

## **A Reference Guide for Cryogenic Properties of Materials\***

**J. G. Weisend II, V. Flynn, E. Thompson**  
**Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309**

**R.P. Reed**  
**Cryogenic Materials, Inc.**  
**Boulder, CO**

### **Abstract**

A thorough knowledge of the behavior of materials at cryogenic temperatures is critical for the design of successful cryogenic systems. Over the past 50 years, a tremendous amount of material properties at cryogenic temperatures have been measured and published. This guide lists resources for finding these properties. It covers online databases, computer codes, conference proceedings, journals, handbooks, overviews and monographs. It includes references for finding reports issued by government laboratories and agencies. Most common solids and fluids used in cryogenics are covered.

---

\* Work supported by the U.S. Department of Energy under contract number DE-AC03-76SF00515

## Introduction

This is a guide to finding properties of materials at cryogenic temperatures. Over the last 50 years, a large amount of material properties at cryogenic temperatures have been measured and published. For the working engineer or scientist, the problem is frequently not that the desired material property is unknown at cryogenic temperatures but that it is unclear where to find the published data. The goal of this document is to make the properties easier to find. There are 2 caveats to this guide. The first is that it is not meant to be completely exhaustive. The second is that this is simply a guide to the scientific literature and inclusion in this list does not mean the data is somehow “better” or more accurate than other sources.

## Databases

### 1. Cryogenic Information Center

This a commercial database issued on CD-ROM that contains references to more than 146,000 papers, books and technical reports specifically concerning cryogenics. The database includes the cryogenic database formally maintained by the US National Bureau of Standards. The citations go back as far as 1829. Many useful references for cryogenic material properties may be found in this database. The database permits searches by keyword, title, author and year among others. The citation listing is updated on a regular basis. Information regarding the Cryogenic Information Center may be found at:  
<http://www.cryoinfo.org/>

### 2. SPIRES

This is a free online database listing more than 500,000 papers, books, laboratory reports and preprints associated with high energy physics. The database permits searches by keyword, title, author and year among others. Properties of cryogenic materials are not an emphasis of this database. However, references to those properties measured during the development of high energy physics experiments and accelerators are frequently found here. Of particular value are the large number of reports from high energy physics laboratories worldwide that are referenced here. The SPIRES website may be found at: <http://www.slac.stanford.edu/spires/hep/>

### 3. DOE Energy Citations Database

This is a free online database of all energy related research funded by the US Department of Energy and its predecessors from 1948 to the present. The

database contains references to technical reports, papers, thesis and books. The database may be found at <http://www.osti.gov/energycitations/>  
A related database, the DOE Information Bridge, contains full text versions of DOE funded work dating back to 1995. This database may be found at: <http://www.osti.gov/bridge/>  
Both these databases permit searches by keyword, title, author and year among others. Both are regularly updated.  
Since these databases deal with much more than the properties of cryogenic materials, the careful use of search terms is required to avoid drowning in irrelevant citations.

#### 4. Defense Technical Information Center

This is a free online database that contains citations to technical papers and reports dating back to 1974. This database allows searches by keyword, title, author and year among others and is regularly updated. The database includes but is not limited to reports from Department of Defense contractors. The database contains references to cryogenic material properties but also to many other topics so careful searching is needed. The database may be found at: <http://stinet.dtic.mil/>

#### 5. NIST Data Gateway

This is a free online database created by the National Institute of Standards and Technology (NIST). It provides links to online NIST property databases. The database allows searching by keyword, material or property. Both cryogenic and room temperature material properties are covered. The database may be found at: <http://srdata.nist.gov/gateway/gateway>

## Handbooks & Overviews

1. Barron, R., Cryogenic Systems, McGraw-Hill (1966).
2. Barron, T.H.K.; White, G.K., Heat Capacity and Thermal Expansion at Low Temperatures, Plenum Press, (1999).
3. Cook, P.; Hands, B.A., Cryogenic Fluids Databook, British Cryoengineering Society (2002).
4. Flynn, T.M., A Bibliography of the Physical Equilibria and Related Properties of Some Cryogenic Systems, U.S. Dept of Commerce.
5. Flynn, T., Cryogenic Engineering, Marcel Dekker (1997).
6. Hiza, M.J.; Kidnay, A. J.; Miller, R.C., Equilibrium Properties of Fluid Mixtures: a Bibliography of Data on Fluids of Cryogenic Interest, Plenum Press, (1976).
7. Jacobsen, R.T.; Penoncello, S.G.; Lemmon E.W., Thermodynamic Properties of Cryogenic Fluids, Plenum Press (1997).

8. Johnson, V.J. (ed.), Properties of Materials at Low Temperature, Pergamon Press (1961).
9. Johnson, V.J.; Diller, D.E., Thermodynamic and Transport Properties of Fluids and Selected Solids for Cryogenic Applications, National Bureau of Standards, (1970).
10. Kanagaraj, S.; Pattanayak, S., Measurement of the thermal expansion of metal and FRPs, Cryogenics, Volume 43 Number 7 (July 2003).
11. McClintock, R.M.; Gibbons, H.P., Mechanical Properties of Structural Materials at Low Temperatures, National Bureau of Standards, (1960).
12. Mann, D. (ed.) and Reed, R.P. (assoc. ed.), LNG Materials and Fluids, a User's Manual of Property Data, National Bureau of Standards, Boulder, Colorado (1977).
13. Powell, R.L.; Blanpied, W.A., Thermal Conductivity of Metals and Alloys at Low Temperatures: a Review of the Literature, National Bureau of Standards, (1954).
14. Reed, R.P. and Clark, A.F., (eds.) Materials at Low Temperatures, American Society of Materials (1983).
15. Reed, R.P. (ed.), Cryogenic Materials Data Handbook, PB 17809, Office of Technical Services, Washington, D.C. (1962).
16. Reed, R.P. and Clark, A.F. (eds.), Materials at Low Temperatures, American Society for Metals, Metals Park, Ohio (1983).
17. Reed, R.P., Materials studies for magnetic fusion energy applications at low temperatures, IX, National Technical Information Service, (1986).
18. Rosenberg, H. M., Low Temperature Solid State Physics, Clarendon Press (1963).
19. Scott, R.B., Cryogenic Engineering, Met-Chem Research (1988).
20. Schwartzberg, F.R. et al, Cryogenic Materials Data Handbook, Air Force Materials Laboratory, AFML-TDR-64-280 (1970).
21. Simon, N.J.; Reed, R.P., Structural Materials for Superconducting Magnets, Handbook of Stainless Steel Properties, for Office of Fusion Energy (DOE), National Bureau of Standards, Boulder, Colorado (1982-1985).
22. Teed, P.L., The Properties of Metallic Materials at Low Temperatures, Wiley, (1950)
23. Van de Voorde, M.H., Low-Temperature Irradiation Effects on Materials and Components for Superconducting Magnets for High-Energy Physics Applications. CERN, Geneva (1977).
24. Warren, K. A. and Reed, R.P. (eds.), The Tensile and Impact Properties of Selected Materials from 20 to 300 K, NBS Monograph 64, National Bureau of Standards, Boulder, Colorado (1963).
25. Weisend II, J.G. (ed.), Handbook of Cryogenic Engineering, Taylor & Francis (1998).
26. Wigley, D.A., Mechanical Properties of Materials at Low Temperatures, Plenum Press, (1971).
27. Cryogenic Materials Data Handbook, PB 191809, National Bureau of Standards, Boulder, Colorado (1963).

28. Handbook of Materials for Superconducting Machinery, Batalle (1977).
29. Materials of Construction for Use in a LNG Pipeline, TP761.L503, American Gas Association, New York (April 1968).
30. Materials Properties Data Book, volumes 1-3, Aerojet Nuclear Systems Company, Sacramento, California for Space Nuclear Propulsion Office, NASA, Cleveland, Ohio (1970).
31. Metallic Material Specifications for ITER Magnets, Annex 1, Metallic Materials Mechanical- and Thermal-Property Database, Superconducting Coils and Structures Division, ITER EDA, Naka Joint Work Site, Japan (13 March 1997).

## Conference Proceedings

1. Advances in Cryogenic Engineering, Volumes 1 – 48, Plenum Press

These are the proceedings of the Cryogenic Engineering Conference / International Cryogenic Materials Conference which is held biannually (odd years) in North America. As roughly 50 % of this conference concerns cryogenic materials, these proceedings can be quite useful.

2. Proceedings of the International Cryogenic Engineering Conference

These are the proceedings of the International Cryogenic Engineering Conference which is held biannually (even years) in Europe or Asia.

3. Applied Superconductivity Conference, IEEE Transactions on Magnetics
4. Proceedings of the Magnet Technology Conference

## Journals

1. *Cryogenics*, Elsevier Science – Monthly refereed journal covering all aspects of cryogenic engineering and science

## Properties of Fluids

### I. Computational Codes

1. HEPAK

This is a commercial product that calculates the thermophysical properties (both state and transport properties) of Helium. The program is valid for a wide range

of helium temperatures and pressures including the superfluid regime. More details about this program may be found at <http://www.cryodata.com/>

## 2. GASPAK

A commercial product very similar to HEPAK except that it calculates state and transport properties for a 33 different fluids including Helium, Hydrogen, Oxygen, Neon, Carbon Dioxide, Nitrogen and various refrigerants. More details about this program may be found at <http://www.cryodata.com/>

## 3. NIST 12 (NIST Thermodynamic and Transport Properties of Pure Fluids Database)

A commercial program created by the National Institute of Standards & Technology very similar in nature to GASPAK. More details about this program may be found at <http://www.nist.gov/srd/nist12.htm>

## II. Monographs

### 1. Helium

- a. Arp, V.D.; McCarty, R.D.; Friend, D.G., Thermophysical Properties of Helium-4 from 0.8 to 1500K with Pressures to 2000MPa, National Institute of Standards and Technology (1998).
- b. Atkins, K.R., Liquid Helium, Cambridge University Press (1959).
- c. Bennemann, K.H.; Ketterson, J.B., The Physics of Liquid and Solid Helium, Interscience Monographs and Texts in Physics and Astronomy, v. 29, Wiley (1976).
- d. Brooks, J.S.; Donnelly, R.J., The Calculated Thermodynamic Properties of Superfluid Helium-4, American Chemical Society and the American Institute of Physics for the National Bureau of Standards (1977).
- e. Burton, E. F.; Smith, H. G. ; Wilhelm, J. O., Phenomena at the Temperatures of Liquid Helium, Reinhold Publishing Corporation (1940).
- f. Cook, G.A., Argon, Helium and the Rare Gases: the Elements of the Helium Group, Interscience Publishers (1961).
- g. Dobbs, R., Solid Helium Three, Oxford University Press (1994).
- h. Donnelly, R.J., Quantized vortices in helium II, Cambridge University Press (1991).
- i. Galasiewicz, Z.M., Helium 4, Selected Readings in Physics, Pergamon Press (1971).
- j. Gibbons R.M.; Kuebler, G.P., Research on Materials Essential to Cryocooler Technology: Thermophysical and Transport Properties of Argon, Neon, Nitrogen, and Helium-4, Air Force Materials Laboratory (1968).
- k. Keesom, W.H., Helium; with 258 illustrations, Elsevier (1942).
- l. Keller, W.E., Helium-3 and Helium-4, Plenum Press (1969).

- m. Kropschot, R.H.; Birmingham, B.W.; Mann, D.B, Technology of Liquid Helium, National Bureau of Standards (1968).
- n. Lane, C.T., Superfluid Physics, McGraw-Hill (1962).
- o. London, F., Superfluids, Dover (1960).
- p. Mann, D.B.; Stewart, R.B., Thermodynamic Properties of Helium at Low Temperatures and High Pressures, National Bureau of Standards, (1959).
- q. McCarty, R.D., Thermophysical Properties of Helium-4 from 2-degrees to 1500-degrees K with Pressures to 1000-atmospheres, National Bureau of Standards, Boulder, Colo. (1972).
- r. McCarty, R.D., The Thermodynamic Properties of Helium II from 0K to the Lambda Transitions, National Bureau of Standards (1981).
- s. McClintock, P.V.E. ; Meredith, D.J . ; Wigmore, J.K., Matter at Low Temperatures, Wiley (1984)
- t. Sychev, V.V.; Selover, T.B., Thermodynamic Properties of Helium, Hemisphere Publishing Corp (1987)
- u. Tilley, D.R.; Tilley, J., Superfluidity and Superconductivity, Hilger (1990).
- v. Van Sciver, S.W., Helium Cryogenics. International Cryogenics Monograph Series, Plenum Press (1986).
- w. Wilks, J., The Properties of Liquid and Solid helium, Clarendon Press (1967).
- x. Wilks, J., An Introduction to Liquid Helium, Clarendon Press (1987).

## 2. Hydrogen

- a. Little, Arthur D., Hydrogen Handbook: a Compilation of Properties, Handling and Testing Procedures, Compatibility with Materials, and Behavior at Low Temperatures. Air Force Flight Test Center. (1960).
- b. Mackay, G.D.M., Properties of Some Hydrogen Bonded Liquids, Nova Scotia Technical College. (1959).
- c. McCarty, R.D., Hydrogen Properties in Hydrogen: Its Technology and Implications, V.3, CRC Press (1975).
- d. McGee, H.A., Chemical Reactivity of Hydrogen, Nitrogen, and Oxygen Atoms at Temperatures below 100 K, Georgia Institute of Technology (1966-1973).
- e. Pratt & Whitney Aircraft Group. Cryogenic H<sub>2</sub>, Pratt & Whitney Aircraft Division of United Aircraft Corporation (1960).
- f. Scott, R.B.; Denton, W.H.; Nicholls, C.N., Technology and Uses of Liquid Hydrogen, MacMillan (1964).
- g. Shaffer, A.; Rousseau, J., Thermodynamic Properties of 20.4K Equilibrium Hydrogen, Air Force Systems Command (1961).
- h. Souers, P.C., Cryogenic Hydrogen Data Pertinent to Magnetic Fusion Energy, National Technical Information Service (1979).
- i. Ulybin, S.A.; Malysenko, S.P., The TS-diagram of Normal Hydrogen Between 16 and 100K and at pressures of up to 500kg/cm<sup>2</sup>, Israel Program for Scientific Translations (1969).

- j. Verkin, B.I.; Selover, T.B.; Ghojel, J.I., Handbook of Properties of Condensed phases of Hydrogen and Oxygen, Hemisphere Publication Corporation (1991).

### 3. Nitrogen

- a. Burnett, E.S., Temperature Entropy Chart of Thermodynamic Properties of Nitrogen, U.S. Bureau of Mines, (1950).
- b. Coleman, T.C.; Stewart R.B., The Thermodynamic Properties of Nitrogen, University of Idaho Engineering Experiment Station (1970).
- c. Gibbons R.M.; Kuebler, G.P., Research on Materials Essential to Cryocooler Technology: Thermophysical and Transport Properties of Argon, Neon, Nitrogen, and Helium-4, Air Force Materials Laboratory (1968).
- d. Jacobsen, R.T.; Stewart, R.B., Table of Thermodynamic Properties of Nitrogen, University of Idaho (1972)
- e. Jacobsen, R.T.; Stewart, R.B.; Jahangiri, M., Thermodynamic Properties of Nitrogen from the Freezing Line to 2000K at Pressures to 1000MPa, American Chemical Society and the American Institute of Physics for the National Bureau of Standards (1986).
- f. McGee, H.A., Chemical Reactivity of Hydrogen, Nitrogen, and Oxygen Atoms at Temperatures below 100 K, (1966-1973).
- g. Millat, J.; Wakeham, W.A., The Thermal Conductivity of Nitrogen and Carbon Monoxide in the Limit of Zero Density, American Chemical Society and the American Institute of Physics for the National Institute of Standards and Technology (1989).
- h. Pearson, W. E., Transport Properties of N<sub>2</sub> gas at Cryogenic Temperatures, National Technical Information Service (1974).
- i. Stephan, K.; Krauss, R.; Laesecke, A., Viscosity and Thermal Conductivity of Nitrogen for a Wide Range of Fluid States, American Chemical Society and the American Institute of Physics for the National Bureau of Standards (1987).
- j. Sychev, V.V.; Selover, T.B., Thermodynamic Properties of Nitrogen, Hemisphere (1987).
- k. Wood, R.E.; Baer, F.W.; Boone, W.J., Thermal Conductivities and Prandtl Numbers of Nitrogen from 133 to 740 K Between 1 and 240 Atmospheres. U.S. Dept of Interior, Bureau of Mines (1971).

### 4. Argon

- a. Cook, G.A., Argon, Helium and the Rare Gases, Interscience Publishers (1961).
- b. Gibbons R.M.; Kuebler, G.P., Research on Materials Essential to Cryocooler Technology: Thermophysical and Transport Properties of Argon, Neon, Nitrogen, and Helium, Air Force Materials Laboratory (1968).
- c. Jaques, A., Thermophysical Properties of Argon, Fermi National Accelerator Laboratory (1988).



- d. Roder, H.M.; Perkins, R.A.; Nieto de Castro, C.A., Experimental Thermal Conductivity, Thermal Diffusivity, and Specific Heat Values of Argon and Nitrogen, National Institute of Standards and Technology (1988).
- e. Stewart, R.B.; Jacobsen R.T., Thermodynamic Properties of Argon from the Triple Point to 1200K with Pressures to 1000MPa, American Chemical Society and the American Institute of Physics for the National Institute of Standards and Technology (1989).
- f. Younglove, B.; Hanley, H.J.M., The Viscosity and Thermal Conductivity Coefficients of Gaseous and Liquid Argon, American Chemical Society and the American Institute of Physics for the National Bureau of Standards (1986)

## 5. Oxygen

- a. Brewer, J., Thermodynamic Data on Oxygen and Nitrogen, Air Force Systems Command (1961).
- b. Hust, J.G., A Bibliography of the Thermophysical Properties of Oxygen at Low Temperatures, Dept of Commerce, (1962).
- c. McGee, H.A., Chemical Reactivity of Hydrogen, Nitrogen, and Oxygen Atoms at Temperatures below 100 K, Georgia Institute of Technology (1966-1973).
- d. Roder, H.M., Transport Properties of Oxygen, Science and Technical Information Branch (1983).
- e. Stewart, R.B.; Jacobsen, R.T., Table of Thermodynamic Properties of Oxygen, University of Idaho (1972).
- f. Sychev, V.V.; Selover, T.B.; Slark G.E., Thermodynamic Properties of Oxygen, Hemisphere Pub. Corporation (1987).
- g. Wilhoit, R.C.; Chao, J.; Hall, K.R., Properties of Condensed Phases, American Chemical Society and the American Institute of Physics for the National Bureau of Standards (1985).
- h. Zuckerwar, A.J., Sound Speed Measurements in Liquid Oxygen-Liquid Nitrogen Mixtures, National Technical Information Service (1985).

## 6. Neon

- a. Gibbons R.M.; Kuebler, G.P., Research on Materials Essential to Cryocooler Technology: Thermophysical and Transport Properties of Argon, Neon, Nitrogen, and Helium, Air Force Materials Laboratory (1968).
- b. Perkins, R.A.; Roder, H.M., Experimental Thermal Conductivity and Thermal Diffusivity Values for Neon and Mixtures of Neon and Nitrogen. National Institute of Standards and Technology (1999).

## 7. Xenon

- a. Grisnik, S.P., Measurement of Xenon Viscosity as a Function of Low Temperature and Pressure, National Technical Information Service (1998).

## Properties of Solids

### I. Computational Codes

#### 1. Cryogenic Material Properties Program (CMP)

This is a commercial product that allows the calculation of material properties for 35 different materials including G-10, aluminum alloys, stainless steel alloys and titanium. The properties available include: yield strength, thermal conductivity, electrical resistivity and thermal expansion. The valid temperature range is generally between less than 4 K up to the melting point. Information about this program may be found at: <http://www.cryoinfo.org/>

#### 2. CRYOCOMP and METALPAK

These are commercial software packages that permit that calculation of material properties for a number of solids. CRYOCOMP will produce properties for 60 different solids including copper, stainless steels, and aluminum. Properties include: specific heat, thermal conductivity, and electrical resistivity. Mechanical properties are not covered. The properties are generally calculated between 1 K and 300 K. METALPAK is similar to CRYOCOMP except that it calculates properties for 14 metals. More details about these program may be found at <http://www.cryodata.com/>

### II Monographs

#### 1. Aluminum

- a) Cryogenic Properties : Aluminum and Aluminum alloys : (January 1970-October 1988) : citations from the Engineering Index Database, National Technical Information Service (1988).
- b) Corruccini, R.J., Electrical Properties of Aluminum for Cryogenic Electromagnets, National Bureau of Standards, (1964).
- c) Inouye, F.T., Properties of Large 7079 Aluminum Alloy Forgings in a Cryogenic Environment, National Aeronautics and Space Administration (1966).
- d) Kaufman, J.G., Properties of Aluminum Alloys: Tensile, Creep, and Fatigue Data at High and Low Temperatures, ASM International (1999).
- e) Ko, H-C; Stuve, J.M.; Brown, R.R., Low-Temperature Heat Capacities and Enthalpy of Formation of Aluminum Sulfide (Al<sub>2</sub>S<sub>3</sub>), Dept. of the Interior, Bureau of Mines (1976).
- f) Passell, L., The Thermal Conductivity of Aluminum at Low Temperatures. (1955).
- g) Reed, R.P., Aluminum Alloys for ALS Cryogenic Tanks : Comparative Measurements of Cryogenic, Mechanical Properties of Al-Li Alloys and

Alloy 2219, Edwards Air Force Base, CA, Phillips Laboratory, Propulsion Directorate, Air Force Systems Command (1991).

- h) Simon, N.J.; Drexler, E.S.; Reed, R.P., Review of Cryogenic Mechanical and Thermal Properties of Al-Li Alloys and Alloy 2219, NISTIR 3971, National Institute of Standards and Technology, Boulder, Colorado (1991).
- i) Stuve, J.M.; Ferrante, M.J., Low-Temperature Heat Capacity and High-Temperature Enthalpy of TiA13, U.S. Bureau of Mines (1974).

## 2 Stainless Steel

- a) Calfo, F.D., Cryogenic Fracture Properties of Thin AISI 301 60-percent cold-reduced sheet at various angles to the rolling direction, National Aeronautics and Space Administration (1969).
- b) Iyer, S.H., A Review of Steel Properties at Low Temperatures, Montreal: Transportation Development Centre, (1980).
- c) International Nickel Limited, Materials for Cryogenic Service: Engineering Properties of Austenitic Stainless Steels, International Nickel Limited, (1974).
- d) Nachtigall, A.J.; Klima, S.J.; Freche, J.C., Fatigue of liquid rocket engine Metals at Cryogenic Temperatures to -452 F (4 K), Clearinghouse for Federal Scientific and Technical Information (1967).
- e) Reed, R.P., Study of cryogenic storage tank fatigue life: low temperature mechanical testing of AISI 304 and 310 stainless steels, U.S. National Bureau of Standards (1971).
- f) Reed, R.P. and Horiuchi, T. (eds.), Austenitic Steels at Low Temperature, Proceedings of the International Cryogenic Materials Conference, Kobe, Japan, 1982; Plenum Press, New York (1983).

## 3 Copper

- a. Beyer, R.P.; Ko, H-C., Low-Temperature Heat Capacities and Enthalpy of Formation of Copper Difluoride (CuF<sub>2</sub>), Dept. of the Interior, Bureau of Mines (1978).
- b. Ferrante, M.J., Low-Temperature Heat Capacities and High-Temperature Enthalpies of Cuprous and Cupric Sulfides, Dept. of the Interior, Bureau of Mines (1978).
- c. King, E.G.; Kelley, K.K., Low-Temperature Heat Capacities of Copper Ferrites (with a summary of entropies at 298.15 K. of Spinel Minerals), U.S. Dept. of the Interior, Bureau of Mines (1959).
- d. Reed, R.P. and Mikesell, R.P. (eds.), Compilation of Low Temperature Mechanical Properties of Copper and Selected Copper Alloys, NSB Monograph 101, National Bureau of Standards (1967).
- e. Simon, N.J., Cryogenic Properties of Copper and Copper Alloys.
- f. C17000-C17510 Tensile Properties: preliminary draft/VII. NIST, Fracture and Deformation Div. (1988).

- g. Simon, N.J.; Drexler, E.S.; Reed, R.P., Properties of Copper and Copper Alloys at Cryogenic Temperatures, NIST Monograph 177, National Institute of Standards and Technology, Boulder, Colorado (1992).
- h. Stuve, J.M.; Richardson, D.W.; King, E.G., Low-Temperature Heat Capacities and Enthalpy of Formation of Copper Oxysulfate, U.S. Dept of the Interior, Bureau of Mines (1975).

#### 4 Lead

- a. Vyrostek, T.A., Thermal conductivity of Pb-alloys and aspects of superconductivity, Kent (1971).
- b. Weller, W.W.; Kelley, K.K., Low-temperature heat capacities and entropies at 298.150 K of lead molybdate and lead tungstate, U.S. Dept. of the Interior, Bureau of Mines (1964).

#### 5. Polymers

- a. Hartwig, G., Polymer Properties at Room and Cryogenic Temperatures, Plenum Press (1994)
- b. Perepechko, I.I., Low Temperature Properties of Polymers, Pergamon Press, (1980).
- c. Serafini, T.T.; Koenig, J.L. Cryogenic Properties of Polymers, M. Dekker (1968)

#### 6. Composite Materials

- a. Tensile and Shear Properties of Crossply Carbon Fibre Reinforced Plastics at Cryogenic Temperatures, (1997)
- b. Clark, A.F.; Reed, R.P., Nonmetallic Materials and Composites at Low Temperatures, Plenum Press, (1979).
- c. Hartwig, G.; Evans, D., Nonmetallic Materials and Composites at Low Temperatures 2, Plenum Press, (1982).
- d. Hartwig, G.; Evans, D., Nonmetallic Materials and Composites at Low Temperatures 3, Plenum Press, (1986).
- e. Reed, R.P., Golda, M., “ Properties of Cold-to-Warm Support Straps”, *Cryogenics*, Vol. 38, 39-42 (1998)
- f. Reed, R.P., Golda, M., “Cryogenic Composite Supports: A Review of Strap & Strut Properties”, *Cryogenics*, Vol. 37, 233-250 (1997)
- g. Reed, R.P., Golda, M., “ Cryogenic Properties of Unidirectional Composites”, *Cryogenics*, Vol. 34, 909-928 (1994)
- h. Singhal, S.N.; Johnes, W.F., Mechanics of Composites at Elevated and Cryogenic Temperatures, American Society of Mechanical Engineers, (1991).
- i. Young, W.C., Bibliography of References: Mechanical and Electrical Properties, Specific Heat, Thermal Expansion of Epoxy and Epoxy Composites at Cryogenic Temperatures, Cryogenic Data Center, (1976).

This is a guide to finding properties of materials at cryogenic temperatures. Over the last 50 years, a large amount of material properties at cryogenic temperatures have been measured and published. For the working engineer or scientist, the problem is frequently not that the desired material property is unknown at cryogenic temperatures but that it is unclear where to find the published data. The goal of this document is to make the properties easier to find. There are 2 caveats to this guide. The first is that it is not meant to be completely exhaustive. Many useful references for cryogenic material properties may be found in this database. The database permits searches by keyword, title, author and year among others. The citation listing is updated on a regular basis. This paper presents property data and information describing the various cryogenic applications for nonmetallic materials. Until very recently, this classification of materials was usually ignored for structural applications at cryogenic temperatures. Basically, there are three reasons for the reluctance of designers to use this family of materials. First, there were essentially no cryogenic mechanical and physical property data available. I want to research various the properties of various materials, namely tensile strength at cryogenic temperatures (~20K). I was wondering if a freely available database of material properties exists. temperature material-science. Share. Asking for help, clarification, or responding to other answers. Making statements based on opinion; back them up with references or personal experience. Use MathJax to format equations. MathJax reference. To learn more, see our tips on writing great answers. Draft saved. Cryogenic Application Guide. Quality flow control products paired with expert advice. ©2018 Rego. Globe valves gate valves check valves relief valves high pressure valves needle valves diverters regulators manifolds cylinder equipment. Quality materials, innovative, long-lasting design and operational excellence are built into every product we manufacture. That is how we can offer a 10-year product warranty—double that of other companies. Designed, manufactured and 100% tested in the USA. APPLICATION. Liquid cryogenic delivery systems. The key to fast freezing and fresher foods. Chilling, freezing, preservation and carbonation are just some of the ways cryogenic gases help preserve and transport foods and beverages.