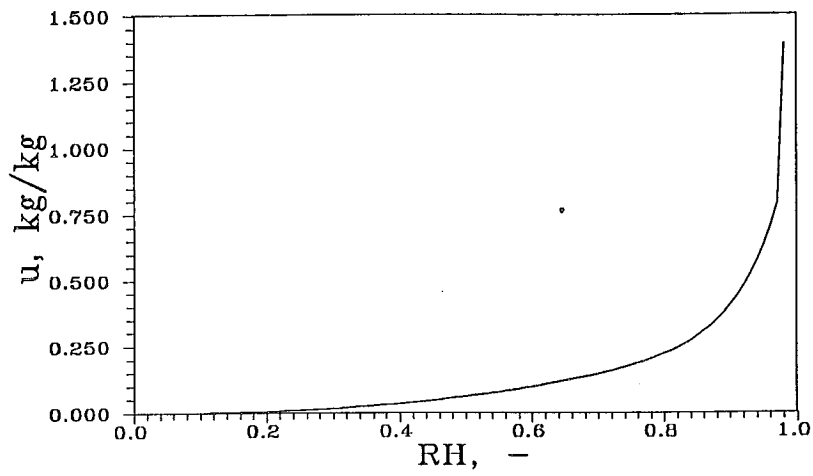


Figure 1. Sorption isotherm.

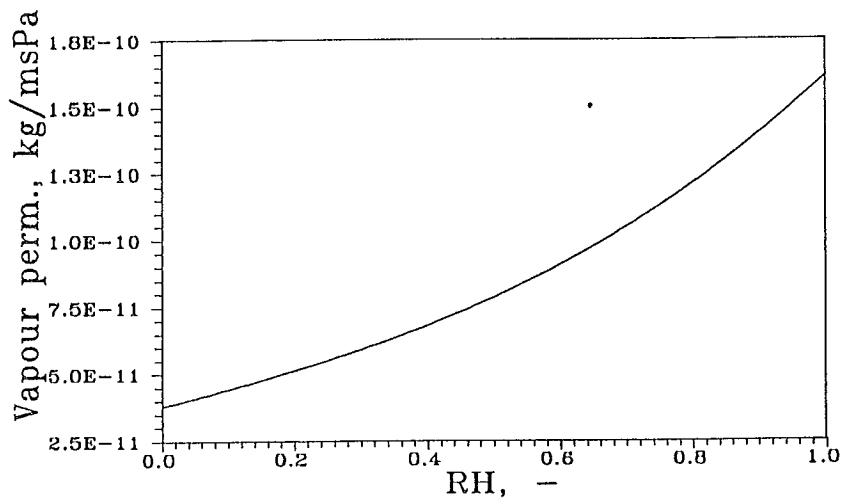


Figure 2. Vapor permeability.

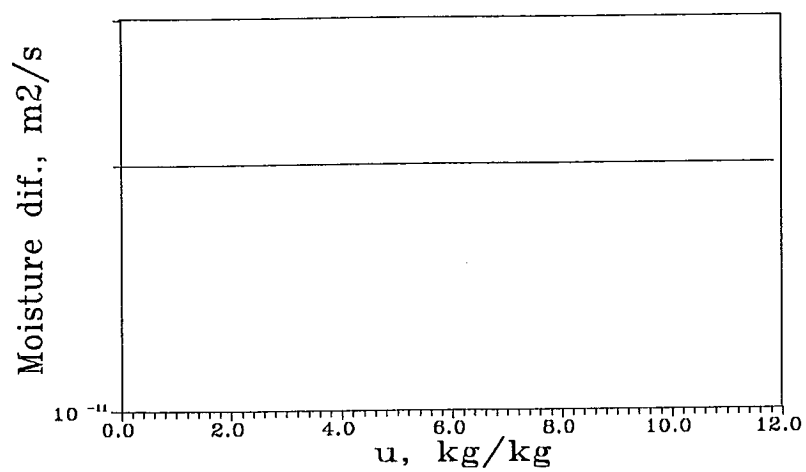


Figure 3. Moisture diffusivity.

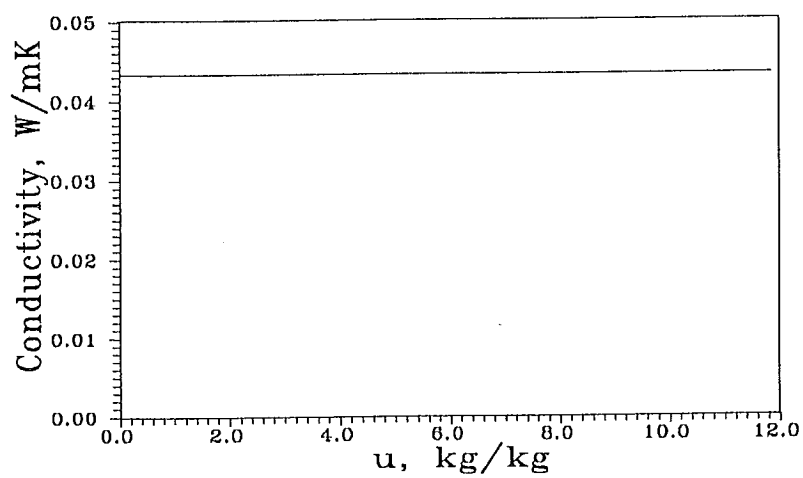


Figure 4. Thermal conductivity.

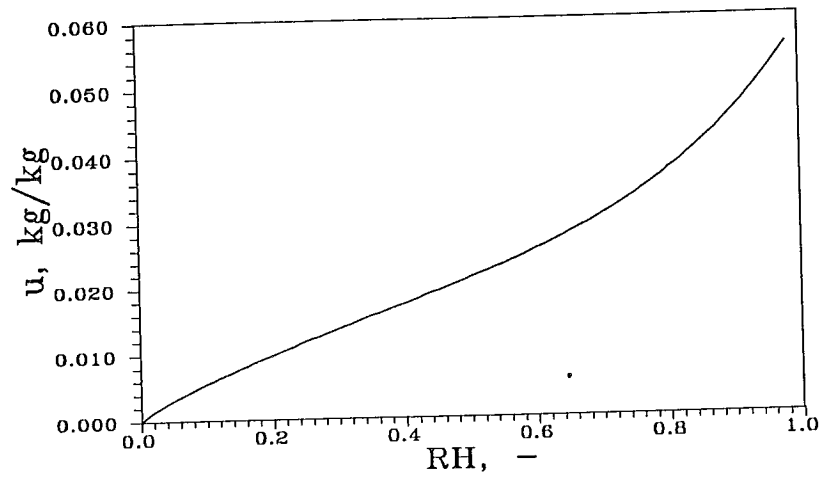


Figure 1. Sorption isotherm.

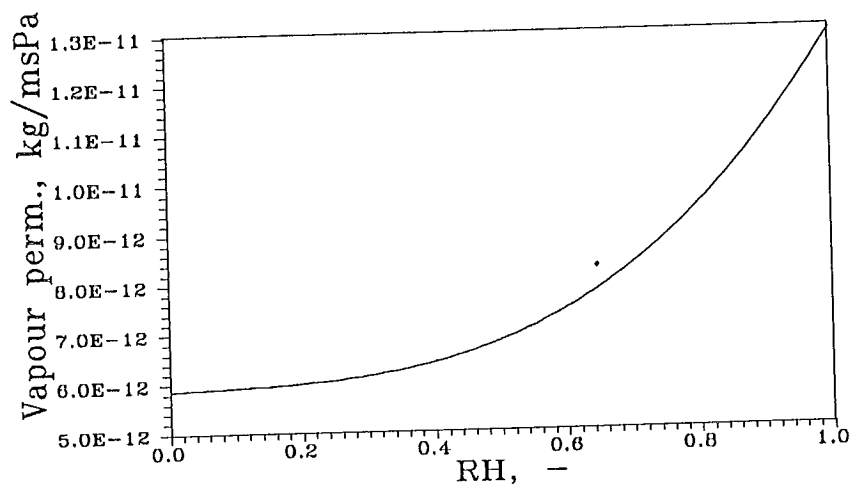


Figure 2. Vapor permeability.

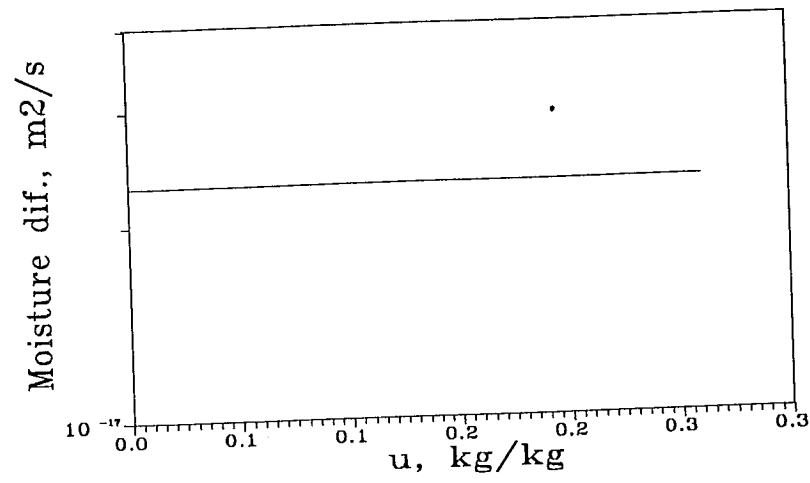


Figure 3. Moisture diffusivity.

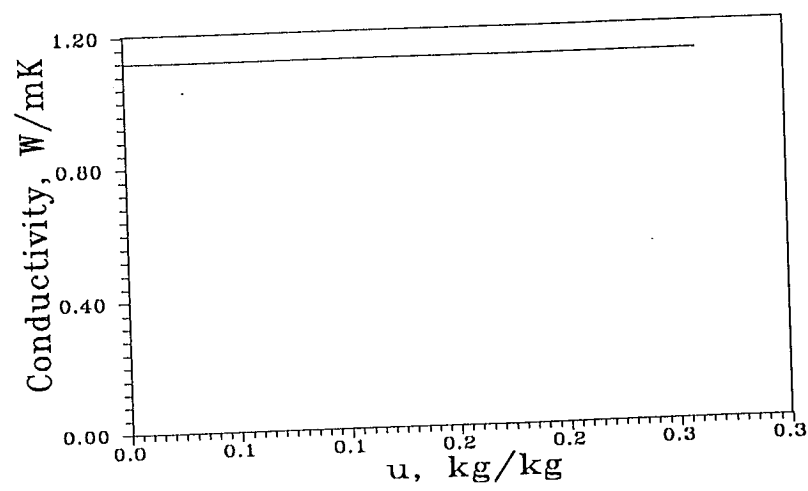


Figure 4. Thermal conductivity.

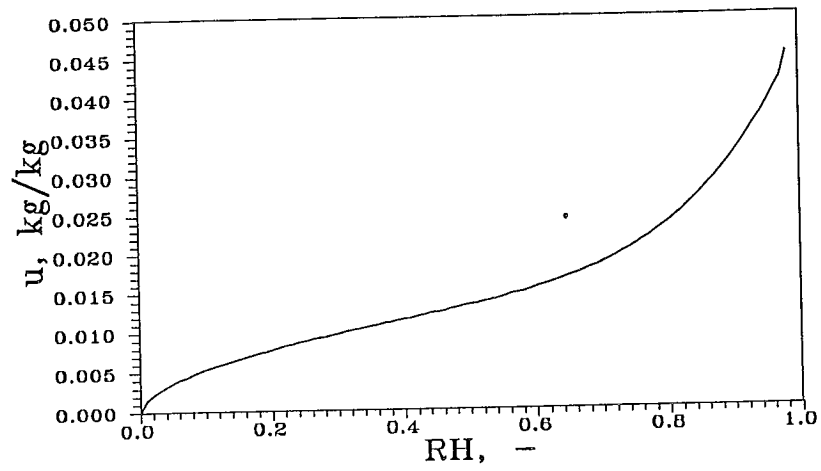


Figure 1. Sorption isotherm.

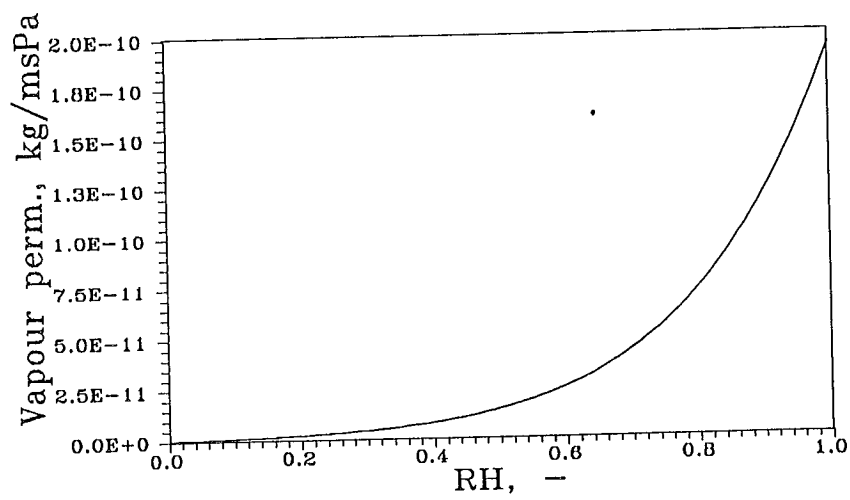


Figure 2. Vapor permeability.

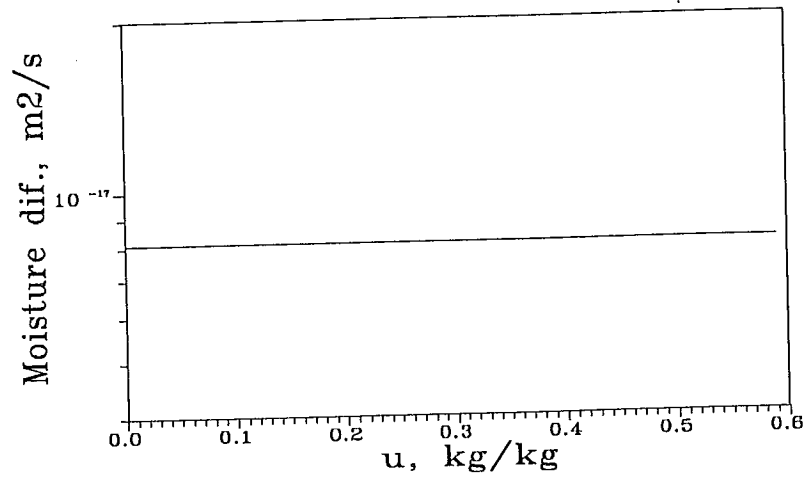


Figure 3. Moisture diffusivity.

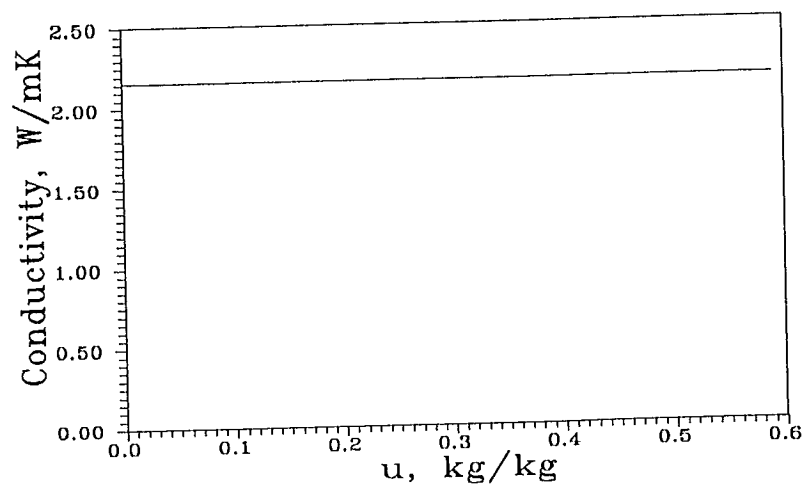


Figure 4. Thermal conductivity.

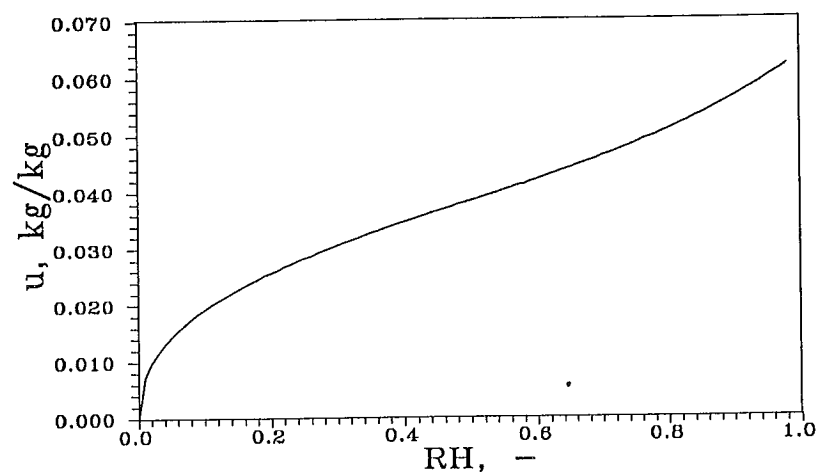


Figure 1. Sorption isotherm.

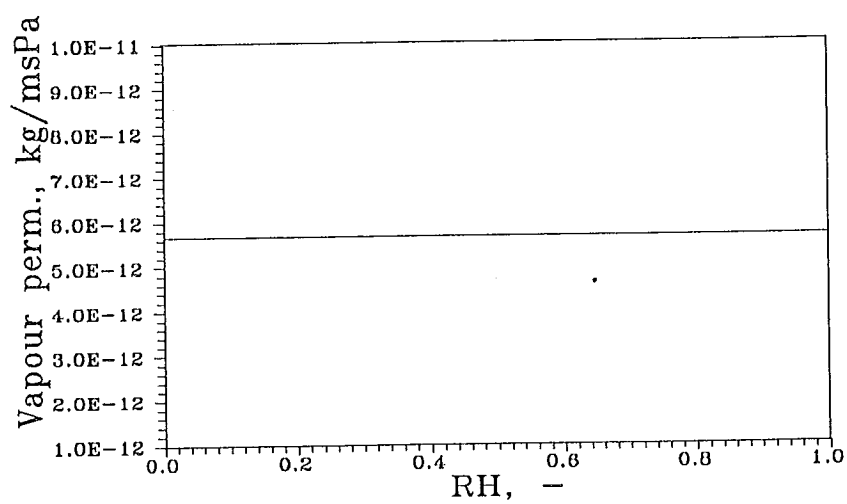


Figure 2. Vapor permeability.

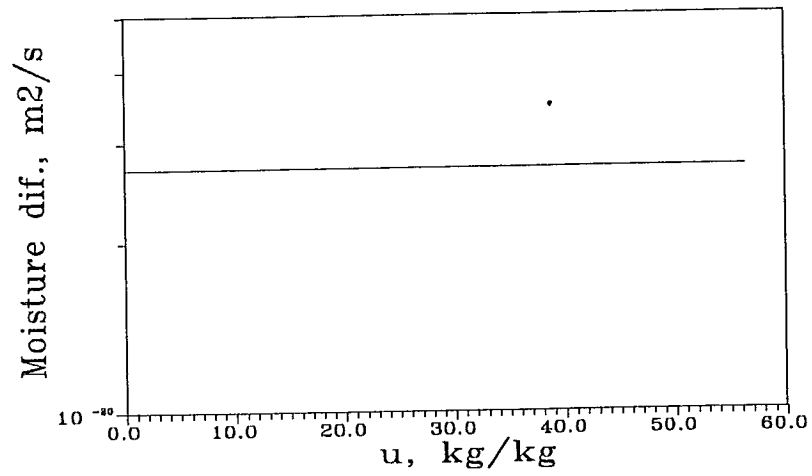


Figure 3. Moisture diffusivity.

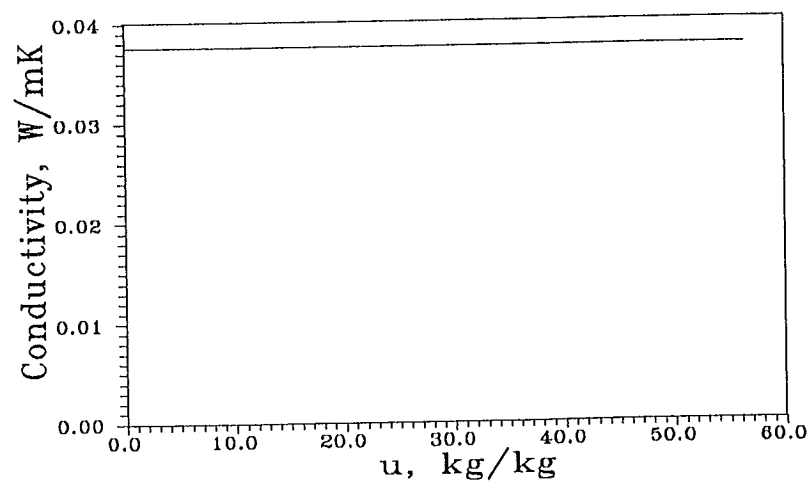


Figure 4. Thermal conductivity.

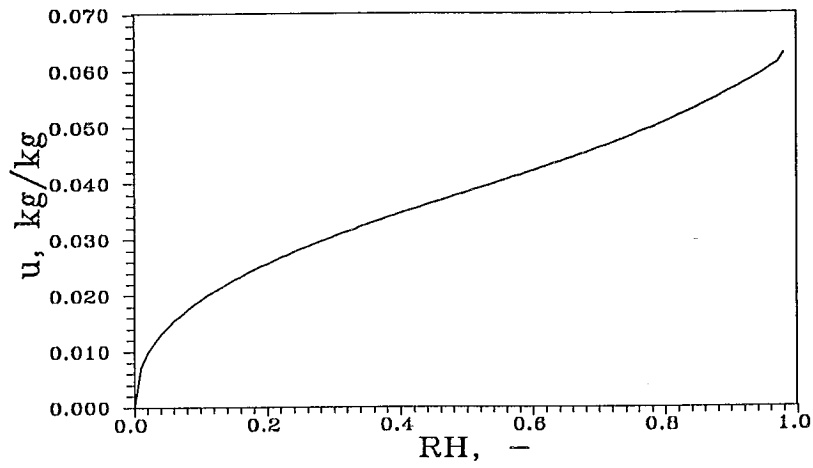


Figure 1. Sorption isotherm.

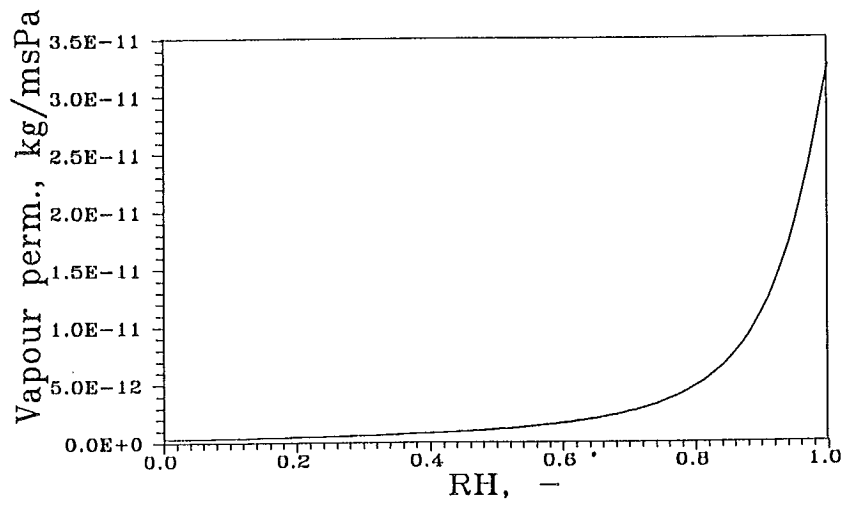


Figure 2. Vapor permeability.

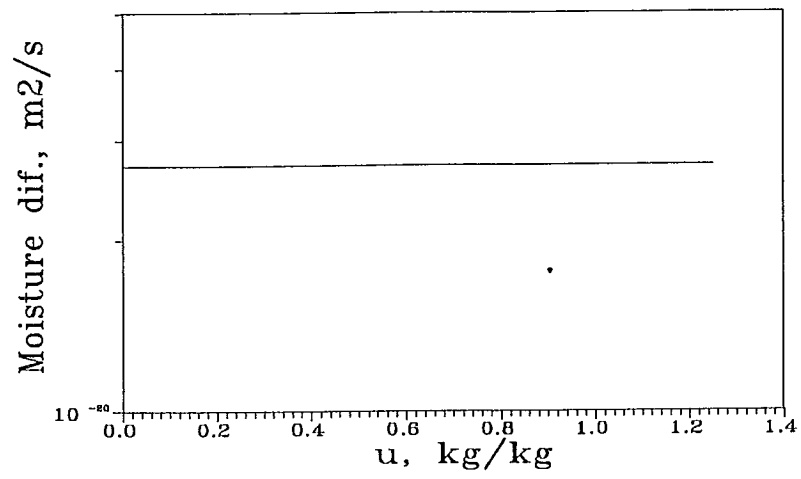


Figure 3. Moisture diffusivity.

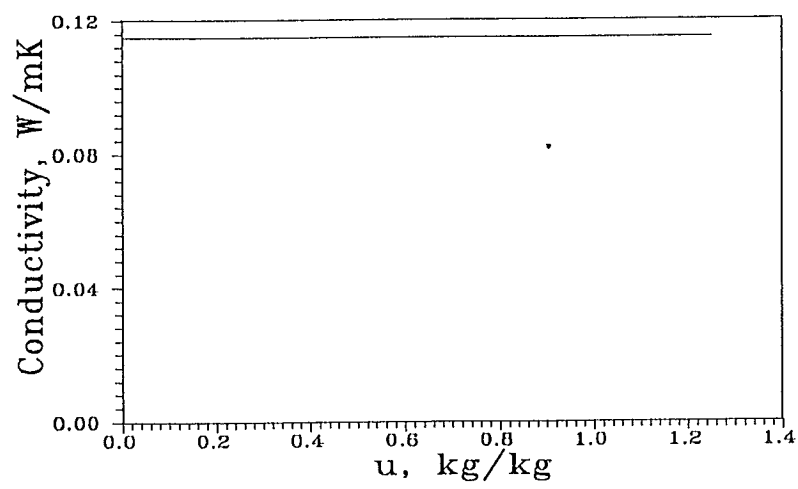


Figure 4. Thermal conductivity.

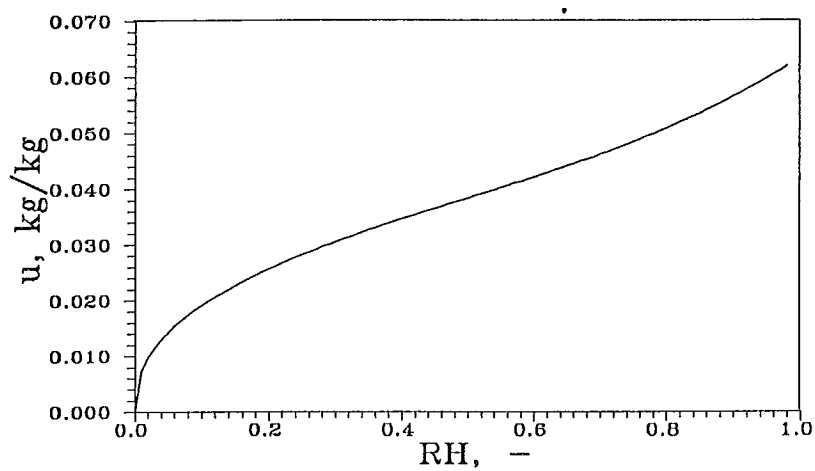


Figure 1. Sorption isotherm.

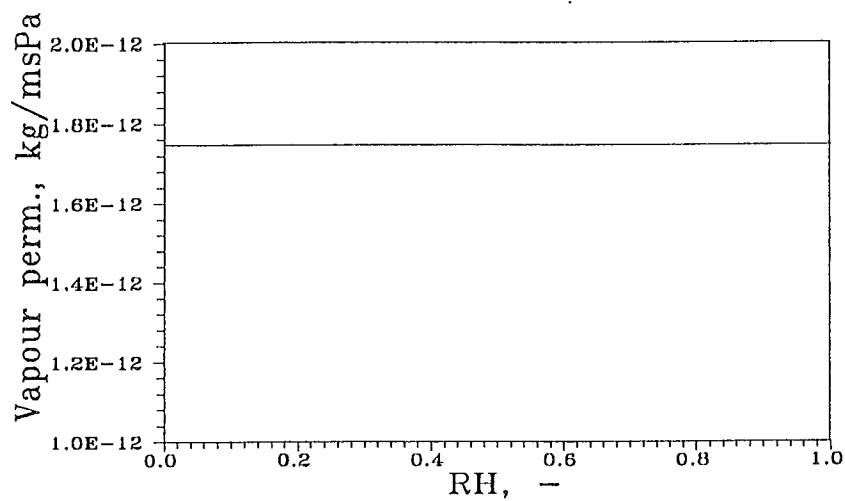


Figure 2. Vapor permeability.

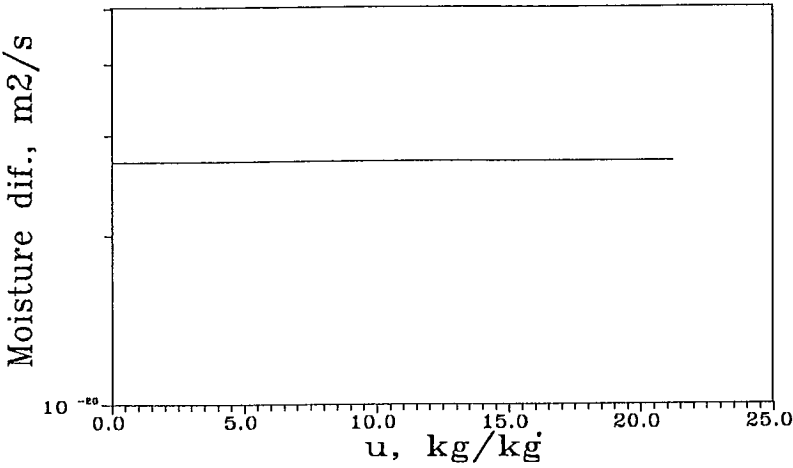


Figure 3. Moisture diffusivity.

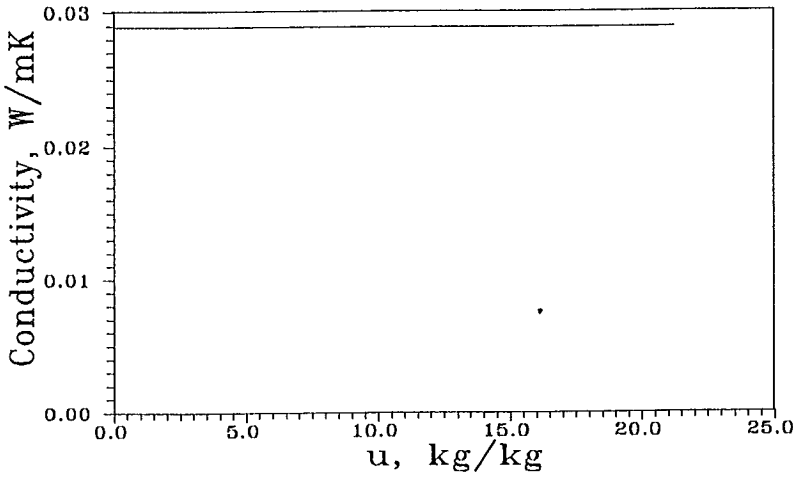


Figure 4. Thermal conductivity.

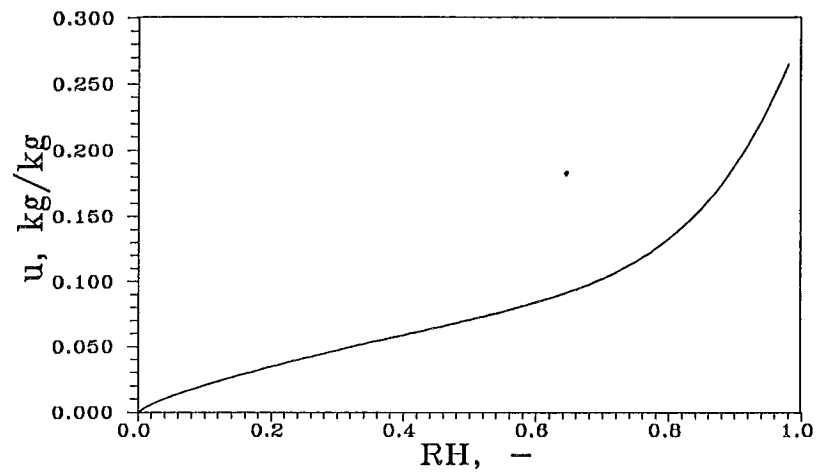


Figure 1. Sorption isotherm.

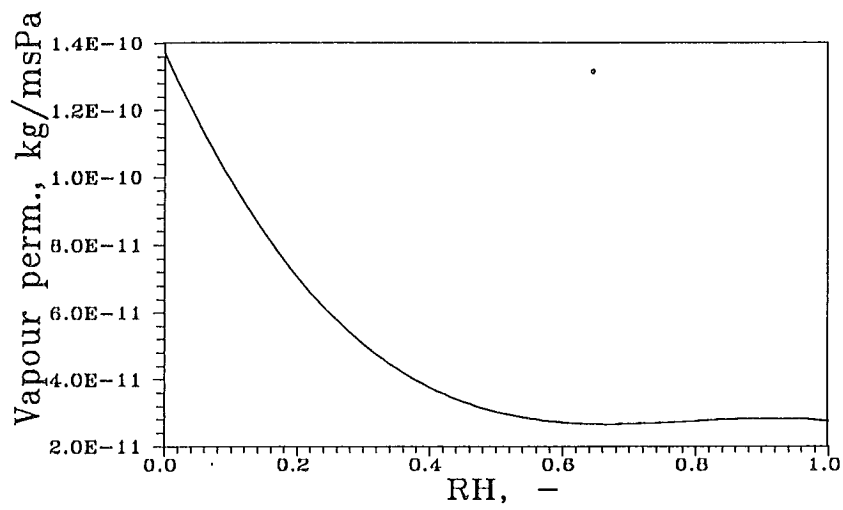


Figure 2. Vapor permeability.

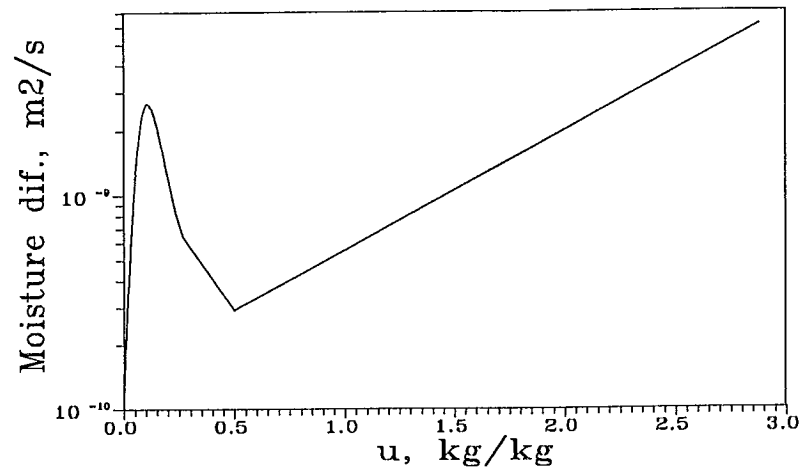


Figure 3. Moisture diffusivity.

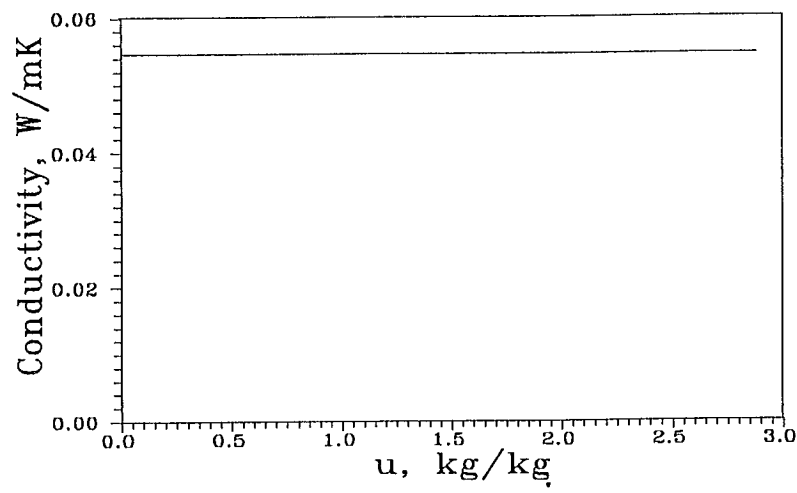


Figure 4. Thermal conductivity.

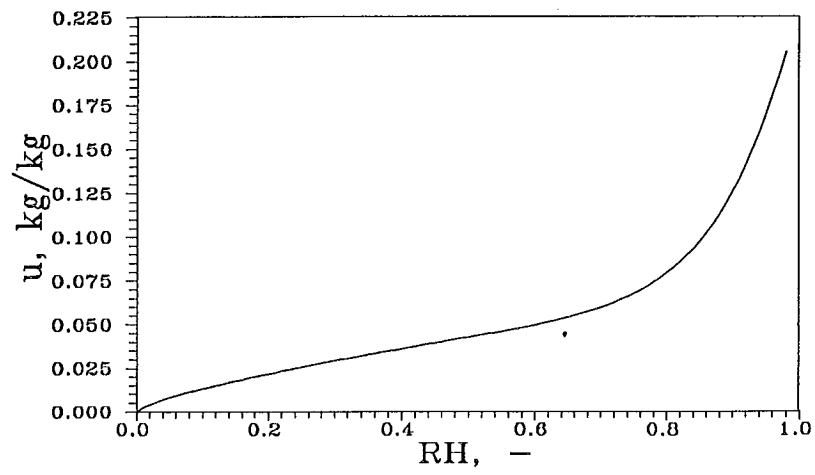


Figure 1. Sorption isotherm.

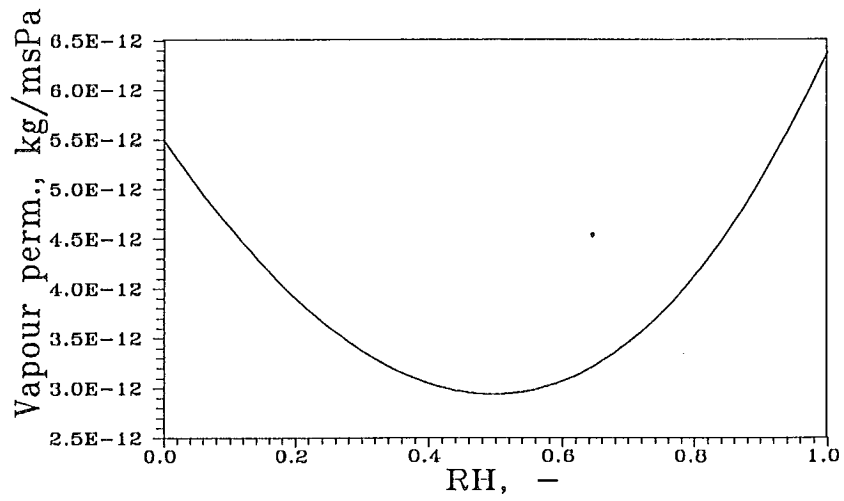


Figure 2. Vapor permeability.

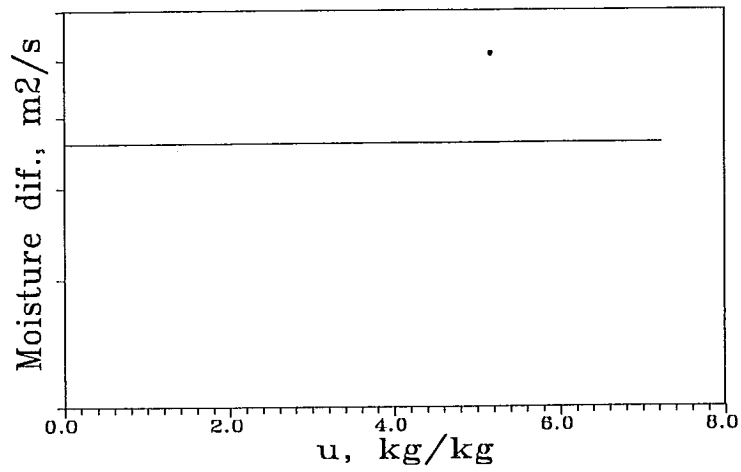


Figure 3. Moisture diffusivity.

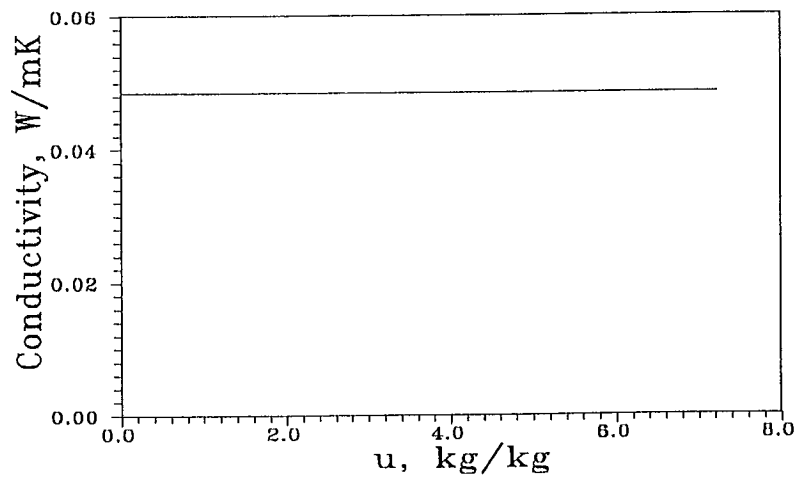


Figure 4. Thermal conductivity.

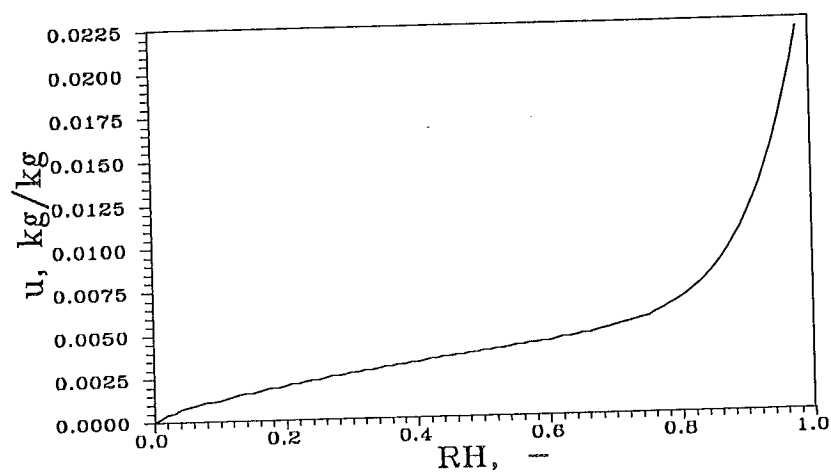


Figure 1. Sorption isotherm.

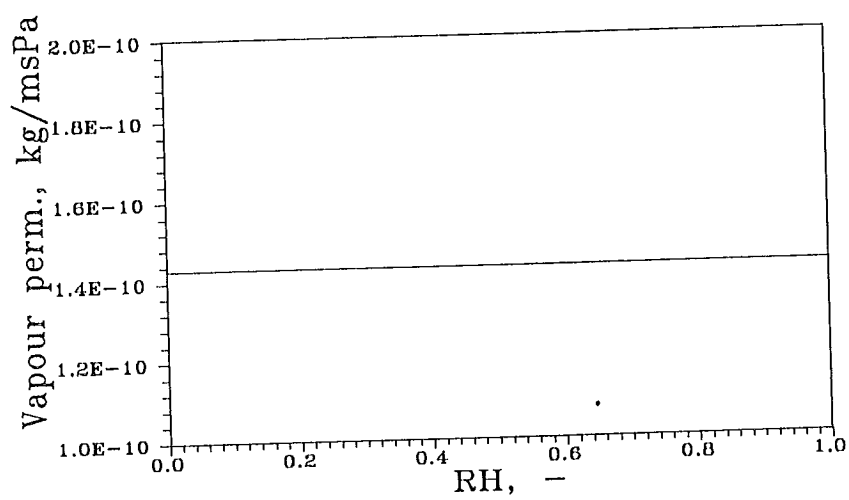


Figure 2. Vapor permeability.

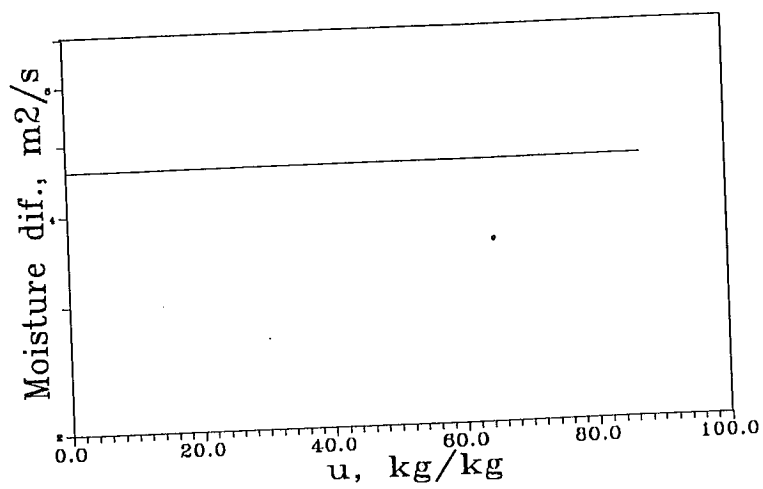


Figure 3. Moisture diffusivity.

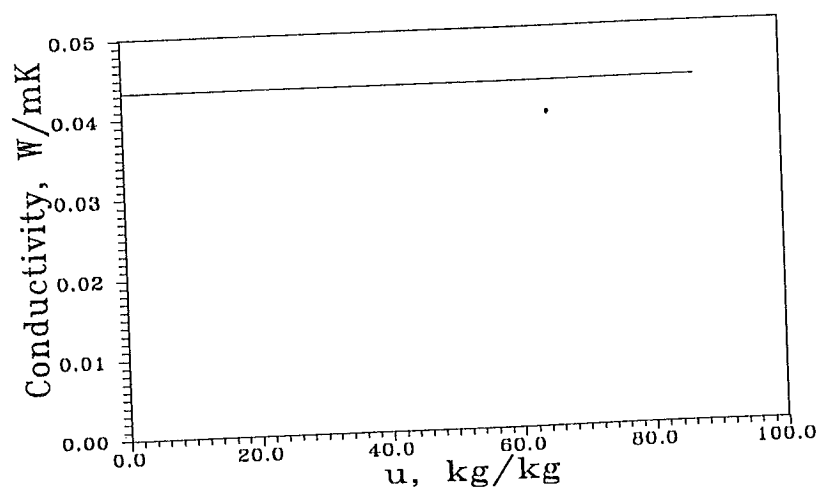


Figure 4. Thermal conductivity.

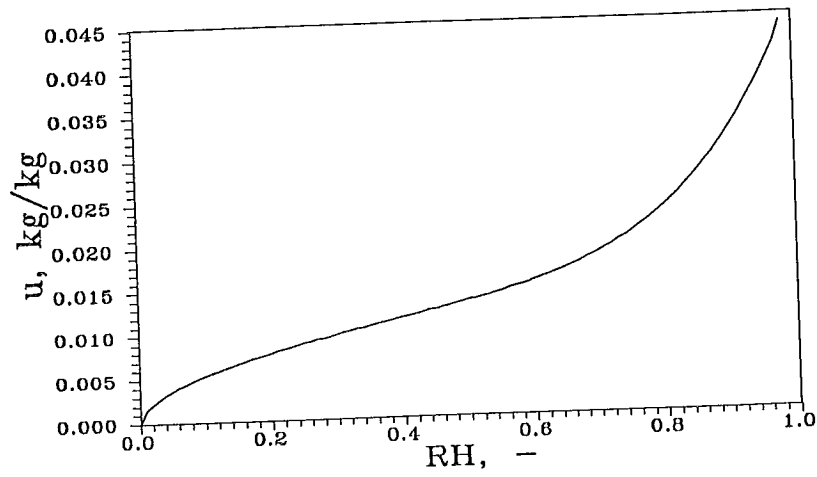


Figure 1. Sorption isotherm.

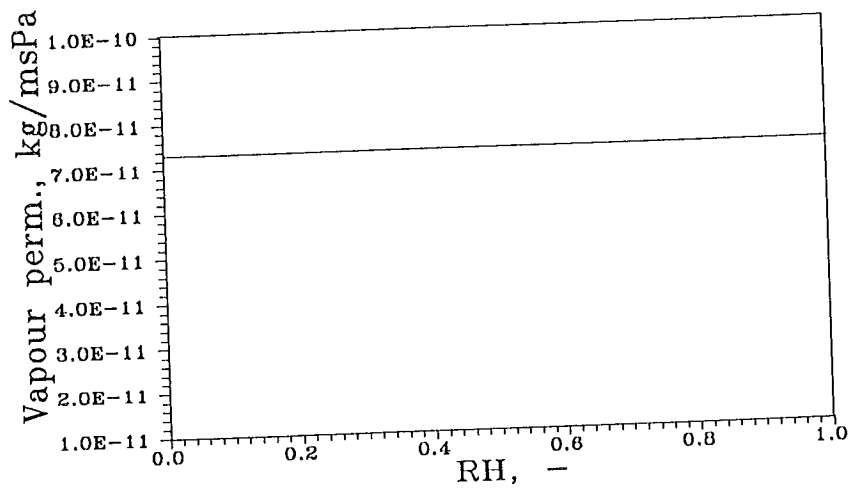


Figure 2. Vapor permeability.

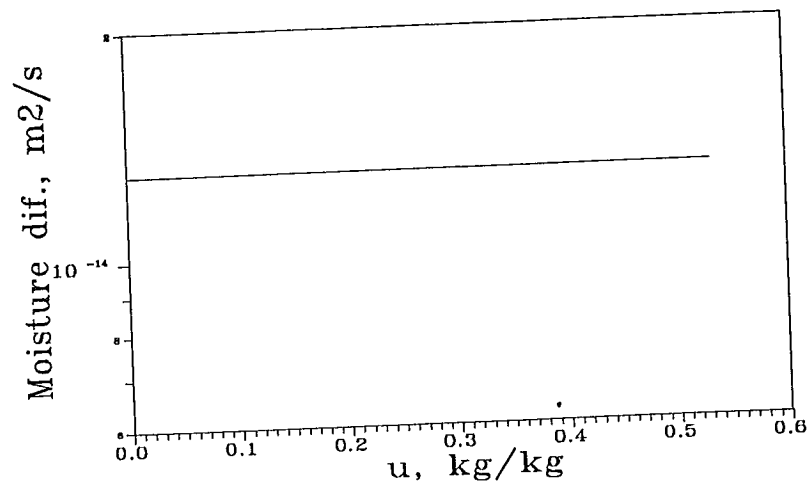


Figure 3. Moisture diffusivity.

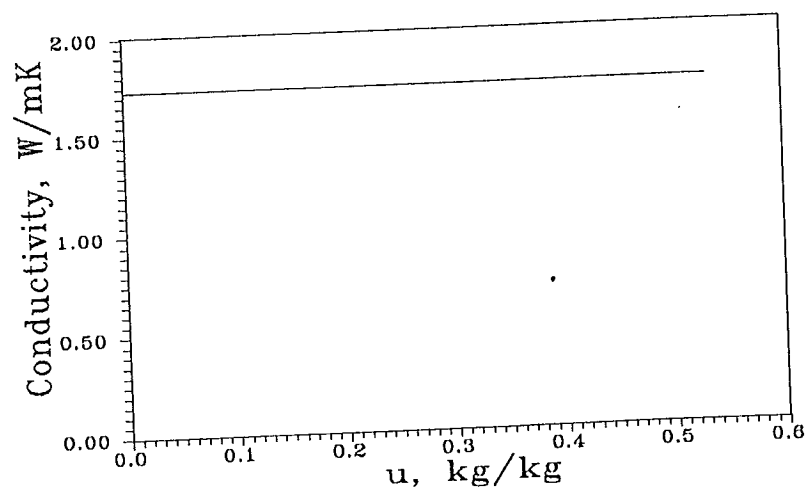


Figure 4. Thermal conductivity.

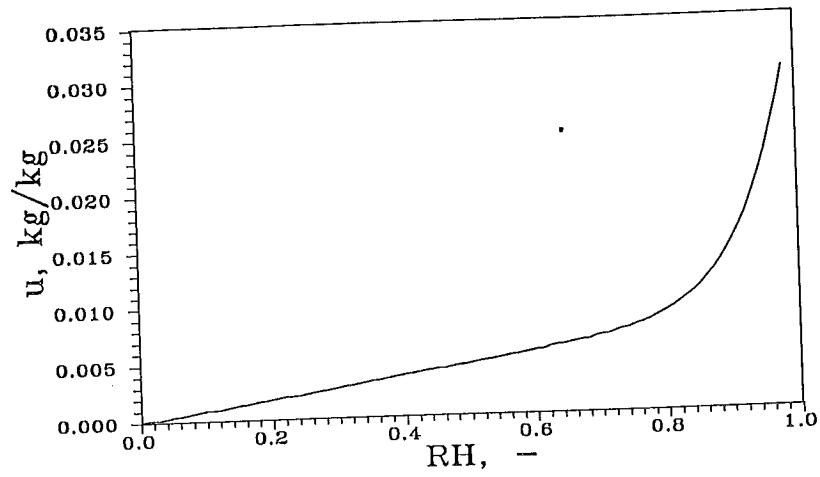


Figure 1. Sorption isotherm.

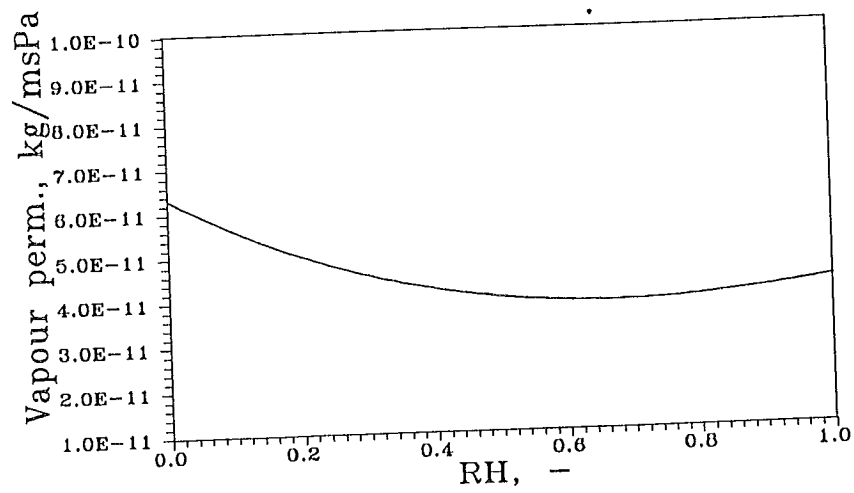


Figure 2. Vapor permeability.

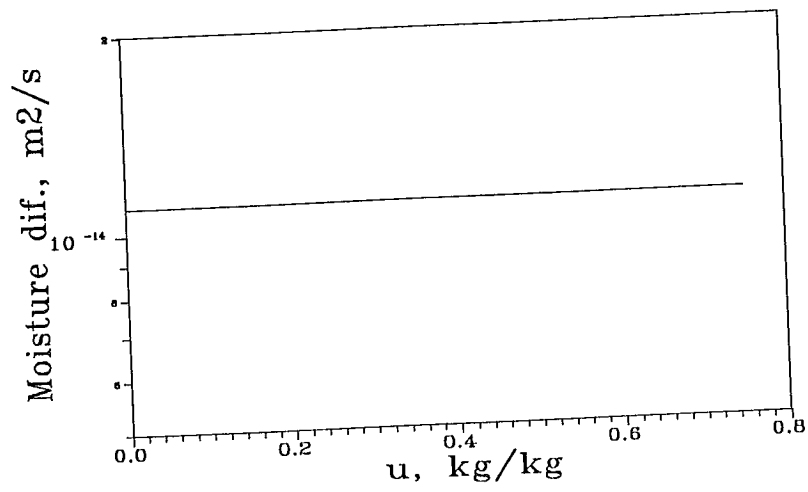


Figure 3. Moisture diffusivity.

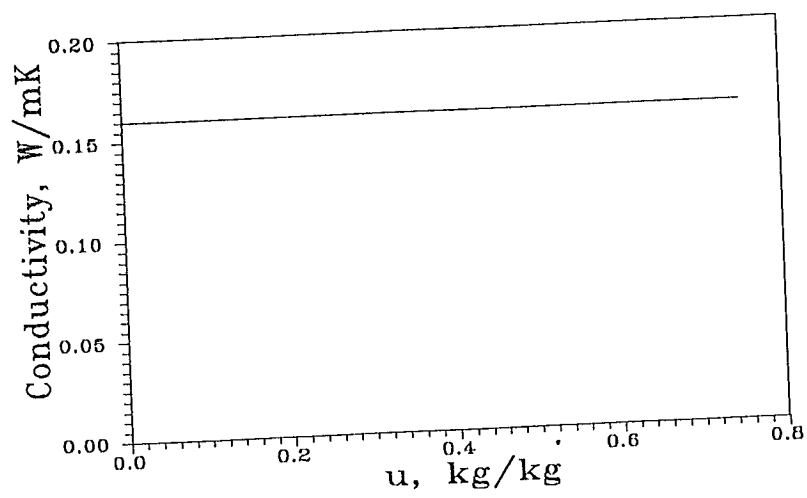


Figure 4. Thermal conductivity.

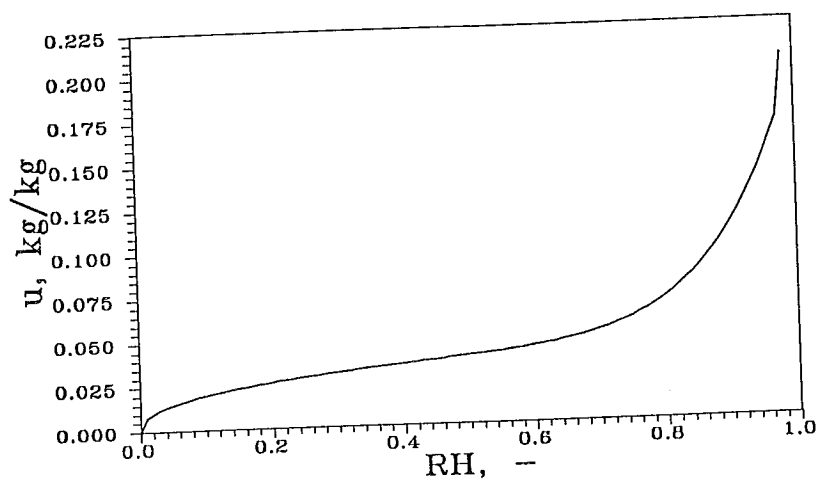


Figure 1. Sorption isotherm.

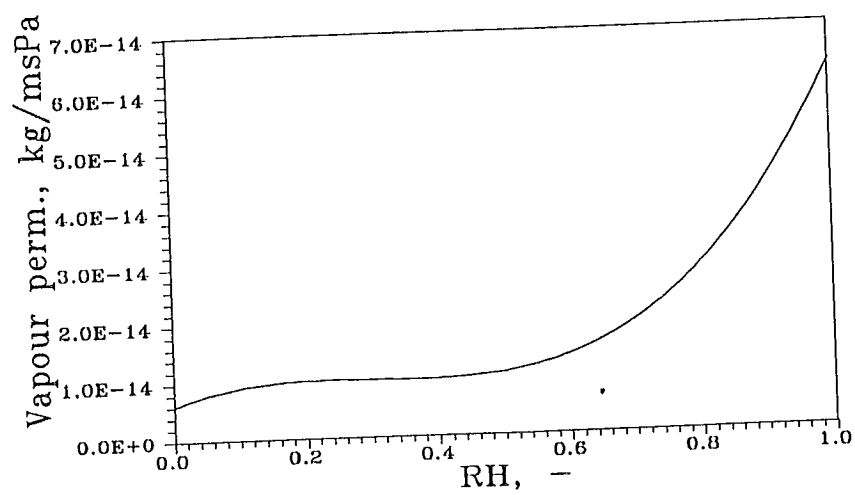


Figure 2. Vapor permeability.

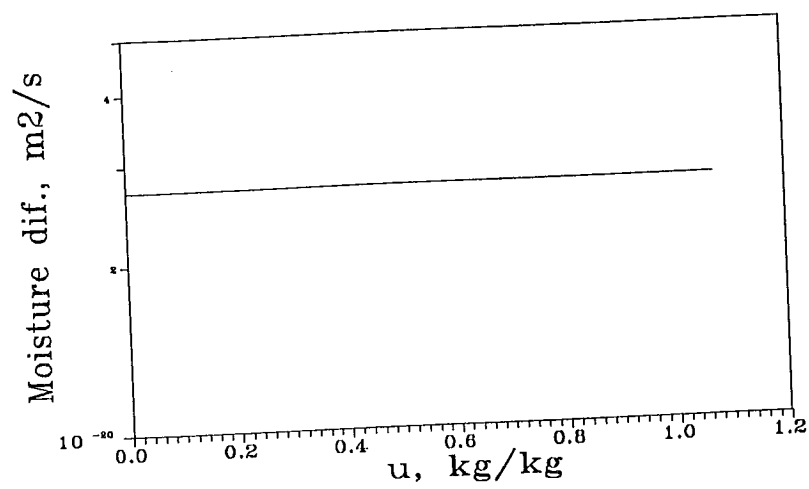


Figure 3. Moisture diffusivity.

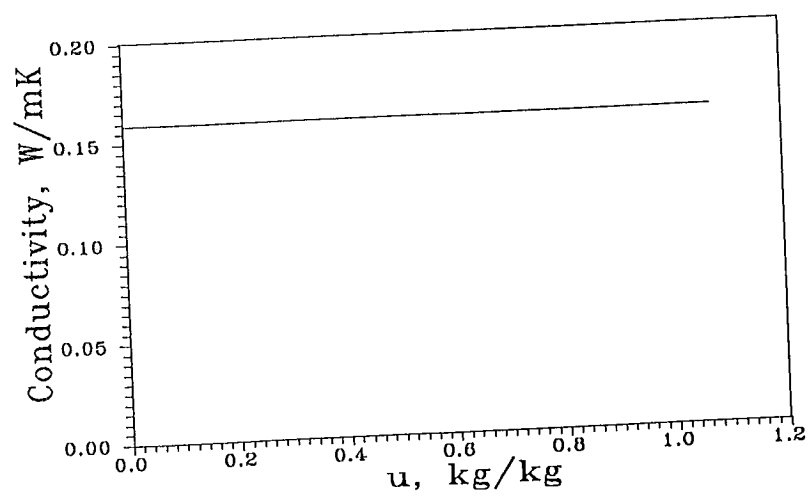


Figure 4. Thermal conductivity.

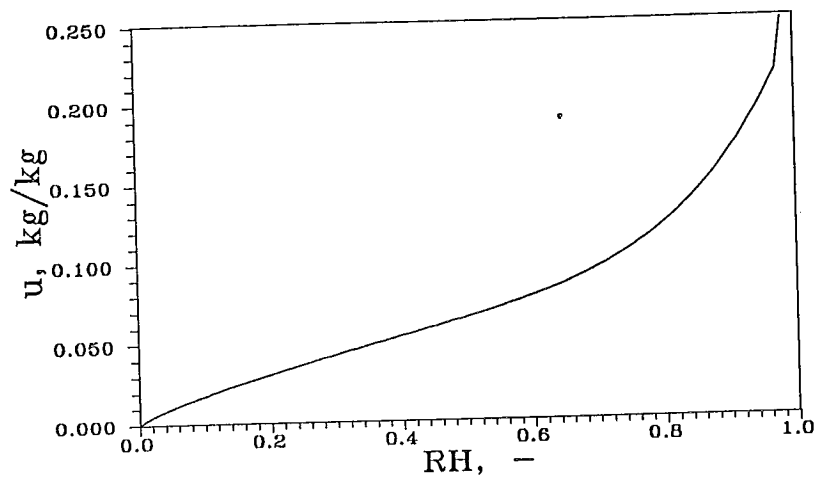


Figure 1. Sorption isotherm.

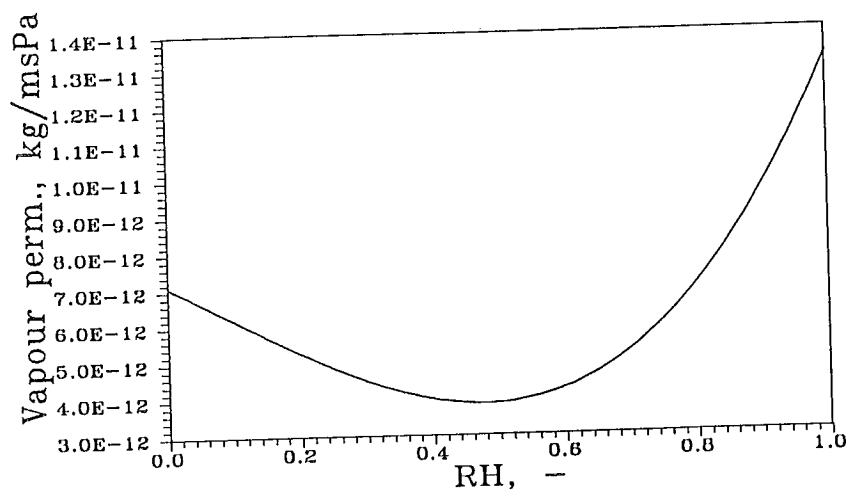


Figure 2. Vapor permeability.

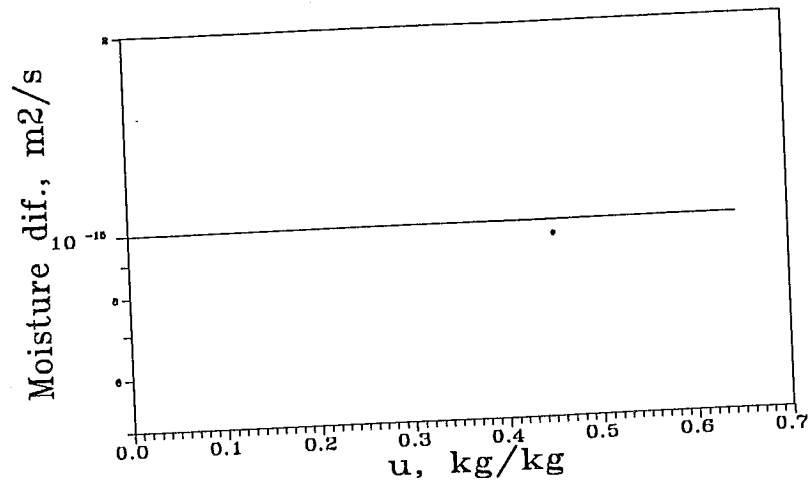


Figure 3. Moisture diffusivity.

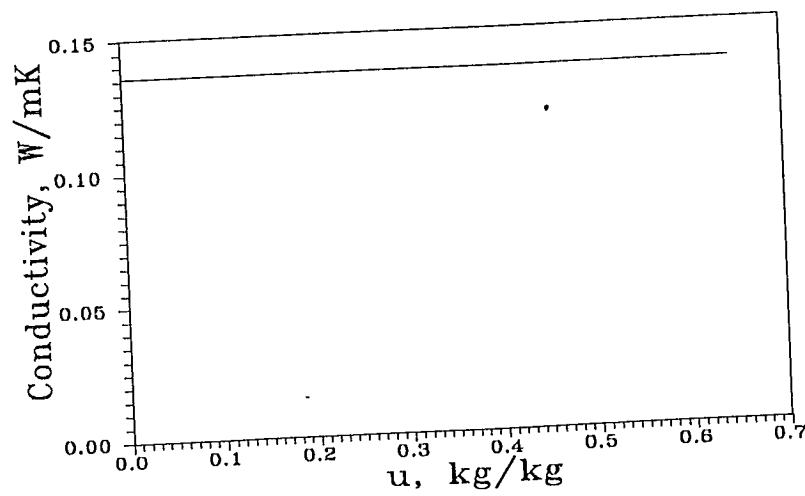


Figure 4. Thermal conductivity.

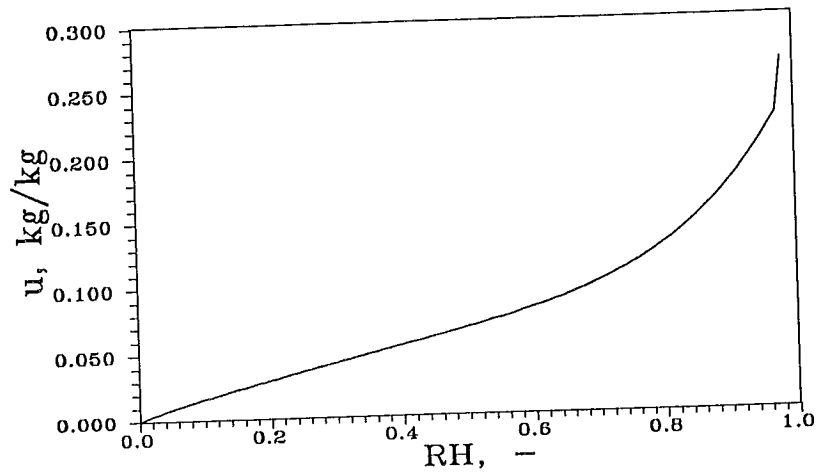


Figure 1. Sorption isotherm.

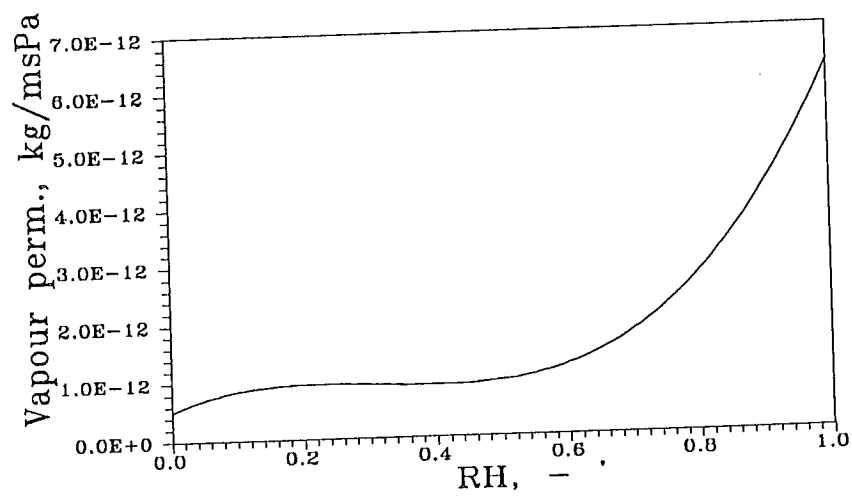


Figure 2. Vapor permeability.

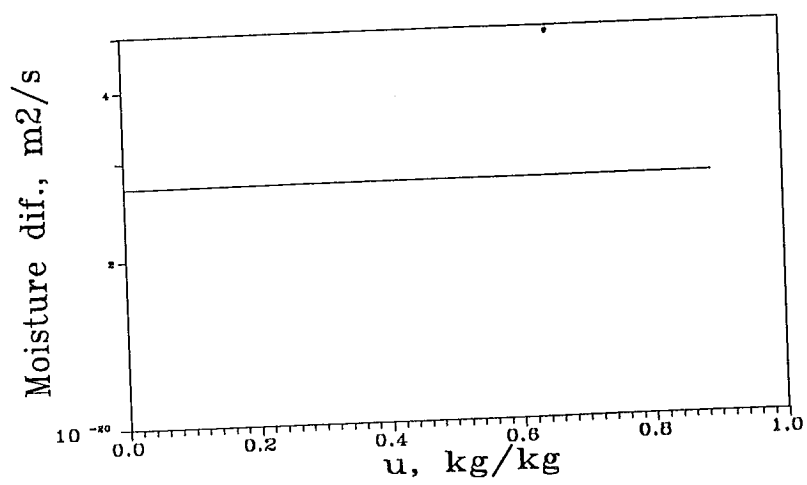


Figure 3. Moisture diffusivity.

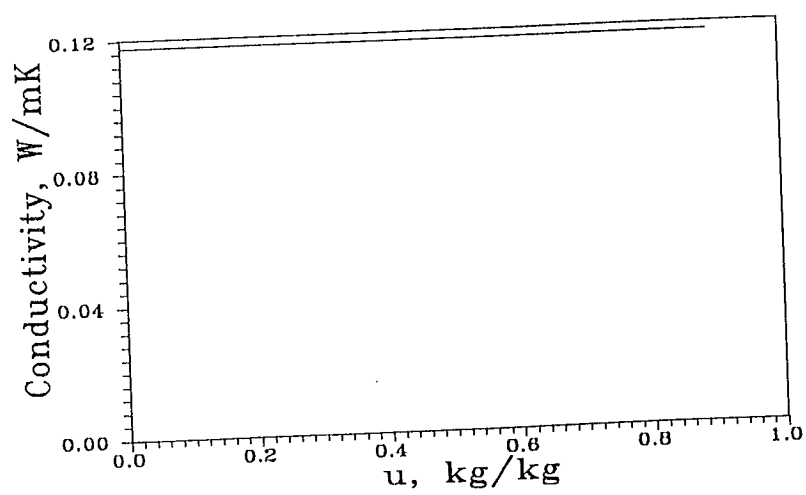


Figure 4. Thermal conductivity.

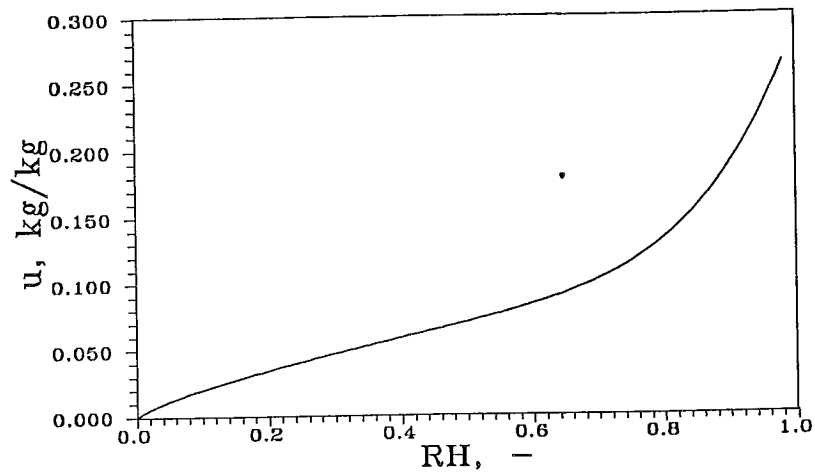


Figure 1. Sorption isotherm.

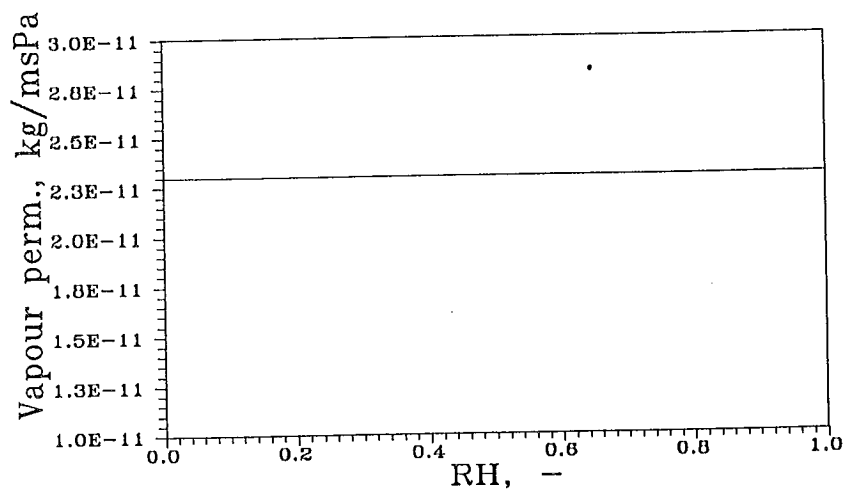


Figure 2. Vapor permeability.

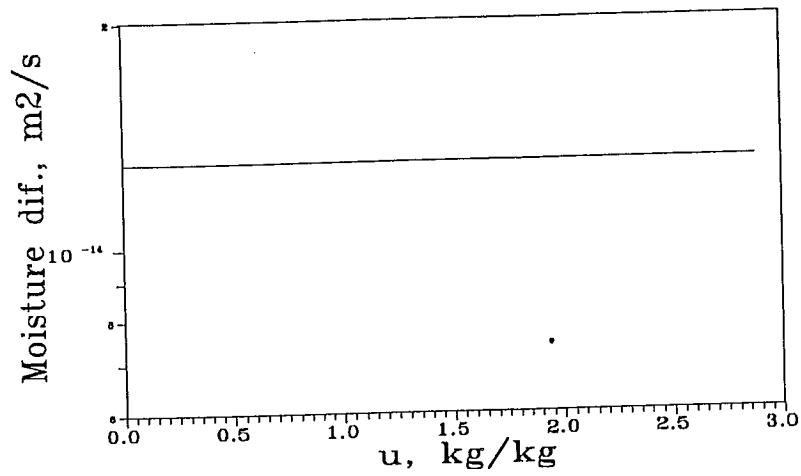


Figure 3. Moisture diffusivity.

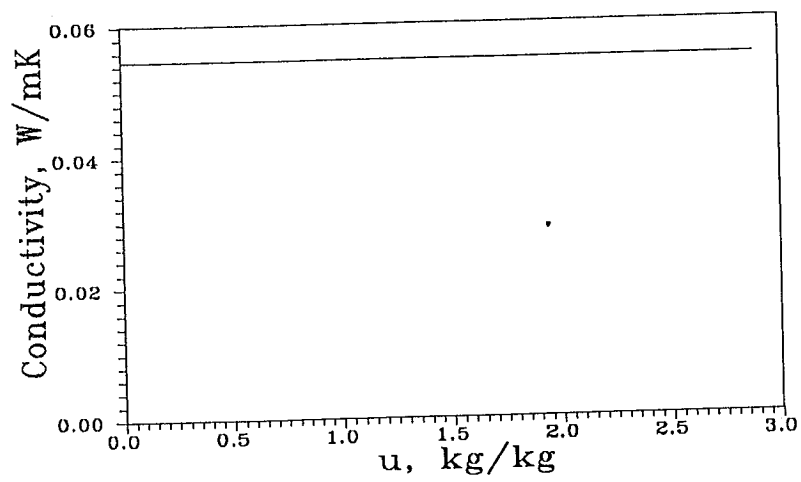


Figure 4. Thermal conductivity.

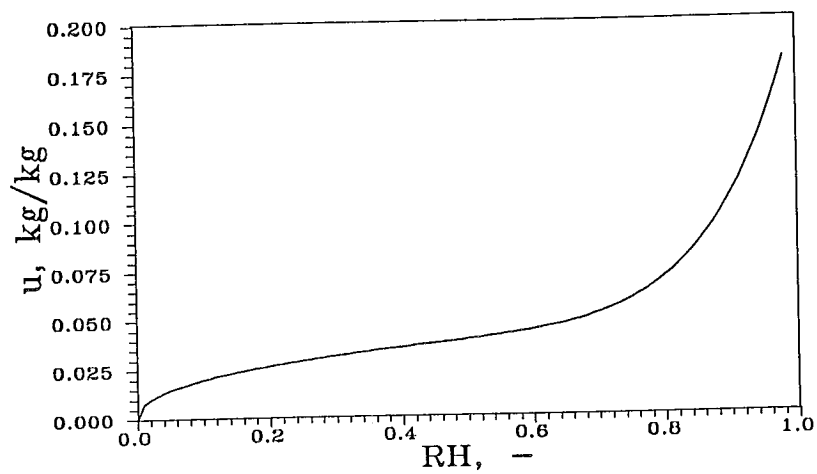


Figure 1. Sorption isotherm.

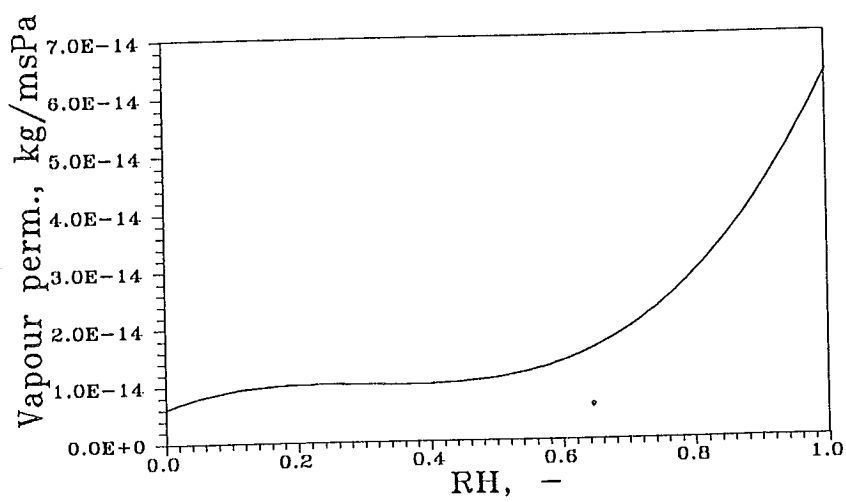


Figure 2. Vapor permeability.

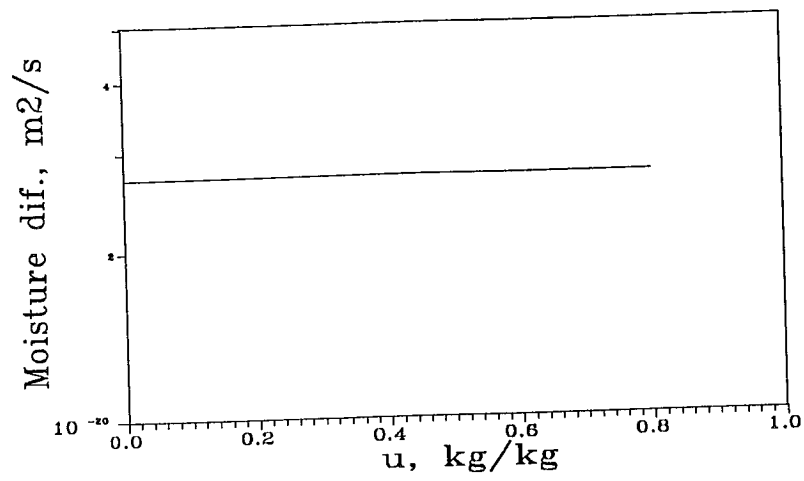


Figure 3. Moisture diffusivity.

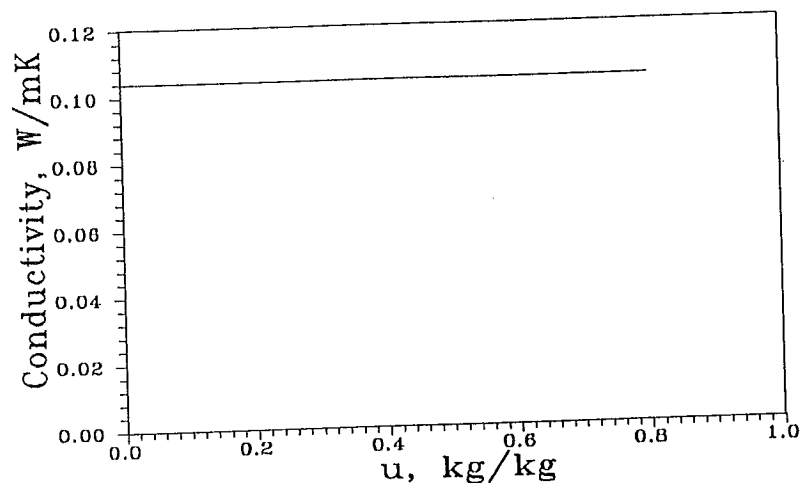


Figure 4. Thermal conductivity.

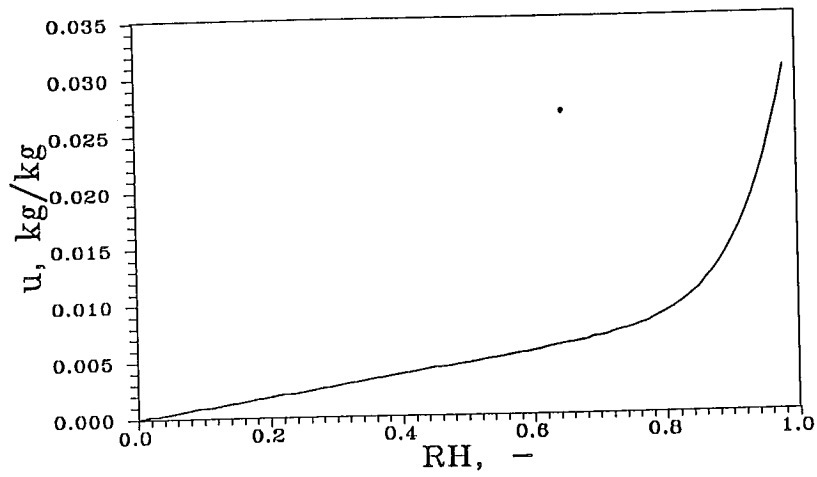


Figure 1. Sorption isotherm.

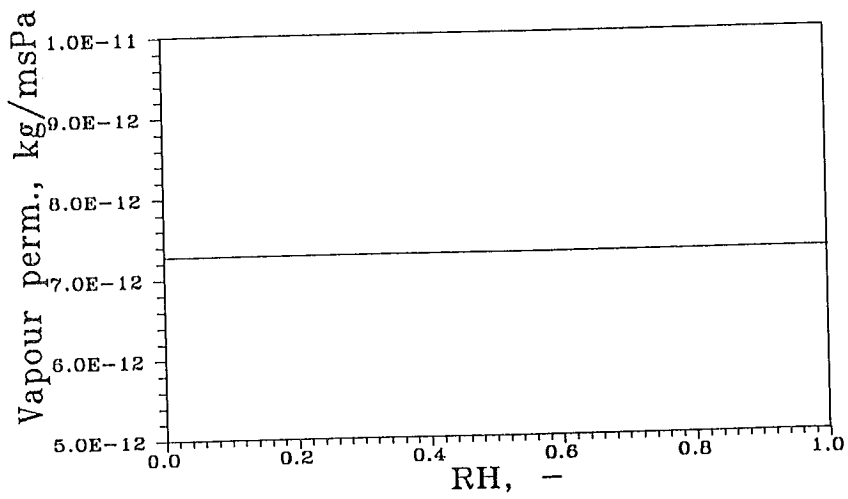


Figure 2. Vapor permeability.

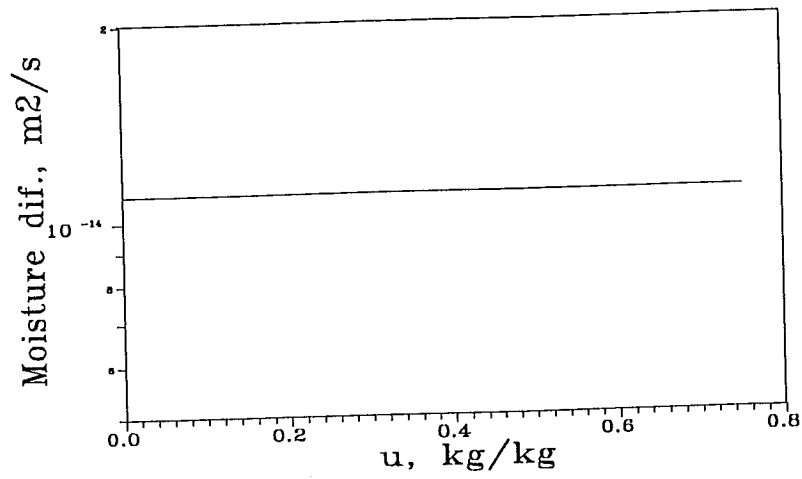


Figure 3. Moisture diffusivity.

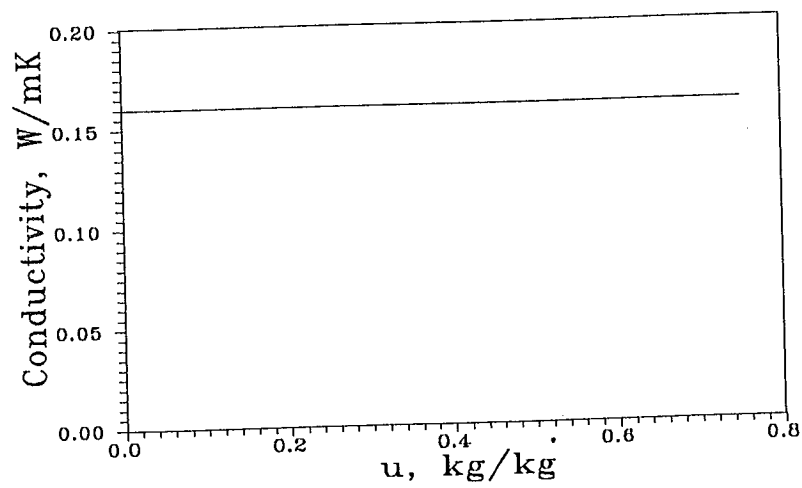


Figure 4. Thermal conductivity.

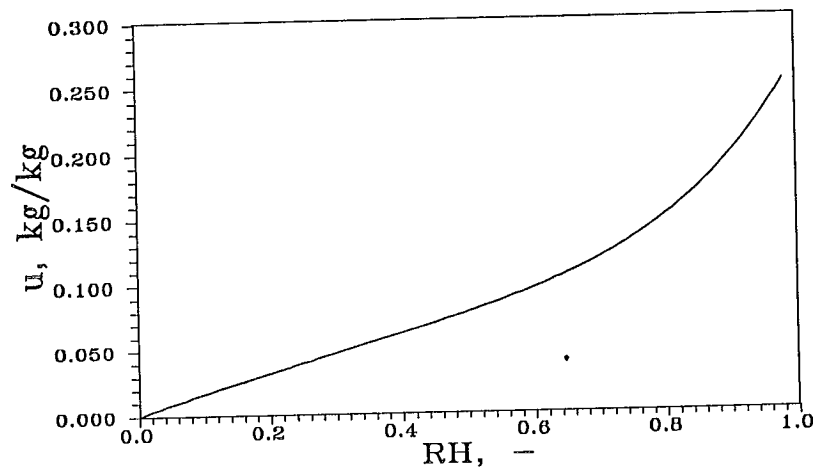


Figure 1. Sorption isotherm.

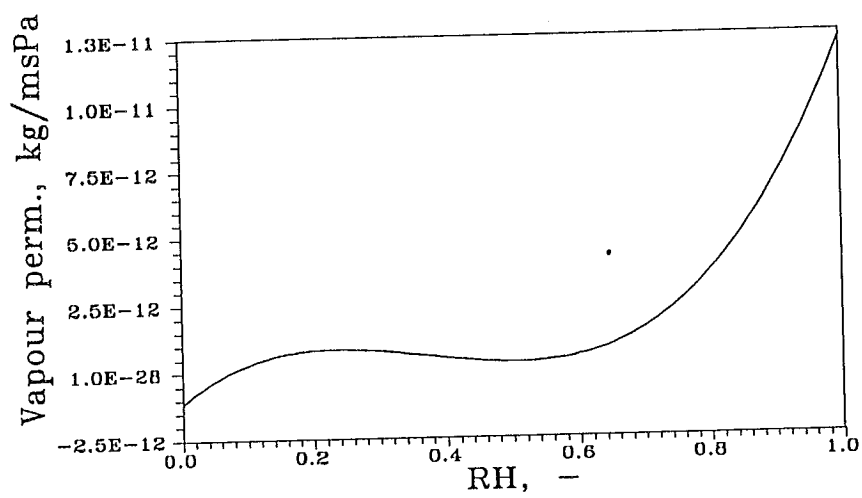


Figure 2. Vapor permeability.

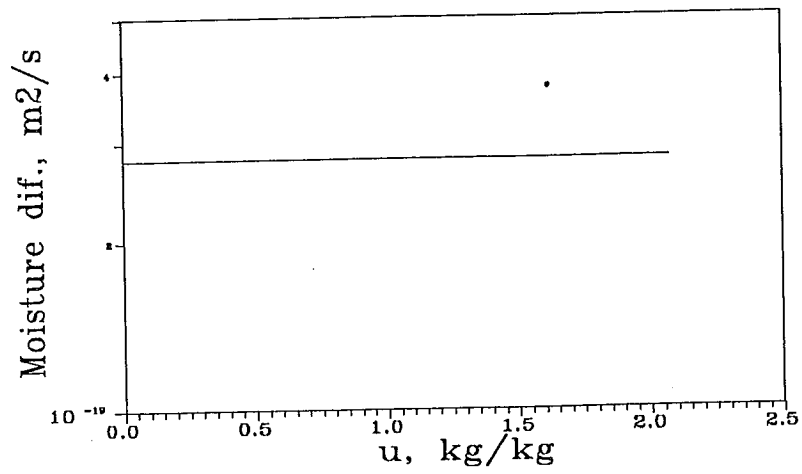


Figure 3. Moisture diffusivity.

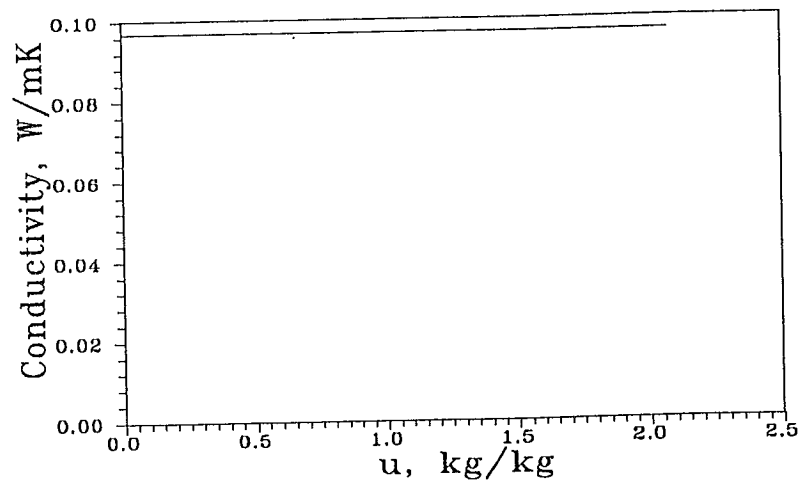


Figure 4. Thermal conductivity.

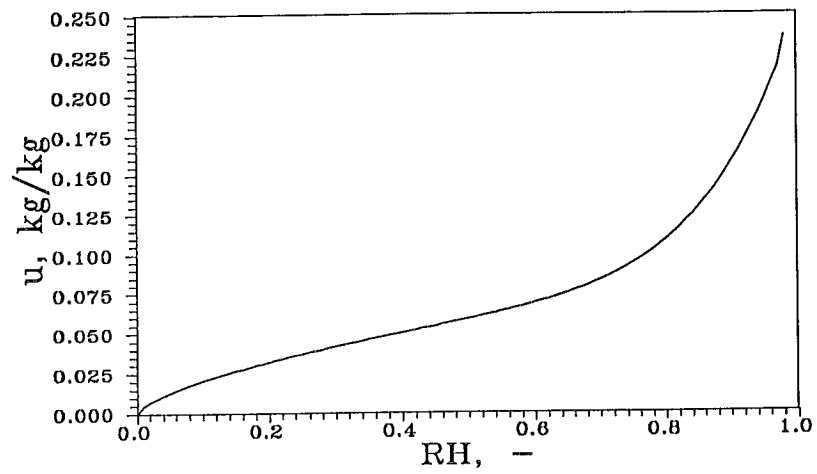


Figure 1. Sorption isotherm.

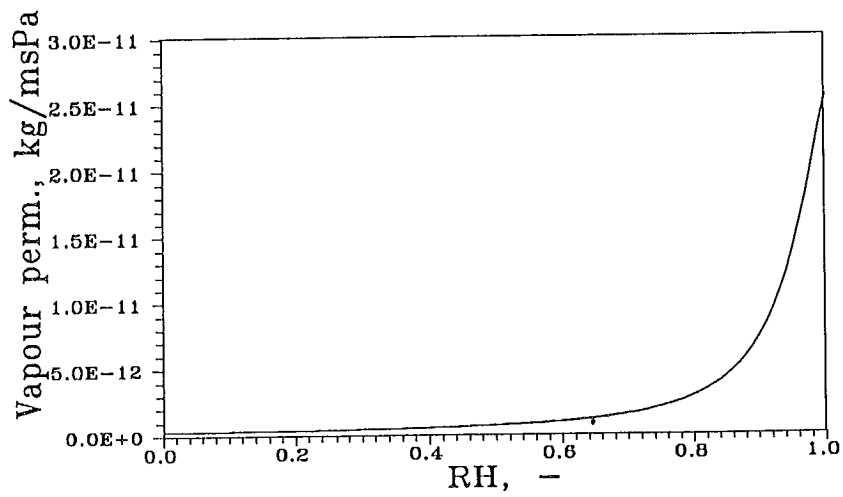


Figure 2. Vapor permeability.

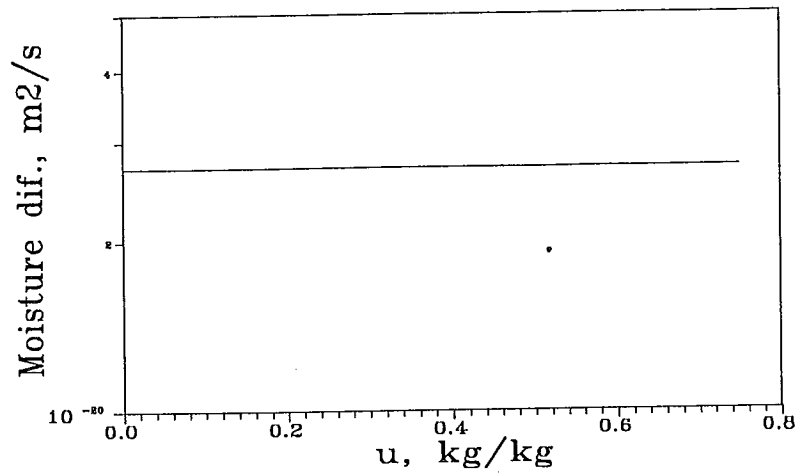


Figure 3. Moisture diffusivity.

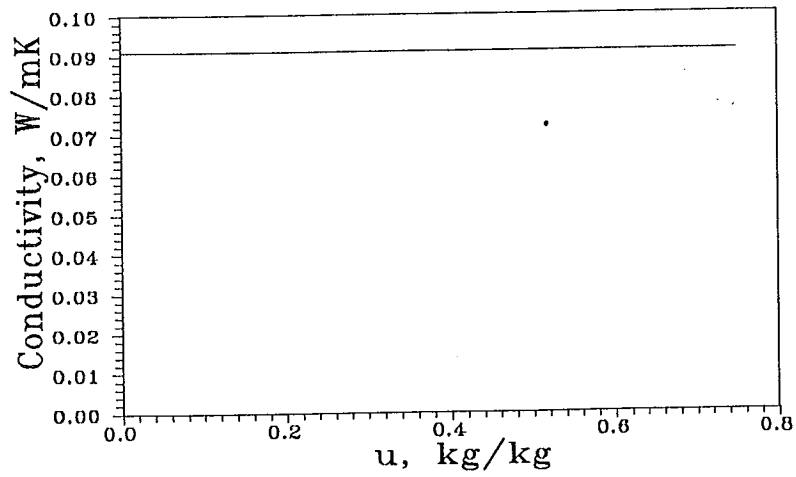


Figure 4. Thermal conductivity.