Gordon Research Conferences: Supplemental Information

Colby Junior College

Scientific Information Problems in Research

Illness has effectively taken Ken Zabriskie out of circulation at a crucial time. Consequently, responsibility for the development of the program and the administration of the conference has devolved on an Ad Hoc Committee of past chairmen: Karl F. Heumann, Francois Kertesz, Douglas B. Remsen, and Robert A. Harte, chairman.

13 July. Informal mixer.

14 July (*morning*). Overview of published user studies.

14 July (*evening*). William Paisley, "Criteria of user studies."

15 July (*morning*). Karl F. Heumann, chairman, International non-government organizations. FID: Ralph E. McBurney, president; IFLA: Sir Frank Francis, president; and IFIP: Speaker to be designated.

15 July (*evening*). Harrison Brown, chairman. UNISIST, the Joint ICSU–UNESCO feasibility study for a world system for scientific information. Speakers: Scott Adams and J. Ronald Smith.

16 July (*morning and evening*). Francois Kertesz, chairman. Impact of secondary services' tapes on user patterns. Speakers: Arthur Herschman, Arthur Elias, Gloria Smith, and Robert McRorie.

17 July (*morning*). Bart Holm, chairman. Advances and problems in chemical structure handling.

17 July (*evening*). Douglas B. Remsen, chairman, "The sex syndrome in documentation," Phyllis Parkins and Jeanne Poyen.

18 July. User study desiderata, a panel discussion. Panelists: Mary Herner, Harold Wooster, and Robert A. Harte, moderator.

Interested individuals are encouraged to register through the procedures outlined in the announcement of the Gordon Research Conferences [*Science* **163**, 1085 (1969)]. Correspondence explicitly concerned with the program may be directed to Robert A. Harte, 9650 Rockville Pike, Bethesda, Maryland 20014.

Measurements in the High-Pressure Environment

Physicists and chemists have long had the opportunity to correlate experimental results from different laboratories through use of the International Practical Temperature Scale. The possibility of developing an analogous pressure scale was the theme of an international symposium entitled "Accurate Characterization of the High Pressure Environment," held at the National Bureau of Standards, Gaithersburg, Maryland, 14–18 October 1968.

The symposium was attended by about 140 participants from the United States and abroad. Other countries represented included Canada, England, France, Japan, South Africa, the Soviet Union, Sweden, and West Germany. Thirty-eight papers were presented, and four panel sessions held, covering research at high pressures in static systems and in shock wave experiments.

The tone of the meeting was effectively set by the opening speakers, who emphasized the importance of improved accuracy in measurements at high pressures and in calibrations relevant to such measurements. The point was made that in current work, involving a wide range of phenomena and many types of apparatus, a series of "interlocking" standards is needed.

About one-fourth of the papers dealt with matters relevant to selection of reproducible and reversible reference points on the pressure scale—so-called "fixed points"—indicated by phase changes in selected substances. The importance attached to establishing such agreed-on fixed points was indicated by these papers and the discussions throughout the week. On the final day these matters were considered by an informal committee, and the following outline of the report of this committee and of the ensuing floor discussion summarizes the informal consensus reached.

It was recommended that phase transitions and accompanying pressures shown in Table 1 be used as pressure fixed points. The fixed points recommended represent equilibrium values.

Users are to consider the fixed points as exact. The values of "present estimated uncertainty" are given only to indicate the range within which a value may be expected to shift as a result of improved measurements in the future. The reproducibility of pressures based on these phase changes may be better or poorer than these uncertainties and, in any given case, depends strongly on technique. It is the responsibility of the experimenter to establish reproducibility and hysteresis for his own apparatus and technique, and the relationship between his experimental values and the above equilibrium values.

In addition to the five points listed in Table 1 covering the pressure scale up to 77 kilobars, a consensus was reached that the cesium II to III and III to IV transitions on *increasing pressure* be taken as 42.5 kilobars and 43.0 kilobars, respectively, with a present estimated uncertainty of 1 kilobar, and that the tin I to II transition be tentatively used as a fixed point with an equilibrium transition value of 100 kilobars and a present estimated uncertainty of 6 kilobars.

In addition to the fixed point of 7.569 kilobars at the freezing pressure of mercury at 0°C, the committee favored use of the mercury melting curve to establish other reference pressures up to 15 kilobars, corresponding to the freezing pressure of mercury at about 36.8°C. It recommended that such reference pressures be based on the Simon equation, adjusted to agree with the value 7.569 kilobars at 0°C as follows:

$$P = 38227\left[\left(\frac{T}{234.29}\right)^{1.1772} - 1\right]$$

where T is the temperature in kilobars on the International Practical Temperature Scale (1948), and P is the pressure in bars. Small adjustments in this equation will be needed when the new temperature scale, IPTS 1968, is used.

Several pressure scales derived from equations of state of cubic solids were proposed at the meeting. Both metallic and nonmetallic substances, such as the cesium halides, were considered. Sodium can be treated most accurately from the theoretical viewpoint, but its high chemical reactivity is inconvenient. Aluminum can be treated by quantum mechanical methods if parameters are adjusted to fit some of the observed properties. Both aluminum and copper have been investigated experimentally as

standards in shockwave measurements. These metals also could be used as standards in x-ray measurements.

The new data on copper and aluminum shock standards have been used to reevaluate the equation of state of several other metals that have been used in determination of pressure based on x-ray measurements of lattice constants.

Sodium chloride has been used most often as a reference material in recent applications of x-ray methods for estimating pressure. An informal committee on equation of state standards considered requirements in this application such as high compressibility, low yield strength, chemical stability, availability of accurate data over a wide range of pressure, and other properties. The committee selected sodium chloride first, with copper and aluminum as alternates.

Four evaluations of data relevant to the sodium chloride scale now are available, including two which were presented. In these evaluations differences in reported pressures are less than the combined errors (about 4 percent) at pressures from 25 to 300 kilobars. When these sodium chloride scales are combined with x-ray data on sodium chloride media in which transitions of bismuth and barium have been studied, the computed transition pressures lie within the uncertainties indicated in the table above for barium and for bismuth III to V.

The committee recommended that a single sodium chloride scale be adopted and that it be adjusted to give values of pressure as close as possible to those selected for the fixed points. An average of the two most recent sodium chloride scales would very nearly fulfill these requirements. An exact fit of selected fixed points appears unlikely without arbitrary adjustments in the equation of state. Nevertheless, a provisional sodium chloride scale consistent to within experimental error with the fixed points selected for the region below 100 kilobars is attainable and, if accepted, could be very useful.

The committee suggested more comprehensive theoretical and experimental investigations of the equation of state of cubic solids in order to improve currently available scales. In particular, changes in the vibrational energy states of solids with volume are required in order to obtain accurate theoretical formulations of the equation of state and related properties.

Temperature in high-pressure experiments is normally measured by thermocouples. However, pressure affects the relation between electromotive force and temperature for a thermocouple, provided there is a thermal gradient within the pressurized region. The reality of this effect is readily shown by subjecting two dissimilar thermocouples (such as Pt-Pt 10 percent Rh and chromel-alumel) to the same conditions of high temperature and pressure and monitoring the difference in apparent temperature. In various solid-media apparatus there are differences on the order of 25°C between the apparent temperature simultaneously read by chromel-alumel and Pt-Pt 10 percent Rh couples at 1000°C and 40 kilobars.

Table 1.

Transition	Fixed-point pressure (kilobars)	Present estimated uncertainty (kilobars)
Mercury freezing point at 0°C	7.569	0.002
Bismuth I to II transition at 25°C	25.50	0.06
Thallium I to II transition at 25°C	36.7	0.3
Barium I to II transition at 25°C	55	2
Bismuth III to V transition at 25°C	77	3

Quantitative evaluation of these effects is most difficult. Direct determinations have been made both in internally heated, solid-media apparatus and in externally heated, gas apparatus. The latter results have not thus far been extended to sufficiently high pressures to permit critical comparison with the solid-media results. Indirect methods have utilized a comparison of phase boundaries determined by experiment with boundaries calculated from thermochemical data. Temperatures determined by thermocouples have also been compared with those determined by the thermal noise technique.

All investigators agree that the pressure effect on the chromel-alumel couple is less than ~ 5°C in the range up to 1000°C and 40 kilobars. Unfortunately, this couple is considerably less stable than Pt-Pt 10 percent Rh in high-pressure cells due to chemical contamination and strain effects. All investigators also agree that the effect of pressure on the Pt-Pt 10 percent Rh couple is considerably larger and that the magnitude of the effect increases with both increasing temperature and increasing pressure. Estimates of the pressure correction for this couple range up to 35°C at 1000°C (for a cold seal at 0°C) and 40 kilobars, but there are sizable differences in the results of various investigations in this range.

A conference concerned with the accuracy of pressure and temperature measurement at high pressures must necessarily be concerned with the "nuts and bolts" of high-pressure experimentation. A number of developments in technique were described which considerably extend the range, quality or accuracy of high-pressure measurements.

Liquid cells have been constructed for use in piston-cylinder and multi-anvil apparatus which permit measurements under perfectly hydrostatic conditions to be made at pressures up to 50 kilobars at room temperature. These cells are jacketed with plastic or stainless steel and are filled with liquids or mixtures of liquids such as pentane, isoamyl alcohol, and methanol. Such cells have remarkable mechanical stability and can be cycled over a wide pressure range. Their use eliminates shearing stresses which are inevitably present in systems employing solid pressure media and which in some instances affect the thermodynamic properties of materials under investigation. An analogous technique for high temperatures is to use molten glass as a pressure medium. Experience with molten Pyrex in high pressure cells suggests that thermocouples are more stable in such an environment than with more commonly used ceramic insulation.

Until recently the pressure range of single-stage, piston-cylinder apparatus was limited to approximately 50 kilobars. This limitation was imposed by the crushing strength of unsupported, carbide pistons. However, such pistons will support stresses up to 80 kilobars if the ratio of the unsupported length of the piston to its diameter is kept considerably below 1. Failure along 45-degree shear planes is thus inhibited. A variation of this technique which permits greater stroke is to segment the unsupported length of the piston with binding rings. These binding rings slide back along the piston as they make up on the face of the pressure vessel during the compression stroke.

The possibility of using second-order phase transitions as secondary calibration standards has aroused considerable interest. Second-order transitions proceed without volume discontinuities and theoretically without hysteresis. The change in Curie temperature with pres-

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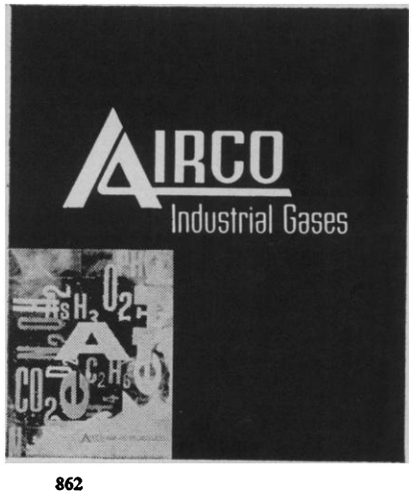

sure is promising in this regard although the effects thus far studied are rather small. For example, the dT/dP slope of the Curie temperature curve for nickel is 0.35°C per kilobar. Other materials, such as ferrites, may show larger effects.

New developments in shockwave research now permit a derivation of the fusion curve (P versus T) of copper extending into the million-bar range. When combined with accurate measurements of temperature and pressure in the static high-pressure range (1100° to 1300°C and 0 to 60 kilobars) the fusion curves of several substances, such as copper, silver, and others, could be used for *in situ* checking of calibrations of high-pressure, high-temperature apparatus. However, in a broader perspective, accurately determined fusion curves may permit solution of some rather fundamental questions in geophysics and astrophysics involving extrapolation of phase diagrams to very high pressure and high temperature.

The kinetics of shockwave processes are being investigated from several viewpoints. These include lattice dynamic models of shocks in solids and experimental investigation of nonequilibrium processes at relatively low shock strengths in many cases. The behavior of shocks in regions of phase changes are especially interesting. The rate at which such changes occur depends upon the types of lattices involved and the orientation of the lattice with respect to the direction of the shock. From the viewpoint of pressure standards, additional studies of the transformation of iron at about 126 kilobars were reported in the meeting. These confirm this fixed point as being the most accurately determined fixed point above 100 kilobars.

The symposium was sponsored by the National Bureau of Standards and the Geophysical Laboratory of the Carnegie Institution of Washington. Expenses were covered by a grant from the National Science Foundation. The papers presented, together with discussion from the floor and summaries of panel sessions, will be published as a Special Publication of the National Bureau of Standards.

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Oceanology

The American Management Association's briefing session, Oceanology—The Challenge to Industry, was held 24–26 February 1969 in New York City. The meeting was attended by 250 persons and addressed by Vice President Spiro Agnew, Senator Clairbone Pell, Rear Admiral O. D. Waters and many other leaders of industry, commerce, government, and the academe.

Its stated purpose was an attempt to supply answers to certain questions concerning the future of oceanology, such as:

1) How much time, planning, and money will the new Administration be willing to commit to oceanology?

2) What is the most effective way to manage the specialized, technical, and personnel functions of oceanic business?

3) What changes is the status of oceanology can we expect to see in the next 5 to 10 years?

4) What is the immediate and long-range profit outlook?

The sessions of 24 February dealt with the current status and immediate outlook for oceanology.

Senator Pell's keynote address presented a general analysis of the report of the Marine Science Commission report. He conceded that few people would agree with it completely in its present form. However, he advocated the two principal thrusts of the report—the need for the establishment of a new independent agency to spearhead the national oceanographic program and the recommendation for a substantial increase in expenditures for the program in the coming decade.

Pell further noted that ocean programs must be justified by "pay-off" rather than "spin-off." Our ocean programs involve roles of government and industry, and government's role in development of technology ends when its programs have established the feasibility of economic "pay-off."

Further presentations concerning the Marine Sciences report were made by Richard Geyer, Charles Baird, and James Crutchfield. They suggested that the concentration of government agencies and effort into a single, powerful, national oceanographic and atmospheric agency (NOAA)—a kind of "wet NASA"—would materially enhance our effectiveness in dealing with oceanography's complex problems.

Vice President Agnew's invitation had come at a time when he was still