under the supervision of William S. Benedict. The available data on thermal conductivities of gases have been evaluated and tabulated by Ralph L. Nuttall, and some viscosity data have been furnished by Francis C. Morey.

Several experimental investigations for the determination of thermal data are in progress in the Heat and Power Division of the NBS. Among these are measurements of the heat capacities C_p, of carbon dioxide, water vapor, and freon 12 by Joseph F. Masi; measurements of thermal conductivities at high pressures and temperatures, by Ralph L. Nuttall; and measurements of vapor pressures by the author. Some of these investigations were undertaken simultaneously with the project for the compilation of data, to fill in gaps where data were urgently needed.

As a preliminary step in the compilation of the tables a card file of over 1000 references was prepared, primarily by a search of Chemical Abstracts back to 1926, but also by consulting survey articles and reports such as the group of papers on gas properties published by this Society.[5] This file of references is gradually being processed as the tables are prepared, and in proportion as the references are read and evaluated, the file becomes more and more valuable. It is planned to maintain this file not only to promote the preparation of the tables, but also to aid in answering inquiries for thermodynamic data. The NBS receives a large number of such inquiries each year. These are welcomed, for it is one of the functions of this Bureau to supply or indicate sources of scientific information when these are known to members of its staff. Letters of inquiry are very useful to us as an aid in planning our future program.

Plans for the Future

In the immediate future we expect to devote a large part of our effort to the tabulation of real gas properties. Ideal gas tables have been more readily available and our progress with them has been more rapid, but the properties of the real gases are necessary for accurate calculations. In addition to the tables, we plan to prepare charts and diagrams such as Mollier charts and entropy-temperature diagrams that will be more convenient than tables for problems where graphic accuracy is adequate. When most of the data in the field of the project have been tabulated, emphasis will be placed on filling in the gaps with new experimental work, and on revising tables that are out of date. We know already that there will be more gaps than filled places in our outline, and we hope that much new experimental work will be undertaken.

The most urgent needs for new data appear to be in the fields of high temperature and high pressure. Measurements are especially needed of heat capacities and thermal conductivities. A few of these are under way at NBS but much more work is needed.

In several instances unpublished work or work in process of publication has been brought to our attention, and this has been extremely helpful to us. Communications of work in progress will be welcomed by any member of our group. If sufficient information becomes available the project will, if requested, act as a clearing house for information on work in progress in various laboratories. Those who have suggestions or comments concerning the tables, or who wish to obtain copies, should write to Joseph Hilsenrath, Thermodynamics Section, NBS, who is in charge of the project. At present the tables are being issued without charge.

Discussion

J. A. Goff.[6] It is gratifying to note from the paper that excellent progress is being made at the National Bureau of Standards with the preparation of working tables and diagrams of the properties of technically important gases. This is an essential part of any really comprehensive program of gas-properties research and as such is of particular interest to the ASME Gas Properties Committee. Of no less interest to the committee are the Bureau's offer to act as a clearing house for information on work in progress in various laboratories and its plan to maintain a relatively complete file of gas-properties references. These are tasks that the committee hardly can hope to do itself in view of the difficulty it has encountered in obtaining financial support. The NBS-NACA Tables of Thermal Properties of Gases project, which the author describes, is sure to reveal serious gaps in existing knowledge regarding gas properties, and in so doing will render a valuable service.

Although the Bureau claims not to have placed extreme emphasis on accuracy in the present stage of its program, it is obvious that it has exercised great care in the selection and appraisal of the data it has so far tabulated. At the same time, its selection of units in terms of which to express the data seems ill-advised. Its claim that convenience in use is gained by selecting R as the unit of entropy and RT_0 as that of energy is difficult to allow. It is true of course that the probable error of the ratio $c_p°/R$, for example, is slightly less than that of $c_p°$ itself, but this has nothing to do with convenience. In the opinion of the discusser, tables of $c_p°$ itself with suitable conversion factors would have been a good deal more convenient and only very slightly less accurate than tables of $c_p°/R$ with suitable conversion factors.

The writer also wonders why the Bureau proposes to tabulate the specific-heat ratio c_p/c_v since this cannot be substituted for k in the familiar expressions $pv^k = \text{const}$, and $a^2 = kgpv$, for the isentropes and the acoustic velocity, respectively, of a perfect gas with constant specific heats, to determine the isentropes and acoustic velocity of an actual gas with variable specific heats. There is considerable confusion on this point which tables of c_p/c_v would only serve to perpetuate.

In the auxiliary tables of conversion factors the symbol "cal" is understood to designate the thermochemical calorie which has recently been redefined as equal to 4.184 absolute joules exactly. The Btu referred to in these auxiliary tables is defined in terms of this calorie by the conversion factor 0.99934 Btu·g·°C/cal·lb·deg F. It is unfortunate that the simple numeric unity, has been lost in the struggle for individuality; perhaps something can yet be done to restore it.

C. N. Warfield.[7] The compilation of thermal properties of wind-tunnel and jet-engine gases as described in the paper is a valuable contribution in that it presents the results of an extensive search for existing data and makes available to the engineer and scientist in convenient form what appears at the present time to be the best available values. The NBS staff is to be commended especially for the convenient form in which these data are made available, and for the expeditious manner in which the results have been released.

An examination of the 16 tables that are listed in the paper gives rise to comments on a number of specific topics as follows:

Nomenclature. Neither symbols, subscripts, nor superscripts are defined in the tables. A convenient reference, or list of such definitions, would be useful.

Ideal Gas State. A comparison of Table 2.10 with the tables of reference 5 thereto (Curtiss and Hirschfelder, U. Wis. Report, APL No. CM-472) reveals that the values listed for specific heat and for enthalpy correspond to the ideal zero-pressure state,

[5] Symposium on Gas Properties, Trans. ASME, vol. 70, 1948, pp. 621 ff.

[6] Dean, Towne Scientific School, University of Pennsylvania, Philadelphia, Pa. Mem. ASME.

[7] Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Md.

whereas the values listed for entropy correspond to a pressure of 1 atm. A statement of this fact would avoid confusion in regard to the use of the entropy values tabulated.

Although Report No. CM-472 is not listed as a reference for Table 11.10, a similar comparison indicates that the values of entropy for molecular nitrogen have been treated as in the case of dry air.

However, in Table 7.10 (for molecular hydrogen), it is conveniently stated that all values are for the "ideal gas state for a pressure of 1 atmosphere."

Thermal Conductivities. Table 2.42 lists values of thermal conductivity of dry air at various temperatures, but fails to give any indication concerning variation with pressure. Presumably the values listed are for a pressure of 1 atm, and a statement to this effect would be helpful. This comment is also applicable to the other tables for thermal conductivity, excepting only Table 5.42 (for steam) in which thermal conductivities are listed for 11 pressures (from 1 atm to 300 atm), as well as for various temperatures.

It is important to call attention at this time to the fact that some of the values listed may not be valid for direct use in those applications involving very rapid changes in pressure, temperature, etc., such as occur in shock waves and possibly in other applications in supersonic aerodynamics. In this connection the NBS tables on relaxation phenomena are awaited with considerable interest.

Author's Closure

Dean Goff raised a question as to the advisability of the choice of dimensionless units. We wish it were possible to find a set of units with dimensions acceptable in all fields where our tables will find use. We are sympathetic with Dean Goff's point of view, but his selection of units would not have universal acceptance. Dimensionless variables were chosen because aerodynamic physicists and engineers, for whom these tables were undertaken, showed a greater preference for them than for any set of dimensional units. This may be so because dimensionless variables and properties are in general use in aerodynamics. From the NBS-NACA tables that are now in dimensionless units, tables in any other units may be prepared with little trouble.

Our conversion factors are so chosen that those who wish to work with calories will obtain values in terms of the thermochemical calorie, while those who prefer Btu's will obtain the kind of Btu that they are accustomed to. We believe that this is the way each group wants it. The thermochemical calorie = 4.1840 abs joules, and the Btu = 1055.040 abs joules. These are independent definitions. In these units, specific heats in calories per gram degree C are nearly, but not exactly, equal to specific heats in Btu per pound degree F. If the I.T. calorie is used, the equality becomes exact. Such a relationship has some advantage, but will probably not induce the users of either the thermochemical calorie or the present Btu to change their accustomed units.

With regard to Dr. Warfield's suggestion that symbols, subscripts, and superscripts be defined, it may be of interest that an introductory table for the series is being prepared. This table is to contain the definitions referred to and also lists of basic constants and conversion factors. Dr. Warfield's other comments are also well taken and we expect to adopt his suggestions in the preparation of future tables.

The careful consideration that the discussers have given to the NBS-NACA tables is much appreciated.