

The Care of Historic Musical Instruments

Edited by Robert L. Barclay

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Edinburgh 1997

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Preface

The central theme of this book is managing the retirement of historic musical instruments from active service, whether they are in the hands of individuals, private collectors, or museums. The book is intended to provide a wide range of guidance on the many aspects and demands of this change of status, and an equally wide access to the resources, advice and support available to collections. It is not the authors' intention to provide guidelines on returning historic instruments to working condition, although one chapter deals with the decisions that should be taken concerning those instruments that must continue to work for their living.

Considerable attention is paid to the materials of fabrication and their degradation, because understanding these aspects is considered the prerequisite of thoughtful care. The treatment procedures described have been selected not only for their economy and ease of application, but also for their non-invasive nature. At all stages, the reader is urged to develop a knowledge of what material is being treated, when to stop a procedure, and when to call on the help of specialists.

The idea for this book arose from a workshop on the care of historic instruments from the museum perspective organized by the Museums & Galleries Commission of the United Kingdom, and hosted by the Horniman Museum in London in 1994. Information on this subject is urgently needed because, with the current interest in performing music of earlier periods in a historically informed fashion, the historic instruments themselves have become the focus of attention. Although from the museum perspective there is no fundamental difference between a historic musical instrument and any other complex, functioning museum object, it is sometimes necessary to regard instruments as a special case. This results from a quite natural focus upon function as opposed to form. At the risk of generalizing, the instrument owner or custodian with a professional music background is likely to approach an instrument from the functional perspective, directing attention to its use in producing music, while the custodian with a background in museum studies, materials science or conservation is more likely to see the object in terms of its materials of fabrication and the means available for analyzing, stabilizing, and preserving them. While neither of these opposing approaches, if carried to their extreme, is truly tenable, the focus on functionality without regard to preservation causes the information embodied in historic instruments to become a diminishing resource. In order to preserve their information value for the future, guidelines on their care and maintenance are essential.

A number of organizations have raised awareness of the vulnerability of musical instruments. The International Musical Instrument Committee of ICOM (CIMCIM) has produced Recommendations for Regulating the Access to Musical Instruments in Public Collections and Recommendations for Conservation of Musical Instruments. The Museums & Galleries Commission has published Museums of Music and Standards in the Museum Care of Musical Instruments. A compilation of literature on musical instrument conservation and technology has been co-published by the International Institute for Conservation and the Getty Conservation Institute in a dedicated volume of Art and Archaeology Technical Abstracts. Even so, few practical guidelines on the day-to-day care of this kind of artifact have been published. To some extent, basic care and conservation can parallel that provided for most complex museum objects, but there are enough specific problems to justify a specialized focus. This is especially the case when considering historic instruments that must earn their keep - those kept in functioning condition are especially vulnerable.

This book represents the pooled efforts of seven contributors who attempt to provide a wide, practical coverage. However, in order to keep the book to manageable proportions, the temptation to duplicate existing material on the general care and conservation of collections has been largely resisted. If an excellent publication already exists, the reader is referred to it for specific information on how to proceed, what materials to use, and where to acquire them. In addition, the resource list at the end of the book is intended to acquaint readers with the wide range of information and assistance available, both nationally and internationally. It is hoped that this book may also help in developing a network among museums and those in the private sector with similar problems concerning historic musical instruments.

The authors would like to acknowledge the assistance of the John S. Cohen Foundation, the Canadian Conservation Institute, the International Musical Instrument Committee of ICOM, the Museums & Galleries Commission, and the Horniman Museum in the preparation of this book and the events that preceded it. The contributions of Sophie Georgiev and Edwinna von Baeyer of the Canadian Conservation Institute in the preparation of the manuscript, and Arnold Myers of the University of Edinburgh Collection of Historic Musical Instruments for the cover design, are also gratefully acknowledged.

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Ethics and the Use of Instruments

J.S. Odell, C. Karp

Musical instruments are similar to other functional objects because they have moving parts, or require physical interaction to fulfil the purposes for which they were made. Musical instruments, clocks, small craft and ships, automobiles, arms and armour, hand tools, furniture, and industrial machinery are typical of the wide variety of functional objects found in museums and private collections. In most history museums, functional objects predominate.

The sound they can produce is the primary aesthetic component of most musical instruments, and the reason why they were made. Thus there is always pressure from collectors and musical instrument makers, the general public, and from many museum staff to restore them to playing condition so that their musical qualities can be appreciated — in the words of one museum director, "to take them out of their glass cases and let them sing." In the past, restoration and maintenance of museum instruments for use in performance was often taken for granted. Today, museum professionals increasingly question such active, hands-on use of accessioned objects. The educational and aesthetic value of such use is often undeniable, but the potential for wear and tear, and loss of original substance is equally great. Restoration work, though always well intentioned, has often been detrimental to the long-term preservation of the instruments, and is considered by many to be inconsistent with standards of practice long accepted for other classes of museum collections, such as paintings and fine arts. Even in the case of museum instruments for which restoration to playability seems an appropriate option, it is always much more easily proposed than safely executed.

Present enjoyment is hard to resist, but since a museum artifact is held in trust for the future as well as the present, one should always consider whether a present use or restoration proposal will close off interpretation options for future curators and visitors. No matter how much it may please an influential individual or special interest group today, many of the objects in our care will be viewed and used by future visitors and scholars in ways that are different than those we imagine today. It is, therefore, clear that collections of musical instruments (and other

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functional objects) provide some problems for museum staff, which differ from those of fine art collections. Nevertheless, their treatment can and should be judged by exactly the same standards applied to treatments of paintings, sculpture, and the decorative arts.

Codes of Ethics and Standards

Several national and international organizations of curators, conservators, and other museum professionals have adopted codes of ethics and standards that provide a good basis for sound conservation decisions, including those concerning restoration and performances using musical instruments. (The most relevant codes are listed in the bibliography.) Published and used for decades, these codes have stood the test of time without major revisions or fundamental changes to the underlying concepts. Most of them were originally written for the needs of fine art collections, and some codes may require interpretation when applied to functional objects. Additional guidelines are needed for the restoration to playing condition of musical instruments, and for the situation when a decorative, functional, or technical component of an instrument is compromised by excessive attention to one aspect at the expense of others.

Treatments of functional objects should conform to the codes of ethics and standards of practice published by appropriate national and international conservation organizations. Based upon some fundamental principles drawn from the code of ethics of the American Institute for Conservation (AIC), but common to most of them, the following guidelines may help select treatment alternatives that respect and protect aesthetic and functional values, as well as the technical and historical evidence contained in functional objects.

Some relevant sections of the AIC code require:

- that respect be shown for the "aesthetic, historic, and physical integrity of the object";
- that "although circumstances may limit the extent of treatment, the quality of the treatment should never be governed by the quality or value of the object";
- that one "avoid the use of techniques, the results of which cannot be undone if that should become desirable";
- that "a conservator may supply little or much restoration, according to a firm previous understanding with the owner or custodian" but that he or she may not modify "the known character of the original"; and

 that a written report (supplemented with photographs) detailing the object's condition, the proposed treatment, and the actual materials and methods used in the treatment be made and provided to the owner.

All the above quotations are taken from earlier versions of the AIC code of ethics, but the essential points they make have been maintained through subsequent editions.

Guidelines

Standards of the Maker

No museum object should be restored to a state of functional operation unless the result will meet the minimum standard of its original maker, or of a competent historical user, or if it will not be properly maintained thereafter.

As an example, one sometimes encounters harpsichords restored using strings of incorrect gauge, tuned to the wrong pitch, or with a badly regulated action. On such an instrument, any museum demonstration will not respect the aesthetic intent of the original maker's work, even though it may be enjoyable to a modern audience. As well, there is often pressure to restore an object for some special event, even if it is uncertain that staff or other resources will continue to be available to maintain it against gradual wear and tear and operational stresses.

Equal Consideration of All Aspects

All aspects of the instrument should be given equal consideration when planning and carrying out its treatment. These include:

- original function;
- original decoration;

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- later historic functions;
- changes in decoration during any later period of historic use;
- visible or suspected evidence of its history of design, manufacture, or use;
- earlier restorations and repairs.

Instruments have commonly been restored with singled-minded attention to either the decorative or the functional aspect — to the exclusion and detriment of the others. The warped soundboard of a harpsichord may be flattened by applying heavy blocks and internal braces, which improve its external visual appearance but ruin its resonance. Instruments have been completely repainted in a manner loosely consistent with the general style of the period without protecting or respecting traces of original or later decoration that remain on the object and are unique to it. Few early harpsichords or pianos retain their original plectra, hammer coverings, damper cloth or strings, because most traditional restorers usually replace all such material with either a modern equivalent, or a more or less careful reconstruction based on historic principles. They have assumed that these components will produce a better sound and more reliable mechanical function. Although such assumptions are sometimes true, replacing historic material destroys the value of these parts of the object for later study and is inappropriate. It must be discouraged even at the risk of disappointing a performer, curator, or craftsman who sincerely wishes the instrument to look and sound its best. This is not to say that restoration or reconstruction is never appropriate, but it should be undertaken only as an infrequent, and thoroughly researched, last resort rather than as a normal, standard practice.

There are some recommended alternatives. At one extreme is substituting a copy for the untouched original, and at the other, retaining removed parts for future study, and carefully documenting altered mechanical adjustments and other ephemeral data, such as parts that wear out and are routinely replaced during the instrument's working life.

Justification for Functional Restoration

Restoring an instrument to functioning condition should not be considered unless an extremely important historic, technical, or aesthetic quality can only be determined by actually operating the artifact, and only if this information cannot be gained in some other manner.

All functional restorations are necessarily more intrusive than basic conservation treatments and always result in more loss of the original fabric of the artifact. Some original substance is always lost, as is evidence of performance practice, mechanical working clearances, and other adjustments. Evidence of successive stages of decoration and changes of function is often present on an instrument and is preserved in a manner analogous to archaeological strata. Such evidence is very easily lost or obscured. This topic is expanded upon in the introduction to Chapter 6 (Basic Maintenance of Playing Instruments).

Prevention

Particularly for large collections, the question of wise use of available resources must always be considered. If resources are limited — as they usually are — the welfare of the entire collection will be better served by attention to the storage and exhibition environment and through basic preservation treatments, rather than through a series of restorations of individual objects, each consuming hundreds of hours and incurring further maintenance.

Factors against Functional Restoration

There are a number of factors that argue against functional restoration:

- The instrument is unique.
- The instrument has original ephemeral features that will be lost or altered.
- The function is obscure and unlikely to be determined as a result of restoration.
- The condition of the instrument is such that an accurate achievement of its original quality of function is unlikely.
- The function is so well understood that no new information is likely to be gained.
- The instrument is fragile or subject to significant wear during use.
- The use of a copy would be possible.
- The skills and other resources required for restoration, subsequent ongoing maintenance, and use consistent with historically appropriate standards are unavailable or only marginally available.
- The resulting functional use will be not be recorded in any permanent form accessible to others.

Factors for Functional Restoration

On the other hand, there are some factors that favour functional restoration:

- · The instrument is mass-produced, and many similar examples exist.
- The instrument has been previously restored and most ephemeral features have already been lost.
- The instrument can be easily put into working condition without loss of substance or ephemeral features such as adjustments and clearances.
- The original function can be reestablished, and useful information about it is expected to be gained as a result.
- The instrument is sturdy, durable, and not subject to significant wear during operation.

- Using a copy would not give results equivalent to those produced by the restored original.
- Skills and other resources are available to restore and use the instrument so it will operate in a manner consistent with the standards of the period of origin.
- Skills and other resources are available to provide for the ongoing care and maintenance of the instrument.
- A permanent and accessible record will be made of the resulting functional use through sound recording, filming, video-taping, or other suitable means.

Playability and "Soundability"

Restoring historic musical instruments to playability is the most contentious subject debated in the organo-museological community. One reason for the lack of agreement is that the notion of playability is not well-enough defined to resolve the issue. Both sides agree that extant older instruments are a vital source of knowledge about period musical practice. The opponents of restoration argue that the truly authentic musical instrument is not a restored version of an instrument that was transformed to suit changing musical fashion throughout its working life, was more or less worn out in the process, spent a century or two in an abandoned state, and was finally placed in the hands of a skilled, present-day musical instrument maker who might have known little of period instrument-making practice. They argue that the truly authentic instrument is a *reproduction* of that relic, to the best of present knowledge and ability, in a state equivalent to what it was when new.

Aside from the desirability of hearing an original instrument speak, the proponents of restoration argue that it is impossible to determine which surviving instruments are worth reproduction unless the initial material can be evaluated in playable condition. This dilemma could be mitigated if it were realized that musical instruments can often be coaxed into providing useful audible evidence without first being subjected to invasive preparation. For example, any windplayer knows that tapping a fingerhole will produce a percussive sound of the same pitch as that produced by blowing into the instrument. This is not a trivial matter; this phenomenon can be used as the basis for a measuring routine for determining the pitches of an otherwise passive instrument. Further information can be gained by using the numerous devices for artificially blowing wind instruments, which have been described in the literature on acoustics. Similarly, fretted and keyboard instruments do not need to be fully strung to evaluate a useful portion of their tonal characteristics. The stringing used for such purposes does not need to generate the same tension

required by full playing condition. A great deal of progress could result from making a distinction between "soundability" and playability, where the former can often be achieved without any prerequisite restoration.

Conclusion

Musical instruments of historical or artistic importance can and should be treated under the same theoretical principles as other cultural property. Existing standards, such as the AIC and similar codes, provide an adequate and widely accepted basis for such decisions. Because of their diversity of material and structures and the very different and sometimes conflicting ways in which musical instruments are valued and used by their several publics — historians of art, professional musicians, amateur enthusiasts, historians of technology, craftsmen, and casual museum visitors — supplemental guidelines to the ethical codes are also needed. Those offered here have proven helpful in practice, while other possible approaches are discussed in the literature cited in the bibliography. This topic is dealt with further in Chapter 6 where the decision-making process regarding maintenance of playing instruments is outlined.

M. Cassar, R.L. Barclay

This chapter concentrates on conservation assessments, which outline methods for identifying problems, and strategies for environmental control, which deal with control options and their advantages and drawbacks. Assessing problems and managing the environment of even the smallest collection is an intricate task. The following notes provide an outline of some of the factors to be considered, and possible approaches to solving problems. For general guidance for non-musical collections the reader is referred to *Museums Environment Energy* and *Environmental Management: Guidelines for Museum and Galleries* by Cassar, and to "Relative Humidity in Museums, Galleries, and Archives: Specification and Control" by Michalski. The specific environmental requirements of musical instruments, and economical and straightforward methods of monitoring, are discussed thoroughly by Karp in "Storage Climates for Musical Instruments."

Conservation Assessment

The four main influences affecting indoor environment are the weather, the building, the engineering or environmental services (such as heating, lighting and air conditioning), and human beings.

These factors create conditions that put a collection at risk, namely:

- fluctuating humidity and temperature;
- excess light;
- · the presence of pollutants and pests;
- the way instruments are handled or used; and
- the activities taking place within the galleries.

Risks can be reduced if they are managed as part of an overall collection care plan. An effective plan must, therefore, be based on accurate information about the collection and its surroundings. The questions that need to be asked are:

- What is the general condition of the collection, the building and the internal environment?
- How are objects displayed, stored, handled and moved?
- How are the collections used?

Gathering information is fundamental to collection care, but data gathering must ultimately lead to constructive improvements. A conservation assessment covering the necessary ground will compile the evidence needed to develop a long-term environmental strategy. There are three phases:

Collection Condition Survey

This will identify individual instruments needing conservation, and will also provide information on the physical condition of the whole collection. The survey will include evidence of how instruments are used by staff and researchers and, in a broader sense, how they may be affected by visitors.

Profile of Existing Environment

A compilation of data from suspected problem areas should run concurrently with the collection condition survey. This will provide information on which to base control improvements. The following should be assessed:

- The appropriate range of environmental variables to be measured.
- How monitoring is or will be organized.
- What equipment is or will be used.

If regular monitoring has never taken place, a quick snapshot of conditions can be obtained by monitoring relative humidity, temperature, and light near known vulnerable instruments. Monitoring equipment ranges widely in price, quality and applicability, so before purchases are made professional sources should be consulted. When developing a long-term monitoring programme, the following questions should be asked:

- · What variables should be monitored, and why?
- · How much data should be collected?
- Are there plans for routine analysis and interpretation of data?
- What will happen to the data after processing?
- What equipment is needed?
- What equipment already exists?
- Is there training available in the use of this equipment?

- Are servicing, maintenance, and calibration going to require extra time and money?
- Who will be responsible for monitoring, and will the person have sufficient authority to report to senior management?
- What is the budget?

Building Shell Survey

This survey should start with external and internal inspections of the building shell. An initial building appraisal may be undertaken by a conservator or curator walking through the premises. It may be necessary to follow this with a detailed survey for which an architect or building surveyor must be engaged.

The aim of a conservation assessment is to provide information upon which to build an environmental strategy. The combined information obtained from the surveys on collections condition, environmental conditions, and the building will help formulate an environmental strategy. The assessment should be reviewed periodically by museum staff so that it can continue to be used as a reference point for decisions on:

- capital expenditure for building improvements;
- purchasing and installing new equipment and upgrading or replacing of old equipment;
- training for museum staff on how to use and calibrate monitoring equipment, record and interpret data, and operate and evaluate control equipment; and
- preventive and condition-based maintenance programmes covering the building and services.

Strategies for Environmental Control

Relative Humidity and Temperature

An environmental management strategy can be defined as a framework for preserving collections by maintaining continuous and stable housing conditions. This strategy can only be effective if it reflects the realities, the opportunities, and the constraints to be faced when trying to fulfil a collections care role. The constraints are often most easily to defined, and may include:

- the physical limitations of buildings;
- finite resources;
- the perceived need to achieve an "ideal" standard of environment control.
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Also, when establishing environmental control, there is often a great difference between a theoretical ideal and what can realistically be attained. This situation can create misunderstanding if impossibly high standards are set. In promoting the need for environmental control, two factors must be emphasized:

- Environmental control is good practice: inhospitable conditions accelerate the rate of decay of materials. Early action taken to control the environment can reduce the rate of deterioration.
- Environmental control enables custodians to bid more convincingly for financial assistance from public and independent sponsors: demonstrating a track record of care can persuade sponsors that money is worth investing in an organization.

Once a need for improvements has been established, a decision should be made on the most suitable approach to achieve and sustain environmental control. There are a number of options from which to choose, all of which will require a cost/benefit appraisal:

- whether to move the instrument or collection to another location;
- whether improvements can be carried out on the current site;
- whether to attempt building-wide, or localized control;
- whether to opt for active or passive control.

Active control involves the use of machinery to maintain chosen levels, while passive control relies upon natural responses of the building and the artifacts. Many musical instruments are composite objects, containing a wide range of sometimes incompatible materials. They have often been preserved in uncontrolled conditions for many years, in spite of their mixture of environmentally sensitive and physically robust materials. However, it must be understood that the kind of uncontrolled conditions encountered in a solid, well-built historic house will be dramatically different from those of an out-building or attic. A conservation assessment should indicate if objects kept in such conditions have been exposed to passive environmental control, and whether maintaining the status quo would be more practical than using an active, mechanical system with its drawbacks of reliability.

The level of funding will dictate how the strategy can be put into practice:

 Collections with ample funding might concentrate on incorporating as many passive design features as possible within a building, and choose construction materials that can buffer the effect of the weather.

- Collections with adequate funding might concentrate on localized, zonal, or microenvironmental control around the instruments, using passive means where possible.
- Collections with little or no money should work at the staff level to improve the management of existing resources (time, money, equipment, staff, etc.) in order to maximize their effectiveness at controlling the environment.

Given the reality of limited resources, a strategy should be developed that will deliver the greatest conservation cost/benefits, and that will meet the needs of the most vulnerable objects in the collection. In recent years, the growing acceptance that environmental control may be achieved by different means has led to a thoughtful reappraisal and questioning of the need for strict mechanical control of relative humidity and temperature.

In historic houses it has been difficult to balance the sensitivity of the fabric of the building with that of the contents. A widening of the relative humidity range to something appropriate to local conditions has been found acceptable, because tighter control risks damage to the building. This relaxation has in most cases not affected the contents. This is not to suggest that it is now acceptable to digress from "tight" control in every circumstance, and in the case of functioning keyboard instruments tighter control is certainly warranted. Decisions should be based on an understanding of collection care needs. For example, the vulnerability of instruments to relative humidity fluctuations should be established by studying their method of construction and amount of degradation before deciding on a wider control range.

It may be found unnecessary to spend money on equipment to control relative humidity to $\pm 2\%$ when the benefit to objects is almost indistinguishable from $\pm 5\%$ or higher. Relaxation of norms has some important advantages:

- It permits a more flexible approach to managing the environment by introducing a greater range of control options.
- It makes providing basic care to a greater number of objects possible, achieving more with existing resources.

An environmental strategy should offer a wide range of control possibilities. Sustainable environmental improvements are those that achieve maximum effect with minimum running and maintenance costs. There are seven possible approaches:

 Not heating the building provides shelter only. If the building is well ventilated, internal conditions will follow external conditions. The one obvious advantage of no heating is low running costs, but the disadvantages are that relative humidity is usually too high, which during cold weather causes widespread condensation and deterioration of the building. It is clearly not a strategy for an occupied building unless the climate is very temperate.

- Conventional heating with room temperature control is well understood and is suitable for people. However, the air will often be too dry in cold weather, particularly if ventilation volumes are high. Energy costs will also be high if the building is draughty or poorly insulated. Where possible, heating the whole building to comfort levels should be avoided. Conventional heating is dangerous to objects made of organic materials, especially if overheating occurs when the outside temperature is below freezing. The building needs to be relatively well insulated and airtight. Nevertheless, the lowest temperature practicable should be chosen.
- Heating with humidification consists of conventional heating enhanced by local or centralized humidification. To use this combination a building must be well insulated, and have good air and water vapour tightness. It provides comfort for people, while avoiding the dangers of low relative humidity for objects in winter. However, it also brings with it relatively high running costs. It is vital to have accurate control, reliable equipment, and good air distribution. Extra humidity controls with alarms should be fitted to shut down the humidifier if the relative humidity goes above limits. While this approach is useful where comfort is also needed, humidification can cause condensation dampness in walls, roofs, and adjacent unheated spaces.
- Conservation heating maintains relative humidity during winter months within an acceptable range for objects by linking heating with humidistatic control. It is extensively used in temperate climates in historic houses that are closed in winter. Internal conditions are cool in winter, typically 5°C above external temperatures. Conservation heating is best suited to largely unheated storage spaces, and it may be uncomfortable for winter visitors. Its advantage is its low power requirement and modest operating costs. As well, it may be possible to use the existing heating equipment with some modification. A disadvantage is that relative humidity rises in the summer because the temperature required to limit it is too high. It is effective in buildings that are not very airtight and where in summer higher relative humidity may often be acceptable. Supplementary dehumidification may be added to mitigate this effect.
- Dehumidification is only used in unheated, airtight buildings. It is
 particularly useful for metal collections that require a dry environment
 all year round. However, this environment is uncomfortable in winter

unless heating is added. It can better limit relative humidity than conservation heating, and it is an energy-efficient option where heating is not needed for objects or people. Refrigerant dehumidifiers may not work well under about 10°C, and may heat the air too much. Desiccant dehumidifiers using inert silica gel should be used. Maintenance costs of dehumidifiers can be high.

- Stability of temperature and relative humidity by high inertia works with massive, airtight, and well-insulated buildings. This kind of passive control may be supplemented by low-powered heating, ventilation, and humidity control. This approach can produce a stable relative humidity with a relatively low input of energy. It is particularly useful for densely stored organic materials and archives. Because internal heat gains must be kept to a minimum, and because appropriate low-powered services can prove difficult to design and control, this approach may not be appropriate if occupancy levels are high.
- Full control should, in theory, provide a wide range of options for heating, cooling, ventilation, and humidity control, but to be most effective, the building needs to be well insulated, and have good air and water vapour tightness. Potentially, full control can be tailored to any specification, and is an attractive choice if future needs are unknown or uncertain. Capital, energy, and maintenance costs tend to be high. It should be limited to areas with high occupancy or exacting needs. Full control demands good design, monitoring and maintenance.

Controlling the musical instrument environment is a complicated and exacting task. The above notes are designed to serve as a general guide when considering options and weighing alternatives. Technical assistance from specialists in heating and ventilating engineering, the museum environment, and the conservation of musical instruments should always be sought before any major changes are considered.

Air Quality

Preserving the wide range of organic and inorganic materials found in musical instruments is complicated by the presence of atmospheric pollutants. Even if the museum is not near a known source of gaseous pollutants, the 20th century atmosphere, urban and rural, is contaminated by sulphur dioxide from the burning of fossil fuels and more importantly, by nitrogen oxides and ozone from vehicle emissions. Also, gaseous pollutants generated within the museum are being identified as a growing problem, so materials used for display and storage must be selected with the conservation needs of musical instruments in mind.

Pollutants react readily with bright, non-ferrous metals especially highly polished silver, copper, brass and bronze. Organic materials such as vegetable-tanned leather, parchment and paper are weakened by sulphur dioxide, nitrogen oxides produce loss of strength and fading of dyes in textiles, while ozone causes changes in natural pigments, rubbers and plastics. Particulate matter such as dust and dirt, if allowed to accumulate, will cause abrasion and soiling of all surfaces.

Solutions to this problem depend upon financial resources and building design. The following approaches are graded in order of expense:

- The most effective method is to install filters in the air system of a building. They clean gaseous and particulate matter from the air. These systems require expensive and complex installation.
- Absorbent cloth, charcoal and similar materials can be placed in storage cabinets or display cases to absorb pollutants. Wrapping papers that inhibit tarnish are also available commercially. Organic materials susceptible to pollutants can be wrapped in buffered tissue paper and kept in acid-free enclosures when in storage. This option requires high maintenance.
- Keeping metal artifacts dry retards corrosion. Excluding water vapour is more important than excluding hydrogen sulphide when protecting silver; hence, an airtight bag with low permeability is important. Excessively dry environments for organic materials are not recommended due to the potential for desiccation.
- Protective coatings are occasionally applied to metal instruments. In cases where a protective coat is needed, pure micro-crystalline wax is used. Lacquers are generally not recommended for historic objects because they are difficult to remove, and they change the appearance of the instrument. Also, when a protective film breaks down it can cause localized corrosion, giving an ugly and uneven pitted surface.

Most of these preventive measures give no indication when the inhibiting, coating, or absorbing material is exhausted. In the case of metals, one would like to know before tarnishing begins, but in the absence of this, a regular inspection routine is needed, which will establish by experience when to change the material. A visible piece of highly polished silver, included in the storage or display as a reference, can indicate sulphurous pollution.

Lighting

High levels of visible and ultraviolet light, and excessive heat which often occurs at the same time, cause irreversible damage to a wide range of organic materials and pigments. These are sometimes not given serious attention by traditional users of musical instruments and exposure to light is occasionally even maintained to be beneficial. Any exposure will have some deleterious effect on organic materials, and exacting standards to minimize light damage have been established. The most sensible approach by custodians of individual collections is to devise protection against light damage, considering both the conservation of the instruments and the acceptable level of access. Light damage is a commonly identified problem in collections, and is the subject of a vast literature. Measures to protect against light damage are described in the National Trust's *Manual of Housekeeping*, particularly the appendix describing methods for protection against light. The subject is also dealt with briefly in section 15 of *Standards in the Museum Care of Musical Instruments*, while Thomson covers the subject in detail in *The Museum Environment*.

R.L. Barclay

Guidelines on general care of musical instrument collections include strategies for coping with a wide range of problems arising from handling and use of collections. This chapter deals briefly with supporting, storage, physical handling and travel. General standards for protecting musical instruments from physical damage are outlined in section 13 of the Museums & Galleries Commission publication *Standards in the Museum Care of Musical Instruments*. The *National Trust Manual of Housekeeping* provides additional information, and Gilles and Putt's *The ABCs of Collections Care* provides a practical and wellorganized approach.

Support for Display and Storage

Support of musical instruments is dealt with only briefly in the literature, so the notes that follow are fairly extensive (Barclay, "Instrument Mounts"). For both storage and display, it is often necessary to create custom-made mounts or supports for instruments that will remain in the same position for extended periods of time. Changes due to gravity are often so slow that they are not readily perceptible and, to complicate matters, they rarely take place as predicted. It is impossible to predict, for example, that a wooden flute will sag in the centre if supported only at its ends. Often the solitary exception will be regarded as proof that support guidelines for museum artifacts are over-cautious. However, there is ample evidence to the contrary in museum collections.

The terms stress and strain are used interchangeably in conversation, but their meanings in a physical sense are very different. Stress is the force applied to an object; strain is the change in shape of the object resulting from the stress. For example, a valve spring is under compression stress when the valve is being held down, and the strain is evident in its change of shape. When the valve is released the stress is removed and the strain is relieved because the elastic limit (high, in the case of the spring) has not been exceeded. Once the elastic limit is exceeded, a point of irreversibility is reached. In this case, the spring would remain distorted after the load had been lifted. Every substance has a measurable modulus of compressibility and elasticity. Stress beyond the elastic limit of an object results in permanent deformation.

In summary, the effect of gravity on an object may cause:

- Elastic deformation: the artifact returns to its previous shape if the stress is released. Many materials are elastic at very low stresses.
- Inelastic deformation: the artifact does not return to its previous shape when stress is

Figure 1. A typical stress/strain curve.

released. The deformation is permanently set. Many materials have very low elasticity and may break at moderate stresses.

Musical instruments are especially vulnerable to damage because of their intricate construction, often delicate components, and the stresses induced by tension and compression of components. However, the simple relationship of stress and strain is complicated by the effects of time. Three factors need to be considered:

- A gradual deformation over time is called creep. An object may not at first show any deformation under stress loads, but with time the changes will begin to be visible. Very slow changes in shape or dimensions are difficult to notice because one is not normally accustomed or trained to look for them. Deformation from creep is always permanent. Distortion of the cheek-to-bentside joint, the wrestplank-tocheek/spine joints, and the wrestplank-to-facia joint of keyboard instruments are prime examples.
- Embrittlement, molecular crosslinking, and oxidative degradation of organic materials all reduce the elastic properties of components of instruments. Metals suffer corrosion and embrittlement, the "season cracking" on brass being a perfect example.
- Old treatments can have weakening effects on the structure of an instrument. Such weaknesses can be induced by either poorly repaired damages, badly designed components, or adhesive, solder, welding, etc.

Thus, a museum musical instrument may require support for three reasons:

- For structural reasons if the instrument is inherently weak, or is in a deteriorated condition. What may appear to be an adequate and stable structure in the short term may prove to have critical drawbacks when viewed over a period of many years.
- For display reasons, the instrument must be shown to advantage, often angled towards the viewer or raised above the ground. Although display design sometimes requires supporting objects in an unnatural way, the visual appearance of the mount must not compromise its main function.
- For handling reasons, it may be safer to mount the instrument on a rigid support. Instruments that have fragile surfaces or structures, like attached textile, loose components, etc., are best mounted on rigid supports so that during examination the support, rather then the instrument, is handled.

These three factors justify supporting most instruments that must remain static for long periods. But supports can fail to fulfil their functions for five reasons:

- The points of support are wrongly placed, causing distortion of the object. When designing a support, it is necessary to take into account the force of gravity and to ensure an even distribution of weight.
- The instrument is poorly held or precariously balanced. Lateral shocks may occur from movement of the display due to human action or, in extreme cases, movement of the whole building. Clips or security lines should be added for safety.
- The points of contact are not padded, causing abrasion or distortion. Mounts made of hard plastic, metal or wood must have sufficient surface area in contact with the instrument to prevent abrasion, and should be padded with a soft, non-reactive material. This is extremely important for varnished wooden surfaces.
- The mount is made of a material which may affect the instrument. Materials of known long-term stability and chemical inertness should be used for mounts (Tétreault and Williams).
- The material used to make the support is obtrusive. Even if the four conservation considerations above have been addressed, a mount can still be aesthetically unattractive.



Display techniques for museum objects are well covered in the literature (e.g., Witteborg), and specific information on instruments can be found in Eliason and Hellwig, and Barclay, *Anatomy*.

Storage

In a storage area, dynamic considerations come into play. A mounted instrument on display can be considered static and protected, but in storage there may be a need to remove items for examination at frequent intervals. The instrument may belong to a study or teaching collection,

or it may simply be in a drawer that experiences a great deal of in-and-out movement during examination of other specimens. The high level of traffic in an active museum storage causes the following points to be considered:

- Can crowding of storage be minimized to limit handling of instruments during routine examination?
- Are instruments easily accessible without needing to disturb others in front of them?
- Do the storage drawers run smoothly, or do sudden shocks when opening and closing cause specimens to roll or slide?
- Are handling techniques, or lack of control over handling, causing damage?

Storage conditions for museum objects are well covered in the literature (e.g., Barclay, *Care*; Johnson and Horgan).



Figure 2. A mount for a flute showing support for the instrument along its length. Soft, resilient padding should be added at points where the instrument rests on the mount.



Figure 3. A typical mount for violin showing soft padding at points of contact, and fine monofilament security lines to prevent accidental slippage.

Handling

Handling historic instruments safely and carefully is largely a matter of common sense. Following are a few basic notes on areas that may not be immediately obvious.

Polished metals are readily affected by incautious handling. The salts and oils from skin can cause corrosion of metals very easily, so always wear clean cotton gloves when handling metal instruments. Clean pairs of gloves should be placed in locations convenient to the storage areas as a reminder and inducement to handlers. However, gloves can snag on loose flakes, splinters, or corrosion, and they may cause highly polished and smooth objects to slip out of one's grasp.

Metal instruments should always be well supported during transport and display. Slides, mouthpieces and other potentially loose items should be secured. It is tempting to think that metal objects are very durable, but this is not always the case. For example, brasses that have been stressed during manufacture (i.e., sheet brass instruments) can be very weak, and can crack along the grain boundaries of the metal when put under further stress.

Organic materials deteriorate in a bewilderingly large number of ways, all of which potentially cause weakness. Leather bellows may be badly degraded and be easily damaged by one incautious inflation; apparently stable wooden instruments may be tunnelled by furniture beetles, and so on.

Below is an examination of various conditions, categorized by the substrate (i.e., the material of which the object is made), and the coating applied to its surface. Each of the conditions shown below can be assessed by eye without extensive training. Simple guidelines for cleaning, handling, storage, and display are indicated in the key.

Substrate

Condition	Example of Material	Guideline
Cracked	wood, metal, other brittle material	1
Fibrous	wood, textiles, etc.	2
Flaking	corroded metal, degraded wood	3
Porous	wood, corroded metals	4
Powdery	corroded metal, rotted wood	5
Rough	unfinished metal (casting), wood	6
Smooth	polished metals, ceramics, glass	7

Coating

Condition	Example of Material	Guideline
Flaking	brittle paint with lost adhesion	3
Porous	thick accretions or pigment	4
Powdery	coatings with little or no binder	5
Rough	poorly applied finish	6
Smooth	varnishes, paints, plating, etc.	7

Key to Handling Guidelines

- Cracks in the object may indicate poor physical strength, especially if they are deep. Assess the strength of instruments and place them on supports if necessary.
- 2. Fibrous surfaces are very attractive to dust and difficult to clean. Keep such items well covered, or in boxes or drawers.
- 3. Flakes can catch on gloves or clothing. Handle as little as possible. Place the instrument on a support for carrying and examination. Some form of consolidation may be necessary if there is evidence of deterioration.
- 4. Porous objects may be perfectly stable, but their surface can absorb dirt and moisture. Never wet clean a porous surface. Keep the items well covered, or in boxes or drawers.
- 5. Powdery surfaces may be very fragile. Handle as little as possible. Place items on a support for carrying and examination. Some form of consolidation may be necessary if there is evidence of deterioration.
- 6. Rough surfaces can catch on gloves or clothing. Handle as little as possible. The rougher the surface, the more likely dust and dirt will stick. Keep covered.
- 7. Smooth objects should be handled with soft gloves, although glass and ceramics can slip if not handled carefully. Cleaning by gentle dusting is usually very simple.

Travel

To a great extent, the problems presented for travel of musical instruments are no different than those of many other museum objects. The category of musical instruments, however, is so wide that it can contain potentially any material known, and in any state of deterioration. Also, because instruments are made to produce sound, and many of them are also intended to be portable, they are likely to be lightly built, of thin construction, highly finished, and under stresses of various kinds. In addition, much of their essential structure can be concealed or appear deceptively robust. In other words, they should be treated as carefully as the most fragile museum objects. It is not over-cautious to assume that they are more fragile than they may actually be. Related information on packing and shipping is available in Hellwig "Packing"; and Tétreault and Williams.

Strategies to Counter Biological Attack

The greatest peril to organic materials, such as wood, cloth, felt, leather and quill in the enclosed spaces in instruments, is insect attack. Carpet beetles, woodboring beetles, moths and other insects prefer sites that are dirty, poorly illuminated and undisturbed. Signs of infestation usually become apparent only after the damage is done. Small piles of frass, shed cocoons or exoskeletons, or fresh holes all indicate active infestation. Fumigation has been routinely practised in the past, but public health regulations, resulting from research into biological poisons, have become much more stringent. There has also been some debate over the effects of certain fumigants on materials of fabrication. Several alternative, environmentally responsible methods have been proposed, including low temperature of around -20°C (CCI Notes 3/3), elevated temperature of around 50°C, and inert atmospheres. Of these, asphyxiation by carbon dioxide or nitrogen are becoming the preferred methods, although some work still has to be done on the effects of changes in moisture content of artifacts during treatment.

Insects can be affected by inert atmospheres in two ways: they may suffocate and they may fall into narcosis. When nitrogen is used, the insects die of suffocation because of insufficient oxygen. There must be very little oxygen in the nitrogen atmosphere for the process to be successful (0.1% or less), which makes this procedure technically demanding. On the other hand, placing insects in a carbon dioxide atmosphere has the effect of stimulating the insects' respiratory receptors causing the fine balance between carbon dioxide and oxygen to become upset, resulting in narcosis. The effect takes place in a relatively low carbon dioxide concentration, so there is no need to exclude oxygen entirely from the atmosphere. Thus, the process is easier to apply and less time-consuming and costly. Small instruments are placed in a chamber filled with carbon dioxide from a tank of the compressed gas. Larger objects may be enclosed in a sealable polyvinyl tent or chamber. A level of approximately 60% CO₂ must be maintained during the treatment. Time of exposure depends upon the species of the insect, and its development phase. The Canadian Conservation Institute is planning a publication on this topic.

Preventive cleaning and regular inspection forestall insect attack. Access to many parts of musical instruments for cleaning is extremely awkward

and sometimes demands disassembly. This is especially so with keyboard instruments. In the case of keyboard instruments maintained in playing condition, cleaning should only take place infrequently, when another problem warrants the disassembly, or when there is a reasonable suspicion of infestation. The cleaning process itself should be given plenty of time, so that adequate care can be taken. If infestation is found, it may be necessary to seek specialist advice (Pinniger; and Dawson and Strang, *Insect Problems*).

Fungal attack occurs in areas of high relative humidity, above approximately 65%. The popular belief that fungal growth requires elevated temperatures is not true. Spores may lie dormant on organic materials for long periods of time and only become active when conditions are right. The best preventive measure is to lower local relative humidity, especially during periods of dampness, check for damp spots, move instruments into areas of higher air flow, and establish programmes of regular inspection (*CCI Notes* 8/1; Dawson and Strang, *Fungal Problems*).

Larger musical instruments are an ideal habitat for vertebrate pests, especially when they are in storage or unattended. Mice, bats and other such pests are better dealt with by trapping, blocking the means of access, and establishing programmes of inspection and regular cleaning (Dawson and Strang, *Vertebrate Pests*).

Materials

R.L. Barclay, F. Hellwig

This chapter introduces some of the chief materials used in musical instruments. It describes briefly methods of fabrication, working characteristics, and the causes of deterioration. The conservation treatment of the materials described here is covered in Chapter 5. Among the many publications on the materials of artifacts, *An Introduction to Materials*, in the Science for Conservators series, and *The Organic Chemistry of Museum Objects*, by Mills and White, are especially recommended.

Metals

Metal Production

With a few exceptions, metals exist in nature as ores. They are generally in a stable oxidized condition. As we know by observation, metals are relatively unstable — they will corrode if allowed to do so. This is because a metal exists in a high energy state and is therefore reactive. As it oxidizes, it moves to states of lower energy where it is less reactive and thus more stable. The lighter metals are much more reactive, and as one progresses up the electrochemical series, the metals become denser and less reactive.

Exceptionally stable or well-protected metals are found pure in nature. The metal is referred to as "native" in this case. Silver and copper are sometimes found in the pure state, while gold always occurs in the metallic form. The remaining metals are found as ores. They are "oxidized", but not necessarily with oxygen. The term "oxidized" refers to the chemical process. Metals may be combined with many different elements and compounds. The oxides are most common for metals like iron and aluminum, while copper may be combined with sulphates, carbonates and so on.

Once mined, these ores must be refined, and because the metals are at their most stable, lowest energy state, an input of energy is required to refine them. This is done by heating the ore under certain conditions until the fluid metal becomes separated from the slag. This is the process known as smelting. c

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two or more metals. This mixing has the function of enhancing the usefulness of the material by combining the properties of individual metals. For example, zinc and copper are combined to produce brass. Iron is mixed with a non-metal, carbon, to produce steel.

Many metals in artifacts are composed of alloys, which are mixtures of

Metals have three specific properties as elements:

- malleability
- ductility
- conductivity

Malleability enables metals to be worked into shape by beating. Ductility enables metals to be drawn into wires or rolled into sheets. The facility to conduct electricity is not greatly important to conventional historic instruments, but it has significant effects on the processes of corrosion. One might also say that metals are machinable, but when the process of cutting at the tip of a tool is examined it is evident that a combination of malleability and ductility allows the metal to "flow away" from the cutting tool. Malleability and ductility may be greatly modified by alloying. *The Nature of Metals* by Rogers provides a solid introduction to this topic, while Barclay provides a synopsis in *The Art of the Trumpet-maker*.

Fabrication

A wide range of techniques exists for shaping and finishing metal. There are four basic stages, each with subdivisions:

Forming

Casting, forging and rolling where ingots of metal are given their initial shape.

Shaping

Milling, turning, spinning, grinding, stamping, cutting, and drilling, where the final dimensions of the piece are established.

Assembling

Welding, soldering, brazing, riveting, bolting, crimping, and shrinking, where pre-made parts are put together. It is also worth noting that adhesives have been used occasionally to join metal parts.

Finishing

Plating, burnishing, polishing, etching, painting, lacquering, engraving, chasing, embossing, enamelling, and patinating, where the piece is finished for decorative purposes or for further protection.

Instruments or components routinely pass through all of these stages and as the number of processes applied multiplies, so does the difficulty of deciding in retrospect exactly what was done to them originally.

Corrosion

Corrosion is commonly seen in everyday life as rust, patination, etc. Corrosion is the compound of pure metal (or alloy) with a non-metal. All metals (except gold and a few other rare metals) are inherently unstable, and have a strong tendency to combine with non-metals (oxygen, water, sulphur, chlorine, etc.) to form compounds. Metals are always trying to return to their natural state by losing the energy that had been used to convert their ores into metal in the first place. This readiness of metals to corrode is a property of their atomic structure. The same structure that gives them their uniquely useful properties (malleability, ductility, conductivity, and strength)

makes them susceptible to corrosion.

Oxidation can occur in dry conditions at the metal surface. A fresh surface is especially reactive and forms bonds with available electron recipients in the surrounding atmosphere. If a strong, even film is formed, it will protect the metal against further corrosion because it forms a barrier against



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Figure 4. Cross section of a metal surface, showing the negative charge and the reaction with positively charged ions in the atmosphere.

other electron recipients. More active forms of corrosion need water, in addition to reactive agents in the air. Aqueous corrosion is an electrochemical process in which water, particularly "impure" water containing dissolved chemicals, acts as an electrolyte (conductor).

Some metals are more prone to corrosion than others. Metals are arranged in order of reactivity or potential for corrosion in what is known as a galvanic series. The metals at the lower end are regarded as base, while those at the upper end are called noble. In practical terms, if two metals are in contact (e.g., as an alloy, or a plating, or as soldered or joined components), the one lower down in this series (the more base metal) will corrode before the metal higher in the series (the nobler metal). For example, if an iron object is suspended by a copper wire in an environment containing sufficient humidity, the iron will corrode at the point of contact with the copper. The further apart the metals are on this scale, the greater will be the reaction between them. Such a reaction may also take place within alloys, which are a mixture of two metals. Conditions such as access of oxygen, concentration of solution, irregularities in metal, etc. cause accelerated corrosion. This "bimetallic" corrosion can cause confusion in identifying metals. In an alloy, the baser metal corrodes first, causing a deposit of its characteristic corrosion

products on the surface of the artifact. Silver alloyed with copper may develop a green crust; brass may appear copper-coloured due to "dezincification."

The Corrosion Environment

For corrosion to take place the main ingredients are water, oxygen and salts, although all three are not required for a reaction to take place. Of the salts, the most destructive are the chlorides which, unfortunately, are very prevalent, and highly soluble. It is extremely difficult, if not impossible, to render metal stable in presence of chlorides. Both copper and iron combine with chloride ions to form corrosion products, which are unstable above approximately 35% relative humidity.

The rate at which corrosion proceeds is temperature dependent; it will proceed faster at elevated temperatures, more slowly at reduced temperatures. For example, silver tarnishing occurs twice as fast at 29°C than it does at 18°C. The destructiveness of corrosion products depends upon whether the corrosion products are stable, and whether there is a change in volume during the corrosion reaction.

Passivation

A passivation layer occurs when all the negatively charged metal atoms at the surface have reacted with an oxidant. A thin, even and resistant layer is commonly seen on iron components which have a stable, dark brown surface, and on brass, which develops a stable patination if undisturbed. The amount of protection provided by a passivating layer depends on the porosity and completeness of the film, its chemical reactivity, and its density relative to the metal. If large amounts of gases other than oxygen are present (e.g., atmospheric pollution or volatile products from display and storage materials) a protective film may not be formed. If no film is formed, or if the film is porous, passivation does not occur.

Corrosion of Specific Metals

Iron is a common metal in fittings of musical instruments. It is fairly low down on the galvanic series and thus prone to corrosion under a wide variety of conditions and environments. Its corrosion products are many and complex, and depend on the environment and how the metal was formed. It is unlikely that parts and fittings of museum musical instruments will be found in an extremely deteriorated condition, but light surface corrosion will very likely be encountered (*CCI Notes* 9/1, 9/5, 9/6 and 9/8).

Copper causes fewer problems in musical instruments than iron, but is still found in a wide range of corrosion states. It combines with chlorides, sulphur compounds, carbonates, nitrates, etc. to produce a wide

range of colours and textures, some of which are sought as patinas. Oxides are red or black; carbonates are green or blue; chlorides are either waxy grey-white or light green and powdery; and sulphates are blue or green (CCI Notes 9/1 and 9/3). Generally, copper corrosion products form even, coherent layers that often preserve the details of the original metal surface. However, as with iron, chloride ions are the most reactive with copper, forming a white, waxy layer that is extremely unstable. When combined with oxygen and water this layer rapidly converts to a light green powder with loss of all detail and structure. Sometimes known as "bronze disease," the corrosion continues under favourable conditions until the metal is consumed. Copper alloys, such as brass and bronze, are susceptible to corrosion of the least noble of their elements. Brasses are particularly prone to stress cracking or "season cracking," where weakening and embrittlement are caused by inter-granular corrosion. This is often stimulated by exposing the brass to atmospheric pollutants, particularly ammonia. Brass is made of copper and zinc. Sometimes brass can lose its zinc preferentially to copper at the surface. This is known as dezincification and makes the brass appear much more coppery. It is often a result of extreme chemical cleaning with acids. This surface enrichment, as it is called, can confuse identification of the metal.

Silver is relatively noble and less susceptible in general, but it does combine with chlorides and sulphides. Silver sulphides cause the classic blue-black iridescent tarnish, while silver chlorides are white initially, but are light-sensitive, and on exposure turn deep purple-grey. Chloride films are unlikely to be found in indoor conditions, and are usually only encountered on archaeological material. Sulphide tarnish, on the other hand, is a very common museum and household problem. Because people have a low tolerance for tarnish on silver, instruments are vulnerable to physical damage caused by abrasion and loss of surface when polished (*CCI Notes* 9/7). Silver is often used on instruments as a thin plated layer over a baser metal. If the baser metal is exposed by scratches or polishing, bimetallic corrosion may occur.

Lead and its alloys are used in instruments for their weight and softness. When lead corrodes slowly in pure air, it forms lead oxide, a dull grey passivating layer. In the presence of impurities, it can form other oxides (red, yellow, or brown), sulphates (dark grey or black) or carbonates (grey-white or white). Most of these products are relatively stable, but lead has a strong reaction with weak organic acids (acetic, formic, etc.) and forms a loosely adherent, whitish powder. This is basic lead carbonate, an active form of corrosion. Some building, display, and storage materials can cause this because they are sources of weak organic acids. Lead is often alloyed with other metals, particularly tin, for use in organ pipes or as a solder for components made of other metals. Lead weights inserted into keys or jacks as balances are prone to corrosion due to their close contact with wood (*CCI Notes* 9/1).

Wood

Wood is perhaps the most used material in traditional instrument making. This is due to its unique combination of qualities: almost unlimited availability, almost immediate readiness to be fabricated (depending on traditions of using fresh or seasoned material), relatively easy workability, mechanical strength, elasticity, suitable vibrating properties, resistance to chemical influences, few changes with age, and beauty of texture. However, there are also properties that under certain circumstances may create severe problems: continued dimensional reaction to changes in the humidity of the surrounding air, fragility when in thin sections, and vulnerability to attack by fungus and insects. In the following section, most of these properties will be dealt with in some detail, but the questions of biological attack and the countermeasures used today are so wide ranging that their discussion is beyond the scope of this text.

The Structure of Wood

Woods from two groups of trees are used in musical instruments: softwood from gymnosperms (i.e., coniferous trees) and hardwoods from angiosperms (i.e., leafy trees). The terms softwood and hardwood are somewhat unclear because they do not reflect the mechanical hardness of the materials; some softwoods are harder than some species of hardwood, and certain hardwoods may be softer than certain softwoods.

In addition, material from palms, grasses, and other plants is also used in musical instruments, although by definition such materials should not be called woods because they lack the cambial secondary growth characteristic of softwoods and hardwoods.

When describing wood structure, three planes — cross-sectional, tangential, and radial — are distinguished. Unless the orientation of the surfaces of the wood lies accurately in one of these directions, determining its species can be impossible. This is especially true when the wood is viewed under a magnifying lens or with a microscope.

The structure of softwoods is simpler than that of hardwoods because they appeared earlier in



Transverse (cross section)





Figure 5. Transverse, tangential and radial cuts of wood.



Figure 6. Microscopic features of a typical softwood. Note the difference between late and early growth, and the resin canals. (Adapted from K. Mägdefrau. Botanik: Eine Einführung in die Pflanzenkunde. Heidelberg: Carl Winter Verlag, 1951.)



Figure 7. Microscopic features of a typical hardwood. Note the large diameter vessels clearly visible in the cross section. (Adapted from K. Mägdefrau. Botanik: Eine Einführung in die Pflanzenkunde. Heidelberg: Carl Winter Verlag, 1951.) the evolution of plants. The predominant features of softwoods, are visible to the naked eye, and appear more clearly through a magnifying lens.

Under a 10-power hand lens, the resin canals characteristic of spruce (*Picea*), larch (*Larix*) or Douglas-fir (*Pseudotsuga*) will show clearly in a good cross-sectional cut. The presence of resin canals distinguishes the above species from such woods as fir (*Abies*), true cedar (*Cedrus*), cypress (*Cupressus*) or yew (*Taxus*). Botanical names are very helpful in clearly describing a wood species. The common names of many woods are quite misleading. For example: the northern white cedar and western red cedar are not cedars, but members of the genus *Thuja*. The eastern red cedar belongs to the genus *Juniperus*, which is a member of the family *Cupressaceae*, and so on.

The structure of hardwoods is differentiated by a larger number of specialized cells. The presence of vessels characteristically distinguishes softwoods from hardwoods. Vessels are clearly visible in such woods as oak, balsa, plane and chestnut. In other species, they may be so small that they are hard to detect even with the aid of a lens, as is the case with boxwood. When the vessels are distributed evenly throughout the cross section, the wood is known as a diffuse-porous hardwood; when the vessels appear grouped in annual rings, the wood is known as ring-porous hardwood.

Annual rings appear in both softwoods and hardwoods growing in climatic zones that experience seasonal changes of both temperature and rainfall. In spring, when there is an abundance of water, large cells with wide cell lumina (openings) are produced, then as the ground dries later in the year the cells become more substantial with thicker walls and smaller lumina. These annual rings determine the appearance of many wood species and allow a determination of the tree's age. However, the brown or black stripes observed in rosewood (*Palisander* or *Dalbergia*) are deposits of coloured material in certain stages of the tree's growth, independent of regularly occurring climatic changes.

Another important feature in both softwoods and hardwoods is the formation of rays — cells running radially between the centre of the tree and the bark — that contribute much to the visual appearance of wood. Typical examples of woods with pronounced and easily visible rays are beech, oak, and plane. Rays also play an important role in the swelling and shrinking of wood. To identify the species of wood, these and many more details are used in combination. In some cases, only a microscopic analysis can reliably identify the species in question. Hoadley's two publications on identifying wood are recommended.

The various anatomical features of wood, together with physical properties like density and chemical make-up, and the inclusion of extractives or solids, all determine the texture, colour and odour of the wood, as well as its hardness, resistance to insects, fungus, and physical decay, gluing properties, and general workability.

Identifying Wood Species

A high proportion of woods described in museum catalogues are falsely identified and so, in practice, one should mistrust stated wood species unless the wood has been microscopically examined. Although some woods are recognizable with experience, there is a limit to what one can see with the naked eye at the wood surface. There is never a problem recognizing oak, chestnut, or yew, but many species are quite difficult to distinguish from each other. The various kinds of pine and larch can be quite difficult, spruce and fir are very similar, willow and poplar are superficially alike, and so on. This applies to an even higher degree to the almost endless varieties of tropical hardwoods.

While a non-specialist can examine some species of wood successfully with a hand lens, microscopic determination is much more challenging, and needs special training, continuing practice, and costly equipment. The quantity of wood needed for microscopical examination can be quite small — samples 1 sq. mm and 0.02 mm thick are more than sufficient but such samples must always be taken by the person who is doing the microscopy. An immediate check of the sample is necessary to ensure that it is perfectly oriented, as well as thin enough to show all the required details.

Wood Species Used in Musical Instruments

There is hardly a wood that has not be used in musical instruments. However, in many Western instruments there are typical, characteristic choices: coniferous woods, particularly spruce, are used for their resonating quality in the soundboards of lutes, guitars, instruments of the violin and viola da gamba families, keyboard instruments, etc. Hardwoods like maple or walnut are selected for structural areas. At the same time, the choice of species is determined by availability in the region of manufacture. Cypress is, therefore, an obvious preference for many instruments of Italian manufacture. In a violin of Italian origin, cypress and walnut would be obvious combinations, while the choice of spruce and maple, standard since the late 17th century, indicates a more northern origin of this type of instrument. Tough, durable woods, such as beech and oak, are often used in areas of high stress such as wrest planks and frames. A wide variety of woods are used for their decorative quality, whether it be colour, grain pattern, or texture.

Wood and Moisture

Wood consists of basically three groups of chemical compounds: cellulose, polyoses, and lignin. The former two are highly reactive to moisture (hygroscopic) while lignin is much less so. The behaviour of wood under the influence of moisture is mostly determined by cellulose. It forms fibre bundles that are longitudinally oriented and partially crystalline. These properties account for the stiffness along the length of a tree stem, and also for the hardness of the wood. Both the composition of cellulose and the structure of the cell walls allow easy adsorption of large quantities of water in vapour form. In addition, once all the receptive sites for water adsorption in the cells have been saturated, water can exist within the cells in liquid form.

The changing amounts of water vapour adsorbed on the surface of the cell walls determine the dimensional changes of wood. When wood is at equilibrium with the air around it, moisture may be given off to the surrounding atmosphere, or it may be absorbed from the atmosphere into the wood. Thus, conditions in the environment determine the moisture content of wood, and thereby its swelling and shrinking. Moisture content in relation to relative humidity in the air is shown in the graph.

This graph provides average values and needs correction for individual wood species, especially in the higher range of relative humidity. For the middle range of temperature and humidity, however, this graph is quite adequate. Wood shows a different reaction to moisture changes along





each of its three axes — longitudinal, tangential, and radial. The ratio of reactivity between the three directions is:

Longitudinal	= 1
Radial	= 10
Tangential	= 20

Thus, for every unit of change in the longitudinal direction, there is 10 times as much change radially, and 20 times as much tangentially. In practice, the longitudinal changes are small enough that they may be ignored. Thus, with humidity fluctuations in the surrounding air, there is little or no longitudinal change, and the tangential response is double that of the radial. The actual amount of shrinkage or swelling depends on the density, the degree of coloured heartwood formation, and the quantity and kinds of extractives, to name only the most important factors.

The following table provides average percentages for dimensional change with a 1% change in moisture content of various woods:

Wood species	Percentage change	
	radial	tangential
spruce (Picea abies)	0.17	0.32
pine (Pinus sylvestris)	0.17	0.32
maple (Acer spp.)	0.15	0.26
oak (Quercus spp.)	0.20	0.32
walnut (Juglans regia)	0.20	0.27
linden (Tilia spp.)	0.19	0.28
poplar (Populus spp.)	0.15	0.28
ebony (Diospyros spp.)	0.27	0.30
Brazilian rosewood (Dalbergia nigra)	0.24	0.37

To calculate an example: a cube of oak of 100 mm on a side is in equilibrium with 20°C and 55% relative humidity. The RH is then lowered to 40%, which leads to a decrease from 10% to 7.5% moisture content once the new equilibrium has been reached. This decrease will result in negligible longitudinal shrinkage, and shrinkages of 0.5% radially and 0.8% tangentially. This corresponds to a decrease of 0.5 mm radially and 0.8 mm tangentially. Such small figures may not seem important until one considers the back of a viol or the soundboard of a harpsichord. When the above calculation is performed using the figures for maple and spruce respectively, including the width of the wood in question, the results indicate the large extent of movement.

Such dimensional changes take place only if the piece of wood is unhampered while the alterations in its environment are taking place. For restrained pieces of wood, there are two scenarios depending upon loss or gain of moisture:

 If wood is losing moisture, the forces of shrinkage may be stronger than the internal cohesion of the wood. This will result in open cracks. However, not all such forces lead to fracture because wood possesses an elastic quality that minimizes the formation of cracks. (This effect, due to plasticity and elasticity, will be discussed in the next section.) As an example, a violin or viol top that is glued all around its edges may undergo moisture loss without the formation of cracks.

• If the dimensional changes are in the opposite direction, where the wood is swelling due to a gain in moisture, this will lead to a structural change at a microscopic level. The cells become compressed. Then, when the wood is subsequently dried, the compression will become apparent in permanent shrinkage and the formation of cracks. This effect is called compression shrinkage, and the damage can be observed in many wooden constructions where flat pieces of wood are restrained in their movement by cross-glued bars. The resonating surfaces of guitars, viols, or keyboard instruments often show such signs.

Theoretical values for dimensional changes often differ from measured values when surface coatings, such as paints and varnishes, have been used because they prevent or inhibit free exchange of moisture with the air.

Plastic and Elastic Behaviour

Wood may be called a visco-elastic material, which means that it displays both viscous and elastic properties. Viscous behaviour means that wood tends to conform to the shape of the space in which it is confined under the influence of gravity or other force. Viscosity, creep, or plasticity are the terms applied to this phenomenon, depending on the material described. (For wood, the words plasticity and creep are used.) Like a liquid, wood can "flow" or "creep" but, of course, its viscosity is very high. As an example, a wooden flute supported only at its ends will eventually adopt a new shape by forming a curve that will slowly increase as it reacts to the force of gravity. This behaviour is characteristic of liquids, although the time scale for wood is many orders of magnitude longer. The flute will not return to its original straightness, but will remain bent until an opposite force is applied, if that were actually possible.

Wood is also elastic. This term describes the behaviour wood exhibits after it has been under stress. A string instrument bow is tightened for playing yet returns to its original shape after the hairs are detensioned (for example, see Figure 1 in Chapter 3). Woods used for bows are chosen specifically for their elastic properties. Plasticity and elasticity of a particular wood depend upon its moisture content. Maximum plasticity is reached once all fibres are saturated by water (fibre saturation point). Minimum plasticity occurs when wood has been dried in an oven and thus deprived of all its moisture. In musical instruments plasticity and elasticity are very important. Plasticity may prevent cracking, while elasticity maintains the intended shape and particularly the vibrational properties. On the other hand, plasticity is responsible for any deformation that will take place even under the most strictly controlled conditions.

Environmental Requirements

When wood is dried after it has been felled in the forest, it loses moisture until it is in equilibrium with its surroundings. The wood is then described as dried, or seasoned. Because this depends on the ambient conditions, dryness is a relative term. An object made of wood cut, dried, worked, and stored in the Sahara region will have a very different moisture content than an object from the damp and foggy Po region of Northern Italy. To prevent further loss or gain of moisture, and subsequent dimensional changes once the object is transferred to a museum, the object's original climatic conditions should ideally be maintained. However, in practice this is hardly feasible, and in many cases not even desirable, because an instrument will most probably already have adapted to some other humidity level. Also, the presence of other materials on wooden musical instruments make absolute specifications difficult to establish. For storage or display purposes, a compromise climate has been recommended (Karp, "Storage Climates").

The Aging Process of Wood

The tonal beauty of early violins and other string instruments is often attributed to the instrument's age, which is said to have a special effect on wood. Two aspects of aging must be considered in the context of musical instruments: visual modifications during aging, and changes in mechanical properties.

Visually, on exposure to light, coloured wood slowly fades, while woods originally light in colour tend to darken. Thus, on an instrument or any other wooden object exposed to light, yet protected from weathering, all the colour shades of the woods will eventually meet somewhere in the middle. While the overall effect can be very attractive in many stringed instruments or woodwinds, it is very disturbing in the case of marquetry or inlays made of differently coloured or dyed woods. These slow colour alterations indicate chemical changes on the surface of the wood, but they have no effect on an instrument's tonal qualities.

Few investigations into the ageing process on the physical and mechanical properties of dry wood have been made. There are many examples of dry wood that has been protected from biological attack by fungi and insects for thousands of years. While some studies seem to indicate that the density of wood increases with time, other research suggests the opposite. Certainly, the rate of water absorption is apparently unchanged over time. It has recently been shown that under continuous forced vibrations, the stiffness of wood is increased and the damping coefficient decreased, but such observations are difficult to interpret because the physical and mechanical data of wood species generally show such wide variation. In addition, one cannot discount the subtle and indefinable interactions that take place between the musical instrument, the musician, and the auditor. To simplify, it is a safe assumption that the properties of dry wood alter very little, if at all, with time.

Wood and Musical Properties

Another feature of wood properties is the playing-in process that both musicians and listeners know so well. There is no explanation for the changes that occur between the newly-finished state of a wooden instrument and the state once it is in playing condition. However, a hypothesis concerning metal organ pipes might perhaps explain what happens in wood. The vibrations of the air column in an organ pipe execute a periodic mechanical impact on the pipe's walls in those places where the vibrations have their maximum amplitude. Though this is a very small mechanical force, it may in the course of years harden the metal and thus modify its qualities, which were even throughout the pipe at its manufacture. Certainly, organ makers insist that old, used pipes have a much nicer tone than new ones. Although not yet verified, it could be that the geometry of the vibrating air column imposes itself on the material of fabrication.

It is, however, a mere myth that instruments "lose their voices" unless they are played regularly. Instruments may indeed lose some of their easy response if not played for a longer period of time, but the tonal qualities are easily regained once the instrument is adjusted and settled to playing condition. Thus, the so-called "maintenance" that the splendid violins on display in the City Hall of Cremona receive by being played every day, contributes to the risk of damage, rather than to the upkeep of their musical value.

Choosing Wood for Repairs

Assuming that repairs are to be made, and that qualified personnel are on hand, there are two questions to be addressed: the selection of a suitable wood species, and the quality of the piece of wood to be used. The wood used in a repair should normally be the same species as that of the original. However, in many cases it is difficult or impossible to match the texture and figure of the original. This may happen with figured maple, rosewood with coloured stripes, etc. In this case, a plain-textured wood is often used so that it can be painted afterwards in order to imitate the texture of the surrounding material. Limewood is often used in this way.

The shortcomings of repairs to musical instruments usually relate more to the quality than to the kind of wood used. Some conservators prefer to use well-seasoned wood that has acquired a brownish colour, matching the colour of the original. Orientation of the piece to be inserted is important. Earlywood and latewood in the original and repair must lie in the same direction and the angle between the longitudinal fibre axis and the wood surface must also be matched.

Skin Products

Skin is composed of proteins, which are long assemblages of amino acids, also called poly-peptide chains. The kinds of amino acids and their number and order in a poly-peptide chain dictate the kind of protein. There are some 22 known amino acids, but only 12 of these are found predominantly in skin components. The toughness and durability of skin is a characteristic of its chief protein, collagen, which forms a network of fibrous bundles. Flexibility is provided by a similarly formed protein appropriately named elastin. Water resistance is provided by keratin, which comprises the outer surface of the skin, and also forms hair, nails, and horn. A final protein, albumin, provides a matrix and is involved in transporting nutrients within the skin.

Skin is composed of four layers; the epidermis on the outside, the dermis just below this, the corium which comprises the body of the skin, and the hypodermis, which lies on the inside. The inner and outer sides of skin products often show two characteristic textures. During the preparation process, the epidermis and hypodermis are usually removed, leaving the smooth-sided dermis, and the fibrous-sided corium. Thicker skins are often split during processing, and various textures can also be applied, so the inside and outside of the skin may not be obvious.



Figure 9. Cross section of skin, showing the epidermis, the grain layer and the corium.

A wide range of techniques have been applied to processing skin products. Among the finished materials are rawhide, parchment, semi-tanned skin, smoke-tanned skin, chamois (fat liquored), alum tawed skin, and vegetable and mineral tanned leathers. In addition, many special treatments have been applied to the finished product including boiling (*cuir bouilli*), patent leather, texturing, etc. The chief products used in musical instruments are rawhide and parchment (untanned skins) and leather which has undergone a chemical tanning process.

Rawhide and Parchment

Once skin has passed through a pre-treatment process, but before being turned into leather, it can be used for making artifacts. In this state it is known as rawhide. Rawhide can be used in a number of places where its shrinkage as it dries can be used. For example, wooden components may be covered with rawhide in its wet state so that when the hide dries it exerts powerful contracting forces, pulling the wood joints tightly together. Similarly, drum heads can be made of wet rawhide, which tightens on drying to produce a taut membrane.

Rawhide is very susceptible to moisture, and if wetted sufficiently it will putrefy. Because no tanning process is used, the collagen molecules are still reactive to water. In its normally dry state it is extremely tough and intractable, and may fracture if bent or twisted. Wetting and subsequent drying will cause very high shrinkage.

Parchment is prepared from pre-treated skin that is still in the wet, swollen stage. The critical stage comes when the wet skin is stretched on a frame while allowed to dry. Unlike the process of making leather, where the skin is not under tension, the individual fibres are stretched during drying. This causes them to pack more tightly to each other and allows them to be held in place when the matrix material dries. Thus, having dried under tension, the skin is hard, flat and relatively thin. The skins of small animals are generally used for making parchment, particularly calf, goat and sheep. Sheepskin parchment is the most common. In order to whiten the skin and make the surface smoother, various fillers like chalk, talc, and whiting are rubbed in after the skin is degreased. The surface is sometimes treated with an abrasive, such as pumice or brick dust, to even out the texture.

When stored below 50% relative humidity, parchment is very durable. However, higher levels of RH may cause it to shrink and cockle very badly as the stretched collagen fibres attempt to regain their original shape. Parchment can also embrittle with age causing stretched areas to tear.

Fish skin is used in some wind instrument paddings. It is high in keratin and has excellent flexibility and good resistance to moisture.

Leather

Vegetable tanning is the oldest, true tanning process. A tanning liquor is prepared by adding the bark, leaves or twigs of certain plants to water. The basic process involves suspending the skins in the tanning liquor while beating and manipulating them. At the beginning, the skin is plump, soft and porous. The leather produced at the end of the process is hard and inflexible, and requires a treatment called currying to restore the softness and "feel". During currying, fats and oils are worked into the damp leather which is then allowed to dry out. Tallow and cod liver oil are commonly used in commercial processes. In some cultures, where older techniques are still employed, the tanned hide is simply manipulated by hand to soften it.

Most of the world's supply of leathers is now mineral tanned, although the process is only about a century old. Thus, mineral-tanned leathers may be found in more recent instruments, but the leather on the majority of historic instruments will be vegetable tanned. Chromium salts are predominantly used in mineral tanning, and the process is thus known as "chrome tanning." Other salts, particularly zirconium, have recently come into use.

Vegetable tanned leathers are generally quite stable, but in musical instruments they are most often used in places where flexibility is necessary, such as the hinging of piano hammers. Organ bellows combine flexibility with air-tightness. In such high use locations, old leathers can become mechanically deteriorated through constant flexing, and the materials used by the tanner to soften the leather may also dry out and become ineffective. Some vegetable-tanned leathers suffer from red rot, which is a deterioration brought on by exposure to sulphurous pollutants in the atmosphere. In extreme cases of red rot, the leather becomes light brown and very powdery, and disintegrates.

Bone and Ivory

D

Bone is usually used in musical instruments for its decorative effect, or where surfaces require wear resistance. Bone tissue consists of organic and inorganic materials forming a compact matrix. The organic portion consists mostly of the fibrous protein, collagen, and constitutes approximately 50% of the bone. In the natural process of ossification, the fibrous framework of collagen becomes surrounded by crystals of a complex tricalcium phosphate and calcium hydroxide known as apatite. The long bones, which are the ones predominantly used as raw material for musical instrument parts, have an outer shell of very hard and compact bone (the periosteum) surrounding a less dense portion traversed by the socalled Haversian system which conducts blood vessels through the bone. When bone is cut and shaped it is the Haversian canals that give it its characteristic appearance. On some very dense structural bones, this

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pattern may not be noticeable to the naked eye due to its very fine structure, so bone can be mistaken for ivory. Even though it contains a relatively high proportion of organic material, bone is not very sensitive to moisture.

Ivory is the teeth of mammals and is formed in the soft tissues of the jaw. A crown of enamel is laid down by specialized cells, and it takes on a honeycomb appearance. Apatite is laid down by the cells, as in bone, except that here the cells are not incorporated into the crystal structure. As the crystals form, the organic portion is squeezed out to the sides. This accounts for the comparative density and hardness of tooth material compared with bone. In a fully-formed tooth the organic portion is around 1%. In cross section, a differentiation is visible between the enamel on the upper surface and a second material, dentine, which forms the body of the tooth from the crown to the root. The root is held into the bone of the jaw with a third substance called cement.

Elephant tusks have been the major source of ivory in the making of musical instruments, although narwhal tusks and teeth from other animals have also been used. Ivory is used for wear-resistant surfaces such as key facings, for decorative inlays, and for lathe-turned parts of wind instruments. Occasionally whole instruments have



Figure 10. Microscopic features of bone, showing the Haversian system much magnified for clarity.



Figure 11. Cross section of ivory tusk, showing the enamel (the outer layer), the dentine (the body of the tusk) and the cement that holds it in place in the jaw. been made from it, especially woodwinds. Elephant ivory has a characteristic growth pattern that makes cut pieces of it easy to recognize in cross section (*CCI Notes* 6/1). Like bone, it is comparatively resistant to moisture, although because it is more brittle, cracking is more commonly observed. Both ivory and bone yellow with age, especially in areas that are not exposed to light.

Keratinous Materials

Horn

Horn is a keratinous material derived from the epidermis. Other kinds of keratinous tissue include nails, claws, hair, hooves, and feathers. Unlike the skeletal materials bone and antler, keratin is deposited within the cells, which eventually became so overloaded that they die. The outer surface of the skin itself is composed of keratin, but this soft tissue is continually growing upwards and being sloughed off as the cells die. In horns, the dead keratinized cells are retained, and are continually added to from below. The horns of cattle, sheep, goats, and antelopes comprise a hard sheath surrounding an underlying bone core projecting from the frontal bones of the skull.

Because horn is a relatively plastic substance, from very early times it has been worked into various shapes. It is heated by boiling in water until it becomes flexible enough to form into quite complex shapes. In the 19th century, techniques were developed for grinding horn to a powder in strong alkalis, then re-forming it with heat and pressure. The resulting artifacts in no way resemble the original form of the horn.

Horn is used occasionally in the bodies of musical instruments, such as the traditional hornpipes, and is also used as an inlay for decorative purposes. It is very resistant to moisture, but can delaminate internally and crack with age.

Quill

The quills used for the plectra of plucked string instruments are made from portions of the shafts of large bird feathers, such as those of the crow. They are composed of keratin which, like horn, is an outgrowth of the epidermis of skin.



Figure 12. Cross section of a horn, showing the horn as an outgrowth of the epidermis, and the interior bone.

Like horn, quill is a flexible, water-resistant and fairly durable material, but as it dries and loses natural oils it becomes brittle.

Baleen

In earlier times baleen was known as whalebone, and it is now written as one word to distinguish it from the bones of whales. It is a keratinous substance, produced from the epidermal region within the jaws of whales. In cross section, it resembles a tightly bundled sheaf of hairs surrounded by a matrix. It is used in musical instruments for its springy qualities, and can be encountered in the actions of some keyboard instruments. It is a flexible, water-resistant and fairly durable material, but has a tendency to delaminate and become brittle.

Glass

Glass is a viscous liquid that consists of a rigid, but random, network of molecules. The network former is silica, to which is added a number of fluxes to give it desirable working properties. The oxides of sodium, potassium and lead are commonly used as fluxes, and calcium oxide is added to make the glass insoluble in water. The relative proportions of these substances are critical in determining the stability of the glass. Unstable glass is characterized by a number of symptoms including

cracking (not related to mechanical damage), sweating, crusty deposits, and crizzling. If the glass appears damp or sticky to the touch or shows any lack of transparency, fine cracking, or surface deposits, it is probably suffering form what has come to be called glass disease. This subject is covered in detail by Newton in Conservation of Glass. Glass is used for making wind instruments, and for the sound-producing components of some idiophones.

Synthetic Organic Materials

Since the 19th century, synthetic materials have been used in a wide range of manufactured objects. The chief ones encountered in musical



ufactured objects. The chief *Figure 13. Detail of a feather, showing the barbed* ones encountered in musical *construction, and the parts used for making plectra.*

instruments are the variations of cellulose nitrate used as substitutes for ivory in key facings and decorative elements, and ebonite, used as a substitute for dark-coloured hardwoods in wind instruments. The long-term stability of these materials was improperly understood at the time of their manufacture and deterioration is often evident.

Cellulose nitrate (or nitrocellulose) is found under a variety of names including celluloid, french ivory, and collodion. It can be made to look like ivory, tortoiseshell, horn, nacre, and many other organic animal materials. In musical instruments it is usually found in synthetic key facings, which have been grained and figured to look like ivory. It contains a volatile plasticizer, camphor, which can diffuse through the plastic and vaporize from its surface. This leaves the material brittle and subject to shrinking and cracking. In extreme cases, the plastic crumbles into small cubical fragments. Nitrocellulose is notoriously unstable, especially when prepared for such applications as photographic film, and in a highly nitrated form it is used as a high explosive. While the material used for keyboard facings and similar parts is relatively stable and non-reactive, it remains highly flammable and can degrade badly under some conditions (*CCI Notes* 15/3).

Ebonite has been used since at least the middle of the 19th century for making woodwinds. It is a highly vulcanized natural rubber created by adding a large proportion of sulphur under heat and pressure. It is subject to deterioration, producing acidic exudates, which can attack the fittings of the instrument or other associated materials. Moisture stimulates this reaction (Bacon).

Coatings

Many methods have been used to modify the surfaces of musical instruments. Wherever a surface has been modified by applying another substance, there is the potential for physical and chemical interaction. And because coatings are often used to disguise or alter surface appearances, there is also the potential for confusion and misidentification. A huge range of possible surface modifiers exists, so close examination, thorough documentation, and a knowledge of the construction techniques of objects, are necessary before any decisions about care, and especially treatment, can be made.

A coating can be applied to a surface in the form of a fluid, it may be a solid which is adhered to the surface, or it may be a metal deposited electrically from a solution of salts. The fluids may be single substances, like oils or waxes, or they may be solutions, emulsions or suspensions. Solids, such as wood, metal, paper, or leather, may be applied to a surface as veneers or inlays. Surfaces may also be modified by applying chemicals. Nine basic categories of surface coating are defined:

- pigment
- paint
- lacquer or varnish
- oil or wax
- veneer
- paper, leather or textile
- enamel or glaze
- plating
- patination

Although the following notes refer mostly to substrates made of wood and metal, many other materials might have similar coatings. For example, leather can be painted or lacquered, ceramics can be glazed, and many other materials may have their surfaces modified in various ways.

Pigment

One of the simplest ways of modifying the surface of an object, especially one made of wood, is by applying raw pigment to its surface. Such natural earth pigments as ochres and umbers can be used, while black wood ash from the fire, and white clay are common. This class of coatings is characterized by the fact that it has no binder; the pigment is either applied dry, or in a slurry with water.

Usually, porous surfaces such as wood and other fibrous vegetable materials are coated in this way because the pigment adheres easily and is not rubbed off quite so readily with use. Movement of the underlying material (usually wood) has little effect on loosely bound pigments, because they do not form an intact film, but are scattered over the surface.

Paint

Paints contain pigments for colour and surface effect, as well as a binder such as a drying oil or a resin in solution. Binders hold the pigment more firmly to the surface. Smooth metal surfaces, such as the interiors of brass instrument bells, may be painted, and rougher, fibrous surfaces, like the bare wood of soundboards, are also painted.

Painted surfaces are easier to maintain than those covered in dry pigment, provided no deterioration has taken place. However, complete films on objects that expand or contract can crack and loosen. This problem is mostly seen on wooden objects and paintings on canvas, but paints on metals which have been heated and cooled may also show the same symptoms. Adhesion between the paint and the surface may also fail with time, and cause flaking and loss. In addition, the binders in paints may undergo deterioration, primarily due to the effects of light and oxygen, which can cause breakdown of the film, powdering, and changes in colour.

Lacquer or Varnish

The natural colours of surfaces are often enhanced by adding transparent coatings, which have a "wetting" effect, and thus saturate the colours. Lacquers usually consist of resins or gums deposited by drying of a solvent, while varnishes may also contain drying oils. Lacquers and varnishes differ from paints in that they are transparent (the term lacquer is used here in its European sense). Such transparent coatings may contain pigments or dyes to modify the apparent colour of the surface.

Lacquers and varnishes are sensitive to light. On exposure, they can become degraded, exhibiting yellowing, cracking, and loss of adhesion. As with paints, complete films applied on objects that expand or contract can become cracked and loosened. This problem is mostly seen on wooden surfaces, but transparent coatings on metals that have been heated and cooled may also show the same symptoms. Breakdown of lacquers on metals can cause spotty local corrosion.

Oil or Wax

Oils and waxes are dealt with together here because both are often applied to wooden objects to saturate the colours and to add a measure of protection. Both drying and non-drying oils may be applied. A wide range of waxes may be used, from hard materials such as carnauba to soft ones like beeswax. These substances are generally applied to porous surfaces to decrease their porosity, but they may also be applied to smooth surfaces like metal or stone. Characteristically on porous objects, the application soaks in so there is no clear distinction between the surface of the substrate and the surface of the coating.

Surfaces that have been treated with materials that only dry slowly, or not at all, tend to collect accretions with use, and to collect dust when not handled regularly. In general, such surfaces are durable and stable, except where the coating has been applied very thickly, or where the surface is smooth and lacks adhesion. In the latter cases, the oil or wax may flake away leaving lighter-coloured areas. Such finishes are usually encountered on ethnographic instruments, but bare wood in traditional European workshops was sometimes treated with linseed oil or wax as a protective measure.

Veneer and Inlay

Veneer is always wood, but inlay can be wood, metal, ivory, tortoiseshell, and many other materials. Veneer covers the substrate entirely, usually for decorative purposes. Inlay may also cover the whole surface, but can also appear in selected areas to enhance lines or provide decorative relief.

Where two differing materials are in intimate contact, physical and chemical reactions between them are possible. Veneers on musical instruments are prone to splitting and loosening due to movement of the underlying wood, either by changes in relative humidity or by distortions due to tension. Metals used in contact with wood may corrode due to the hygroscopic property of the wood and the presence of corrosive extractives.

Paper, Leather or Textile

Paper, leather and textile are grouped here because their use on the surfaces of instruments tends to be similar. Paper on instruments takes two forms: decorative linings covering large surfaces, and paper labels applied in discrete spots. Paper is usually applied to the surface with pastes made from starches, although hide glues or gums may also be used. Leather is used as a covering and reinforcement, particularly on wooden wind instruments that have been pieced together. Cornetti, serpents and oboes da caccia often have a thin leather covering attached with hide glue. Textiles are sometimes used as reinforcements for wooden constructions; for example the linings of string instrument resonators.

Paper, leather and textiles are all very fragile and subject to wear, fading and embrittlement. On wooden objects, fluctuation of relative humidity can cause the covering to tear as the wood expands and contracts. These materials, and their adhesives, are also very susceptible to moisture. Exposure to light can cause embrittlement of paper and textiles, and the fading of pigments used on them.

Enamel or Glaze

Enamels and glazes are hard, vitreous substances baked onto surfaces, usually metals, at high temperatures. The term "enamel" is sometimes used for paints that are applied at room temperature, and occasionally baked (or stoved), but this is not true enameling. Enameled surfaces are rare on musical instruments, but the nameplates of Viennese fortepianos are often enameled metal.

Enameled or glazed surfaces can suffer from crazing (a very fine cracking) due to differential movement of the substrate. Often crazing is incipient, meaning that it is a feature of the surface and unlikely to worsen unless subjected to poor conditions. Crazing is often valued as a decorative feature of surfaces. Enameled metal can show flaking if it has been stressed or distorted, or subjected to fluctuating temperatures.

Plating

A plating is a coating of metal, usually deposited onto another metal to enhance its appearance or resistance. Typical platings are silver on copper to increase value and attractiveness, and chromium or nickel on steel or brass to enhance resistance to corrosion and wear. Metals are sometimes deposited on surfaces other than metals, the most common being the gessoed gold leaf decoration applied to harps and other highly decorated instruments. Thin platings are done chemically from solution, by evaporating mercury from an amalgam, or by applying an electric current to a metallic salt under closely controlled conditions. Tinplate and galvanized iron are produced by dipping sheet steel in molten tin and zinc respectively. Thicker platings are sometimes achieved by sandwiching the metals together and heating them to cause surface amalgamation.

Adhesion between layers of metals can fail, especially where corrosion has occurred, or where the surfaces were not cleaned sufficiently before plating. Galvanic corrosion can take place between dissimilar metals in the presence of salts and water, especially where gaps in the plating exist. Thin platings are particularly sensitive to polishing and may be worn through very easily in high spots.

In surfaces where gilding has been applied to a non-metal, particularly wood or gesso, there is a risk of great fragility. Movement of the substrate can cause cracking and loosening. Gold, tin and silver leaf applied to such surfaces are also very thin, and susceptible to damage by abrasion.

Patina

Patina can develop naturally or it can be an artificially applied surface modification. The term is used to describe a wide range of surfaces; but when artificially applied it is most commonly defined as the chemical treatment of metals. Brasses are treated to produce many colours, including brown, black and green. Nineteenth-century English brass instruments sometimes have a black surface which, if in bad condition, can be mistaken for mere tarnish. Iron and steel are often heated to produce colours ranging through yellow, mauve, blue and black, and such colours are often seen on springs and tuning pins. The highly prized patina on wooden instruments results from use, although artificial means of ageing or enhancing appearance are sometimes employed.

Because patinations on metal objects are chemical features of the surface atoms, they are usually very thin, and they are therefore susceptible to abrasion and chemical attack. Naturally developed patinas are often aesthetically valued and may also provide information on the use of the instrument.

Composite Objects

A composite object is one made of more than one kind of material, and most complex musical instruments fall into this category. The potential for deleterious interaction between their components is very high. For example, when a metal and a non-metal are joined closely together, deterioration of both components is often accelerated. Iron in contact with wood will corrode much more quickly than by itself, and at the same time the structure of the wood will be attacked. Similarly, copper or brass attached to leather will experience accelerated corrosion. Organic materials such as hardwoods and leather are often quite acidic which causes metals in contact with them to be attacked. Also, materials used in maintaining artifacts (for example, leather dressings) can encourage corrosion.

The following notes refer primarily to the interactions between wood and metal, but many of the principles are common to composites of metals with other organic materials, and other combinations of materials.

Metals and Wood

The combination of wood with iron (or steel) is common in musical instruments. Silver, and copper and its alloys (brass, bronze, etc.), are also combined with wood, particularly in the keywork of woodwinds. Because most composite objects are made from either iron or copper alloy components, these are detailed here. Deterioration between metal and wood can show either chemical or physical symptoms.

In common with other reactive metals, iron is most stable in dry conditions. Water is the chief initiator of corrosion reactions, so the drier the metal is, the slower will be any chemical reactions. However, cellulose, of which wood is made, readily absorbs water. If the cellulose has excess water, corrosion reactions may occur with any metal in contact with it. On the other hand, the presence of metal ions in aqueous solution (from corrosion reactions) causes deterioration of both the cellulose and lignin components of wood.

Copper and its alloys cause similar deterioration. Copper salts are more damaging to wood than those of iron. In addition, copper can react with organic acids in wood and any oils used in its treatment, and form copper oleates, acetates, palmates, etc. These are generally soft, waxy, bluegreen substances that generally do not cause disruption of the metal due to their softness.

The corrosion products of both iron and copper are often larger than the metal from which they came, and rise above the original surface. Wherever wood and metal are closely joined, expanding corrosion products compress the wood, causing splitting or similar damage. At the same time, dissolution of the cellulose by metal ions in solution can collapse the cell structure of the wood. Staining of the wood caused by dissolved metallic salts is also very common. If relatively fresh wood is combined with iron, further drying can cause cracking as the metal resists the movement of the wood.

Stable Composite Objects

From the above, it would seem that metals and wood cannot exist together for a very long time without destructive reactions taking place. Nevertheless, as the majority of stable musical instruments demonstrate, a level of stability is achieved. A stable, non-reactive composite of metal and wood will have achieved stability by three possible mechanisms:

- The metal has developed a thin passivating layer that prevents further corrosion from taking place. This can occur on both iron and non-ferrous metals.
- The moisture content of the wood is low enough that corrosion reactions are not initiated.
- The wood contains extractives like oils and waxes that retard corrosion or provide a physical barrier.

In many cases, a combination of all three mechanisms is responsible for stability.

Degraded composite objects can be very fragile because of damage due to corrosion products, and weakening of the wood cell structure due to metal salts. High relative humidity may accelerate corrosion, while low relative humidity will affect wood. Stabilizing composites of metals and wood presents major problems where active corrosion is taking place, and where some form of environmental control is considered necessary. A dry environment is preferred for stabilizing metals. However, dry environments for wood usually result in cracking, warping and other distortions. Obviously, a compromise is necessary in such cases. In general, a relative humidity of around 35% will stabilize most corrosion products, while not subjecting the wood to extreme conditions.

Wood and Other Substances

Many other substances are combined with wood for both functional and decorative reasons. Decorative materials like shell, ivory, and bone are attached to wood or inlaid into its surface. Chemical reactions between such substances do not cause significant changes to their stability, but some physical reactions can occur. Because wood moves in response to changes in relative humidity, any non-reactive material firmly attached to it will set up stresses as movement occurs. Inlays buckle and push away from the surface, resistant inlays can crack the surrounding wood, and so on. Also, where wood is combined with other woods, if the grain directions are not aligned, differential shrinkage can cause damage.

R.L. Barclay, C. Karp

Treatment is approached in the following sections in two ways: by material of fabrication, and then by type of instrument. The first section generally describes applicable techniques for a wide range of materials and conditions, and the second deals with the problems of specific musical instruments.

Basic advice on the care of displayed musical instruments is provided by the *National Trust Manual of Housekeeping* and similar texts, but the following guidelines address treatment needs that go beyond routine "housekeeping" duties. It is assumed that once any of these techniques has been performed on an instrument, ongoing care will be exercised to keep it in good condition. It is pointless to clean and stabilize instruments if they are then returned to the conditions that contributed to their state.

The techniques described here require some simple equipment and a knowledge of its use, and a few materials and supplies. Commercial products should be used with some caution because their ingredients are often not known and manufacturers can change formulations without notice. Recommended products are noted in the text. Some familiarity with musical instrument terminology is assumed.

The conservation profession is widespread and accessible, so if there is any doubt about treating an instrument, resources are available. This is especially important when suggestions or recommendations for treatments have been made that go beyond simple stabilization and presentation. The resource list at the end of the book includes the addresses of some national conservation associations, advisory bodies, museums and funding agencies.

Justifying Treatment

Before performing any treatment on an instrument, several questions must first be addressed:

- · What caused the deterioration?
- · What techniques have been used in its construction?
- Is it stable?
- What did it look like originally?
- Is its appearance acceptable now?
- What do we want it to look like?
- What do we hope to gain by treating it?

Articulating these questions develops a justification for action. Because of the nature of musical instruments, the variety of possible fabrication techniques, and the range of possible conditions, it is essential to learn as much about the object as possible.

- What caused the deterioration? Characterizing the state of the instrument is the first step before taking action. It is not possible to treat deterioration unless its cause is well understood.
- What techniques have been used in its construction? An understanding of the instrument's construction in a historical context is necessary when deciding or modifying treatments.
- Is it stable? This requires a knowledge of deterioration mechanisms specific to the instrument in question, and at least a visual and tactile understanding of what instability, fragility, and deterioration are.
- What did it look like originally? Answering this question will indicate how the treated instrument might differ in appearance from its original state, while also helping to focus attention on the changes its appearance may have undergone over time.
- Is its appearance acceptable now? Objects often acquire a patination with age that is certainly not part of the maker's intention, but nevertheless can be informative, aesthetically pleasing and protective.
- What do we want it to look like? Will treatment make the instrument look more original, more authentic, or more attractive, and how are these terms understood? What do we understand about the way it should appear? Is our impression of the appearance compatible with the way it should appear in the museum context?
- What do we hope to gain by treating it? This is the key question. Is the instrument to be treated:
 - to make it look better?
 - to make it work better?
 - to stabilize it?
 - to gain information?

All the above six categories suggest further questions, none of which can be answered fully here. The questions serve two purposes. First, by asking questions we initially put the brakes on our hands. This is one of the less understood functions of documentation — it obliges us to rationalize our approach and create a logical and answerable sequence of steps. Secondly, by asking questions, we gain a better understanding of the material under our care and our approach to it. Inevitably, though, no matter how conscious one is of the above questions, it is difficult to provide all-encompassing guidelines; each instrument raises specific problems.

Review of Cleaning

Definition of Surface

Before considering any treatment that might have an effect on the surface of an instrument, it is necessary to define exactly what we understand the surface to be. At first glance it seems obvious; it is simply the interface of the material with its environment. In other words, the level where the artifact stops and its surroundings begin. But it is rarely, if ever, so simple. True surfaces are often very irregular; they may have finishes and other coatings; they can be abraded with use or built up by accretions. Although the definition of the true surface of an object is by no means easily decided, it is important to know what the surface is composed of and how it was created.

The attractiveness of a surface to dust, dirt and accretions with use depends upon its nature. For example, a rough or fibrous surface may not attract airborne dust more readily, but it will help it stay in place. On the other hand, the same rough or fibrous surface will cause accretions of use to accumulate faster than they would on a smooth surface.

Definition of Dirt

Dirt is a negative word; it carries connotations of undesirability and removal. However, it is defined here in a very wide sense and must be understood to include any accretion that an instrument has acquired since its manufacture. There is good dirt, and there is bad dirt. Therefore, once a surface has been defined, the presence of dirt on it must also be defined. And it is also necessary to decide whether the dirt can be removed without damaging the object, or whether it *should* be removed. This topic is dealt with in detail in *Cleaning*, in the highly recommended Museums & Galleries Commission "Science for Conservators" series. The following notes paraphrase, but the reader should consult the source for details.

A dirty surface can actually be a very complicated phenomenon because the dirt may consist of foreign material, chemically combined material, or a mixture of both.

- Foreign matter. This is material that does not originate from the instrument, but which has settled on it. Examples are dust blown in from outdoors, and grease or dirt caused by handling.
- Product of alteration. This is material that originates from the instrument, and which has then been transformed by chemical reaction with its environment. The most obvious example is corrosion products on metals, but many other substances, such as wood and leather, oxidize on exposure to the atmosphere.
- Physical mixture. This is a mixture of material from the instrument and foreign matter. Any porous or fibrous surface can absorb dirt in solution in water, which then dries out leaving the dirt and the object indistinguishable. Tide lines on wood that has been wetted and dried are physical mixtures of dissolved dirt and wood fibres.

Why Dirt Should be Removed

Removing dirt from the surface of an historic instrument must be done for a very good reason. The following reasons describe why dirt should be removed:

- Abrasion. Some dusts, especially those carried into a building during construction work, can be very abrasive. Handling dusty objects can scratch the surface, and might embed granules in the object. This is especially important with varnished wooden instruments or highly polished metal ones.
- Attraction of pests and mould. Organic dust, found most often in the inaccessible interiors of instruments, provides nutrients for many organisms including fungi and insects.
- Sites for reaction. Dust provides a focus for chemical reactions, particularly corrosion on metals. When relative humidity rises dust can attract moisture, thus stimulating oxidation reactions.
- Chemical reaction. Some forms of dirt chemically react with the surface, and thus change its nature.
- Masking. Dirt and dust can mask a surface, obscuring details and giving the object an unpleasant appearance.

Why Dirt Should Stay in Place

On the other side of the argument, there can be good reasons why dirt should not be removed:

- Potential for damage. Removing dirt might be so difficult that it causes damage to the surface of the instrument. From a conservation point of view, this is the chief reason to be cautious when dealing with dirty surfaces.
- Protection. A layer of dirt may be protecting a surface, and its removal might cause a further undesirable reaction between the surface and its environment.
- Information. The dirt may contain information useful to the interpretation of the instrument or its context.
- Aesthetics. Patterns of dirt may contribute to the appearance of an old instrument.

If dirt were simply to settle on an object by gravity, it is reasonable to assume that it could be easily removed by turning the object upside down. Obviously, this does not happen, so the dirt must bond to the surface in some way. In fact, there are several ways in which dirt can stay in place. These are, in order of removability, mechanical attraction, electrostatic attraction and chemical bonding.

General Principles of Cleaning

Once it has been decided that the dirt is undesirable and that removing it is necessary, the techniques for removal must be tested. Spot tests should be made in unobtrusive places on the instrument to determine what the dirt is and how easily it can be removed. If the dirt cannot be removed by any of the techniques described in these notes, it must stay there.

It should be decided if cleaning is truly needed and how far it should go. What is "museum dirt" and what is "dirt from use"? Can one be removed and not the other? As a rule of thumb, more recent dirt from handling and storage in inadequate conditions will be easier to remove than dirt accumulated on an instrument from use. Learning to distinguish between the two, and knowing where one stops and the other begins is acquired by experience, and is not easy to teach.

Review of Techniques

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These techniques are dealt with in some detail later, but a brief review is presented here for emphasis. For the purposes of general surface cleaning of historic objects, the techniques can be divided into either mechanical, solvent or chemical.

 Mechanical cleaning. This includes any method that relies on the physical action of one object upon another. It includes blowing, dusting, rubbing, erasing, abrading and chipping, and can be done with the range of tools from soft brushes to hammers and chisels. Mechanical cleaning works best when the dirt and the surface are well defined; in other words, where the dirt and the surface are easily separated without damage.

- Solvent cleaning. Solvent cleaning involves the use of any fluid that has the capacity to dissolve or loosen dirt from a surface. There are a variety of mechanisms involved in solvent cleaning including:
 - Dissolution, where dirt is dissolved in a solvent and washed off the surface.
 - Softening, where dirt is softened and can be removed mechanically.
- Chemical cleaning. This involves chemical reaction (oxidation or reduction) that occurs between the surface of the object and a cleaning medium. The methods include:
 - Enzyme reaction, where an enzyme is used to catalyse a reaction. Such techniques are most often used in cleaning organic residues from paper and textiles.
 - Sequestering agents, where molecules cluster around positive or negative ions causing them to become soluble.
 - Electrochemical and electrolytic reactions, which are especially used in cleaning metals.

Treatment of Wood

Cleaning Surfaces

All instruments require some minor cleaning as part of their routine care. Cleaning wooden surfaces is relatively straightforward if the guidelines below are followed. One should always begin with the least aggressive cleaning method and move up the scale only if considered necessary:

- soft brush and vacuum cleaner
- stiff brush
- eraser powder
- adhesive rubber
- gum eraser
- damp swab

Soft Brush and Vacuum Cleaner

In the majority of cases (where firm, stable surfaces are involved), surface cleaning can be done using a soft brush and vacuum cleaner. Dust can be brushed from the surface into vacuum cleaner nozzle with a soft paint brush.

The nozzle should be covered with cheesecloth held in place with a rubber band to prevent small pieces being accidentally sucked up. A speed controller is useful for regulating suction (see below). Vacuum cleaning should not be done if loose pieces, powdery surface coatings or delicate components are present. Soft brushing without the vacuum cleaner is possible if the surface will permit it.

For access to intricate areas (i.e., underneath the strings or between the keys of a keyboard instrument), a narrow hose attachment can be made for the nozzle of a vacuum cleaner. A piece of 4 mm bore flexible plastic tubing can be attached to the nozzle with tape.

Because the narrow tube constricts air flow, the vacuum cleaner motor may overheat. This can be relieved by providing a pressure relief hole in the nozzle, which is covered by a finger when in use, or by connecting a speed control into the vacuum cleaner circuit. If the latter technique is chosen, an electrician should be consulted, because certain kinds of alternating current electric motors cannot be controlled without damaging them.

A miniature vacuum cleaner of the type used in the electronics industry is useful for the finer

applications in conservation, or one can be constructed by reversing the flow of an aquarium pump (*CCI Notes* 18/2).

cleaner nozzle.

Stiff Brush

Where the surface condition of the object allows, a stiff bristle brush may be used to remove ingrained dirt. However, it must be remembered that wood is relatively soft and that damage to the top layers of cells, particularly in degraded wood, is a possibility. Injudicious cleaning may enhance grain patterns by selectively wearing away the softer, early growth.

areas rings or keyboard hose de for n cleaner. Hexible ttached

Figure 14. Brushing dust into a vacuum cleaner nozzle.



Figure 15. Hose attachment for a vacuum



Figure 16. Microscopic cross section of wood, showing the effects of wear due to abrasive cleaning, which has enhanced the difference between early- and latewood cells.

Eraser Powder

Draughtsman's eraser powders may be used to remove ingrained dirt from relatively sound surfaces. There are a number of kinds of powders; the ones made from natural rubber are considered the best. The powder is rubbed in with the finger tips until cleaning is seen to be effective. The powder should not be used on objects that are cracked or have uneven surfaces where the powder may be left behind. After cleaning with rubber, the surface must be well vacuum cleaned. Over-cleaning or patchy cleaning is very easily done with rubber powders.

Adhesive Rubber

Adhesive rubber is partially vulcanized natural latex used as an eraser in drafting, and also sold by conservation materials suppliers. It can lift dirt off fragile surfaces. It should be applied by pressing onto the surface to be cleaned, not rubbing, and should be discarded as soon as it is dirty. The surface to be cleaned must be sound and intact as this can be a very aggressive method.

Gum Eraser

If the above treatment is either ineffective or too time-consuming, a solid gum eraser can be used. These are made of natural rubber and are less abrasive than those made of PVC or filled rubber. Once again, over-cleaning is easily done.

Damp Cleaning

There are some circumstances when damp cleaning can be done. A small cotton swab should be wetted with distilled water and squeezed almost dry. It is applied with a rolling motion, lifting dirt off the surface while hardly depositing any water at all. As soon as the swab becomes soiled it should be discarded. This technique should only be used where all else has proved unsatisfactory. It is best used on surfaces which have a sound, intact finish because dampness will raise the grain of bare wood. Small tests on unobtrusive areas should be done to ensure that nothing other than dirt will be removed.

Cleaning Cracks

Old cracks in wooden components become filled with disfiguring and potentially damaging accretions. Removing dirt from such areas is a delicate process that can do more harm than good if not carried out with great care. It is necessary to assess what kind of material one is dealing with, checking to see if it is loose dust, or a heavier accretion like wax polish, dried oil, or varnish. Then the edges of the crack should be checked for soundness; it is unwise to remove dirt if the surrounding wood becomes damaged in the process. In general, loose dirt in cracks in sound wood can be removed using a vacuum cleaner with a thin hose attachment, or by blasting compressed air from the sort of portable container used in the electronics industry. Very fine forceps may also be used to remove more resistant particles, a procedure best carried out under a low magnification. Very resistant material should be left in place if there is any likelihood of damage resulting from its removal.

Repair

Repairing wooden objects is a task for a specialist, but minor repairs can be made to loose veneer, detached edgings, and other accessible damages. It is inefficient to readhere loose wood if the surfaces to be joined are not clean. This means removing dirt and other accretions, followed by softening and removal of old adhesive. Traditionally, watersoluble natural glues were used. These can usually be softened by applying dampened blotting paper or cotton batting. Spilling excess water onto surrounding surfaces should be avoided. The moisture-absorbent material should not be soaking wet. Once the water has been left in contact for half an hour or so, the old adhesive can be gently scraped off.

Occasionally traces of old glue provide a "key" to the original position of detached components, so it is sometimes advantageous to leave these traces in place, because they allow precise repositioning of parts in their original location. This is especially applicable if the glue is not on structural components.

Readhesion should always be done with a natural adhesive, not a synthetic modern product. Adhesives such as the commonly-used white glues are very convenient, but are difficult to re-dissolve. Using natural glue will ensure that the repair can be taken down in the future if necessary. Adhesives traditionally used for fine woodwork were hide glues, applied while hot and allowed to cool in place. The techniques for hot gluing are hard to master, so for the occasional repair by the non-specialist, it is better to use a liquid hide glue, or a fish glue. These can be injected or brushed into the joint, slightly thinned with water if necessary. A hypodermic syringe is the best tool for putting the glue exactly where needed, and nowhere else. Only the minimum amount necessary for the join should be used. Once applied, the join should be compressed briefly by hand to remove excess glue. Any glue that oozes out should be wiped off before clamping.
The secret of a good glue join is in the closeness of the parts, which is achieved by efficient clamping. Natural glues are poor gap fillers, so the less glue there is in the join, the stronger will be the finished result. A wide range of clamps is available from specialist woodworking suppliers, the size and type of clamp depending upon the work to be done. Clamps are never brought directly to bear on old surfaces; there must always be some form of padding between the jaws and the work. Also, silicone paper, wax paper or thin plastic film is applied so that any excess glue that may ooze out will not stick to the clamp or pad. Small pieces of 2.5 mm thick Plexiglas (Perspex) with smooth, bevelled edges are useful as clamping pads. It is advisable to do a "dry run" by attaching all the clamps and pressure pads, without applying the glue, to check the security of the join. However, this may not be possible or advisable when the pieces involved are too small or vulnerable to breakage themselves.

Repairing damages by gluing is a relatively complicated process. It is far better not to do it than risk making things worse by doing it poorly. If the equipment is at hand, it is advisable to practice on a few worthless pieces of wood first to get the feel for all the things that can go wrong.

Treatment of Metal

Pros and Cons of Polishing

Polishing removes metal and its associated corrosion products from the surface of an artifact, thus exposing a clean surface. It is important to realize that polishing *always* removes original material. On a microscopic level, a metal surface is uneven, so when polishing takes place the high spots are removed preferentially.

Commercial metal polishes vary in their abrasive properties from the very mild to the extremely coarse. Only a few polishes are considered useful for historic material, and even these must be applied with great

caution. Because metal is always removed from the surface, the treated piece becomes thinner and decorative detail is worn away. Also, there is no point in polishing the metal parts of an instrument if it is destined to return to its corroded or tarnished condition fairly quickly. Polishing entails the responsibility, first, of removing original material forever and, second, of maintaining the newly exposed surface.



Figure 17. Microscopic cross section of a metal surface showing how polishing to remove tarnish always removes metal as well.

Metals occasionally have an artificial, chemically applied patination that alters the appearance of the surface. The solid black finish of some 19th century brass instruments has been confused with tarnish and has been incautiously treated.

Basic Treatments

The straightforward conservation techniques dealt with here can be done with limited materials and equipment. More invasive treatments require the services of a professional conservator, either to advise upon or to carry out the procedures. Conservation treatments for metal may be divided broadly into three categories: cleaning, stabilization, and coating.

- Cleaning. This can be achieved mechanically, chemically, electrolytically, or electrochemically. For the purposes of these notes, mechanical cleaning in the form of abrasive removal is the primary technique recommended. Products available for this include cloths, pastes, waddings, and fluids.
- Stabilization. This may be done with or without corrosion products in place. It can involve removing harmful material from the metal, or applying a protective layer to the surface that lowers its reactivity. The protective layer is chemically bonded to the metal and should not be confused with the physical barrier provided by coatings.
- Coating. This is the application of a surface layer (lacquer, wax, or paint) in order to isolate the metal from any hostile aspects of its environment. A coating can protect against pollutants, dust, and the residues from handling, but is never a complete barrier. Small flaws or breaks in the coating can actually induce pitting corrosion.

Cleaning Iron and Steel

Steel wool and oil may be used on thin layers of rust on sound parts such as tuning pins. Fine steel wool (4-0) is lightly moistened with light oil and rubbed in the direction of any existing tool marks — concentric for components that were machine-turned, longitudinal for ones formed by filing or sandpapering. In this way, light corrosion can be removed while maintaining the original appearance of the piece. Care should be taken to confine the treatment to only the metal. The metal piece should be either removed for treatment, or wood or other material in close proximity should be masked with thin plastic sheet. The residual oil has a slight effect as a vapour barrier in preventing re-corrosion but may need re-application periodically. Very fine emery paper (600 grit) can also be used, but only where the rust is highly disfiguring and all original tool marks have been obliterated.

Commercial rust strippers are not recommended. They are often based on acids (particularly phosphoric) and may contain a number of unknown additives. Formulations may change without notice, and it may be difficult to remove residues.

Tannic acid can be applied on an iron surface in order to form iron tannate (a dark blue-black colour), which is stable and acts as a slightly protective layer. This should only be used on forged or cast iron parts whose surface was originally black (*CCI Notes* 9/5, 9/6 and 9/8).

Many steel and iron parts were originally patinated by either heat or chemical treatment. Most tuning pins have an artificially applied black or brown patination, which should not be removed.

Cleaning Copper and its Alloys

Copper and its alloys can be polished provided the surface was originally highly finished. As with any invasive technique, small tests should be done on unobtrusive areas first to determine the kind of surface that will result, and the type of polish needed. The mildest polish is tried first. It should be remembered that polishing is a very laborious activity, especially on large, complicated brass instruments, and that the resulting surface may in fact increase the visibility of dents and scratches (*CCI Notes* 9/3).

Cleaning Silver

The chief treatment for silver is polishing. This should be done with the finest abrasive cloth, and only on instruments that will be actively protected from further tarnishing. Efforts should be made to keep the appearance of the whole surface even and balanced, and not to concentrate polishing in discrete spots. Only polishing cloths specifically formulated for use on silver should be applied.

Silver dips can be used on parts of instruments that are detached and do not contain hollows or other attached metals. Great care must be taken because silver dip is not discriminating; it will remove all tarnish, giving a very flat appearance to the surface. This is especially important on pieces with etched, engraved or incised decoration. A dip which has been used on any other metal should not be applied to silver because baser metals held in solution will "plate out" onto the silver.

Coatings for silver, and the copper alloys mentioned above, include lacquers and waxes. Generally, lacquer coating is not recommended because it is difficult to remove it later. A thin coating of microcrystalline wax, such as Renaissance Wax, is more innocuous; it can be removed with mineral spirits and reapplied as needed (*CCI Notes* 9/7).

Cleaning Lead and its Alloys

In general, lead and its alloys develop a stable, grey patina that is protective and aesthetically pleasing. Polishing and other mechanical methods should only be used with the greatest caution because of the softness of the metal and the health problems of lead contamination. Occasionally lead develops patches or blisters of corrosion that appear as blemishes on the surface. These can be picked out mechanically, but there is a risk of perforating thin structures like organ pipes. A white, powdery corrosion product is sometimes seen on lead exposed to acids or alkalis, or in contact with wood and other organic materials. Metallic lead and lead reaction products are poisonous, and the advice of a conservator should be sought before starting any treatment.

Wax is the most commonly used coating for lead objects although, given adequate storage or display conditions, it is unnecessary. The chief treatment for lead is passive — providing apposite environmental conditions.

Repair

Old metals that have become damaged are among the most complicated materials to repair and are best left in the hands of experts. The wide range of original methods of joining components rules out provision of even basic guidelines. In general, soldering techniques, which require heating the metal, are not recommended because they change the microscopic characteristics of the metal, and possibly affect acoustics. Synthetic adhesives for metal are increasingly used, but their application is a specialized field.

Treatment of Other Materials

Cleaning Skin and Leather

Before beginning cleaning it is important to identify the material. Unprepared skin is sensitive to moisture and will shrink if wetted; leathers are more resistant. The resistance of skin products to moisture is as follows:

- rawhide and parchment
- alum tawed skin
- semi-tanned skin
- semi-tanned and smoked skin
- fat liquored (chamois) skin
- vegetable-tanned leather
- mineral-tanned leather

least sensitive

most sensitive

Cleaning treatments in order of increasing aggressiveness are:

- soft brush and vacuum cleaner
- stiff brush
- saddle soap
- eraser powder
- adhesive rubber
- gum eraser
- damp swab
- wet swab

Cleaning Rawhide and Parchment

This category includes drum heads and other membranes, action hinges, and roses from some string and keyboard instruments. These materials can only be cleaned dry. One should begin with a soft brush and a small vacuum cleaner to remove loose surface dirt. If necessary a stiffer brush may be used if the surface permits. Further cleaning may be carried out with eraser powder or a gum eraser. Over-cleaning with the eraser happens quickly and an uneven appearance can result. String and keyboard instrument roses are very fragile. Material used in such applications as the hinging of fortepiano hammers may have become very brittle with continuous flexing.

Cleaning Leather

Leather is most commonly found in bellows, air bags, keyboard mechanisms, hinges, and a variety of other locations where flexibility is the chief requirement. In older instruments the leather is likely to be vegetable tanned and thus moderately resistant to water. It can be cleaned with a damp swab, but dry cleaning with a brush should be done first to ascertain the adhesive qualities of the dirt. Applying a solution of a neutral detergent (less than 1% in water) on a damp swab is most effective on leather which has a smooth, intact surface. Saddle soap can be applied as a cleaning agent on leather that is dirty but sound. It also makes the leather more supple. Leather that shows evidence of red rot is impossible to treat without using specialized techniques (*CCI Notes* 8/2).

Softening Rawhide and Parchment

Untanned skin cannot be softened without causing shrinkage. Applying water to rawhide and parchment can cause complete dissolution. Oils have traditionally been applied to skin surfaces that are in use, but they cannot be recommended here because they cause excessive darkening and leave the surface sticky. No softening treatment can be recommended.

Softening Leather

Vegetable-tanned leather can be relaxed by applying water. However, liquid water may cause staining and tide lines as dirt is carried into the fibres. It is better to use a humidity tent made of polyethylene sheeting to raise the ambient humidity in order to relax leather fibres. A fungicide must be added to the water in the tent to prevent mould growth during humidification. Clearly, this technique can only be applied where it is possible to detach the leather parts. Many leather dressings are available on the market, but these were primarily manufactured for use on working leather such as saddlery and bookbindings where flexibility and suppleness are required. This is not the case with many historic objects. British Museum Leather Dressing, for example, was formulated for use on book bindings, but has been generally misapplied to all kinds of leather artifacts. Almost all leather dressings cause darkening of the surface and changes in surface texture. The oily or greasy ones also attract dust and insects. Unless it is absolutely necessary to provide flexibility to stiff leather, no leather dressing should be applied. This is especially so for leathers with a soft surface.

In one exceptional case saddle soap may be used: the smooth (grain) side of vegetable-tanned leather, if it is in sound condition with no surface cracks or defects, may be polished. Saddle soap is applied sparingly with a soft cloth and buffed to a shine. This acts as a cleaner and also gives a fine protective coating to the leather. Saddle soap is alkaline — it contains saponified fatty acids (triglycerides) — while the natural pH of leather is around 4 (acidic). There has been some debate on the efficacy of applying an alkaline material to a naturally acidic one, thus neutralizing it or, at least, somewhat raising its pH. So far no detrimental effects have been noted.

Cleaning Bone, Ivory, and Horn

Although bone, ivory and horn are relatively resistant to moisture, it is advisable to try mild mechanical cleaning methods before using solvents. The cleaning method will be dictated by the condition of the surface and the extent of cleaning desired. Cleaning methods in order of aggressiveness are as follows:

- soft brush and vacuum cleaner
- stiff brush
- eraser powder
- adhesive rubber
- gum eraser
- damp swab
- ethanol/water mixture
- ethanol
- mineral spirit
- acetone

Only under extreme conditions will it be necessary to use strong solvents. Normal "museum dirt" can usually be removed mechanically with less aggressive methods. Deposits of dirt in cracks in ivory can be removed carefully with sharpened wooden picks. Metal tools should not be used. Caution in cleaning highly carved and decorated ivory is recommended because removing all accretions in the lower relief of the design can leave a bland and uninteresting appearance.

Yellowing of ivory (key facings, wind instruments, etc.) is usually not reversible by any cleaning method. The traditional methods of metal polish, toothpaste, and bleach cannot be recommended. Exposure to ultraviolet light causes a bleaching effect on ivory, thus it is occasionally recommended that keyboards be exposed to sunlight to keep the ivories white. This is not a desirable treatment for historic objects (*CCI Notes* 6/1).

Repair of Bone, Ivory, and Horn

Ivory and bone instruments or components may sometimes be split or broken. As a general rule, adhesive repairs to ivory, bone, and horn are work for a specialist. Some damages can be repaired, but only if there is no distortion of the broken pieces. Often bone and ivory warp when drying out or when subjected to fluctuations in humidity. Cracking usually results from the relief of built-in stresses, and change in shape after breakage almost always results. It is not advisable to attempt realignment of warped pieces by clamping (for example) because further stresses will be set up in the material and cracks may form elsewhere.

Clean, well-aligned breaks may be glued with a PVA emulsion white glue. This glue yellows with age, so it is advisable, first, to make the join as close as possible using the minimum of adhesive and, secondly, not to spread the glue right to the outer edges of the break. Thus, when yellowing takes place the join will still be invisible. PVA emulsions require overnight drying when used on less permeable materials because they dry by evaporation. Hide glue has also been used successfully for repairs to bone and ivory. Repairs made with these adhesives cannot be expected to be very strong. Stronger bonds might be possible with polyester and epoxy resins, but they are almost impossible to unglue at a future time.

Horn is not as easy to glue. Its surface resists the penetration of most synthetic resins, which then tend to peel off. However, damages to horn will not be encountered as often because it is more flexible and thus is less likely to crack.

Treatment of Synthetic Organic Materials

Cellulose nitrate and ebonite, two materials used in musical instruments since the 19th century, deserve special attention. Cellulose nitrate goes under a number of names including celluloid, French ivory, and collodion. The symptoms of degradation are brittleness and yellowing. A simple test can be applied to verify the presence of nitrocellulose, and if extensive degradation is present it may be necessary to remove the material (*CCI Notes* 17/2). In such cases the advice of a conservator should be sought (*CCI Notes* 15/3).

Deterioration of ebonite is accompanied by an exudation of acidic material. If this is suspected, a simple test with pH paper will confirm the presence of acidic materials. In such cases the advice of a conservator should be sought (Bacon).

Cleaning of Textiles

Textile materials usually associated with musical instruments include the felts and cloths used as packings and paddings. Thorough cleaning of textile materials often involves immersion in solvents and detergents, but this is rarely necessary for the functional parts of instruments. A more conservative approach relying upon dry mechanical techniques is advised here. The parts to be cleaned should be detached from the instrument where possible, although if this will disturb the instrument's set-up, mechanical cleaning must be done *in situ*. The condition of the textile should first be assessed very carefully; often woollen material used in felts and dampers may be so badly degraded that even gentle cleaning can be damaging.

Soft, open felts are particularly prone to accumulating larger sized particles of dust, insect casings, and other detritus. This is particularly noticeable beneath keyboards. Large, superficial material should first be removed from the surface using a pair of fine forceps. Once the larger particles are removed, a piece of cheesecloth should be spread over the whole textile and held down firmly by placing weights at its edges. The piece can then be vacuum cleaned through the cheesecloth using a speed controller as described earlier. If this level of cleaning proves insufficient it will be necessary to consult a textiles conservator (*CCI Notes* 13/7).

Treatment of Coatings

The following notes cannot deal in detail with the treatment of all surface finishes. They are intended to indicate possible treatments for deteriorated surfaces and give some direction on how to handle most coatings found on musical instruments in a preventive fashion.

Pigment

Loosely applied pigments are among the most difficult materials to deal with. They are often fragile and powdery, and can be easily smeared or removed by handling. This kind of surface is customarily seen on ethnographic instruments made from organic materials. If possible, these instruments should not be handled directly, but lifted and moved by a support such as a tray or trolley. Covering an instrument to protect it from dust is essential because it is often impossible to distinguish between dust and pigment during cleaning.

Consolidating fragile surfaces is often necessary, but it is rarely accomplished without some change to the surface appearance. If consolidation is considered essential, the change in the nature of the surface must be thoroughly discussed and a true understanding of the projected treatment gained by tests or research.

Paint

Deteriorated paint surfaces require careful handling because loose pieces can be easily caught on gloves and clothing, and lost. Controlling relative humidity is important where the flaking is suspected to be related to movement of the wood or any other organic substrate on an instrument.

The composition and deterioration of painted surfaces is a very detailed study, and all work done on loose and flaking paint should be performed by a specialist. Flaking paint surfaces are consolidated by running a suitable consolidant in solution or emulsion under the flakes. Where distortion of the paint film has taken place (e.g., the flakes are curved upwards, or cupped), heat and pressure may need to be applied. Occasionally, the solvent used for the consolidant will soften the paint, allowing capillary action to flatten the flakes. Losses in painted surfaces are sometimes inpainted, or retouched, to preserve the overall appearance of the object.

Lacquer or Varnish

As with painted surfaces, instruments that have loose or flaking varnish and lacquer must be carefully handled. Control of relative humidity is important where flaking is suspected to be related to movement of the wood or other organic substrates.

Lacquers and varnishes can be readhered to their substrates under some circumstances, but success depends upon the relative transparency of the solution used in consolidation, its refractive index compared with that of the varnish film, and the effectiveness of penetration below the loose flakes. Transparent coatings can become more obtrusive after consolidation. In some circumstances lacquers and varnishes that are clearly not original are removed during treatment and reapplied.

An intact lacquer or varnish that is dull, but which shows no cracks or gaps in its film, can benefit from wax polishing. The best choice is a white paste wax with no added colorant or perfume, and especially without silicone. Silicones are added to many commercial paste waxes to give a high shine and resistance to moisture, but their disadvantage is that once applied they are difficult to remove later. Plain white paste wax can be applied thoroughly to the finished surface with a soft cloth and allowed to dry to a dull film before buffing to a shine. Build-up of excess wax around attached hardware should be avoided. It is not necessary to wax polish at frequent intervals unless the instrument is handled excessively.

Oil or Wax

Wax and oils were often applied to bare wood at the time of manufacture. Cleaning problems are compounded by the difficulty in distinguishing between accretions acquired with use and later accretions acquired during storage. Thus, one might be able to see surface dust, but be unable to arrive at a cleaning technique that removes it, but leaves earlier accretions in place. Careful and systematic cleaning, with an understanding of the nature of the original surface, usually gives acceptable results.

Although not a surface treatment, it is worth mentioning that wax was occasionally used as an aid in tuning by using it to adjust the size of woodwind holes. Also, instruments made to be played either left or right handed may sometimes have one of the lower holes for the little finger filled with wax. Traces of such wax found in woodwind holes should remain undisturbed.

Veneer

Instruments with loose veneers and inlays should be handled carefully to avoid snagging on gloves and clothing. Areas with loose pieces should be inspected regularly to ensure that the process is not continuing.

Loose inlays and veneers are relatively easily readhered provided there is no distortion. However, the reason the pieces have become detached is usually due to the substrate having moved, often in response to changes in relative humidity. In this case, careful reshaping or complete replacement are sometimes necessary. Metal inlays are more problematic to readhere due to the difficulty of finding an adhesive which is strong enough, yet still removable. Traditionally, bone or hide glues were used, and although not strong they still have the virtue of removability. Most work on veneers and inlays is specialized in nature.

Enamel or Glaze

Enameled metal can quite often have a crazed appearance and yet still be stable. Surfaces of objects should be checked for soundness and handled with care if flaking or destructive crazing is present. A stable temperature is advisable for enameled metals.

Flaking enamels can be readhered in some circumstances, but specialist assistance should be sought. Crazing on ceramics and similar substances is rarely treated.

Plating

Polishing plated surfaces is not recommended unless done infrequently and with very mild abrasives. Chemical cleaning methods can be employed, but only if the plating is intact. Electrochemical effects can take place in gaps in plating where the base metal is exposed, causing dissolution and redeposition of baser metals.

Gold or silver leaf applied to non-metal surfaces must be treated extremely cautiously. If the surface is stable and intact, light cleaning with a soft brush can be done with safety. Water should never be allowed to come in contact with gilded surfaces. If there is any evidence of cracking or loosening of such finishes, specialized help should be sought.

Artificial Patination

Patinated metal objects should be handled with gloves unless actually under treatment. Objects should be kept covered to avoid abrasive dust. Because corrosion of the underlying metal destroys patination, precautions should be taken to ensure that metals are well protected.

Patinated metals must be treated with extreme caution, especially in places where an artificially oxidized surface may give clues to heat treatment of parts. Polishing of such surfaces is not recommended.

Treatment of Composites

Most musical instruments are composite objects. If it is possible to take the object apart without damage or compromise, this should be done. Many instruments joined with screws or bolts can, in most cases, be disassembled. In many cases, though, disassembly is impossible. Following are notes on both cases.

If the parts can separated, they should be treated individually using appropriate techniques for each material. It is generally advisable to remove *all* corrosion products from metal parts before reassembling a composite object because corrosion is often disruptive, and can be reactivated in the future. Usually such corrosion products occur where metal and wood are in close contact, so their removal is often not visible on the reassembled object. Chemical treatments such as stripping, which are normally not recommended for visible surfaces, may be used in this case. Distortion of wood by corrosion products often means that repair of the wood is necessary before reassembly. The alignment of both metal and wood parts should be checked before any glue joins are made. A protective layer such as wax or lacquer should be applied to the metal before reassembly.

Where parts cannot be separated, it is only possible to treat the visible surfaces. The metal must be treated by whatever method is found appropriate, but the wood must be well protected from contact with chemicals and materials used when treating metals. Oil and tannic acid solution will leave permanent stains on wood, and marks can be left by metal polishes and carelessly applied mechanical methods. In general, treatments for wood will have no effect on the metal, so covering and masking is often not necessary when working on wooden components. Treatment documentation should make it clear that full treatment is not possible while the parts are immovably joined. Iron stains on wood are a common occurrence. They are usually orange or light brown and disfiguring, and can cause decay of the wood. Stain removal techniques usually result in further softening and degradation. If cleaning and stain removal have been done, wood parts may need consolidation to strengthen them.

Stains from copper salts are green or blue and tend to be more difficult to remove. Complexing agents such as EDTA are sometimes successful in removing stains but, as with iron, the wood may be further damaged as a result. Corrosion products from the reaction of copper with organic materials can usually be removed mechanically, followed by swabbing with acetone or turpentine substitute to further clean the surface. Solvents should be used sparingly on wood because substances in can be carried further into the wood by capillary action.

Treatment of Instruments by Type

Following are a few guidelines that reinforce and augment rather than duplicate the treatment information already given. These guidelines apply to static, displayed instruments; any further treatment required may be found in the next chapter.

Keyboards

Keyboard instruments, if normally kept at playing tension, can be maintained in that condition provided no new distortion is detected. (Detecting of distortion requires accurate and thorough monitoring of dimensions.) If accelerating distortion leading to structural damage or persistent action malfunction is suspected, detensioning should be considered. Detensioning a wood-framed instrument has very serious consequences for its future, and should not be undertaken lightly. Professional consultation is strongly advised before, during, and after such a process.

The process of slackening the strings should be undertaken over a period of weeks, to avoid shocking the structure by suddenly relieving it of tension. Using a well-fitting tuning key, begin detensioning in the centre of the compass and work alternately to the bass and the treble by octaves in the pattern of setting a temperament (i.e., by fifths and fourths). Unlike normal tuning, all sets of strings should be detensioned together, rather than consecutively. In other words, do not detension one eight-foot register of a harpsichord before beginning to detension the other eight-foot, or the four-foot. Because every string cannot be detensioned simultaneously, the pitch on any one string should not be lowered by more than a semitone at a time, otherwise there is a risk of breaking those strings not yet slackened. Detuning every string by semitone increments can be done on a daily basis. Iron-framed instruments

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can stand a much more accelerated schedule of detensioning. On completion, the strings should have just enough tension to lie straight, and remain on their tuning pins.

Exterior wood finishes that are in sound condition can be wax polished if necessary, but such work is time-consuming if done properly, and the results may not warrant the effort. Small tests of wax polishing can be made to determine the degree of change in appearance and time taken to achieve the result.

The chief collecting places for dust are between and under the keys, and on the soundboard under the strings. Dust can be lifted with a small brush while the nozzle of a vacuum cleaner is held close by. Alternately, two vacuum cleaners can be used, one set to blow the dust away and the other to suck it up. A fine jet of air can be directed from the blowing vacuum cleaner by constricting the opening of the pipe, but this may cause overheating of the vacuum cleaner if done to excess. Caution should be taken when working beneath the keys because textile padding materials may be quite degraded and fragile. Also, the lifting action of the suction can fluff felts up, thus changing the regulation of instruments in playing condition. Painted decorations on soundboards should also be treated with caution because they are in a protected area, and are sometimes more fragile than they appear (McTaggart). Brushes with metal ferrules should be avoided, especially when working between the strings, and other places where the brush fits tightly and could cause scratching. Brushes with completely wooden shafts, like those used in Japanese paper conservation, can be used, or the metal parts of brushes can be wrapped with a soft material such as plastic sleeving.

String Instruments

It is not necessary to keep string instruments at playing tension while on display or in storage. In fact, if their structural condition is unknown, it may actually be injurious. However, in the case of bowed instruments, the bridge, soundpost, and tailpiece are maintained in position by the strings. Sufficient tension should, therefore, be applied to keep the strings taut and the loose components in place. In other cases, it is sufficient to keep the strings straight and well aligned. This advice is opposite to that provided by some makers, maintainers, and restorers of string instruments, but their arguments are based on the assumption that the instruments are either in a playable state, or should be made so.

The loose ends of metal strings projecting from hitch pins, tuning pegs, etc. can abrade finishes. It is not necessary to trim the ends of the strings, and this should certainly not be done if they are old. String ends should be bent away from contact with delicate surfaces. It is especially important to prevent wire string ends from damaging the instrument when strings are being removed, replaced, or tuned. A little adhesive tape applied temporarily to the ends will help.

Before adjusting the tension of strings, the tuning pegs or machine heads should be carefully examined. All mechanical parts should have the potential to move smoothly before any effort is made to turn them. A small amount of light lubricating oil — enough to coat without excess - can be applied to the bearing surfaces of metal parts. Tapered wood pegs sometimes seize in their sockets. Abrasion of the wood, and even cracking of the pegbox, can occur if they are turned incautiously without first checking their freedom of movement. If a peg appears to be seized or moves stiffly, sideways pressure should never be applied. The peg may be gently turned back and forth with a pulling motion so as to release it. Be careful that the string wrapped around the peg does not find its way between the peg and the socket. If gentle pressure fails to move the peg, the advice of a specialist should be sought. Once woodto-wood components have been separated, their contact surfaces can be rubbed with a thin layer of soft soapflakes to which a small amount of chalk dust has been added. This will avoid seizing in future while still providing grip. Hill's Peg Compound is recommended.

Interior cleaning of instruments with accessible soundboxes is recommended if they have been kept in dirty conditions or if loose dirt is visible. An air jet from a small piece of soft, flexible plastic tubing can be directed into the interior while the dislodged dust is collected by a vacuum cleaner nozzle. This must be done with care, and the approach will depend upon the instrument. Potentially fragile items like maker's labels and parchment linings should be dealt with cautiously. It is not necessary to clean interiors regularly.

Woodwind Instruments

Cleaning woodwind bores may be necessary if obvious deposits of dirt are visible. Dirt can attract museum pests and moisture under certain conditions. Nylon or other stiff bristle brushes should not be used on wooden instruments because they can be abrasive, but softer brushes with natural bristles can be recommended. The standard tools for tapered bores are well-cleaned turkey feathers. Pull-through swabs are used for bores that are parallel, or nearly so. A square of silk stitched onto a thin shoelace, into the other end of which suitable weighting has been inserted, is recommended. Another method is to use the flute player's thin wooden stick which has an eyelet at one end into which a silk square is inserted. The size of the silk square is critical; it must be small enough to pass through easily. Commercial pull-throughs can be recommended as long as they are lint free, adequately compressible, and have no bare metal weights. No oil should ever be applied to the bores of historic instruments. Metal keywork on wooden instruments sometimes suffers from corrosion due to contact with oils and acids in skin, lubricants, or cleaning substances used on the wood. This corrosion is usually fairly soft and can be removed mechanically with a sharpened wood stick, followed by gentle swabbing with turpentine substitute or a similar mild, petroleumbased solvent. Wood surfaces must be protected from contact with the solvent by placing a small square of Mylar or polyethylene under the key being worked upon.

Keywork should be free-moving and in good mechanical condition, even in static instruments, because there is always the potential for damage during examination. All pivots should be checked for smoothness of operation, and the existence and condition of springs verified. A small quantity of light lubricating oil may be applied to the pivots and joints of metal instruments, but no lubricant should be applied to mechanical components of wooden instruments unless done extremely cautiously. Lubricating oils are difficult to remove from wood and can cause permanent staining. The keywork on old instruments can be in a very delicate condition, and nothing beyond light maintenance should be attempted. Under no conditions should mechanical work be done on keywork of wood-bodied instruments.

Padding on keywork should be treated very cautiously. The traditional adhesives, shellac and sealing wax, may be used sparingly when readhering loose pads. Shellac may either be dissolved in alcohol or melted by applying gentle heat to the key. Modern stick adhesives, such as those used in electrically heated glue pistols, may also be used. The choice of adhesive may be influenced by cosmetic considerations. Any adhesive appearing at the edge of the pad needs to be as invisible as possible. Adhesive should be used sparingly to form the weakest, most easily removable bond possible. Padding should never be removed unless it is unequivocally not original, and is completely useless or deleterious. Any original materials that must be replaced should be saved.

Joints of instruments should be checked for secureness. Loose joints can fall apart unexpectedly, while tight joints can contribute to further damage. Joints may be loose because thread bindings have deteriorated or have been improperly applied. In general, it is better not to rebind joints, but to store and display the instrument in such a way that its weakness is accommodated, and known to those who handle it. The cross sections of old wooden instruments may have become elliptical due to differential shrinkage of the wood. Under these circumstances it may not be feasible to return the joints to their original state.

Where joints between wood components are seized, or move stiffly, extreme care is needed. Any force applied to the parts must be rotational and longitudinal only; a combined pulling and turning effect rather than separate, rectilinear twisting and pulling. The pieces should never be rocked sideways in relation to each other because this places strain on the joint and will cause the wood to crack. It is common for thread bindings to loosen from a tenon in a manner that makes it difficult, if not impossible, to separate the joint. Stiff joints can be eased by wrapping one hand on either side of the joint, pressing the hands closely together, setting the line of their contact at a slight angle to the axis of the bore, and then rotating the one hand against the other. However, it may be unlikely that the joint can be rotated more than a few degrees in this manner due either to design constraints (keywork and other features) or to the joint having become radially deformed over time. Therefore, the joint must be returned to the starting position, but without losing the extension. This process may need to be repeated many times, and it will often be necessary to use a pair of fine forceps to pick out little bits of the binding as it becomes visible through the slowly widening gap.

Metal, horn or ivory reinforcement rings are often placed over the socket ends of woodwind joints. Shrinkage of the underlying wood can loosen these pieces. In order to prevent them moving, it is often necessary to bulk out the space between the ring and the wood with strips of very thin paper. The thickness of the the paper should be chosen carefully so that the pieces *do not* fit tightly together.

Brass Instruments

Effective cleaning and minor treatment of brass instruments is best done after disassembly. However, instruments should only be taken apart using the correct tools and techniques. Old brass is particularly susceptible to damage and it can be, paradoxically, very soft or excessively brittle. Screw threads and other components can seize together and may need very careful cleaning and freeing before any stress is put upon them (Prytulak). Lack of lubricants on slides and other moveable parts may cause undue friction if carelessly disassembled. Conversely, excess old lubricants can cause a build-up of sticky deposits that restrict free movement. If the metal appears dry and unlubricated, disassembly should be done very carefully. Lubricant residues can be cleaned from metal components with a petroleum-based solvent applied with a cotton swab or a small square of cloth. Thicker build-ups can be first picked away with a sharpened wooden stick or toothpick. Metal tools should not be used. Removing lubricants with solvents leaves the metal vulnerable to damage. It is essential that cleaned parts be kept apart until fresh



Figure 18. The correct way to disassemble an instrument at the joints. The rotary and longitudinal forces are applied incrementally. There is no rocking movement between components.

lubricant is applied, because dry reassembly can easily cause abrasion. Notes on the kinds of lubricants recommended are included in the following chapter.

Parts of metal instruments that have seized together are the most problematic to treat. If moderate force does not move them, there are three possible recourses: lubrication, heating, and ultrasonic treatment. A very fluid lubricant — a light machine oil in a volatile solvent base, known as penetrating oil — can be applied around the component and allowed to penetrate the join by capillary action. A dam of soft paraffin wax can sometimes be built around the joint to form a pool and encourage the oil to flow where it is needed. Once penetration is judged to have been effective, moderate force is applied again. Slight warming with a stream of hot air can assist penetration, but this should only be done if there is no surface finish such as lacquer, paint or patination on the instrument. Open flames should never be used. Ultrasonic treatment is often effective, but it requires expensive equipment and should be referred to a specialist.

Residues of old abrasive polishes are often found on brass instruments, especially in intricate areas of design or inaccessible places. These deposits are usually powdery and are often light green in colour due to reaction with copper. It is possible to remove this material with a sharpened wood stick, although it is tedious and time-consuming. The deposits can be moistened with a little distilled water to soften them, and the area dried once the deposit is removed.

Full-scale polishing of old brass instruments rarely produces aesthetically acceptable results, but if this approach is chosen one should try to achieve an overall balance in appearance. This means choosing a milder polishing treatment and working lightly over the whole surface, slowly bringing all parts to an even appearance. Chemical methods of cleaning non-ferrous metals have been used, but their control is difficult and they should only be applied by a specialist.

The interiors of old brass instruments usually hide extensive corrosion. Although corrosion is quite often passive, there are occasions when it can become active. Disassembly of valves, tuning slides, and other detachable components will help when examining the interior. The only truly effective way of assessing conditions in long and convoluted tubing is with a bore scope. This is a fibre-optic viewing device with a builtin light source that can be inserted to a considerable depth. If traces of brightly coloured corrosion are visible, it will be necessary to remove and stabilize it. Nylon bristle cleaning brushes for use on brass instruments should be used to remove loose deposits. Selecting the correct brush size for the bore is important. Once as much loose material is removed as possible, the affected area should be coated with wax to isolate and stabilize it. A soft, white paste wax, such as Renaissance Wax, should be diluted to a creamy consistency with a petroleum-based solvent, and then applied by pulling a piece of folded cloth soaked in the mixture through the bore on a string. The cloth must fit smoothly, but not tightly, into the bore. This treatment is the most expedient under the circumstances, but it may not provide complete stabilization. A conservator should be consulted if the corrosion appears heavy or unstable.

It has been reported that the playing quality of some brass instruments deteriorates markedly after interior cleaning. It is argued that deposits of passive corrosion in the interior, built up during the playing life of the instrument, contribute in some way to idiosyncratic tone formation. While this contention has never been tested systematically, it is mentioned here as an advisory.

Percussion Instruments

Drum heads should not be kept at playing tension, especially in locations where controlling relative humidity is not possible. Wherever feasible, heads should be slackened enough so that they lie flat, but are not under great strain. Machine screws and other tension adjusting fittings should be verified to be in working condition before any adjustments are made. A minimal amount of light lubricating oil can be applied to the bearing surfaces of metal parts. Correctly fitting keys should always be used. Where tension is maintained by buffs sliding on cords, a thorough examination of both the leather and the cordage will reveal the state of preservation. Leathers and natural fibres can become extremely degraded and embrittled, and are easily damaged by incautious adjustment. Slackening should proceed slowly and incrementally to avoid sudden shock, especially to wooden structures. Painted designs on drum heads should be examined very closely as detensioning proceeds in case relaxing the skin causes the paint to loosen.

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Basic Maintenance of Playing Instruments

M. Waitzman, R.L. Barclay, J.S. Odell, C. Karp, F. Hellwig

Using any object causes wear and degradation, which implies that routine maintenance and repair, and replacement of worn components will be necessary. Wear with use may be obvious and require continual attention, or it may be difficult to detect over a period of days, weeks or months, and only become significant, harmful and obvious over a period of years. This is a well-known problem when exhibiting light-sensitive collections such as textiles and watercolours, and analogous problems occur when functional objects are repeatedly handled, operated, and maintained. As outlined in Chapter 1, if using historic instruments is a policy of the individual or collection, hard decisions must be made. The few factors that may weigh in favour of a functional restoration have been discussed, including the proviso that "the instrument has been previously restored and most ephemeral features have already been lost." The conditions that must be met under these circumstances, in addition to those cited earlier, are that:

- the instrument is already in working condition and its continuing use will not detract from its technical and cultural value;
- the instrument is in a stable and safe condition;
- qualified expertise is available for regular tuning, maintenance, consultation and monitoring;
- the owner or custodian has a clearly articulated policy on the instrument's use, which meets the standards of ethics and practice of an appropriate national conservation or museum organization;
- the instrument is not to be treated as a working tool in the everyday world, but that its historic value is understood and appreciated; and
- every effort is made to make players and audiences aware of the speculative nature of the instrument's "original sound."

Only when all these conditions are fulfilled can the use of historic musical instruments be considered. Even then, the future place of the instrument in the collection, and its long-term care and maintenance, must still be causes for concern.

Concepts such as "acceptable risk" and "historic value" when applied to projected restoration projects have such large subjective components that they become virtually meaningless when formulating the general guidelines presented in this book. Many musical instruments have historic value that is beyond all question; for example a single known violin labelled with the verifiable date 1526. Others, such as one example taken directly from a 1996 factory run of 10,000 plastic clarinets, would be judged expendable. Most collections will contain material that is distributed along the full spectrum between these extremes. No two collections are likely to contain the same distribution and, consequently, no generally applicable conservation guidelines can be issued other than the above-stated, extremely important basic principles.

The value of a collection is often determined by the proportion of significant material that it houses. The value of the conservation approach is determined by its ability to consider every single object in a collection on its own terms. Although flexibility is a requisite aspect of the conservator's everyday practice, the bulk of writing on the subject of conservation addresses situations where a dogmatic stance is necessary or, at the very least, defensible. The authors of this book have often gone on record as regarding many of the practices described here as being unacceptable under any circumstances. Such inflexibility is often justified because it can never be assumed that the individual responsible for treating an object can judge when deviation from a "hard line" might be permissible; all the more so when the objects of the treatment can be both invaluable and wholly irreplaceable.

This chapter on maintenance is included for several reasons. In the first place, it has been written with a clear statement of warning to the reader: the description of a procedure does not provide any *a priori* indication of when its use is called for. More importantly, it does not confer the ability to carry it out. Every word contained here is intended to provide the reader with an adequate understanding of selected conservation problems to enable a meaningful discussion with competent specialists about the scope of the assignments to be given to them.

A second, significant, reason for the change in attitude is the continuous expansion of the period with which the historically oriented conservator must deal. Period material now includes virtually all instruments not in current production. A vintage instrument from the 1930s is as likely to be entrusted to a museum conservator as to a commercial repairperson. Similar conditions apply, for example, to synthesizers that are only a few years old, no longer in production, and clearly significant to the history of electronic instruments. It is no longer possible to define the importance of an instrument simply in terms of its age. As a corollary to this, it is not possible to exclude modern workshop practices from the conservator's immediate concern.

Finally, even the most dogmatic of the authors of this book knows full well that the objects of their attention have been "restored to playability" even when the risks were of staggering dimensions, and that the practice continues. The following notes are therefore intended to alert the reader to the complexities inherent in any decision to continue playing status, and to emphasise the need for qualified care of such instruments. To provide detailed instructions on how to regulate complex historical instruments such as harpsichords, pianos, and bowed strings would be inappropriate here. The required skills depend upon a combination of formal education and apprenticeship, plus the judgement gained by years of practical experience and specialization in treating a particular type of instrument.

Keyboard Instruments

Because keyboards comprise a large proportion of historic musical instruments maintained in working condition, their complexity and range of materials demand that their treatment and maintenance be done only by, or under the close supervision of, someone with extensive and specific experience with instruments of the particular national style and period. The following detailed coverage indicates the range of problems that may arise. This section is devoted to stringed keyboard instruments with primarily wooden frames and structures. Specific guidance on the moving parts of organs and mechanical instruments is generally beyond the scope of this book, but much of the information on the functioning of other instruments is equally applicable in these special cases. Contacts and references listed in Resources provide a departure point in seeking advice which will always be required.

Environmental Considerations

General environmental guidelines for wooden instruments are detailed by Karp in "Storage Climates." Harpsichords, clavichords, and pianos that are strung and kept at a playable pitch, comprise a special category of wooden structures for which regulated ambient conditions are extremely important. Because of the tension exerted by the strings, exceeding several tons on large fortepianos, keyboard instruments have a delicate equilibrium from which many normal weather patterns can easily displace them. Even small virginals and clavichords are resisting tensions near to the limit of what their comparatively lightly built structures can bear. This makes these instruments particularly vulnerable to damage by exposure to adverse or unstable conditions. Maintaining benign levels of relative humidity and temperature, which vary as little as possible throughout the year, is therefore all the more critical.

Structural Concerns

All structural repairs are outside the realm of the routine, and if required will often dictate retiring the instrument, but such measures as maintaining a stable environment and closely monitoring the areas within the structure at highest risk, are essential to at least minimize attrition due to irreversible distortion. It is a common fallacy that because instruments were designed to be kept at playing tension, it is best for them.

Structural distortion shows in tensioned keyboard instruments in predictable ways. The pull of the strings, interacting with the structure of the instrument, generally causes not only a corkscrew deformation, but also a lifting and folding in of the tail and cheek. Such distortion puts many structural joints at risk. Among these are: the cheek-to-bentside joint, the wrestplank-to-cheek/spine joints, and the wrestplank-to-facia joint. The wrestplank itself may bow in the centre, or even become detached from its support blocks in the cheek and spine, causing the facia (or nameboard) to lift with it. Many 18th century English harpsichords and pianos provide startlingly severe examples of all these types of distortion. This underlines the previously stated caution, that seemingly infinitesimal short-term effects can become ruinous over longer periods.

Hitchpin rails show the strain of string tension where it is resisted nearer to 90°. Thus, the extreme bass and treble hitchpin rails often bear the brunt of the tension, becoming either detached from the case sides, or worse, splitting along the line of the hitchpins. The process of separating from the case sides can be very slow, depending on environmental conditions, and action should be postponed as long as possible. Repair often involves replacing the compromised portion of the hitchpin rail, although consolidation treatments of the original material have also been performed successfully. Whatever course is taken, the original structure and components of the instrument are further compromised, and transfer of stresses from strong, new components may further weaken original material.

Soundboards respond very quickly to changes in environmental conditions because they are thin. In damp weather, boards are likely to dip or "trough." Equally, they may "crown' causing the four-foot bridges (together with their pins, of course) to rise and foul the eight-foot strings. Usually, faults associated with crowning and troughing disappear when conditions return to normal and no remedial action is required. In dry conditions, the soundboard will shrink and may split in the treble area, where it is held most rigidly. Hairline splits will probably close up again once the air becomes moister, but larger, unsightly splits may, for acoustical or cosmetic reasons, require attention. Successful repair of splits using long-grain wooden fillings, relies on the instrument being returned to very stable conditions. Otherwise, the areas of extraordinary strength along the filling's glue lines could cause the comparatively weaker board just beyond them to split when dry conditions arise again. In damp conditions when the board swells, the filling can also cause damage, because it will need to be accommodated in a space formerly occupied only by the old material.

The relative flexibility of the stringband (soundboard-bridges-string assembly) can cause seemingly unrelated problems with the action. In harpsichords, for example, a fall in the stringband can result in mild to severe damper inefficiency. This occurs because the dampers, mounted in the jacks as part of the action, rest ultimately on the robust case bottom, and remain comparatively stable in the vertical plane. The humidity-sensitive soundboard, on the other hand, can move down, taking the strings with it, out of contact with the dampers. Conversely, when the soundboard rises, the jacks may hang from the strings by their dampers. This begins to produce grooves in the dampers, making them incrementally less efficient in the event of a subsequent fall in the stringband.

Exteriors

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Any instrument subjected to use is at risk of being damaged by mishandling even before a single note is played. Because lids are sometimes heavier or lighter than anticipated or have unexpected hinged flaps, an experienced or trained person should be responsible for lifting them. Sometimes hinge pins are missing or work themselves loose, and a lid or flap can come away in an unsuspecting person's hands. Lid hooks and locks should not be used. First, they act as restraints on a large flexible area of wood, which otherwise would be free to expand and contract according to changes in humidity. Secondly, the hooks and eyes may no longer align perfectly. Finally, unwary players may attempt to lift a locked lid and damage it.

Inserting a prop or lid stick is no more straightforward. The soundboard should never support the weight of the lid. Instead, the bottom of the propstick should rest, depending on its shape, on the inside lower cheek moulding or on the case side (cheek) itself. The tip of the stick should be positioned in its lid housing or against the lid moulding. The security of the joint between the lid and its moulding should be checked periodically. A lid should never be left propped open for long periods.

Harpsichords, Spinets, Virginals, and Clavichords

Despite the work of builders, scholars, and researchers over a period of several decades, much of the technical information about how these early keyboard instruments were set up (how they felt and sounded) remains frustratingly sketchy. Instruments that retain old or original ephemeral parts, such as strings, cloths, and plectra, are now exceedingly rare and are the most valuable source for advancing knowledge in this area. Expert advice should be on hand during the initial documentation of these and all other historic keyboard instruments. No thought should be given to putting them into playing condition if these materials are extant. They will, nevertheless, require continuing care and maintenance.

Clavichords possess a struck action, making them the true antecedents of the piano. Instruments in which one set of strings, struck at different points, serves as the sounding length for more than one note, are known as fretted clavichords. All others are said to be unfretted. Harpsichords, spinets and virginals all possess the same plucked action, with jacks, plectra and register(s).

General Guidelines

Despite variations, plucked keyboard instruments, when well-regulated, are reliable in their behaviour. Every plectrum, for example, should repeat — re-pass its string — even when the string has stopped vibrating and the key is released very slowly. Some types of action are capable of quicker repetition than others. Some muselars, for example, or virginals in which the bass strings are plucked near the centre, cannot be expected to repeat as quickly in the bass as instruments where the excursion of the string at the point of pluck is less broad. Nevertheless, long, fast trills should be possible on all instruments from at least middle C (C_4) upwards. Every note should damp after being played when the key is released.

When more than one set of jacks is engaged and a key is depressed very slowly, resisted or supported by another finger underneath the key, the jacks should pluck their respective strings not simultaneously, but consecutively, in a constant order throughout the compass. This non-simultaneity is known as the stagger. The distance between plucks should not vary appreciably on adjacent notes, though it may change gradually from bass to treble.

Keyboards

The whole of the action rests on (or in the case of clavichords, is fixed into) the keyboard(s). It is, therefore, crucial that nothing upset the level of the keyboards or individual keys, once the action has been set up. There should be as little variation as possible in level among adjacent keys, although overall key level may taper perceptibly from bass to treble.

Keys should respond quickly and quietly when played. Each key has a pin about which it pivots at the balance rail (the middle member of the keyframe), and one other guide point. Front guided keys normally have pins on the touch rail (the proximal member of the keyframe) over which the keys run. Back guided keyboards may have a rack, a series of vertical wooden slots, in which metal pins or slips of smooth wood, which protrude from the distal ends of the keys, run. Other guide materials, though less common, include whalebone (baleen), ivory or metal sheet. Other back-guided methods include having each key travel between two pins or along one pin located in a channel in the distal end of the key. Such pins would be driven into the distal member of the keyframe.

When a key sticks or otherwise malfunctions, it is imperative that a specialist familiar with the action be called upon to establish where the fault lies. Treatment may involve removing the keyboard(s) from the instrument. Usually, keyframes simply rest inside the keywell, but sometimes they are fixed into place with turnbuckles, sliding pins or slats, or screws, and sometimes, as part of a restoration, the keyframe was screwed in place through the bottom boards of the instrument. Withdrawal of the keyframe is best done by a specialist.

A change in humidity frequently causes intermittent sticking of keys. In such cases, interventive treatment may be unnecessary because the fault will disappear when the humidity returns to normal. Sometimes, the key can be freed simply by rubbing it gently up and down over the pin on which it is binding, or by lightly burnishing surfaces where the key appears to catch. Dust in the rack slot or key mortise can also cause a key to stick.

Perversely, worn or enlarged balance (or other) mortises can also cause keys to stick. This type of fault very often appears when keylevers are cranked, by design, or run diagonally from one guide point to another. Such keys wear unevenly, and begin to rock, catching on the sides of the mortise or guide slot. Sometimes the effects of mild wear is ameliorated by attaching several layers of paper (for example, brown gummed paper 0.06 mm thick) on either side of the mortise, on top and bottom if space permits, limiting excess diagonal travel and helping the key to run true. This is only a temporary measure, and eventually the mortise or slot will require repair as wear progresses. If either the mortises or the jacks are original, one should think hard about playing the instrument at all.

Jacks

All historic jacks, although they vary widely in size, style, and exact materials of construction, perform the same functions and are made up of the same components. The jack holds the plectrum rigid while it is forced past the string creating a sound, damp the sound afterwards, and position the plectrum for sounding again. The jack, which stands upright on the distal end of the key, is an elegantly simple mechanism for accomplishing these purposes. It consists of a wooden body with a channel in which a wooden tongue is pivoted, and with slot(s) or hole(s) for damper cloth. The tongue is broached to accept a plectrum, and a spring at the back of the tongue allows it to work as an escapement.

The spring is made of a boar's bristle, or metal (usually brass) wire or sheet. The spring helps to hold the tongue forward as its plectrum is forced past the string on the depression of the key, and permits the tongue to retract, so the plectrum can re-pass the string on release of the key. If necessary, all of these spring materials can withstand skilled adjustment, to weaken or strengthen their effect, by gentle flexing in the appropriate direction.

Historic jack design lacks nothing, and contains nothing superfluous. The adjustments devised by late 19th and 20th century restorers, however ingenious, never actually improved the performance of jacks. On the contrary, in this context they invariably act as hindrances. When original jacks have acquired adjustment screws, or have been replaced with over-engineered modern ones, the best course is to have them set correctly at the outset (at known temperature and relative humidity levels) and then forget them. Using them may cause real problems, developing elsewhere in the structure, to be ignored, and they may mask significant changes in the regulation.

In order to work well, jacks need to travel up and down freely in their register slots (see also Registers below), but without excess side-to-side movement. The normal motion of the jacks wears them and their register slots, so that their fit may become too loose. Applying an appropriate number of layers of brown paper to the bearing surfaces of the jack body improves the fit, and is easily removable. However, thickening the jack body in this way will contribute to the inevitable enlargement of the register slot. If the instrument is to be used, such wear is preferable to the uneven wear and unreliable performance occasioned by loose-fitting jacks. Note that each jack is individually fitted to its register slot, and each plectrum voiced for its one string. Jacks are *not* interchangeable.

Registers and Lower Guides

In historic harpsichords, the design of jacks cannot really be considered independently of their registers. The registers (together with the lower guides, when present) not only hold the jacks upright, but they also generally provide the surface which limits the retraction ("flyback") of the tongue. In this way, the register helps to determine the speed and reliability of repetition. Whatever the style, registers were almost always made as accurately as possible. In addition, they reflect, probably more than any other single part, the original setting out of the instrument.

If movable registers begin to stick, this could indicate that, under the tension of the strings, the register gap is closing up. The reasons for such structural instability should be investigated. Among the questions to consider are: could the instrument be too heavily strung, are the gap spacers failing, is the relative humidity too high or fluctuating too much, or can the instrument still support strings at playing tension?

The overall movement of registers, from "on" to "off" position, usually needs to be no more than 1 mm. If changes in humidity begin to make a whole register sound too loudly, the insertion of thin pieces of paper (about 0.03 mm, the thickness of a cigarette paper) one at a time, in the "on" position of the register on the case side, can alleviate the temporary problem. (See also Machine Stops, below.)

Specialist advice should always be sought when leather-covered, or decorated registers, or those which form part of a machine stop mechanism, require modification.

Buff Battens

For general advice on maintaining leather and cloth refer to Chapter 5. Buff battens, also known as harp or buff stops, and mistakenly as lute stops, consist of a series of leather or cloth pads, which, when engaged, act upon the sounding length of a set of strings to dampen the normal incisive harpsichord sound. The batten is usually controlled by means of a manual stop lever or pedal. Sometimes the batten is divided, allowing the player to choose the effect for the treble and bass independently. To help minimize wear, buff battens should be disengaged after use. In addition, the pads provide a site for corrosion to begin if left in contact with the strings.

The shape and size of the pads vary considerably, as does the manner of fixing them to their wooden batten, located directly behind the nut. This could be with an adhesive or with small nails or household pins. If detached pads are to be reattached with adhesive, always specify animal glue applied sparingly to the bottom surface and kept well away from the area of the pad which comes into contact with the string.

Machine Stops

Please refer to Chapter 5 for general guidelines on the care of steel and iron objects. Machine stops are made primarily from forged iron parts, often beautifully crafted. The temper of the steel springs on which the operation relies renders them quite brittle. They are, therefore, vulnerable to breakage if forced or mistreated. The mechanisms are often housed in boxes on the side of the instrument, and exposed moving parts may stand clear of the bottom boards. All are vulnerable when the instrument is being moved.

These devices, which vary in concept, design and mechanical realisation, all facilitate quick changes of timbre or dynamic level by means of a pedal or knee lever. They may involve the withdrawal of one or more registers and often, the simultaneous engagement of another. With the machine stop engaged, players do not need to take their hands away from the keys to effect the change. It is imperative that players are instructed in the use of each machine stop. In particular, they must

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never attempt to move the handstops of the registers that form part of a machine stop when the machine stop is engaged. Doing so will disturb the regulation, and may damage the machine mechanism and other action parts. Where possible, machine stops should be disengaged after use.

Each machine stop should be considered individually, but the operation, engagement, and withdrawal of any of them should be quiet. Sometimes, a very slight depression of the pedal on engaging or withdrawing the machine stop facilitates a quieter operation and reduces wear and tear by helping to align metal leaf springs and hooks as they interlock or disengage. Advice should be sought before adjusting the end stops of registers which form part of a machine stop mechanism (see also Registers above). Such alterations could affect more than one register and damage the machine mechanism itself. An unusual resistance in engaging the stop or depressing the pedal, or a squeaking or grinding sound associated with any function, indicates a fault which should be investigated by a specialist. Use should be discontinued until the fault is rectified.

Once set up, the mechanism itself should not be tampered with. Ease of adjustment and maintenance were not design priorities in typical English machine stops. Sometimes complete disassembly, including removing the registers, is required to make a small adjustment consisting of, perhaps, one turn of a threaded metal part.

Tangents

General guidelines on the care and treatment of brass and other metals are outlined in Chapter 5. Clavichord actions are probably the most deceptively simple, with keys comprising the only moving parts. The tangents, fixed at the distal ends of the keys, not only define the sounding lengths of the strings, but also activate them.

Unfretted clavichords may be tuned, within the normal limitations, as the player wishes, but the layout of the tangents largely determines the temperament in which fretted clavichords must rest (see Action Types above). Once the tangents in such instruments are fixed into place, there is very little latitude for modification. Evidence suggests that early makers of fretted clavichords bent tangents to achieve correct tuning, although it is risky to bend them as a measure of routine maintenance because brass can become very brittle with age. Also, in the absence of reliable information about specific examples, bending tangents to obtain varieties in tempering can be philosophically unsound. Ideally, temperament takes into account what the past placement of the tangents implies (see also Tuning below), but after restoration the present tuning may not faithfully reproduce the instrument's original temperament. If tangents work loose, specialist advice should certainly be sought.

Listing

The importance of the listing in clavichords is frequently not appreciated. This is the cloth usually woven between the dead lengths of the strings in order to dampen them. But the listing also performs other essential functions. The tightness of the weaving, for example, largely determines the touch and key dip. In addition, the characteristics of the chosen cloth enormously affect the quality of the tone drawn from the instrument. Alterations to clavichord listing should only be undertaken in consultation with a specialist.

Tuning

The first responsibility of routine maintenance is tuning, which often reveals other problems before they become serious. Keeping an instrument in tune tends to stabilize it. In conditions of stable temperature and relative humidity, harpsichords and pianos may be able to hold tuning for quite long periods, perhaps three weeks or more, and clavichords, even longer. Adequate tuning can be maintained for relatively long periods following a tuning by a specialist, if unisons, octaves, and four-foot (if applicable) are kept in tune with the temperament octave (the bearings).

It should be noted that the techniques of early keyboard tuning, though beyond the scope of this book, differ substantially from those of the modern piano, and that proficiency at one by no means confers competence at the other. The tuning pins of early instruments are of no standard size or shape, and an ill-fitting tuning hammer can easily damage them. Well-fitting, custom-made tuning hammers are the choice of specialists. In addition, early keyboard instruments, unlike modern pianos, may rest at a wide variety of pitches and in a plethora of different temperaments, which vary according to the harmonic characteristics of the music being played. Among the other factors which may influence a performer's choice of temperament are the dates of the instrument and the music, and in fretted clavichords, the layout of the tangents. Early keyboard instrument tuners should not only be conversant with the different temperaments, but also with how to use them.

Pre-modern Pianos

Action and Moving Parts

A high premium should be placed on the conservation of any piano action that retains original ephemeral or semi-ephemeral parts, such as beak leathers, hammer coverings, damper materials, kapsel stems and forks, bushings and so on. Many of the old materials are difficult to duplicate today, and all modern replacements present certain deficiencies. Our understanding of these actions has not yet reached maturity, and it is primarily through the study of those which remain relatively untouched, that comprehension can be advanced. Expert advice should be sought during the initial documentation of these instruments, whether or not original materials are suspected to be extant. Steps should be taken to discontinue use of any instrument that has original ephemeral parts.

There are many more moving parts in piano actions than in those of the harpsichord family, and far more significant variations among them. Many of the later actions possess an array of original adjustment mechanisms that require skill and experience to exploit to advantage. A seemingly slight change in settings, can produce a panoply of unintentional or unexpected effects. Actions that are not fitted with obvious adjustment points should be approached with even greater care, since changes are less easily reversed. The subtle interactions and relationships among the moving parts cannot always be appreciated simply by peering at drawings, or even at the actions themselves. Experimentation can be enlightening, but damaging. Specialist advice should be sought whenever doubt arises about the causes of problems or possible solutions.

General Guidelines

A well set up action, whether harpsichord, clavichord or piano, is, above all, reliable in its behaviour. A few guidelines apply to all wellregulated pianos. Any change in touch or tone, or failure to perform according to the general guidelines below, may indicate the need for attention. There may be differences between the performance capabilities of square and grand pianos, but the specific variations are beyond the scope of this section.

Pianos, of course, possess struck actions, but unlike clavichords, the striking part, the hammer, on the majority of actions, is designed to be free-flying when it meets the strings. In such actions, on a very slow depression of the key, the hammer should "let off" before it reaches the strings — that is, it should not reach the strings — otherwise it is said to be blocking. The let-off point should not vary appreciably on adjacent notes, though it may change gradually from bass to treble.

A hammer should not bounce against the strings (play more than once on one striking), even when the key is struck at the loud limit of its dynamic range, and even when there are no checks. On checkless actions, the dynamic range may be narrower than on instruments possessing checks. If a hammer bounces on a well-regulated checkless piano, then it is being struck too hard. By the same token, notes should be able capable of very rapid repetition at all intrinsic dynamic levels.

When pedals, knee-levers or hand stops are not in use, the hammer head should strike all the strings associated with its particular note centrally. Pedals and knee levers should operate quietly, and without undue resistance. The whole action is either fixed or ultimately resting upon a piano's keyboard. Any upset in key level can significantly alter the setting up of sensitive early piano actions. Specialist advice should be sought whenever any aspect of a piano's regulation requires attention. Regulation on these, and all keyboard instruments, is an iterative process which may be very time-consuming. Changes in regulation can be expected as an instrument is played in, as temperature and humidity vary, and as a result of wear and tear engendered by use.

There are many types of early piano actions, but a large proportion can be described as resembling, in important respects, the three mentioned below.

The Cristofori piano action was invented by Bartolomeo Cristofori around the turn of the 17thcentury. It was so highly developed and ahead of its time that much of the subsequent history of the piano action is a reinvention or re-discovery of his work. Equally remarkably, he recognised virtually every significant structural requirement of an instrument that was to possess struck rather than plucked strings. The materials upon which the action relies most heavily are wood, leather and cloth, although it also includes wire springs, stems and pivots. Cristofori intended adjustments to be made by bending metal parts or varying the type and thickness of the cloths and leathers. However, no such adjustments should be undertaken on historic instruments without reference to specialist advice.

Vienn'ese actions are often referred to as the *Prellmechanik*, and a growing body of information is now available on the history and constituents of the actions that would have been the most familiar to Haydn, Mozart and Beethoven. In essence, it is an action in which the hammers are pulled (or flicked) into motion, as distinct from the English and Cristofori actions where they are pushed. During the course of the 19th century, the *Prellmechanik*, which had existed side-by-side with the pushed type of action, was gradually supplanted by the latter. The materials used in the action include wood, leather, vellum or parchment, brass and steel, cloth and felt. Regulation procedures are highly instrument-specific. Routine maintenance should rest with someone expert in dealing with the idiosyncrasies of each instrument.

English actions contain the same materials as found in the Viennese instruments described above. Pianos by Broadwood, which were made and, fortunately, survive in relatively great number, reflect a certain standardization, since principles of mass production were employed in their manufacture. Nevertheless, during the long history of the firm, many changes in compass, action design and materials took place. These have still to be adequately chronicled. Any actions, in grand or square pianos, which largely or in part, retain original materials, should be carefully documented and conserved.

Care of Ephemeral Parts

Strings

String breakage can be kept to a minimum by maintaining stable environmental conditions, and allowing the pitch to wander only within narrow limits (in the region of 3Hz above or below its norm at reference pitch). Persistent breakage within an instrument, or on a particular note, suggests an incompatibility among the pitch at which the instrument rests, its scaling, and the string material chosen for the offending note(s). Such problems should be rectified by a specialist. Unavoidable breakage usually results from metal fatigue, and occurs at the string's stress points — where it leaves the tuning pin for the nut, at either end of the hitchpin loop winding, or where it passes over a pin. As with tuning, the techniques of string replacement are far more various in historical instruments than in modern pianos. When making and putting on a new string, care is taken to replicate as nearly as possible the size and style of the hitchpin loop and tuning pin coil, as well as the material and diameter of the old string. A list of string materials, diameters and overlengths may exist from the time of the instrument's last treatment, and surrounding strings can often be a guide to correct downbearing, and tuning pin height. Original strings, or fragments of them, should always be meticulously preserved. Historical reproduction music wire may or may not be metallurgically similar to historic wire, but more important is that its tensile strength lies within the same limits.

Plectra

The materials most often used for harpsichord plectra are natural bird's quill and leather. The longevity of each is directly proportional to how much it is used. The active life of these natural materials can be prolonged significantly by simple maintenance procedures.

Both sides of quill plectra require light lubrication from time to time, so that the top surfaces pluck the strings with the correct amount of friction, and the bottom surfaces re-pass the strings without catching (hanging). The oil on one's own skin is excellent for these purposes, and always to hand, so to speak. It is advisable to check quills both before and after any use. The top surface may need lubrication if the order or spacing of the stagger is upset, if there is an extraordinary resistance to the touch compared with surrounding notes, or if a note sounds peculiarly loud or produces a small grinding sound when flexed against the string. Usually, all of these symptoms are present when light lubrication is required. The offending quill should not be pushed past its string until lubrication is applied. The temptation to lubricate regularly quill plectra to solve no specific problem should be resisted because lubricants attract dust. Too much lubrication also makes strings, and any other parts of the action which come into contact with the plectra, sticky.

Leather plectra can also require lubrication for the same reasons as quill, but even less frequently. Incautiously lubricating leather can spoil the sound, so it should be applied sparingly. Hard leather plectra, which have begun audibly to soften, can sometimes be revitalized by applying, with a fine brush, a minute drop of weak shellac solution to the underside, at the root. This is a task for an expert as the dilution of the shellac is critical and even the slightest excess can ruin the plectrum or the tongue.

The cutting, shaping and thinning of any plectrum material requires experienced hands. Further advice should always be sought when

Cloths and Felts

The information on textiles in Chapter 5 applies equally well to instruments in regular use. If an instrument has rare, original or old cloths, regular inspection and preventive cleaning should be scheduled if necessary. Sensitivity and a long-term perspective is required whenever any decision is made to clean. The process itself invariably removes some of the very material which is being preserved, together with unwanted dirt.

Leathers and Parchments

These materials perform a large variety of functions in early keyboard instruments, as explained above. Like cloths, they are used not only in "passive" roles such as for silencing noise, but also in "active" ones such as damping, the hinging of moving parts, and plucking strings. Many leathers must withstand friction (like those used on check leathers), and repeated battering (hammer coverings), and also be able to resist persistent flexing (beak leathers and leather plectra). In many of the above functions and others, leathers define dimensions critical to the touch and repetition of the action, while the characteristics of the leathers used for plectra, hammer coverings, and dampers largely determine the nature of the tone and decay of notes. Many of the leathers of the type and with the attributes of those used on historic instruments are practically unobtainable today.

The cautions and provisos regarding the cleaning and general treatment of leather and skin products apply equally well to functioning instruments.

String Instruments

Bowed string instruments, especially those of the violin family, are almost unique in the way they have lent themselves to continued use, repair, restoration, and conversion. One cannot continue to play a musical instrument made of thin, fragile wood under constant tension for what amounts to many thousands of hours without a great deal of maintenance; and beyond that, without it passing through changes of musical fashion. It has been said of the violin that: "Even should mishap bruise or break its beauty it can be endlessly restored" (Haweis, *Old Violins*, 1898). This is still true today for the vast majority of working bowed string instruments outside the museum, but it is false to assume that the *modus operandi* of such a well-founded and highly traditional craft as violin repair and restoration can be directly transferred to the museum context. It is never safe to play museum instruments unless they have undergone the ministrations of a highly skilled professional, but in doing so their museum value will be compromised.

It is commonly argued that string musical instruments must be kept in playing condition, and that they deteriorate while on display or in storage. Some violin collections, such as at Cremona, are governed by a policy of daily playing in order to keep them in good condition. There is no supporting evidence for the benefits of this practice, but it is reliably known that the musical qualities of long unused instruments are in no way compromised by their silence.

Should a string instrument have already been brought into stable, playing condition, and should there be a policy that it continues its playing role, it must be regularly maintained, tuned, and adjusted. Unlike those on display or in storage, playable instruments should be kept under tension at almost the appropriate playing pitch. Maintaining historic instruments in this state is the province of those skilled both in modern techniques of practical music and in museum standards.

Preparation

String instruments are almost invariably made of wood, and often with differing woods of contrasting acoustic quality and durability. Soundboards, which are required to take the most tension and compression when under stress, are paradoxically made of softer and more pliable wood than other purely structural components. Thus, inherent weakness even in apparently sound members must be suspected. Any signs of distortion, cracking, displacement or deterioration of wooden sounding components will be a caution against applying any stress to the instrument. Slight buzzes and similar sounds will indicate loose internal bracing.

The adhesive traditionally used for wooden instruments is a collagenbased glue made from hides, skins and bones. It is normally very strong, but is susceptible to degradation by exposure to moisture and continuous stress. All glue joints must be rigorously examined for signs of weakness and failure. This is a highly specialised undertaking. Open cracks or joints should indicate the need for lowering string tension and consultation with a conservator.

The strings found on historic instruments are rarely original, except in the case of recently made instruments, and may often be a different gauge than those originally fitted. Nevertheless, before any restringing is done, the nature and history of the existing strings must be ascertained. Strings that have been removed should never be discarded. The material of any strings newly put on an instrument should carefully be considered. On instruments of the violin, the viola da gamba and lute families, it was standard to use gut even for the uppermost strings, while metal covering of the lowest gut strings is only known since the second half of the 16th century. Strings made totally of metal did not appear before the 1920s. In addition to the material of strings, their production techniques have also undergone considerable development, in particular since the 18th century. Before that time pictorial and written sources show that the lower strings were often twisted from several strands. Such considerations are equally valid for the metal stringing on citterns, mandolins and other types of instruments. Therefore, it should not be assumed that the use of strings made of traditional materials will be safe for the instrument, or will lead automatically to an authentic sound. It is dangerous, and pointless to string an instrument if the original stringing material and tuning are unknown. Also, the pitch at which the instrument was normally tuned should be respected; a tension of even a half tone higher than the original value can have marked deleterious effects. No historic string instrument should be brought up to playing tension in one session; it is necessary to tighten the strings to some previously established low tension and to assess the effect over a period of at least a day. Extra time should be allowed for more sensitive instruments, like those of the violin and viol family. Tensioning continues incrementally until stability at the correct pitch is attained. The type of instrument, its condition, the original pitch and stringing, and many other interrelated factors make specifications impossible to establish.

All tuning devices should be checked for smooth operation and efficiency. The directions provided in Chapter 5 apply equally to playing instruments.

Care During and After Use

Control of the environment is critical to the well-being of all wooden objects. A sudden change of relative humidity that may occur between removing an instrument from its case and beginning playing can be irreversibly damaging, and the opposite is true when returning it to storage after use. It is necessary to know the relative humidity within the instrument's storage container, and within the location where it will be played. A difference of more than 10% between the two values is a warning that damage could result. It is never possible to predict damage due to fluctuations of relative humidity, but it is an ever-present danger.

Highly finished wooden instruments are very susceptible to damage while in use, and every precaution should be taken to ensure that they are handled carefully and that players are fully aware of their fragility and individual foibles. Surfaces should be protected from abrasive contact with the player's clothing, particularly buttons, zip fasteners and buckles, by using soft cloths or other padding.

Players should not be permitted to change the set up of instruments unless under direct supervision or consultation with qualified personnel employed by the museum. The instrument should not be used in a manner inconsistent with either its historic state or with the period it represents. Players should not be permitted to use anachronistic and potentially harmful items (such as chin or shoulder rests for violins) that might cause damage.

When bringing a bowed string instrument to its initial pitch, and when subsequently tuning it, the bridge might alter its angle in relation to the table (when seen from the side). Readjusting this angle should be left to an experienced conservator. Similarly, although the player may have suggestions concerning the adjustment of the soundpost position, this is also a task for a conservator well acquainted with bowed instruments. While the use of rosin is necessary when playing instruments of the violin or viola da gamba families, it is easily deposited on the varnish near the instrument's bridge. An agreement should be reached between the conservator and the player concerning who is responsible for removing rosin. Historical bows that have retained hair from any earlier period should not be used. Such bows may preserve unique data regarding the nature and mounting of the hair. Instead, the player should provide a bow appropriate to the period and style of the instrument.

With plucked string instruments, the relation between the strength of the instrument's construction and the total tension of strings is particularly subtle. For this reason, early lutes are rarely able to support the stresses of playing. If this is done, it should only take place in the presence of a conservator who has specific experience. This also applies to guitars, mandolins and other plucked instruments. Harps are especially difficult because their frame construction is extremely liable to distortion.

As with all other instruments, thorough and accurate records should be kept every time an instrument is used.

Woodwinds

The use of historic woodwinds is problematic because they are made from such a wide variety of materials, and can exhibit a wide range of conditions of preservation. Furthermore, their method of playing incurs rapid changes of temperature and relative humidity, the results of which can be catastrophic. This unpredictable behaviour makes clear guidelines for using early woodwinds impossible to establish. Examination of the conditions outlined in Chapter 1 will show that there are few circumstances under which the woodwinds of a collection can be used. The following notes are intended only to alert readers to the drawbacks of playing such instrument.

The Materials of Fabrication

The rapid rise of relative humidity in the bore of a wind instrument on commencement of playing, and the high relative humidity maintained thereafter, cause reactions with most of the materials used for woodwind instruments. Wood itself is particularly prone to dimensional change under fluctuating relative humidity, even if a finish has been applied to it. Ivory has a low affinity to moisture, but this should not induce a sense of false security; stresses built up in the material over years can be suddenly and catastrophically relieved by sudden changes in relative humidity. Allowing an ivory instrument to be played *always* involves a high level of risk. The susceptibilities of both ebonite and glass indicate that they should never be subjected to playing. Guidance on the care of metal-bodied woodwind instruments is similar to that outlined for brasswind instruments below.

Conditioning Before Use

Conditioning of woodwind instruments before use has been advocated by some museums that are mandated to allow visiting scholars to test instruments in the laboratory. Woodwind players have a well-defined sense of the need for caution when taking a new instrument into service. Initial playing sessions are restricted to a few minutes per day, gradually being extended over the course of a few weeks. The situation with older instruments is similar, but requires much greater care. The overriding concern is the risk of cracking. The humidity and temperature gradients that migrate through an instrument every time it is played create complex patterns of stress that are poorly understood. For example, the average coefficient of thermal expansion of grenadilla wood is much too small to account for the known propensity of instruments made of it to crack immediately upon being blown into when they are "cold". The time necessary for this to happen is, in turn, much too short for any significant humidity gradients to have become established in the body of the instrument. Pending experimental work, one hypothesis is that the waxes and oils in grenadilla become so brittle at low temperatures that they participate dramatically in the aggregate stresses that cause the wood to crack. This example demonstrates that too little is known about the behaviour of woods under these conditions to allow adequate guidelines to be presented.

Also, historical instruments that have survived brief periods of usage often enough to be regarded as "safe" can quite surprisingly crack under what would not be regarded as unusual circumstances. Thus, it may also be reasonable to conclude that the final irretrievable strain that causes a crack to form in an old instrument is part of a cumulative process. It would follow from this that there is no way to know when a woodwind instrument is likely to crack, and there is, therefore, no adequate way to guard against that eventuality. The minimum risk condition is to allow less valuable instruments that are candidates for playing to go into equilibrium with upper range of relative humidity and temperature values. When the moment of ultimate risk is at hand, the instrument can be further raised towards body temperature (tucking it between the body and the upper arm is a tried and true woodwind musician's device) before playing.

Care After Use

Unlike the brasswinds (see below), rapid drying out of the interior of woodwind instruments is not recommended. Free moisture should be removed by the methods outlined in Chapter 5, but thereafter the instrument should be left in the ambient conditions to equilibrate slowly. No air stream should be applied to the bore.

Cleaning after use is essential. In general, the processes described in Chapter 5 are equally appropriate for working instruments. As with all other instruments, woodwinds should be documented fully before, during and after every use, and the written record used as a guide to assessment of their continuing playable condition.

Brass Instruments

Brass instruments generally show every indication of durability, and of all historic instruments their use is the least problematic. Even so, there are many areas where injudicious use can cause harm. Five main areas of concern are dealt with below.

The Materials of Fabrication

The corpus of the instrument and all crooks, tuning bits, slides, and other components must be in stable condition. Old metals can suffer from stress cracking, thinning due to excessive polishing, corrosion, and mechanical stress. There is no substitute for a minute visual and tactile inspection of the entire instrument. All components must be examined closely by eye, and then checked for firmness, first by tapping and pressing, then by gentle squeezing. Even so, while such a close inspection will reveal grosser weaknesses, incipient problems may still go undetected.

The Joins Between Components

Components are joined either by mechanical means or by solder. All mechanical joints must be in stable condition with no play between components. These parts should be disassembled where possible and lubricated periodically. At the same time, the surfaces can be inspected for wear, corrosion or leakage. Mouthpieces, crooks, and other detachable components should be kept separate from the instrument, not left inserted. Soldered joints should be intact and show no signs of corrosion or cracking.

The Surface

The pros and cons of metal polishing are dealt with in Chapter 5. The condition of the surface of a brass instrument is immaterial to the sound it produces, so the choice to polish or not is entirely one of aesthetics. Whatever the surface condition, the metal should be protected from further corrosion during playing. Contact with the skin causes transfer of oils and acids that may etch metal surfaces. The use of cotton gloves is advocated for handling museum material and is now considered a routine practice, but it is unnecessary to stipulate such stringent precautions during playing if routine cleaning is practised. If gloves are not worn, the surface *must* be de-greased after every use by gently wiping with a lint-free cloth dampened with ethanol or iso-propanol (rubbing alcohol). To ensure the alcohols will not affect the lacquers or other finishes, a small test should be made on an unobtrusive area.

The Interior

The insides of unmaintained brass instruments are generally very corroded by the continual passage of moist air from the breath and any pollutants it may contain. If it has not been possible to remove this corrosion, as outlined in the previous chapter, or if its extent is unknown, it is essential to keep the bore dry between playing sessions. This can be done either by directing a stream of warm, dry air through the bore, or by passing absorbent materials through it. Excess condensation should be drained away first either by using the water keys already installed, or by inverting the instrument. Warm air can then be supplied by connecting a hair dryer to the instrument using a section of wide, thinwalled plastic tubing. The point at which the bore can be considered dry is one of judgement and depends upon ambient relative humidity, the temperature of the supplied air, and the amount of moisture within. To absorb moisture directly, small balls of synthetic foam no larger than the bore at its smallest point can be cut roughly to shape with scissors. These are blown through the instrument with a stream of dry air from a compressor or air tank. Successive balls are passed though until the last one is judged to be dry. It is not wise to dry the balls out and re-use them as they will have accumulated contaminants.

Movable Parts

Slides, valves and other movable parts must be maintained in a clean, smooth-working, and lubricated condition. All components that move during playing should be checked thoroughly for any signs of abrasion or wear. The presence of longitudinal scratches and uneven surface appearance on such components signal problems of poor fit, damage, dirt, or excess wear. Many slides are plated to give better wearing qualities. The condition of plating can also be used as an indicator of wear. Matte surfaces and the presence of base metal showing through the plating indicate excessive wear.

No instrument should be disassembled without using the correct tools. It is very rare that modern, standardized tools can be used on early instruments. It is often necessary to make tools for specific tasks, or to adapt commercially made ones. Disassembly and reassembly require specific skills and techniques and a dedicated workspace.

All excess deposits of old lubricants and accumulated dirt should be removed using a mild solvent, such as turpentine substitute applied with a small cotton swab. Parts such as tuning slides, which remain static while playing, should be moved periodically while in storage or on display to avoid seizing. Seizing results when metals remain in close contact with each other for long periods. Parts that are designed to be tight fitting, like tuning slides, are most prone to this. Similar metals, such as brass on brass, are more likely to seize than dissimilar metals, like nickel-plated slide stockings acting on brass tubing, for example. Effective lubrication of such parts is a key to their remaining movable.

The purpose of a lubricant is to provide a thin film of fluid that acts as a barrier to prevent direct metal-to-metal contact between moving surfaces. No valve, keywork, piston, or other moving part of a brass instrument should be operated dry. The type of lubricant used on valves and slides depends critically upon the closeness of tolerance of the components. Working surfaces of older instruments may need very different kinds of lubricants from those used on new ones. Also, lubricants designed and marketed for frequent and continuous use may be inappropriate for less arduous applications. The optimum viscosity to be used for valves in good condition is between 2.5 and 4.0 cSt, but badly worn valves can tolerate or even benefit from somewhat higher viscosity oils. However, if a lubricant is required for badly worn valves, the question of whether the instrument should be played at all arises. As a general rule, a lubricant should be selected within the viscosity range above, and should contain no added solvents. Silicone products have been considered taboo in museum conservation for a variety of reasons, most of which concern their use on wooden surfaces. There is no reason to prohibit their use on metal slides; in fact they have characteristics of longterm stability and easy removal that make them superior to mineral- or animal-based oils.

Movable but non-moving parts, such as tuning slides, should be coated with a lubricant of much higher viscosity, because the low viscosity lubricants recommended for moving parts can flow away from surfaces over long periods of time. A silicone grease very sparingly applied can be recommended. Routine inspection at yearly intervals will ensure that the lubricant is still doing its job. If components are extremely tight, and there is the risk of causing damage by moving them, wherever possible they should be left disassembled.

Care After Use

The above notes include guidelines on care strategies during and after use of brass instruments. The notes on general cleaning and care in Chapter 5 are equally applicable. As with all other instruments, brass instruments should be documented fully after every use, and the written record used as a guide to assessment of their continuing playable condition.

Percussion

The brief guidelines provided in Chapter 5 apply equally well to instruments in playing condition, although it is obvious that sound condition, lack of fragility, and care in handling are all essential. Original or old drumheads, especially those with applied decoration, should never be sounded and should not be kept at playing tension.

Selection and Monitoring of Players

Musicians who wish to work with original material must be selected carefully. A restored early instrument cannot be directly compared with a newly made copy, and the distance between a modern instrument and its early forerunner is even wider. Twentieth- century instrumental technique cannot be readily transferred to early instruments. In fact, in some cases it is dangerous to their mechanical stability to try. If instruments are in good regulation, players should be persuaded to use them as they find them, if at all possible. If a significant number of good players find the setting up of an instrument unsatisfactory, consultation with qualified personnel is advised.

Sensitivity towards historic instruments is an essential attribute of a player's training. Those who wish to use the instruments in a museum collection should be required to establish their credentials and qualifications. An expressed interest in early instruments is a starting point, but this must be underscored by experience and knowledge specific to the instrument under study. An exception may be allowed for young musicians because, having less training, they are more receptive to new ideas and can benefit over a long period from such exposure.

Monitoring the use of the instruments is an ongoing task, and it becomes an opportunity to establish a three-way dialogue among the player, the instrument and the person who provides the care. The latter must be well trained in all aspects of the instruments' function and use, and it must be understood by players from the outset that authority resides in this person. Written memoranda of understanding should always be made and copies added to an instrument's object file. The international musical instrument committee (CIMCIM) of ICOM has tackled this problem in *Recommendations for Regulating the Access to Musical Instruments in Public Collections*. This document was written by a specially convened group of musical instrument conservators and curators, and published by CIMCIM in 1985. It establishes conditions and demonstrates current approaches for allowing museum visitors (instrument makers, historians, musicologists, players, etc.) to physically handle museum musical instruments. The document describes the conditions of access, general protection from damage, measuring tools and techniques, and the conditions for playing, while also touching upon the question of copyright.

Relative Costs

It is often forgotten that the initial cost of restoring an instrument to playability can be dwarfed by the ongoing costs of keeping it in good condition. Aside from maintaining a stable environment, which can be a costly investment in both machinery and time, ongoing care can produce a large, cumulative debt.

If maintenance and regulation is to be an in-house affair, it is necessary to retain on staff a person with the full capabilities and qualifications for the task. Very often old instruments sound and feel very differently from later counterparts, and since it is often necessary to demonstrate techniques to would-be players, an ability to play the instruments competently is a huge asset. In addition, the incumbent must be fully familiar with the construction, conservation and maintenance of the specific types of instruments in the collection. The position will need to be paid at a reasonable rate for such specialized technical work, and must be supported with a well-equipped workshop and monitoring instruments.

If maintenance, regulation, and general overview of the collection is to be contracted out, the frequency and length of visits, the extent of work performed and, of course, fees paid, should all be established in advance. It is also necessary to factor in the costs of preparatory work on the instrument, monitoring of the playing session, and post-playing maintenance and inspection. Also, potential players must be introduced to the instruments and auditioned to ensure that they are capable of working safely with historic material. Such introductions can be costly and time-consuming, but for the well-being of the instruments they are indispensable.

Retiring Instruments from Playing Status

The originality of a historic instrument — its proportion of original and later components — depends upon many factors such as its type, its complexity, fragility and age, and the length of its working life. For

example, a simple natural trumpet with no moving parts is more likely to be found in essentially original condition than would a highly complex pipe organ. Metal objects are likely to fare better than wooden ones; musical instruments that work extremely well will be used much more than decorative or experimental ones. Nevertheless, no historic instrument can be expected to perform forever without its working parts eventually undergoing complete transformation. Many restored musical instruments, particularly keyboards, have become copies of themselves by incremental replacement of worn components, and consequently contain more information about practices during their working lives than they do concerning the practices of their date of birth. As primary documents of a past state, they may tell little, although later accretions have an independent, if secondary, historical importance. On the other hand, there are some playing instruments that are apparently in remarkably original condition, for whatever reason, and thus are primary source material, and more culturally fragile in consequence (Arnold-Forster and La Rue, p. 25).

Retiring from playing status requires acute discrimination of exactly when the instrument has reached the point where too much intervention would be required to keep it working. Nevertheless, many functioning instruments contain little of irreplaceable historic value. It may best serve the collection if they continue to be maintained in playing condition. Because retiring from playing status is a highly complex and multilevelled decision-making process, every effort must be made to preserve the results of the deliberations from the arbitrary. All points of view should be considered at the time the decision is made, and a permanent record of the deliberations should be prepared for inclusion in the instrument's object file.

Conclusion

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Playing original early instruments for historic and aesthetic reasons is philosophically unsound. It is clear that the behaviour of instruments changes with time, and that the sound and feel of a restored early instrument are naturally products of the present, not of the past. Anybody who has compared the character of an original instrument with a close copy will appreciate the world of difference that lies between them. Karp has stated that:

> It is becoming obvious that restored older instruments do not necessarily behave or sound as they did when they were new. Since composers can reasonably have expected to hear their works performed on relatively new instruments — certainly not on 200 year old restored museum pieces — the chronologically original instrument is not necessarily the musically authentic one.

There is an apparent reluctance among custodians of historic instruments to accept the fact that the sound quality that an instrument at present possesses may be widely different from its original quality, and that no amount of introspection and scholarship can capture its true original state. However, it is generally recognised that playing instruments that are in sound enough condition to support it is, and will continue to be, an attractive interpretive function regardless of the veracity of the results.

A. Myers, C. Karp

General Principles

Museum documentation is a lively and fast-developing topic. One of ICOM's International Committees, CIDOC, is particularly active in both encouraging and disseminating information about developments in this area. This chapter introduces general documentation principles and both manual and automated methods that relate specifically to musical instruments.

Documentation is so important that even in small museums and private collections procedures should be codified and made independent of individual people's memories. As in other areas covered by this book, the best documentation practices of private collectors can be up to the standards of professional museum management.

Registration

Objects enter a collection as gifts, purchases, or loans. Items entering as loans either remain as such, are withdrawn, or are later given or purchased and thus become a permanent part of the collection. Every object entering the collection should be allocated a unique number. Larger and busier museums keep entry records (with entry record numbers), as well as accession records. Entry records can include documentation of objects coming into the museum for identification or conservation treatment without any expectation that they will be added to the collection. Entry records, signed by depositor and by the museum, may in some countries have legal importance in demonstrating title to ownership. Entry records are normally made in triplicate with copies going to the depositor, to an archive file, and to an object file.

Registration methods are described in a number of publications cited in the bibliography and will be only summarized here. There is nothing special about registration of musical instruments, except to say that it is sensible for items that function independently to be allocated distinct acquisition numbers. For example, bows for stringed instruments, mouthpieces for brass instruments, and beaters for percussion instruments can be given their own numbers, even when associated with instruments. The nature of associations between items should always be recorded. Cases, ephemeral parts, and accessories rarely need separate numbers if entering the collection associated with instruments, but can be dealt with in documentation along with those instruments. Consistency and accuracy are more important in registration than using technical terms (which may only be learned by the registrar at a later date).

A permanent accession register of all items in the collection should be maintained in order of acquisition number. This is the master list for documentation purposes. For each item, an entry should be made containing date of acquisition, the unique acquisition number, a brief description including the object's own serial number (if any), whether donated, purchased or loaned and name of donor, vendor, or lender. Information should be added to the register, or a separate register made, to record the withdrawal of loaned items and ownership changes of loaned items.

Objects entering the collection should be labelled with their acquisition numbers. Tie-on tags or similar removable methods are preferred for museum material, but if numbers must be applied to the items themselves, they should not be marked by irreversible means. Marking of objects should be durable, if not indelible (Barclay, *Care*, p. 11).

Object Files

Files should be maintained containing documents concerning items entering the collection. These files may include correspondence with donors, vendors and lenders, receipts and conditions stipulated by donors and lenders, and also correspondence and conditions concerning grants towards purchases. Also, lists or files of all objects in the collection can be systematically maintained that contain such information as:

- valuations for insurance purposes;
- location lists;
- display label texts;
- catalogue descriptions of the object and museums research reports;
- photographic and radiographic records; and
- records of loans from the collection.

Care plans containing the following information are another vital component of documentation:

 records of conservation treatment and repairs carried out by the museum;

- condition reports;
- audit records;
- playing logs; and
- condition monitoring reports.

The last four categories are dealt with further in more detail.

The files outlined in the two groups above will not be organized in order of accession number, but the organization of the files should enable all the information held about a particular object to be readily identified. For non-computerized documentation systems, however, indexes may be necessary for information retrieval. These indexes have conventionally been card files — either subsidiary indexes or duplicates of master cards that are kept in different sequences.

Other documents connected with objects may include drawings, makers' trade brochures and instructions, patent specifications, written, audio or video records of the instrument in use, interviews with makers, players and owners, etc.

Security

For security reasons, there should be a regular back-up procedure of these master lists. Either the originals or the copies should be kept at a location other than the premises of the collection. Obsolete files and previous documentation systems should never be discarded.

Cataloguing

Museums exist primarily to preserve the information inherent in objects. The principal means is by conservation of the object itself, but conserving accompanying information is just as important. This information may be associated data (for example, the name of a former player of an instrument), or it can be information observed or measured from the object itself, which will survive even if the object decays or is lost. The contribution of a museum to the making of music or to education greatly depends on the storage and transmission of information.

Wherever appropriate, cataloguing standards should be adopted. The structure of the documentation may be dictated by a system (such as *Spectrum* in the United Kingdom), or a regional co-operative scheme. For specialized collections, published catalogues can, in many cases, be used as models (see, for example, Borders, Gunji, Heyde, Koster and Myers). A cataloguing structure suitable for a general collection of musical instruments, and equally suitable for electronic and manual formats, can be found in CIMCIM *Newsletter* XIV, 1989.

Standards are necessary to ensure consistency in presentation when a number of consultant authors are involved in preparing catalogue copy. The main advantage of computerized systems is that they facilitate revising the data when justified by additions to the collection or by new information about items already held. Another advantage is that collected information can be manipulated and filtered for different purposes without complete re-writing. However, if a computer is not immediately available the documentation processes should not be deferred: data can be keyed or scanned into electronic form at a later date.

A catalogue of museum instruments should relate the knowledge of the craftsmanship of instrument making to the knowledge of historical practice in music making. The description should not only include the physical description of objects, but also an indication of the resources provided by instruments to performers during their working timespan. It is the synthesis of these elements that makes the documentation requirements of musical instruments different from those of non-functioning museum objects. Typical readers of catalogues are players of instruments and instrument makers. The former are interested in the characteristics of historical models and require information that places the instrument in its musical, cultural, and social context, whereas makers require information of a different kind.

In a relatively well-defined area of museum activity such as musical instruments, it is a realistic goal to harmonize methods in order to improve communication. The harmonization of cataloguing methods has for a long time been a feature of professional librarianship, which has developed recognized international standards for both describing and ordering of catalogue information. These standards structure the recorded information about published books and other materials into precisely defined fields, with procedures for recording the information in cases capable of differing interpretation. Standardization ensures that the same book, catalogued by librarians working in different places, will be given identical, or at least compatible, descriptions. For museum documentation, standardization is advantageous for:

procedures

record structure and ordering

terminology

A standardized approach is, of course, made more possible and more necessary by adopting computers and electronic data communication methods, but it is equally feasible for a paper-based system. The systematic, routine recording of information and the production of a published catalogue can be separate processes. Even if a published catalogue is not a high priority, data need to be recorded in a clear, precise way so that eventual publication, on paper or electronically, will be well prepared for. It is impossible to prescribe cataloguing rules that will apply to every single instrument; cataloguers must approach exceptional cases by following the underlying principles of the cataloguing standards. Standard rules should be hospitable to changes in emphasis within categories of information over a period of time, and to the introduction of new categories if and when any aspects of the description of instruments become more interesting to scholars.

Because they are designed to play music, musical instruments do not always conveniently fit into the schemes of classification by which musicologists and curators arrange their information. Instruments can be classified according to their place, time and culture of origin, acoustical principles, their morphology, their materials of construction, their function (either at time of manufacture or at the time of their most recent regular use), etc. Any classification bringing together instruments that share one characteristic will separate instruments that share other characteristics. The most widely used classification is that of Hornbostel and Sachs, which uses acoustic criteria for its primary division and morphology for secondary divisions. This is the most appropriate ordering for the documentation of many collections. A useful supplementary general rule for ordering a catalogue is that similar instruments within a class (e.g., transverse flutes of whatever keywork) should be listed in order of descending nominal pitch.

An instrument should be described in the functional state in which it left the workshop of its last repairer or, if in original condition, its maker. Any faults, damages or losses that have occurred since then can be listed with a description of the object's condition. Although it is interesting to speculate about former states of a modified instrument, these opinions should not be confused with the description of the instrument's condition, but should be given with any other description of repairs to the object. For example, if a bassoon was built as an eight-key instrument, had a ninth key added later, and has since lost a couple of keys, it should be catalogued as a nine-key bassoon; the loss of two keys is described along with other aspects of its condition, and the addition of one key described along with other repairs.

A concise, useful system for describing keywork of wind instruments is that developed by John Dick. This system does not attempt to analyze the mechanism from the engineering point of view, or to describe the keywork fully, but rather to indicate the facilities offered to the player. Where measurements are valuable in indicating playing characteristics, such as drum diameters, trombone bores, guitar string lengths and violin body sizes, these are worth giving.

All measurements should be given in international (SI) units. Consequently, physical dimensions of musical instruments should be given in millimetres or metres only. Cataloguers should state the degree of accuracy associated with their measurements, whether length, pitch, or any quantity expressed numerically. For example, if the diameter of a woodwind finger-hole is stated to be 2.25 mm, it should be clear from the text whether it is within the range ± 0.01 mm or ± 0.25 mm. Where appropriate, the equilibrium temperature and relative humidity at the time of measuring should be stated. If measurements in units in use at the time and place of the instrument's manufacture are thought to be significant, these may follow the data in SI units.

Although some museums still use the Helmholtz pitch nomenclature, it is preferable to adopt the internationally-used American National Standard nomenclature. The note letter is followed by a number (where possible written as a subscript) denoting the octave. C_4 to B_4 is the octave from "middle" C to B in the centre of the treble clef; higher octaves are denoted by higher numbers, lower by lower. Thus the A that is commonly 440 Hz is A4. The cataloguer should make clear wherever necessary whether the actual or the transposed ("written") pitch is meant. For regional instruments where international pitch nomenclature is inappropriate, pitches can be given in terms of the ellis (El). The octave number (where possible written as a subscript) is followed by the pitch in cents above the nearest C below the pitch being described. Thus the pitch of "middle" C is 4/0 El; 440 Hz is 4/900 El. Where the information given is only the opinion or speculation of the cataloguer, it should be clearly indicated, for example by a question mark in parentheses (?).

There is no universally accepted thesaurus of terms used in the study of musical instruments, so in the case of variants, the choice of name or of spelling should follow the usage of *The New Grove Dictionary of Musical Instruments*.

The common usage of auctioneers is also applicable in museum catalogue descriptions:

ascribed to

A traditional attribution with which the cataloguer does not necessarily agree.

attributed to

The instrument is believed to be by the named maker in the opinion of the author(s) or the authority(ies) whose literature or certificates are cited.

by

The instrument is in the cataloguer's opinion the work of the named maker. This category also includes instruments made specially for a dealer and originally sold under the maker's name, and where the actual maker is unknown or unidentifiable.

labelled, stamped, inscribed, etc.

The instrument is not, in the cataloguer's opinion, by the maker indicated but merely bears his or her name. In some cases the instrument may be a later copy or be modelled after the maker indicated.

school of, ... school

The instrument is, in the opinion of the cataloguer, made by a follower of the maker indicated, or is in the style of instruments associated with the area indicated.

workshop of

In the cataloguer's opinion, the instrument is executed in the basic style of the maker and possibly under direct supervision.

The text of any inscription should be prefaced by the method of inscription (such as branded, inscribed, carved, engraved, labelled, stamped, written, etc.). A useful convention is to transcribe the text of the inscription in double-quotes. Line breaks in the original are indicated by a oblique (/). Any trademarks, logos or devices are described outwith the double-quotes, but in sequence of line breaks. If the whole inscription is not given, parts omitted should be indicated by "…". If parts are illegible, they should be indicated by a convention such as "(— - —)". The location(s) of any inscription on the instrument should be indicated. In the case of transliteration from scripts other than the language of the catalogue, the standard orthography used should be cited.

A reference should be made to any other item in the collection directly associated with the item being catalogued. This is standard practice for brass instrument mouthpieces, bows of stringed instruments, beaters of percussion instruments, and instruments built, sold or used in pairs or groups. A cataloguer should indicate whether the association is by design, manufacture, sale or usage, and whether long-standing or recent. In many cases, the curator does not know the nature of the association, but may have good reasons for making an informed guess; in these cases, the guess can also be valuable and should be recorded with some indication of its degree of uncertainty such "possibly", "probably", etc.

When dealing with playing adjuncts, the editorial policy is not necessarily obvious. Some adjuncts are used by players for more than one instrument, and catalogue users may find it helpful to have them placed together in the catalogue so that they can make the kind of comparisons that players make when selecting their equipment. This consideration has to be taken into account when deciding a cataloguing policy for the following:

bows for stringed instruments (not usually associated by makers);

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- beaters for percussion and plectra for stringed instruments (the degree of association varies);
- mouthpieces for brass instruments (often associated by makers of instruments, but commonly provided by different makers);
- crooks for bassoons, horns, etc., and tuning bits (usually provided by instrument makers but commonly dissociated by owners);
- mutes (rarely supplied with or specifically designed for an instrument); and
- strings, drumskins, reeds (ephemeral: any long-standing association is a valuable rarity).

For these, and no doubt for other categories, the editor of a catalogue must consider the size and scope of the collection and the needs of catalogue users. It is suggested that of the above categories, brass instrument mouthpieces, percussion instrument beaters, and bows for stringed instruments are frequently used for playing various brass, percussion and stringed instruments and should be catalogued separately even when associated by manufacture or long usage with particular instruments. Other playing adjuncts can be described in the catalogue as accessories for the instrument they have been associated with most recently, if any. In all cases, the cataloguer should state whether the accessories are known to be those originally supplied by the maker for a particular instrument, whether they are probably original, or whether they are only possibly original.

Published literature and recordings referring to the specific item being catalogued should be cited. Known usage in a particular orchestra, band, etc. should be stated, together with players' names and dates. The names of former owners, collectors and players (in reverse chronological order with dates) should be given. Finally, the names of the cataloguer(s) and date(s) of working should be recorded as part of the catalogue documentation.

Documentation and Monitoring of Instruments

Every musical instrument in a collection should have a care plan setting out a scheme for conservation and curatorial care, coupled with regular assessment of the importance of the instrument to the collection and to the world at large, and its function and use in the museum. A regular review of each instrument's status should be carried out, consulting as widely as possible among professional colleagues. Readers are referred to the Museums & Galleries Commission *Standards in the Museum Care of Musical Instruments*, which outlines this topic in Section 5, "Standards for documentation," Section 6, "Standards for access," and Section 7, "Standards for loan of instruments."

The sub-sets of documentation within the care plan relating to the use of instruments involve four separate kinds of records: condition reports, sounding and playing logs, monitoring logs, and audit records. All such documents must be kept in the object file unique to each item of the collection. Although details vary with the type of instrument and the circumstances, the following guidelines may help determine the kind of information that should appear in these records.

Condition Report

A full condition report made before and after use is an essential feature of good museum practice. It can follow the same form used for documenting artifacts for loan exhibitions. It is necessary that the staff member preparing the report be fully knowledgeable about the operating characteristics of the instrument, not just its form and components. Standard checklists of instrument features can be devised as a timesaving measure provided they are complete enough. Blank outline drawings of instruments should be prepared so that all features of interest can be noted conveniently and unequivocally on them. Because these records constitute the continuing written history of the instrument, detail is essential.

Sounding Log

Audit records contain the results of testing instruments in the museum workshop or laboratory. Every instrument tested should have its performance recorded with at least the following information:

- date of audit;
- auditor(s);
- details on preparation of instrument for audit;
- information on environment;
- duration of audit;
- results obtained; and
- details on treatment of instrument after audit.

Playing Log

Every instrument played should have a unique playing log containing at least the following information:

- date of playing;
- player(s);
- · condition report before use concentrating on working parts;
- · details on preparation of instrument for playing;
- duration of playing;
- information on transportation and environment;
- · condition report after use, concentrating on working parts;
- details on treatment of instrument after playing;
- · recommendations for future use; and
- information on recording, broadcast, etc.

Monitoring

In addition to monitoring condition at the time of use, all instruments in playing condition should be included in a regular schedule of inspection and evaluation. In this way, infrequently played instruments will still have regular attention. Such monitoring need not be as all-encompassing as the three logs described above, but it must identify salient features of the instrument that might be subject to change with time and use.

Audit Records

Audit records contain the results of surveys carried out as asset management requirements of governing authorities or insurers, and are intended to demonstrate that the museum managers have an adequate knowledge of the identity of the museum holdings, their legal status as property, and their location. An audit may be carried out of objects deemed to be particularly valuable, together with a sample of the remaining items, or it may require investigation of all objects in the collection.

Automated Resources

Museums commonly use automated support for their general administration, research and conservation instrumentation, database management, and networked communication. Computers have been used for these tasks virtually since they first became available. Excluding general administration, the most widespread applications are probably collection database management, followed by climate monitoring and control. The most dramatic recent development in electronic resources is the popularization of the Internet and the World Wide Web. This, in turn, was enabled by the advent of ubiquitous desktop computers. These, again in turn, now provide opportunities for the application of a growing variety of digital documentation techniques, which previously were restricted to high-budget experimental facilities.

The process of electronic documentation is divided into the separate stages of data capture, processing, and dissemination. The capture of digital data consists of such activities as entering the description of an object into a database, scanning a photograph, or making a digital recording of the sound of a musical instrument. The processing of such data might include a database search, transforming a digitized photograph into a line drawing, or the spectral analysis of a sound recording. Dissemination could include providing access to a data base system via the World Wide Web, posting a digital image via electronic mail, or selling a compact disk in a museum gift shop.

Databases

Museums started to develop means for automating their documentation systems almost as soon as they had access to suitable computers. The

initial focus was simply to use the computer to store electronic equivalents of conventional card files and, more importantly, to take advantage of the machine's ability to search rapidly through these files.

It subsequently became apparent that there were more efficient and reliable models for structuring the data in automated systems. The development of data modelling methodologies soon became a specialized discipline; one which still retains its importance. At the outset, an overriding concern was the high cost of magnetic storage media. It was common to use terse abbreviations and codes whenever possible in order to minimize the need for space on disks and tape. Redundancy in the stored data was also shunned.

The most often mentioned stages in the development of methodologies are the hierarchical, network, and relational models. The last of these is the only one based on a coherent mathematical theory, and it serves as the basis for a large proportion of present-day database management systems. By definition, the relational model only permits data to be expressed in tables, with a database being nothing more than a set of interrelated tables. (The term "table" is a synonym for "relation." A relational system is so called for that reason alone. There is a popular misconception that a system is termed relational because it reveals relationships.)

For example, one table in a database might state and define the names of all indigenous western Canadian musical instruments. Another would provide biographical data about the makers of these instruments. A third might describe the materials used in the instruments' manufacture. A fourth could describe a specific collection of instruments, including references to relevant data in the other tables. The important feature here is that data relevant to (for example) the Haida rattles would be listed only once in the entire database. The record about each of the many instruments made by the Haida in a given collection would contain a brief reference to the information about them in the biographic table. When structuring a relational system, it is important to note that such things as a maker's name are attributes of a musical instrument. A maker's place of birth is not an attribute of an instrument; it is an attribute of the maker.

In addition to reducing redundancy, the relational approach also enables validation control. If, for example, a collection contained 357 Haida rattles and Haida was listed in the database record for each of them, there would be a large risk of some spelling mistakes. This could, in turn, result in a database search for a spurious object because it was attributed to the Haida by virtue of a spelling error. If at some point research were to reveal that Haida actually should be spelled Haidda, making the appropriate change to a single record in the biographical table would automatically correct the entire database. If there were multiple occurrences of the name throughout the database each would first have to be located, including all inadvertent spelling variations, and then corrected, risking additional misspellings.

Were this section being written two years ago, the only modelling methodology likely to be discussed would be the relational approach. In the interim, however, a significant portion of the museum community has begun to use the Internet as a presentation platform for documentation systems. The software resources normally encountered on the Internet provide little of the sophistication that database management specialists have now come to expect. Not surprisingly, the developers of networking tools have traditionally placed greatest emphasis on communication facilities.

From the database specialist's point of view, the World Wide Web is a major step backwards to a time when the "network model" presented all sorts of difficulties. As will be explained in greater detail below, a definitive characteristic of the Web is that it contains countless documents that provide links to each other. If whatever a link points to should subsequently be changed, or even deleted, there is no mechanism to ensure that a corresponding change is made to the link. Nor can all copies of a document that are maintained under the same name at numerous physical locations, be controlled or remain identical. To put it another way, if a certain museum Web site were discontinued, the many sites which link to it might or might not be informed of this, and thus their data would be faulty.

Some relief is provided by relational systems that support access via the Web. However, such systems are not immune from a higher level version of the problems just listed about the referential integrity of individual documents. It can never be certain that what initially was a link to a relational database will remain so. There are, nonetheless, significant advantages to be gained by freeing individual database systems from these problems.

Research Instrumentation

A traditional focal point of the technical description of a musical instrument in a museum collection is the "technical drawing." Although such drawings are often carefully labelled as intended for research purposes only, it is quite clear that their target audience is instrument makers. The straight lines and clean detail that characterize a technical drawing are, more often than not, gross oversimplifications of the worn, rough and wavy surfaces of centuries-old museum pieces. Nonetheless, since it is difficult to incorporate such unevenness in a reproduction instrument, the simplified technical drawings are readily accepted as accurate documentary records. Creating a digital record also involves the loss of data, this time by definition. In the analog record (a drawing), a single straight line is often used to connect the end points of a surface that is assumed initially to have been at least conceptually straight. A digital record can define that surface in terms of a far larger number of points than just two. So-called 3-D scanners are capable of making contact-free measurements, translating an object into a large number of digital coordinates. These data may then be used to generate everything from technical drawings to the direct control of an automated replication process. Although computerized scanners of this type are not yet available on a consumer level, they are encountered in larger museum installations. There are, however, a variety of low cost digitizing devices that may easily be incorporated into a modestly funded documentation facility. These range from digital callipers to a variety of smaller 3-D scanners, all of which can be attached directly to standard microcomputers.

Facilities for making digital sound recordings are now commonly included in "multimedia" packages for consumer-level personal computers. A "sound card" together with a reasonably inexpensive microphone can easily provide a digital record of an instrument's acoustical output. The software normally provided with such equipment can allow the processing and analysis of these recordings in a way that was formerly regarded as utopian. Similar means are also available for digitizing videotaped performance events. At present, however, the storage requirements for all but the briefest digitized video sequences can be daunting.

The Internet

The intense journalistic interest in the Internet has resulted in its over dramatization in the popular press. The Internet is nothing more or less than a means for providing a communications channel between points A and B. The interesting things about it are the services that are provided via this medium. The Internet is one of many global electronic communications networks. Examples of communication services that currently use the Internet as a transport medium are electronic mail and the World Wide Web. Although the Web was created within the Internet context, it is possible that it will migrate to the high speed networks that within the near future may start to replace the Internet (which is well over 20 years old). Similarly, e-mail has long been available via a number of transport media. A clear distinction must be made between electronic communications media and the digital messages which they are used to convey.

The essence of the Web is what are called "hypertext" documents. These can be understood in terms of the way a conventionally printed book is read. Someone can decide to turn from page 52, on which a reference to a potentially interesting footnote is provided, to page 312 to see the extensive footnote text. In that footnote, reference can be made to another book, which the reader can decide to consult prior to continuing with the first book. In the second book, reference might be made to a videotape which is then viewed before returning to the printed page. A soundbite on the videotape could trigger the desire to listen to a CD containing a full performance of whatever the snippet triggered an interest in. A hypertext document may be visualized in the same way, as a digitized book that provides a convenient means for jumping from place to place within it, and which contains multiple media — sound, video, graphics, etc. If the computer on which this book is stored can establish networked connections to other computers that contain hypertext documents, we can add convenient links to them.

Controversy has long raged about the proper focus for the documentation of a musical instrument. Should the primary concern be placed on its morphological description, its acoustical properties, its use in a musical context, its function in a cultural/social complex, etc.? With the advent of digital multimedia applications it is possible to create a single documentary record of any given instrument and include as many of these facets as appropriate. The use of hypermedia networking facilities allows such documents to be linked into a global aggregate.

Although museums obviously will remain the hosts for their collections, access to the documentary records of these collections no longer needs to be seen in terms of physical access to the museums. As digital imaging techniques become more powerful, the need to visit a museum to see an object may become less acute. Similarly, useful "here's what it sounds like" data can be provided, thus reducing the need to play instruments.

Readings in Electronic Documentation

A great variety of literature is available dealing with the structuring of text-based information in database systems, and the digitization of non-text data. Additional literature about the presentation, location, and retrieval of such material on electronic networks is truly daunting. Except for a very few classic works, it neither possible nor necessary to recommend an individual publication in preference to another. Instead the reader is advised to examine what is available at local bookshops and libraries, and to find books that appear to be relevant, comprehensive and appealing, and then take things from there. Almost all will provide reasonable introductions to their subjects and reference lists for further studies.

Database Modelling and Design

The seminal theoretical work, although likely to be beyond the scope of the casual reader's interest, is Edgar F. Codd's *The Relational Model for Database Management, Version 2.* The suggested point of departure for the application of this work is the latest edition of *Fundamentals of Database* Systems by Ramez Elmasri and Shamkant B. Navathe. Numerous periodicals are available; two of the most relevant are *Database Programming and Design* and *Database Management Systems*. Further guidance may be found in the tutorial material packaged with commercial database management'systems.

Electronic Instrumentation

There is no specific introductory literature on this subject, but the most useful point of access is likely to be the documentation provided with digitizing devices. The two areas of greatest relevance are digital metrology, and digital sound recording. In the former case, this will be scanning equipment. For most users, the initial acquisition will be a flatbed scanner, used for digitizing in a manner roughly analogous to the use of a photocopier. Digitizing sound events will be best introduced in connection with the purchase of a "sound card." However, the most popular sound cards do not have a particularly high recording quality. Useful sources of adequate equipment are more likely to be found among suppliers of electronic musical instruments than in the computer trade.

Everything relating to the Internet — from recreational use, to descriptions of the most intricate services — is described in a multitude of publications, the largest part of which is available without cost on the Internet itself. Because the first encounter with the Internet can be confusing, the most important attribute of any book on the subject is its personal appeal to the reader. The most highly regarded single work is *The Whole Internet User's Guide and Catalog* by Ed Krol. There are several network-based points of entry into the vast wealth of material that the Internet houses. The most useful single source of information relevant to musical instrument conservation is the website of the International Musical Instrument Committee of ICOM (CIMCIM) which contains useful information on a wide range of musical instrument museum activities:

http://www.icom.org/cimcim/

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Resources

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Organizations

Addresses and personnel of associations change relatively frequently. The following addresses were accurate at the time this publication went to press. To keep the list current, space is provided beside each address for new information to be added.

American Musical Instrument Society c/o Shrine to Music Museum 414 East Clark Street Vermillion South Dakota 57069-2390 USA

Canadian Conservation Institute 1030 Innes Road Ottawa Ontario K1A 0M5 Canada

International Centre for the Study of the Preservation and the Restoration of Cultural Property (ICCROM) 13 via di San Michele 00153 Rome Italy

International Council of Museums (ICOM) Maison de l'UNESCO 1, rue Miollis 75732 Paris France

International Institute for Conservation (IIC) 6 Buckingham Street London WC2N 6BA UK

International Musical Instrument Committee (CIMCIM) c/o Edinburgh University Collection of Historic Musical Instruments Reid Concert Hall, Bristo Square Edinburgh EH8 9AG Scotland
Museums & Galleries Commission 16 Queen Anne's Gate London SW1H 9AA UK

Musical Instrument Conservation and Technology On-Line Consortium http://www.micat.org/

The Music Collections Forum Hélène La Rue Pitt Rivers Museum 60 Banbury Road Oxford OX2 6PN UK

Publishers and Distributers

It is not possible to provide addesses for all the publishers of works listed in the bibliography. Following are the addresses of publishers specializing in musical instrument or museum-related topics. In addition, some of the organizations listed above produce publications.

Archetype Books 6 Fitzroy Square London W1P 6DX UK

Butterworth and Co. (Publishers) Ltd. Borough Green Sevenoaks TN15 8PH UK

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The Care of Historic Musical Instruments

The work of seven contributors from a wide range of specializations in the care and preservation of historic musical instruments has been incorporated in this book. Thorough and in-depth guidance is provided on the many aspects and demands of managing the retirement from active service of heritage musical instruments, whether they are in the possession of individuals, private collectors, or museums. Details of the resources, advice, and support available to the custodians of collections are also included.

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