A Scientist's Appraisal of Laboratory Records or 'Tribophysics in Transition

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This article is based on an invited paper presented to the 'Seminar on the Archives of Science and Technology in Australia' held at the University of NSW in September 1985.

The relocation of a substantial Commonwealth Scientific and Industrial Research Organization (CSIRO) establishment at a new laboratory complex presented many problems associated with the proper management and/or disposal of a quantity of scientific objects and raw data as well as laboratory and administrative records. The types of records and objects encountered and appraisal/disposal problems faced are discussed.

Introduction

After many years as a practising experimental scientist I recently found myself to be the wearer of three hats because of an obligation to play three distinct roles: firstly as a creator of scientific records and artifacts, secondly as an apprentice archivist of such records in all their wide variety, and thirdly as a student within the history and philosophy of science area attempting to use such records in the writing of a history of my laboratory.

Before discussing the problems associated with operating within each of these areas I should like to present a brief history of the CSIR/CSIRO Tribophysics Laboratory, dealing in the main with its first ten years of operation. With my third hat on I will naturally illustrate this story with a number of artifacts, some of which might be seen as only peripheral to the actual creation of scientific data. Such material which may be found in the most unexpected places amongst, say, administrative office files, demands careful attention from the archivist during its appraisal. Gems of information are often turned up which may fill in the gaps in an otherwise incomplete story.

The single event which had brought matters to a head was the imminent physical relocation of a laboratory including its staff, apparatus, library, stores, and records (both scientific and administrative) to a distant site. In this case the CSIRO Division of Materials Science had to transfer from its 'Tribophysics Laboratory', built specifically for it some 35 years earlier on Melbourne University Campus to a new site over 30 km away. A proper appraisal of the records and objects that had accumulated over the years was essential in order that unwanted and unnecessary items be eliminated from the great bulk of material awaiting removal. The problems associated with this appraisal are raised in this paper.

A Brief History of the Laboratory

(a) The Origins

The present CSIRO Division of Materials Science came into being on 1st January 1940 as the Section of Lubricants and Bearings. Some four years earlier the Australian Government had decided that its national laboratory - The Council for Scientific and Industrial Research (CSIR) - should extend its activities to secondary industry problems in addition to the already addressed primary industry ones. 'Aircraft and Engine Testing and Research' was foremost amongst the secondary problems of concern. However, Australia at that time had little expertise on the production and maintenance of aircraft bearings or, for that matter, on lubrication and friction in general. Thus should Australia be involved in the war which, by the mid to late 1930's, seemed inevitable, the development of an aircraft industry might present serious problems. As some counter to this, CSIR had already in 1938 established its own Aeronautical Research Laboratory.

In mid 1939 Dr. Frank Philip Bowden, a Tasmanian and at that time a Cambridge don and renowned expert on friction and lubrication, was visiting Australia. Following the outbreak of World War II in September of that year, the realisation that the traditional provision of strategic materials and especially of industrial assistance and 'knowhow' from overseas could be severly curtailed was instrumental in the acceptance of Bowden's offer to assist the Australian Government and, in particular, the newly emerging aircraft industry. Following intensive negotiations between Government, industry and the University of Melbourne, Bowden was appointed to take charge of CSIR researches into lubricants and bearings as from the 1st November, 1939. His brief was to investigate the production and maintenance of aircraft bearings and associated friction and lubrication problems. He was provided with accommodation and some funding by the University of Melbourne and with basic funding by CSIR. Within four years he had built his staff to well over thirty which occupied a substantial part of the newly completed Chemistry Department at Melbourne University.

(b) War Time Programme

Bowden would seem to epitomise the Cambridge tradition of experimental science because of his ability to attack complex problems by means of simple and elegant experiments. But Bowden needed equipment and his entrepreneurial skills showed out in his swift utilisation of Melbourne University Engineering Schools' drafting and machine shop facilities as well as in his considerable ability to 'borrow' instruments from any sources (see Fig. 1). It must be remembered that at this stage Bowden had no immediate support staff.

Form A.S. 11.
TRIPLICATE.

COMMONWEALTH OF AUSTRALIA.

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH.

TRANSFER VOUCHER.

T.V. 361

Approval is requested to transfer the undermentioned Stores from Radio Research Investigations, Melbourne University.

to Dr. F.P. Bowden, Oil Investigations, Melbourne University.

Method of Despatch .... Actual / Anticipated Date of Despatch ....

Postal Address of Transferor is ....

Item.	No. or Quantity.	Marks or Nos.	Ent., Card No.
√ Class 651 AE High-speed Moving-Film Camera assembly, complete with adjustable focus lens, and	1x		1153
3 phase Motors, 50 cycle, 230 volts, codeword "DINER"	2x		1955 1981
√ "Variac", 200-CMH Auto Transformer	1x		~~1182~~ 1882
(S.V. 13586)			

Signature of Transferor C. P. B. Nickson *Signature of Transferee* F. P. Bowden

Date 22 : IV : 40. *Date* 22.4.40

Issued originally to Transferor, *vide* .... of ....

APPROVED— [signature]

Secretary. 19/4/40

N.B.—This triplicate is to be retained by the **Transferee.**

C.14485.

Fig. 1 CSIR Transfer Voucher No. T.V. 361 illustrating the origin of equipment required urgently for the 'War Effort'.

The original work of the new laboratory involved the testing and improving of lubricating oils, the development of bearing materials, and the production and surface finish of aircraft bearings. The investigations into friction led to studies of extremely rapid transient phenomena and, in turn, to the measurement of the muzzle velocity of projectiles by a photoelectric method. Another wartime problem tackled was the safe handling of explosives and the prevention of accidents during their manufacture and subsequent handling. This gave rise to investigations into the mechanism of the detonation of liquid and gelatinous explosives by impact and friction.

This war-time laboratory issued a number of reports of work completed in the areas described above, and such reports detailed fully the various techniques and experimental equipment involved. For example, details of an annexe for the pilot production of aircraft bearings for the Royal Australian Air Force established in 1941 in the basement of the old Chemistry School at Melbourne University are illustrated in one of the war-time research reports.[1] Central to the friction and lubrication work was the so-called 'Stick-Slip Machine' developed by Bowden and Leben several years earlier in Cambridge. This apparatus (see Fig. 2) enabled the coefficient of friction between moving solids in contact to be measured, and, together with a 'wear' machine and a polishing lap for the preparation of very flat standard surfaces[2], was constructed in the Engineering Workshops at Melbourne University.

(c) *Records and Artifacts Produced*

Even the relatively short war-time period produced a great amount of material of a wide variety. Records of the initial negotiations in the setting up of the laboratory were followed by domestic records relating to the day-to-day operations. These ranged from requisitions for supplies, through leave forms to annual financial estimates.

The experimental work led to internal reports of completed work (the first of these in April, 1940, and the total to reach 161 major plus 38 minor reports over a period of some nine years), occasional papers in the CSIR Journal, CSIR Bulletins, and, despite wartime restrictions, papers in overseas scientific journals. And finally there was the continuing series of annual reports beginning in 1940.

Additional to these formal records were details of particular pieces of equipment in the form of the engineering drawings and blue prints required for their construction and, later, documents relating to their disposal such as 'strike off' or 'transfer' vouchers. Unfortunately, in most cases very little remains of the equipment essential to this war work of over 40 years ago, the apparatus having suffered the fate of either destruction, cannibalism or transfer. What has survived, however, is a quantity of experimental observations in the form of photographic negatives and prints as well as specimens and laboratory notebooks. The wide variety in

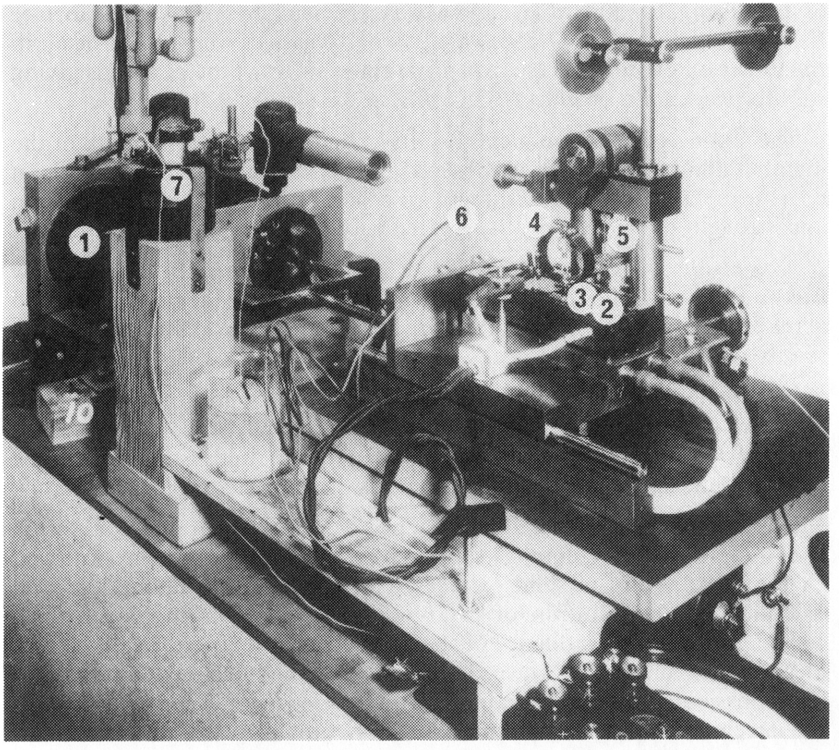

Fig 2. General view of the Bowden-Leben apparatus for measuring friction between sliding surfaces. [Bowden, F.P. and Leben, L. *Proceedings of the Royal Society* A 169 (1939) 371.]

1. cylinders and pistons for driving lower surface; 2. lower surface; 3. hemispherical upper slider; 4. arm for supporting upper surface and spring for applying load; 5. bifilar support for friction arm; 6. thermocouple for measuring surface temperatures; 7. mirror galvanometer for recording surface temperatures on film camera.

the nature of such artifacts makes it difficult to set out strict rules on appraisal and preservation, and, in addition one must consider the actual physical storage space involved as well as the knowledge that the observations enshrined in the 'raw data' have been in most instances worked over to produce the subsequent internal report or scientific paper. One should add to this that the data would have resulted from 'contrived' experiments and would thus have achieved a status of reproducibility.

(d) *Post War Research*

The end of World War II in 1945 brought about a change in leadership of the laboratory. Dr. Philip Bowden returned to his post at the University of Cambridge and in due course was replaced by one of his former Cambridge colleagues, Dr. Stewart Bastow. Changes were also to occur in the direction of various research programmes - war time demands giving way to peace time objectives.

The sliding of metal on metal results in deformation of the bulk of the metal in addition to the more obvious surface damage. Thus the work on bearing metals and wear led directly to general studies on the deformation and strength of metals and the influence of various heat treatments.

As a result of his earlier experiences in the oil industry Stewart Bastow was to initiate studies on the use of various chemical agents which could actually facilitate the deformation of metals and even reduce the energy required in the drilling of rocks.

War time studies of the initiation and propagation of explosives reactions gave way to research into the oxidation of hydrocarbons - studies directed (among other things) towards a better understanding of the oxidative deterioration of lubricating oils.

From the beginning there had been within the Laboratory's research programme a strong emphasis placed on elucidating the physical and chemical properties of solid surfaces. This tradition was maintained and extended by the addition of catalytic studies. These emerged from a consideration of the influence of the detailed atomic structure and degree of perfection of metal surfaces on the manner in which various chemical reactions could take place in contact with such surfaces. Figure 3 illustrates the development of programmes from war time to peace time.

In 1946 the Lubricants and Bearings Section was renamed Tribophysics and in 1948 raised to Divisional status. A laboratory building to house the Division was constructed on Melbourne University Campus and opened officially in 1953 by the Hon. R.G. Casey who, as Minister in Charge of CSIR in 1939, had played a crucial role in the setting up of the original Section. This is the laboratory we have recently vacated.

In 1949, following the appointment of Dr. Bastow to the Executive of the newly constituted CSIRO, Dr. Walter Boas, a leading authority on crystal plasticity and the deformation of metals, was appointed as Chief of Division of Tribophysics. This led to an expansion of studies into the influence on plastic deformation of crystal lattice imperfections, slip, and work hardening. These were complemented by studies of the effects of the departure from ideality of crystal surfaces on interfacial processes such as heterogeneous catalysis and adsorption.

Leaving aside the many ensuing changes in the organisation and structure of the Division and its research programmes, it is sufficient to add that 'Tribophysics' was renamed 'Materials Science' in 1978 and that, as already mentioned, the Division in mid 1985 moved into a new laboratory complex at Clayton, adjacent to Monash University.

The 'tidying up' in preparation for and during such a move has presented many of the problems referred to in this paper.

The Problems

In order to simplify a description of the problems I have had to face in the recent evacuation of our Melbourne University premises I should like to establish three levels of material and artifacts that I have encountered. These are:

(i) the specimens involved as well as the equipment and instruments used together with related documents on construction or acquisition and operation;

(ii) the 'raw' data in the form of numerical, symbolic and graphic records; and

(iii) the whole hierarchy of laboratory notes, internal reports, conference and/or published papers and in some instances monographs. Additional to these would be the periodic summarised reports on all work in progress within the laboratory and finally the ubiquitous annual/biennial Research Reports.

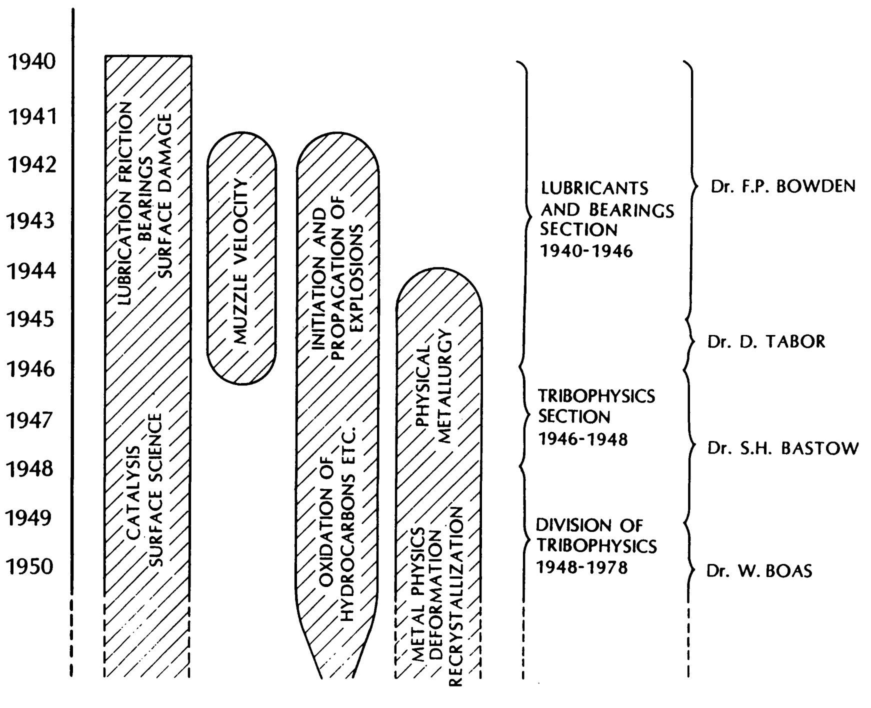

Fig. 3 Change in research and development programmes from war time to peace time.

This classification could be reduced simply to

(i) the hardware;

(ii) the raw data; and

(iii) the written/printed word.

I propose to deal only with some of the more important examples within each category.

(i) THE HARDWARE

(a) Friction Studies - The Stick Slip Machine

On his appointment in 1939 Bowden's first task was to arrange for drawings to be prepared for the construction of the Bowden-Leben 'Stick Slip' friction machine (Fig. 2). The blue prints exist to this day so that, should the necessity arise, a replica could be produced. An original machine was soon put together and this involved the acquisition of auxiliary gear such as galvanometer lamps, thermocouples and millivoltmeters for temperature measurement, an hydraulic system for moving the specimens as well as a moving film camera to record the friction traces and the temperature.

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Form A.S. 12
DUPLICATE

S.O. 4154

STRIKE-OFF VOUCHER

Approval is requested to strike-off charge the undermentioned, for the reasons shown :—

Original Voucher No.	Item	Qty. or No.	Marks or Nos.	Cost	Value	Reason	Entd. Card No.
CV264	Stick Slip Machine No.2.	1x	2009	£252/11/3	£252/11/3	Sent to England.	
CV263	Fall Hammer with spare arm	1x	2019	£30/12/3	£30/12/3	Sent to England.	

Correspondence No. Signature of officer seeking approval R. Muncey.

Stock Sheet No. Division, Station, or Section Lubricants & Bearings.

Approved [signature] Secretary. 4 7 1945

Approved Executive Committee Meeting No. / 19 Date 25th. June, 1945

N.B. This Duplicate is to be forwarded to Head Office with the Original. When approved it will be returned to the Division where it should be filed.

Fig. 4. CSIR Strike-off Voucher No. S.O. 4154 showing the destination of several pieces of scientific equipment.

Without some prior knowledge of the major role this machine played in the initial research programme of the Lubricants and Bearings Laboratory, some tidy-minded draughtsman clearing out his cabinets might well have tossed the blue prints and drawings into the waste bin.

There were at least two friction machines produced for the laboratory; the first of these was taken back to Cambridge University following Philip Bowden's return there in 1945 to set up a Lubricants and Bearings - type laboratory (The Physics and Chemistry of Rubbing Solids) within the Department of Physical Chemistry at Cambridge University. The Strike-Off Voucher No. S.O. 4154 (see Fig. 4) attests to this. The second machine was transferred in 1968 to the Defence Standards Laboratories at Maribyrnong, Victoria, and some six years later retransferred back to CSIRO. Its present location is uncertain.

With the machines have gone the specimen metal plates and sliders each made from metals specific to the task in hand. Thus the surfaces varied from everyday steel to an exotic metal such as platinum; and some sliders had even been rendered radioactive for purposes of measuring minute quantities of material transferred during the rubbing process.

Reference again to Fig. 4 reveals that an item 'Fall Hammer...' was also sent to England. This refers to one of the pieces of equipment constructed for work on the detonation of explosives referred to earlier. This simple equipment is described in many of the war-time reports of the laboratory and an illustration can even be found in Mellor's examination of the role of science and technology during World War II[3].

(b) Atomic Structures of Surfaces - Ball Models

Throughout the history of the laboratory a basic approach has prevailed in which extensive use has been made of a graphic representation of the particulate or atomic nature of solids and their surfaces. Thus matter could be represented as a pile of balls - each representing the position and extent of an atom. The building of such models has required a detailed geometric description of the relative positions of atoms within crystals, and the overall result was that any surface of a solid could be fully characterised merely by building the correct model and putting the atoms (in our case either ball bearings of the appropriate sizes - or even ping pong balls) in the correct positions (see Fig. 5).

Such models have proven of great value in explanations of differences in the chemical, physical, or electronic behaviour of surfaces where wide differences in the closeness of packing of atoms on the outermost layer exist for such crystal surfaces.

What has remained of the hardware are templates or boxes on or in which the base plane for the model can be formed. In addition there remain great quantities of ball bearings of all sizes and colours to represent the atoms of the different elements or those of different coordination. As this 'hardware' represents building blocks for possible on-going work there is no problem regarding its retention.

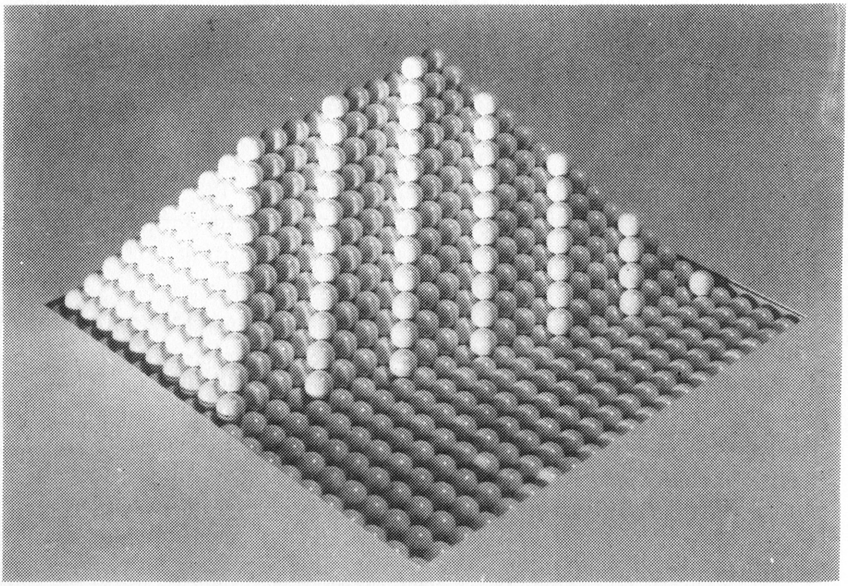

Fig. 5. Ball-model of complex and simple crystal lattice planes. The principal (complex) plane shown has the indices (221) in the face-centred cubic system, the model being based on (100) layers.

(c) Field Ion Microscopy

Some twenty years ago our continuing interest in the nature of the surfaces of materials and, in particular, the atomic arrangement found at metal surfaces led us to construct a special type of microscope with a magnification of the order of one million times and hence the capacity to image individual surface atoms. I must confess to a certain bias in my view of the artifacts that remain inasmuch as I was closely associated with the project which was subsequently to be closed down.

We are now left with something like five generations of 'field ion' microscopes, all designed and constructed in the Division and all of which could be put into working order by the provision of readily obtainable vacuum pumps and sundry power supplies. The alternatives to finding them useful places in other laboratories where they could be resurrected would be to transfer them to technological or science museums or to disassemble them completely. A lack of success in convincing local tertiary institutes to use the instruments as a teaching or research facility has left us with an unsolved problem.

(ii) THE RAW DATA

In our major studies of the physical and chemical properties of solids and their surfaces, extensive use of the photographic technique has produced a large number of images on glass plates, films and even bromide paper. Unfortunately much of the early photographic material has disappeared. This loss would have occurred around 1952 during the shifting of the Division from a collection of army huts to the newly constructed Tribophysics Laboratory on Melbourne University Campus.

What have survived are several collections of glass negatives (1/4 plate) showing optical micrographs of the damage to metals during sliding friction, and the 'ridged' surfaces of silver specimens produced by a process known as thermal etching. As these are complete with laboratory notebooks there is (from an archival point of view) some argument that they be retained. Being of a limited size such collections do not - at least for the moment - present a storage problem. The glass plates associated with the friction and wear experiments have an 'irreproducible' aura about them inasmuch as the original friction machine on which they were produced is at present not available. The same could be said for the surviving 60 rolls of bromide paper showing the 'stick-slip' machine friction traces.

Of much greater moment has been the continuing and inexhaustible production of photographic images (as glass plates and film negatives) via a succession of electron microscopes. The gestation period for such graphic records can be incredibly brief so that after some twenty years the electron microscopes in our laboratory have given rise to more than 110,000 glass plates alone of which almost 100,000 remained with us until quite recently.

With a packaged weight of something like 14 gm per plate we were faced with about 1.5 tonnes of 'raw' data. The decision that such weighty records could be dispensed with as they were not irreproducible was made by those experimentalists who had parented the brood. A comparison could be made of the relative benefits (to the keepers of records, at least) of the use of photographic film over glass. In replacing glass, film gives a more than 1:8 favourable reduction in weight together with an equally favourable increase in storage efficiency.

(iii) THE WRITTEN/PRINTED WORD

Leaving aside handwritten material, including laboratory note books, the question remains as to just how much paper can a given area of study generate. And where does one look to find the relevant material?

Even office records such as conversion, transfer and strike-off vouchers can produce gems of information on the origin or fate of particular items of equipment and many indicate the background to the initiation or termination of specific projects.

The extent to which an area of work can generate typewritten and printed material may be judged by examing the output from several areas of study.

(a) Friction, Lubrication, Bearings and Wear

In the decade 1940-1950 this area of study generated a total of about 125 internal reports, 3 CSIR Bulletins and at least 40 published papers. In 1950 appeared the Oxford University Press Monograph (-400 pages) The Friction and Lubrication of Solids by F.P. Bowden and D. Tabor which contains details of much of the war-time friction and lubrication work carried out at the Lubricants and Bearings Section. Fortunately, good housekeeping has preserved complete sets of the internal reports, most of which were prepared during World War II.

(b) Preparation of clean, flat surfaces of metals by electropolishing

The general studies on the surface properties of metals have demanded the preparation of reproducibly flat, clean and undeformed surfaces. The electrolytic polishing technique was seen as a reliable candidate for the job and was studied extensively in our laboratory during the 1950's. What appeared initially as an internal report in 1947 was updated, enlarged, and issued as a CSIR Report in 1948, as two published papers in 1951, and finally published as a 130 page monograph by Pergamon Press in 1956.[4]

(c) Ball model representation of crystal planes

The geometric considerations essential to the construction of any flat surface plane for specific types of crystal symmetry produced a whole series of scientific papers. As an extension, spherical surfaces were also treated and the overall work for flat surfaces was fully described in a monograph published by Gordon and Breach of New York in 1965.[5]

Conclusions

I hope that I have been able to give some feeling for the rich variety of material that one finds in a research laboratory.

It has not been too difficult to appraise raw data that has already been 'worked through' and which, being generated by means of a deliberate experiment, can be taken to be reproducible. Of paramount importance, however, has been some prior understanding of what the research progammes were all about and some knowledge of the science behind them.

And finally, the warning is not to eschew the dry, out of date housekeeping records generated within the administration. As I have shown they may contain valuable tidbits, at least for the historian.

FOOTNOTES

1. F.P. Bowden and H.W. Worner. 'The Manufacture of Aircraft Bearings in Australia.' *CSIR Lubricants and Bearings Section Report A.43: Bearings Report No. 18.* Mar 3, 1942, CSIRO Archives Series No. 1127.

2. *CSIR Lubricants and Bearings Section 1st Annual Report.* Jan. 1940 to Jan. 1941. Melbourne p. 9. See Figs. 1, 3 and 4.

3. D.P. Mellor. *The Role of Science and Industry. Australia in the War of 1939-1945.* Australian War Memorial, Canberra, 1958. Facing p. 340.

4. W.J. Tegart. *The Electrolytic and Chemical Polishing of Metals,* Pergamon Press, London 1956.

5. John F. Nicholas. *An Atlas of Models of Crystal Surfaces,* Gordon and Breach, New York 1965.