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A BIBLIOGRAPHY OF THE  
THERMOPHYSICAL PROPERTIES OF OXYGEN  
AT LOW TEMPERATURES

BY J. C. HUST, L. D. WALLACE, J. A. CRIM,  
L. A. HALL, AND R. B. STEWART



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U. S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS

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February 1962

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A BIBLIOGRAPHY OF THE THERMOPHYSICAL PROPERTIES  
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ABSTRACT

This bibliography of the mechanical, thermodynamic and transport properties of oxygen below 0°C presents 325 references and is the result of a thorough search of the world's scientific and engineering literature. In addition to searching abstracting journals and bibliographies, the authors reviewed each document for property data and for additional references. Listed for each reference are the properties and the corresponding temperature and pressure range, together with additional pertinent information such as the type of data (i.e., whether the data are derived from experimental measurements, theoretical considerations or as a compilation from other sources), the form and amount of data, etc. An index according to property, sub-indexed for temperature and pressure ranges, and an author index are included.

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\* This bibliography is a result of a study made under contract with the National Aeronautics and Space Administration by the Cryogenic Data Center of the Cryogenic Engineering Laboratory.

## 1. INTRODUCTION

This bibliography presents the results of a search of the world's scientific and engineering literature for the mechanical, thermodynamic, and transport properties of oxygen at low temperatures. While the primary objective was to catalog the literature for the properties of oxygen at cryogenic temperatures, references including information on properties up to 0°C were included. A list of references was first compiled from the abstracting journals and bibliographies (See Section 3. below). Following this review, copies of the documents were procured and the bibliography and other references cited in each document surveyed. Copies of additional documents pertaining to this subject were in turn obtained and inspected for inclusion in this bibliography and also for additional references. In addition to this rather comprehensive coverage of the open literature, citations of company reports and other corporate publications containing information on the properties of oxygen at low temperatures have also been included whenever copies of these documents could be obtained. All pertinent literature reviewed has been listed with no attempt made to evaluate the documents.

The citations have been arranged alphabetically and numbered; the alphabetical sequence has been maintained by assigning to late additions the number of the preceding item followed by an A, B, etc. Following each citation in the bibliography, there is a listing of the properties of oxygen presented in the document together with the temperature and pressure range for which the properties are given. The form of data is indicated, and for tabular material the number of values are reported. From the information listed for each citation, the property index together with a sub-index for temperature and pressure ranges were prepared with a computer program. It should be particularly noted that the remarks on the contents of each document pertain only to the information available on oxygen.

During the time this bibliography was being compiled, the Cryogenic Data Center prepared a digital computer system for bibliography retrieval and completed the coding for the system of the Data Center's bibliography file for properties of fluids. The Data Center made an automated search for the properties of oxygen as the manuscript for this bibliography was being finished and, as a consequence, forty-nine more references were added.

## 2. FORMAT FOR LISTING CITATION AND CONTENT OF DOCUMENTS

The general form for the listing of references is: (1) author, (2) title of the document and (3) publication citation. Abbreviations of the journal names for the listing of references are in agreement with Chemical Abstracts (Chemical Abstracts Service, Ohio State University, Columbus 10, Ohio). Titles of articles published in other than the English language are listed in the original languages of the documents followed by the English translation of the titles, except for a few articles in languages with other than the Roman alphabet, where only the English translation is given.



The documents were coded and the following information listed for each citation:

- a. The properties of oxygen that are included in the documents together with the temperature and pressure range. (The temperature and pressure range follows the list of properties to which it pertains.)\*
- b. The fluids for which property data were included in a document are listed if these fluids are not identified in the title of the paper. This notation is omitted for articles containing information on oxygen only.
- c. The type of data is noted, i.e. whether the data are derived from experimental measurements, theoretical considerations or as a compilation from other sources. The type of data is also indicated in the property index following each citation number by the letters E, T, C, which identifies that citation as (E) experimental, (T) theoretical, and/or (C) compilation.
- d. The form of the data is noted following the type of data together with the amount of tabular data, i.e., tables (number of tabular values), graphs, and/or equations.
- e. The notation apparatus refers to a pictorial or narrative description of apparatus in the document.
- f. The source of data for those documents designated as compilations is referenced by the source document number in this bibliography.
- g. The original language of the publication is noted if it was other than English. In addition, if translations are known to be available for foreign language documents, that information is also given.
- h. Documents that came to our attention too late for copies to be obtained were coded from the abstract only and are so indicated on the last line of the document description.

### 3. ABSTRACTING JOURNALS AND BIBLIOGRAPHIES SEARCHED

The search for references to literature containing information on the thermophysical properties of oxygen was made in the following areas:

- a. Chemical Abstracts, Vol. 19 through 54, (Nov. 13, 1925 through July 10, 1960).
- b. Engineering Index, (1918 through 1959).
- c. ASME Seventy-Seven Year Index, Technical Papers, (1880 through 1956). Index of ASME Transactions, No. 78 through 81, (1956 through 1959).

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\* Most reference books and handbooks were generally coded for property only and no temperature range or pressure range was included with the properties listed. In addition, the temperature and pressure ranges were also omitted on references to state points such as triple point, normal boiling point, critical point, etc. In many cases the pressures and occasionally the temperatures were not given in the document reference. This is most often the case for properties near atmospheric pressure that are essentially temperature dependent only.

- d. Index of the Journal of the American Rocket Society, Vol. 26 through 30, (1956 through 1960).
- e. Retrieval Guide to Thermophysical Properties Research Literature, Y. S. Touloukian, Thermophysical Properties Research Center, Purdue University, Lafayette, Indiana.
- f. Bibliographies and references cited in each document listed in this bibliography.

#### 4. ACKNOWLEDGEMENTS

The literature search for this bibliography has been pursued in part by each of the authors. The original search was started in June 1960, and was not concluded until the manuscript was completed. In addition to the authors listed, the entire staff of the Cryogenic Data Center have contributed by their constant alertness for documents pertinent to this bibliography. In particular, the authors wish to acknowledge the following contributions: Dr. F. E. E. Germann for reviewing and coding all documents written in French or German and for translations of the titles of these papers; Robert Smith for completing his computer retrieval system for the Cryogenic Data Center's bibliography in time to check the completeness of our literature survey; Mrs. Billie Green and Mrs. Jo Ann Kirby for reviewing the bibliography citations; and V. J. Johnson for his many suggestions and criticisms as the search progressed and for review of the final manuscript.

## 5. INDEX OF PROPERTIES

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The letters E, T, C following each citation number refer to the type of data, i.e., E = experimental, T = theoretical and C = compilation. The letters A, B, etc. immediately following the citation number are a part of that number and have been used for late additions to maintain the alphabetical arrangement of the bibliography (documents are arranged alphabetically by first author).

Most reference books and handbooks were coded by property only and were not sub-indexed for temperature and pressure ranges. These reference works are indicated by an (\*) following the citation number instead of the E, T, C coding. Other documents which have not been sub-indexed for either or both the temperature and pressure ranges for all or a part of the data are indicated by a (+) following the citation number in addition to the E, T, C code.

PROPERTY INDEX

1. PRESSURE - TEMPERATURE - VOLUME (OR DENSITY) DATA, COMPRESSIBILITY FACTOR

12 E	13 E	15+T	15ATC	16AT	19BTC	30 TC	31 *	32 TC	33 C
38AE	40+C	42AE	42BE	44 ET	46 E	55 TC	66+T	72+E	73 E
78+TC	79+C	80+C	83+T	84+T	85 TC	92A+C	92B+E	93 E	96 *
104 *	107 E	108 E	108AC	112 E	115 *	120 ET	121+E	123 C	124 T
131A+E	132+E	137BE	137C+T	145 C	148 E	150 E	151 C	152 C	154 ET
155B+C	156 E	157A+C	158+T	163 E	166 TC	171 E	174+EC	178+E	181A+C
183+TC	186 *	187 TC	194AT	195 T	196+	197 E	198+E	199 T	213 E
220 *	231 *	233 T							

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

42BE 44 ET 155B+C 178+E

ABOVE 50 TO 155 K

19BTC	30 TC	32 TC	33 C	38AE	42AE	42BE	44 ET	46 E	73 E
84+T	85 TC	92B+E	93 E	107 E	108AC	112 E	120 ET	123 C	124 T
131A+E	132+E	137BE	145 C	148 E	150 E	151 C	152 C	155B+C	156 E
157A+C	171 E	174+EC	178+E	187 TC	194AT	197 E	198+E	199 T	213 E
233 T									

ABOVE 155 TO 250 K

15ATC	16AT	19BTC	32 TC	33 C	55 TC	84+T	85 TC	107 E	108 E
108AC	120 ET	124 T	137C+T	145 C	151 C	152 C	154 ET	155B+C	156 E
163 E	166 TC	195 T	233 T						

ABOVE 250 K

12 E	13 E	15ATC	16AT	19BTC	32 TC	33 C	55 TC	72+E	84+T
85 TC	107 E	108 E	108AC	120 ET	124 T	145 C	151 C	152 C	154 ET
155B+C	166 TC	181A+C	195 T	233 T					

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

12 E	13 E	15ATC	16AT	19BTC	30 TC	38AE	42AE	42BE	44 ET
46 E	55 TC	73 E	85 TC	93 E	107 E	108 E	108AC	112 E	123 C
124 T	145 C	150 E	151 C	152 C	154 ET	155B+C	157A+C	171 E	181A+C
187 TC	195 T	197 E	198+E	199 T	213 E	233 T			

ABOVE 1 TO 10 ATM.

15ATC	16AT	19BTC	32 TC	42AE	55 TC	73 E	85 TC	93 E	108AC
123 C	124 T	145 C	150 E	151 C	152 C	156 E	187 TC	195 T	197 E
198+E	199 T	213 E							

ABOVE 10 TO 50 ATM.

16AT	19BTC	32 TC	33 C	42AE	55 TC	73 E	85 TC	108AC	120 ET
123 C	124 T	137BE	145 C	148 E	150 E	151 C	152 C	163 E	166 TC
187 TC	194AT	195 T	197 E	198+E	199 T	213 E			

ABOVE 50 ATM.

16AT	19BTC	32 TC	33 C	42AE	55 TC	85 TC	108AC	120 ET	124 T
137BE	145 C	151 C	152 C	163 E	166 TC	187 TC	195 T	197 E	199 T
213 E									

PROPERTY INDEX (CONT.)

2. EQUATION OF STATE, VIRIAL COEFFICIENTS

14+T	15+T	15ATC	16 ET	16AT	29 E	32 TC	33 C	38B+T	53 T
54 T	57+TC	80+C	83+T	83A+TC	84+T	85+TC	96 *	100+C	102+T
103+T	104 *	108AC	110+ET	120 ET	137C+T	151 C	158+T	177+TC	195 T
199 T	202B+ET	204A+E	211 E	214+T	233 T				

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K  
214+T

ABOVE 50 TO 155 K

16 ET	29 E	32 TC	33 C	53 T	83A+TC	84+T	85+TC	100+C	108AC
120 ET	151 C	177+TC	199 T	202B+ET	204A+E	211 E	214+T	233 T	

ABOVE 155 TO 250 K

15ATC	16AT	29 E	32 TC	33 C	54 T	83A+TC	84+T	85+TC	100+C
108AC	120 ET	137C+T	151 C	177+TC	195 T	214+T	233 T		

ABOVE 250 K

15ATC	16AT	29 E	32 TC	33 C	54 T	83A+TC	84+T	85+TC	100+C
108AC	120 ET	151 C	177+TC	195 T	233 T				

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

15ATC	16AT	108AC	151 C	195 T	199 T	211 E	233 T		
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ABOVE 1 TO 10 ATM.

15ATC	16AT	108AC	151 C	195 T	199 T				
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ABOVE 10 TO 50 ATM.

16 ET	16AT	29 E	33 C	53 T	108AC	120 ET	151 C	195 T	199 T
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ABOVE 50 ATM.

16AT	33 C	53 T	54 T	108AC	120 ET	151 C	195 T	199 T	
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PROPERTY INDEX (CONT.)

3. COEFFICIENT OF EXPANSION, COMPRESSIBILITY

30 TC 53 T 54 T 56+T 80+C 83+T 107 E 130+T 131 TC 141 E  
 142 E 186 \* 199 T 207 E 213 E 220 \* 233 T

SUB-INDEX BY TEMPERATURE RANGE

ABOVE 50 TO 155 K

30 TC 53 T 107 E 131 TC 141 E 142 E 199 T 207 E 213 E 233 T

ABOVE 155 TO 250 K

54 T 107 E 233 T

ABOVE 250 K

54 T 107 E 233 T

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

30 TC 107 E 131 TC 141 E 142 E 199 T 207 E 213 E 233 T

ABOVE 1 TO 10 ATM.

141 E 199 T 213 E

ABOVE 10 TO 50 ATM.

53 T 199 T 213 E

ABOVE 50 ATM.

53 T 54 T 199 T 213 E

PROPERTY INDEX (CONT.)

4. SPECIFIC HEAT (HEAT CAPACITY) AT CONSTANT PRESSURE, VOLUME, OR SATURATION;  
SPECIFIC HEAT RATIOS

18 ET	19 E	21+TC	30 TC	33 C	34 E	40+C	57+TC	59 E	61 E
62+C	66+T	75 ET	77 T	78 TC	81 T	83+T	85 TC	92A+C	96 *
97 TC	104 *	106+E	110+ET	115 *	118 T	127+C	134+T	136 E	137 E
139 T	142 E	145 C	147 C	149 E	152 C	155B+C	158+T	176 *	180A+E
181A+C	182 T	184 E	186 *	202+T	202B+ET	204A+E	211 E	213AE	214+T
218 E	219 C	220 *	231 *	232 T	233 T				

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

19 E	34 E	61 E	75 ET	118 T	134+T	136 E	137 E	155B+C	182 T
219 C									

ABOVE 50 TO 155 K

18 ET	19 E	21+TC	30 TC	33 C	34 E	59 E	61 E	75 ET	77 T
78 TC	81 T	85 TC	97 TC	106+E	118 T	127+C	134+T	139 T	142 E
145 C	147 C	149 E	152 C	155B+C	180A+E	182 T	184 E	202+T	202B+ET
211 E	214+T	219 C	232 T	233 T					

ABOVE 155 TO 250 K

21+TC	33 C	59 E	77 T	78 TC	81 T	85 TC	97 TC	106+E	118 T
127+C	134+T	145 C	147 C	152 C	155B+C	182 T	184 E	213AE	218 E
219 C	232 T	233 T							

ABOVE 250 K

21+TC	33 C	59 E	77 T	78 TC	81 T	85 TC	97 TC	118 T	127+C
134+T	145 C	147 C	152 C	155B+C	182 T	184 E	213AE	218 E	219 C
232 T	233 T								

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

18 ET	19 E	30 TC	34 E	59 E	61 E	75 ET	77 T	81 T	85 TC
97 TC	118 T	136 E	137 E	142 E	145 C	147 C	149 E	152 C	182 T
184 E	204A+E	211 E	213AE	214+T	218 E	219 C	232 T	233 T	

ABOVE 1 TO 10 ATM.

78 TC	85 TC	97 TC	145 C	149 E	152 C	213AE			
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ABOVE 10 TO 50 ATM.

33 C	78 TC	85 TC	97 TC	139 T	145 C	149 E	152 C	213AE	
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ABOVE 50 ATM.

33 C	85 TC	97 TC	145 C	152 C	213AE				
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PROPERTY INDEX (CONT.)

5. VELOCITY OF SOUND

10 E	18 ET	32 TC	33 C	38AE	41A+ET	70+E	85 TC	96 *	104 *
110 ET	126 E	130+T	131 TC	139 T	141 E	142 E	146A+TC	158+T	169 E
186 *	193 *	205+C	206+E	207 E	209 E	209AE	210 E	210AE	211 E
213 E	213AE	215A+	231 *	233 T					

SUB-INDEX BY TEMPERATURE RANGE

ABOVE 50 TO 155 K

10 E	18 ET	32 TC	33 C	38AE	41A+ET	70+E	85 TC	126 E	131 TC
139 T	141 E	142 E	146A+TC	169 E	205+C	206+E	207 E	209 E	210 E
210AE	211 E	213 E	233 T						

ABOVE 155 TO 250 K

32 TC	33 C	38AE	85 TC	110 ET	126 E	169 E	209 E	209AE	213AE
233 T									

ABOVE 250 K

33 C	38AE	85 TC	110 ET	126 E	169 E	209 E	213AE	233 T	
------	------	-------	--------	-------	-------	-------	-------	-------	--

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

10 E	18 ET	32 TC	38AE	85 TC	110 ET	126 E	131 TC	141 E	142 E
169 E	207 E	209 E	209AE	210AE	211 E	213 E	213AE	233 T	

ABOVE 1 TO 10 ATM.

85 TC	141 E	210 E	213 E	213AE					
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ABOVE 10 TO 50 ATM.

33 C	85 TC	139 T	210 E	213 E	213AE				
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ABOVE 50 ATM.

33 C	85 TC	210 E	213 E	213AE					
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PROPERTY INDEX (CONT.)

6. VAPOR PRESSURE, SATURATED DENSITIES, MELTING POINTS

2 E	5 ET	5AE	5BT	8 E	9 E	16 ET	17 ET	19AET	23 E
23AE	24 C	28 E	33AE	48 E	50 E	51 E	52 E	58 ET	62+C
62A+E	62B+E	62CE	62D+E	65 E	66+T	73 E	76 E	80+C	83+T
90+E	91 E	92 E	92A+C	96 *	98+T	104 *	105 C	106 E	109 C
111 E	111A+E	112AE	113 E	115 *	119A+T	123 C	125 C	126AE	133 C
137AE	137BE	138 T	144 E	145 C	150 E	150A+EC	152 C	153 E	155B+C
159 E	160 E	161 E	162 E	170 E	180A+E	180BE	180CEC	181A+C	185+T
185AE	186 *	189+E	190 E	193 *	194 E	202A+E	219AE	220 *	221 E
231 *	235 E								

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

5 ET

ABOVE 50 TO 155 K

2 E	5 ET	5AE	5BT	8 E	9 E	16 ET	17 ET	19AET	23 E
23AE	24 C	28 E	33AE	48 E	50 E	51 E	52 E	58 ET	62A+E
62B+E	62CE	62D+E	65 E	73 E	76 E	90+E	91 E	92 E	105 C
106 E	109 C	111 E	111A+E	112AE	113 E	123 C	125 C	126AE	133 C
137AE	137BE	138 T	144 E	145 C	150 E	150A+EC	152 C	153 E	155B+C
59 E	160 E	161 E	162 E	170 E	1Y0A+E	180BE	180CEC	185AE	189+E
190 E	194 E	202A+E	219AE	221 E	235 E				

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

2 E	5 ET	5AE	5BT	8 E	9 E	17 ET	19AET	23 E	23AE
24 C	28 E	33AE	48 E	50 E	51 E	52 E	58 ET	65 E	73 E
76 E	90+E	91 E	92 E	105 C	106 E	109 C	111 E	112AE	113 E
123 C	125 C	126AE	133 C	138 T	145 C	150 E	152 C	153 E	155B+C
159 E	160 E	161 E	170 E	180BE	180CEC	185AE	190 E	194 E	

ABOVE 1 TO 10 ATM.

5BT	19AET	24 C	33AE	48 E	50 E	51 E	62CE	73 E	105 C
106 E	125 C	126AE	133 C	137AE	138 T	145 C	150 E	152 C	153 E
155B+C	160 E	162 E	180CEC	194 E	219AE	221 E			

ABOVE 10 TO 50 ATM.

16 ET	24 C	50 E	51 E	73 E	105 C	106 E	125 C	126AE	133 C
137AE	137BE	138 T	144 E	145 C	150 E	152 C	153 E	155B+C	162 E
235 E									

ABOVE 50 ATM.

125 C	126AE	137BE	144 E	153 E
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PROPERTY INDEX (CONT.)

7. BOILING POINT (NORMAL)

4 E	6 E	7 E	28 E	40+C	56+T	75 ET	78 TC	79 C	80+C
90+E	91 E	92 E	92A+C	94 ET	95 E	106 E	111B+E	148A+C	153AE
155B+C	159 E	160 E	165AE	170 E	181A+C	186 *	203 C	204 C	220 *

8. MELTING POINT (NORMAL)

40+C	61 E	75 ET	78 TC	79 C	92A+C	112 E	118A+T	125 C	126AE
144 E	153 E	155B+C	161 E	172 T	181A+C	186 *	220 *		

9. TRIPLE POINT

5 ET	45 E	80+C	83+T	92 E	98+T	106 E	119 C	123 C	144 E
148A+C	155B+C	186 *	220 *						

10. CRITICAL POINT

16 ET	19BTC	26 E	27 E	33 C	38+C	40+C	43 E	80+C	83+T
92A+C	104 *	106 E	123 C	139 T	140+TC	145 C	148 E	148A+C	150 E
155B+C	158+T	159 E	162 E	166 TC	168 C	181A+C	186 *	234 E	235 E

11. TRANSITION POINTS

5 ET	75 ET	113 E	186 *	220 *
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PROPERTY INDEX (CONT.)

12. PHASE TRANSITION HEATS, LATENT HEATS

1 E	2 E	11 E	16 ET	31 *	33 C	34+E	35 E	39 ET	40+C
42 T	47 E	61 E	62+C	65 E	66+T	67 E	75+ET	78+TC	92A+C
115 *	122A+T	123+C	132A+E	138 T	145 C	149 E	152 C	155B+C	157A+C
175BE	176 *	181A+C	186 *	225 E					

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

34+E    42 T    61 E

ABOVE 50 TO 155 K

1 E	2 E	11 E	16 ET	33 C	35 E	39 ET	47 E	65 E	67 E
122A+T	132A+E	138 T	145 C	149 E	152 C	155B+C	157A+C	175BE	225 E

ABOVE 155 TO 250 K

33 C    145 C    152 C

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

1 E	2 E	11 E	35 E	39 ET	42 T	47 E	61 E	65 E	67 E
138 T	145 C	149 E	152 C	155B+C	157A+C	225 E			

ABOVE 1 TO 10 ATM.

1 E    138 T    145 C    149 E    152 C    155B+C    175BE

ABOVE 10 TO 50 ATM.

16 ET    33 C    138 T    145 C    149 E    152 C    155B+C    175BE

PROPERTY INDEX (CONT.)

13. ENTROPY, ENTHALPY, GIBBS FUNCTION, HELMHOLTZ FUNCTION

37 T	40+C	62+C	66+T	74+T	75 ET	77 T	78 TC	79 C	83+T
85 TC	96 *	104 *	115 *	118 T	120 ET	124 T	132A+E	134+T	137AE
145 C	152 C	155A+C	157A+C	175BE	176 *	182 T	186 *	192 T	219 C
226 T	231 *	233 T							

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

75 ET 118 T 134+T 134+T 155A+C 182 T 219 C 226 T

ABOVE 50 TO 155 K

37 T 75 ET 77 T 78 TC 79 C 85 TC 118 T 120 ET 124 T 132A+E  
 134+T 134+T 137AE 145 C 152 C 155A+C 157A+C 175BE 182 T 192 T  
 219 C 226 T 233 T

ABOVE 155 TO 250 K

77 T 78 TC 79 C 85 TC 118 T 120 ET 124 T 134+T 134+T 145 C  
 152 C 157A+C 182 T 219 C 226 T 233 T

ABOVE 250 K

77 T 78 TC 79 C 85 TC 118 T 120 ET 124 T 134+T 134+T 145 C  
 152 C 157A+C 182 T 219 C 226 T 233 T

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

37 T 75 ET 77 T 79 C 85 TC 118 T 124 T 145 C 152 C 155A+C  
 182 T 192 T 219 C 226 T 233 T

ABOVE 1 TO 10 ATM.

78 TC 85 TC 124 T 137AE 145 C 152 C 155A+C

ABOVE 10 TO 50 ATM.

78 TC 85 TC 120 ET 124 T 137AE 145 C 152 C 175BE

ABOVE 50 ATM.

85 TC 120 ET 124 T 145 C 152 C

PROPERTY INDEX (CONT.)

14. THERMAL CONDUCTIVITY, HEAT TRANSFER COEFFICIENTS

3+E	21+TC	25 E	31 *	40+C	41+C	60 E	63 E	64 E	68 E
78 TC	81 T	86 E	87 E	88 E	88AE	89+C	92A+C	96 *	97 TC
99+T	100+C	101+TC	102+T	104 *	115 *	116 E	127+C	128+C	129 E
135+T	143 *	146A+TC	155 E	155B+C	158A+C	173 E	181+C	181A+C	183 TC
186 *	200 C	201 E	220 *	231 *	236 E	237 E	59 E		

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

135+T

ABOVE 50 TO 155 K

3+E	21+TC	25 E	41+C	60 E	63 E	64 E	68 E	78 TC	81 T
86 E	87 E	88 E	88AE	97 TC	100+C	116 E	127+C	128+C	129 E
135+T	146A+TC	155 E	173 E	181+C	181A+C	183 TC	200 C	201 E	236 E
237 E	59 E								

ABOVE 155 TO 250 K

3+E	21+TC	25 E	41+C	60 E	63 E	64 E	68 E	78 TC	81 T
86 E	97 TC	100+C	116 E	127+C	128+C	129 E	135+T	183 TC	200 C
201 E	236 E	237 E	59 E						

ABOVE 250 K

3+E	21+TC	41+C	60 E	63 E	64 E	68 E	78 TC	81 T	86 E
97 TC	100+C	116 E	127+C	128+C	129 E	135+T	155B+C	183 TC	200 C
201 E	59 E								

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

25 E	60 E	63 E	64 E	81 T	86 E	87 E	88 E	88AE	97 TC
116 E	129 E	155 E	155B+C	173 E	183 TC	200 C	201 E	236 E	237 E
59 E									

ABOVE 1 TO 10 ATM.

25 E	64 E	78 TC	86 E	88AE	129 E	155 E	183 TC	200 C	201 E
236 E	237 E								

ABOVE 10 TO 50 ATM.

25 E	64 E	78 TC	86 E	155 E	183 TC	200 C	201 E	236 E	237 E
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ABOVE 50 ATM.

25 E	64 E	68 E	155 E	183 TC	200 C	201 E	236 E	237 E
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PROPERTY INDEX (CONT.)

15. VISCOSITY

3+E	21+TC	22 T	36+T	38+C	40+C	56+T	59 E	62EET	69 E
71 E	78 TC	81 T	89+C	92A+C	96 *	97 TC	100+C	101+TC	102+T
104 *	112 E	114+	117 E	127+C	128+C	135+T	140+TC	143 *	146A+TC
155B+C	157 T	165 C	177+TC	178+E	179 E	180 E	181A+C	182 T	186 *
191 T	204B E	208 E	212+E	215+E	216 EC	217 E	220 *	222+TC	223 T
231 *									

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

135+T 157 T 178+E 182 T

ABOVE 50 TO 155 K

3+E	21+TC	22 T	59 E	62EET	69 E	71 E	78 TC	81 T	97 TC
100+C	101+TC	112 E	117 E	127+C	128+C	135+T	140+TC	146A+TC	155B+C
157 T	177+TC	178+E	179 E	180 E	182 T	191 T	204B E	208 E	212+E
215+E	216 EC	217 E	222+TC	223 T					

ABOVE 155 TO 250 K

3+E	21+TC	22 T	59 E	62EET	71 E	78 TC	81 T	97 TC	100+C
101+TC	117 E	127+C	128+C	135+T	140+TC	155B+C	165 C	177+TC	182 T
191 T	204B E	208 E	216 EC	217 E	222+TC	223 T			

ABOVE 250 K

3+E	21+TC	22 T	59 E	62EET	71 E	78 TC	81 T	97 TC	100+C
101+TC	117 E	127+C	128+C	135+T	140+TC	155B+C	165 C	177+TC	181A+C
182 T	191 T	204B E	208 E	216 EC	217 E	222+TC	223 T		

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

22 T	59 E	62EET	69 E	71 E	81 T	97 TC	112 E	117 E	157 T
165 C	179 E	180 E	181A+C	182 T	191 T	204B E	208 E	216 EC	217 E
223 T									

ABOVE 1 TO 10 ATM.

22 T 78 TC 97 TC 204B E

ABOVE 10 TO 50 ATM.

22 T 78 TC 97 TC

ABOVE 50 ATM.

22 T 97 TC

PROPERTY INDEX (CONT.)

16. PRANDTL NUMBER

21+TC 37 T 59+E 96 \* 99 T 127+C 231 \*

SUB-INDEX BY TEMPERATURE RANGE

ABOVE 50 TO 155 K

21+TC 37 T 127+C

ABOVE 155 TO 250 K

21+TC 99 T 127+C

ABOVE 250 K

21+TC 99 T 127+C

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

37 T 99 T

17. SURFACE TENSION

5AE 9 E 82 E 83+T 92A+C 92B+E 112 E 122A+T 174+EC

SUB-INDEX BY TEMPERATURE RANGE

ABOVE 50 TO 155 K

5AE 9 E 82 E 92B+E 112 E 122A+T 174+EC

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

5AE 9 E 82 E 112 E

ABOVE 1 TO 10 ATM.

5AE

PROPERTY INDEX (CONT.)

18. ABSORPTION AND ADSORPTION

109AE 125AE

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K  
125AE

ABOVE 155 TO 250 K  
109AE

ABOVE 250 K  
109AE

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.  
109AE 125AE

19. DIFFUSION COEFFICIENTS

3+E 99 T 100+C 102+T 143 \* 146+T 177+TC 182 T 224 E

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K  
182 T

ABOVE 50 TO 155 K  
3+E 100+C 146+T 177+TC 182 T 224 E

ABOVE 155 TO 250 K  
3+E 99 T 100+C 146+T 177+TC 182 T 224 E

ABOVE 250 K  
3+E 99 T 100+C 146+T 177+TC 182 T 224 E

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.  
99 T 182 T 224 E



PROPERTY INDEX (CONT.)

20. PROPERTIES FOR BINARY AND TERNARY SYSTEMS INCLUDING OXYGEN

5AE	16AT	17 ET	19AET	23 E	23AE	33AE	39 ET	48 E	49+E
51 E	62A+E	62B+E	62CE	62D+E	82 E	83A+TC	87 E	88AE	92A+C
92B+E	111 E	111A+E	111B+E	112AE	131A+E	132+E	132A+E	137AE	138 T
150A+EC	171 E	172A+E	174+EC	180A+E	180BE	180CEC	185AE	188 E	193 *
202A+E	204A+E	210 E	219AE	221 E					

SUB-INDEX BY TEMPERATURE RANGE

0 TO 50 K

172A+E

ABOVE 50 TO 155 K

5AE	17 ET	19AET	23 E	23AE	33AE	39 ET	48 E	51 E	62A+E
62B+E	62CE	62D+E	82 E	83A+TC	87 E	88AE	92B+E	111 E	111A+E
112AE	131A+E	132+E	132A+E	137AE	138 T	150A+EC	171 E	172A+E	174+EC
180A+E	180BE	180CEC	185AE	188 E	202A+E	210 E	219AE	221 E	

ABOVE 155 TO 250 K

16AT 83A+TC

ABOVE 250 K

16AT 83A+TC

SUB-INDEX BY PRESSURE RANGE

0 TO 1 ATM.

5AE	16AT	17 ET	19AET	23 E	23AE	33AE	39 ET	48 E	51 E
82 E	87 E	88AE	111 E	112AE	138 T	171 E	180BE	180CEC	185AE
188 E	204A+E								

ABOVE 1 TO 10 ATM.

5AE	16AT	19AET	33AE	48 E	51 E	62CE	88AE	137AE	138 T
180CEC	210 E	219AE	221 E						

ABOVE 10 TO 50 ATM.

16AT 51 E 137AE 138 T 210 E

ABOVE 50 ATM.

16AT 210 E

PROPERTY INDEX (CONT.)

21. JOULE-THOMSON COEFFICIENTS, JOULE COEFFICIENTS

20 E 102+T 103+T 120 ET 123+C 139 T

SUB-INDEX BY TEMPERATURE RANGE

ABOVE 50 TO 155 K

20 E 120 ET 139 T

ABOVE 155 TO 250 K

20 E 120 ET

ABOVE 250 K

120 ET

SUB-INDEX BY PRESSURE RANGE

ABOVE 1 TO 10 ATM.

20 E

ABOVE 10 TO 50 ATM.

120 ET 139 T

ABOVE 50 ATM.

120 ET

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- HEAT CAPACITY (SPECIFIC HEAT)(P=CONSTANT), ENTROPY, FREE ENERGIES (GIBBS FUNCTION) (0 TO 5000 DEGREES K AND 1 ATM.)  
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- 125 KEESOM, W.H. AND LISMAN, J.H.C.  
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AND 0.01 TO 46 ATM.), CRITICAL CONSTANTS  
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J. RESEARCH NATL. BUR. STANDARDS VOL.40, 457-66 (1948)

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- 152 MILLAR, R.W. AND SULLIVAN, J.D.  
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- 153 MILLS, R.L. AND GRILLY, E.R.  
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88 P. UNIVERSITY MICROFILMS, ANN ARBOR, MICH.
- BOILING POINT (NORMAL)  
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- 154 MOLES, E. AND SALAZAR, M.T.  
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XXXIII. ISOTHERMS OF OXYGEN BETWEEN -40 AND -152.5 DEGREES C  
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- 58A NUTTALL, R.L.  
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- 160 ONNES, H.K. AND BRAAK, C.  
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- 167 PERRIER, A. AND ONNES, H.K.  
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ULTRASONIC FREQUENCIES  
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- 200 TSEDERBERG, N.V.  
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- 202A TSIN, N.M.  
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## NOTES



## THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

### WASHINGTON, D.C.

**Electricity.** Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

**Metrology.** Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

**Heat.** Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

**Radiation Physics.** X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

**Analytical and Inorganic Chemistry.** Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research.

**Mechanics.** Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

**Organic and Fibrous Materials.** Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

**Metallurgy.** Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics. Electrolysis and Metal Deposition.

**Mineral Products.** Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

**Building Research.** Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

**Applied Mathematics.** Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

**Data Processing Systems.** Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

**Atomic Physics.** Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

**Instrumentation.** Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

**Physical Chemistry.** Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

### BOULDER, COLO.

**Cryogenic Engineering.** Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

**Ionosphere Research and Propagation.** Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

**Radio Propagation Engineering.** Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

**Radio Standards.** High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

**Radio Systems.** Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

**Upper Atmosphere and Space Physics.** Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

