Book Reviews

Ternary Alloys

Ternary Alloys—A Comprehensive Compendium of Evaluated Constitutional Data and Phase Diagrams: Volumes 1 and 2, Ternary Silver Alloys. Edited by *G. Petzow* and *G. Effenberg*. Principal reviewer: *H. L. Lukas*. VCH Verlagsgesellschaft, Weinheim, Fed. Rep. Germany/VCH Publishers, New York, N.Y., U.S.A. 1988, Vol. 1, 612 pp. Vol. 2, 624 pp. £ 250 per volume (special arrangements for series subscribers). ISBN 3-527-26941-X and 3-527-26942-8

Metallurgists, like any other kind of scientist, have numerous useful tools of their trade, and a few indispensable ones. Prominent among the indispensable ones are phase diagrams. They are equally necessary to researchers who seek to develop new alloys or improve existing ones, and to producers who seek to optimize the properties of standard alloys by modifications to manufacture or heat-treatment. Modern metallurgy would simply not exist without them.

The first really accurate phase diagram (Cu–Sn) was determined by *Heycock* and *Neville*, two Cambridge chemists, and published in 1904. Only 32 years later, a notable German pioneer, *Max Hansen*, published *Der Aufbau der Zweistofflegierungen:* this reported on the phase constitution of 828 metallic systems and included 456 critically evaluated phase diagrams. After the war, three separate revisions and supplements of this work appeared and other critical compilations of binary phase diagrams were published subsequently. The key word is 'critical': somebody has to make judgements between conflicting data and interpretations. To organize and institutionalize, on a worldwide basis, the heavy task of assembling information, evaluating and reviewing it, an Alloy Phase Diagram International Commission (APDIC) was set up some years ago and a journal, *Bulletin of Alloy Phase Diagrams*, instituted.

One might suppose that the availability of so many binary phase diagrams would satisfy the needs of most metallurgists, but in fact alloys become ever more complex, and many contain at least three major constituents. Ternary diagrams have, therefore, become increasingly important in recent years, and many have been evaluated for, and published in, the *Bulletin*. In its last issue an editorial tells the reader that up to now, 635 binary systems have already been evaluated and published in the journal, its Indian sister journal, or in books, and over 400 more are in progress. In December 1988, the *Bulletin* informed the reader, 606 ternary systems had also been evaluated and published, and 408 had been evaluated but not yet published. As a proportion of possible ternary systems (bearing in mind that more than half of the elements are metals) this is still only a very small proportion, but it must be borne in mind that the effort involved in determining a ternary system is much greater than for a binary. (The great English metallurgist *R. S. Bradley*, for instance, spent over a decade of single-minded labor around the middle of the century on the determination of the Al-Fe-Ni diagram alone).

The ca. 2000 binary and ternary phase diagrams now reasonably well established (many others have only been cursorily surveyed) are a truly tiny fraction of the possible total. Figure 1 (note the logarithmic ordinate scale) was published recently by one of the editors, *G. Petzow*, of the volumes under review. Allowing for 100 elements (including a few transuranics) the number of possible 50-element systems exceeds by a large margin the age of the universe in seconds.

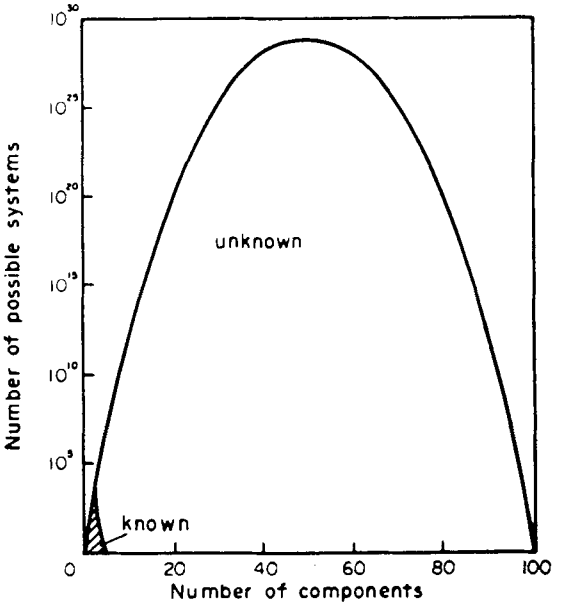

Fig. 1. Numbers of known and unknown heterogeneous systems.

Fortunately, 50ary phase diagrams run into such formidable problems of determination, evaluation and depiction that we can comfortably forget about them; even quaternary and quinary systems, which are occasionally published, are hard to determine and harder to understand when published. What really matters to practitioners is the availability of numerous reliable and conveniently available ternary systems. The new series on which the German evaluators and the publishers have now courageously embarked clearly will fulfil this need.

The two volumes under review incorporate critically evaluated data for 446 ternary systems containing silver, critically updated to January 1988 and based on over 1900 publications of experimental work, taken from the huge database maintained at the Max-Planck-Institut für Metallforschung in Stuttgart, with German Government support. Though

the calculation of phase diagrams from thermochemical data has made great strides recently, this apporach is apparently not yet being used for these volumes, because of the very high standards of accuracy which are being adopted and because of the difficulty in securing adequately precise 'optimization' for the three constituent binaries of each ternary system, which is a prerequisite for ternary calculations. For many though not all of the 446 systems, ternary diagrams are included; evaluated binary diagrams are also included where these are not readily available in one of the standard volumes of binaries already published.

Each system is the responsibility of an individual evaluator, 20 of whom contributed to these two volumes and although half of these 20 are German, many nationalities are represented. Each evaluation was then critically reviewed by one of a small band of reviewers. This has become universal practice in all assessments of ternary diagrams under the broad aegis of APDIC as the present volumes are. The reviewers and the original evaluators, if need be, met to resolve their differences at one of the numerous editorial conferences held at a specially provided rural idyll.

The task of producing volumes like these is truly daunting, quite apart from the successive levels of evaluation and reviewing to which all the work is subject. Finding the original publications (many in exceedingly obscure periodicals); assessing their reliability; turning the diagrams into standard format; finding and assembling crystallographic information about the phases (structure types and lattice parameters are cited); creating isothermal and 'vertical' sections; in particular, drawing up the involved 'reaction schemes' for the more complex ternary systems which have become de rigueur for serious depictions of ternary diagrams, to render them more intelligible; computer-based creation of final drawings and checking of the final printed form... all this has called for a very large team of participants both in Stuttgart, elsewhere, and at the publishers a very long term commitment to a colossal task, as well as generous Government funding without which, the (admittedly) high price of the volumes would have gone right through the roof.

The stated objective of the series is to have so much information not just cited but presented in the volumes, that most users will never need to got to the original literature. In this reviewer's opinion, that objective has been achieved.

The next set of volumes, three in number, on ternaries containing aluminum, is at an advanced state of preparation and is due to be published this year. It should be noted that as the series progresses, the task will become gradually less onerous. This can be appreciated by noting that the two "Ag" volumes incorporate 28 Ag-Al-X systems, and none of these 28 need be repeated in the "Al" volumes. This 'reduction effect' will become more pronounced as successive volumes are published.

There have been other compilations of ternary phase diagrams in book form. First one should point out a book entitled *Phase Diagrams for Ceramists*, published by the American Ceramic Society originally in 1964. This contains information on many binary, ternary, quaternary and even a few quinary systems of ceramics. The ceramists are entirely separate from the APDIC organization. (There are no compilations of phase diagrams of polymers, and indeed very few such diagrams exist. The concept of phase equilibria is only making slow headway in the polymer world, though both theorists and experimentalists are now working extensively on the concept of miscibility and separation of phases in 'polymer blends').

India has played a large part in the international metallurgical effort, and many evaluations have originated there; *Raghavan* in Delhi has published three volumes on Fe ternaries (the latest has just appeared) with one more to come. Even so, the four Indian volumes only scratch the surface of the enormous range of Fe ternaries! In America, a Cu-O-X volume is expected to appear soon (again, clearly, a small subset of Cu ternaries) while in Britain, as a result of work initiated years ago by that prince of evaluators, the late *Geoffrey Raynor*, a volume of Au ternaries is expected to be published soon by the Institute of Metals. The editor of this is *Alan Prince*, who is now the doyen of British evaluators and has played a substantial part in the two Ag volumes under review here. When the Stuttgart team gets to Au, which should not be long in view of its position in the alphabet, arrangements will undoubtedly be made to make full use of the British work, to avoid needless duplication, but presumably the information in the British volume will all be included in the VCH series, which is intended to be as comprehensive as is humanly possible.

It is entirely appropriate that the massive international effort which has created this first fruit, the silver volumes, should be centered in Stuttgart. Many of the early phase diagrams were determined by the German pioneer, *Gustav Tammann*. Germany has long had an indigenous tradition of high-class metallography, including a training program for metallographers which has no equal; metallography (and the ability to judge critically the results of metallographic investigations) is an essential constituent of phase diagram determination and evaluation. *Max Hansen*, the father of phase diagram evaluation, worked at the Stuttgart Institute, and as the editors of the silver volume indicate in their preface, they are seeking to create a sort of '*ternary Hansen*'. In this ambitious task, to judge from its first fruit, they have triumphantly succeeded, and the publishers also deserve every credit for their courage and long-term commitment in bringing this venture to the public.

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