To Play or Not to Play

Corrosion of Historic Brass Instruments

Romantic Brass Symposium 4 • Edited by Adrian von Steiger, Daniel Allenbach and Martin Skamletz

Edition Argus

Musikforschung der
Hochschule der Künste Bern
Edited by Martin Skamletz
and Thomas Gartmann
Volume 15

To Play or Not to Play

Corrosion of Historic Brass Instruments

Romantic Brass Symposium 4 • Edited by Adrian von Steiger, Daniel Allenbach and Martin Skamletz

Published with the support
of the **Swiss National Science Foundation**.

Content

Preface

In February 2017, we had the honour of hosting the annual Congress of the Comité international pour les musées et collections d'instruments et de musique (International Committee for Museums and Collections of Instruments and Music, CIMCIM) in Switzerland, under the motto "Presentation, Preservation and Interpretation. The Challenges of Musical Instrument Collections in the 21st Century". Numerous museum experts, scholars, scientists, musicians and other interested parties accepted our invitation to the lectures, discussions, concerts and museum visits that were organised by CIMCIM, the Hochschule der Künste Bern HKB and the Museum für Musik Basel in collaboration with the Schola Cantorum Basiliensis and the Klingende Sammlung Bern, supported by the Swiss National Science Foundation.[1]

The fourth day of the Congress constituted the "Fourth International Romantic Brass Symposium" and was entirely dedicated to presenting a research project of HKB. This project, entitled "Brass Instruments Between Preventive Conservation and Use in Historically Informed Performance",[2] investigated corrosion inside historical brass instruments and possibilities for their preventive conservation when they are played either for research purposes or in historical performance practice projects – this in itself being one of the prime topics of CIMCIM. Keynote speeches, presentations of the results of the research project, and case studies from museums and music academies with practical experience complemented each other in the best possible way. While it was impossible to find a single solution to the dilemma as to whether a historical instrument should be played or removed from performance – a dilemma that is in any case impossible to solve conclusively with regard to any specific, individual instrument – a consensus nevertheless emerged in our discussions that would in practice allow museums both options. On the basis of these research results, it should be possible for CIMCIM to formulate recommendations for the future use of brass instruments.

The present volume brings together the results of the above-mentioned research project, supplemented by a selection of the papers from the Congress that focused on brass instruments. Martin Skamletz introduces the history, development and design of the research projects on brass instruments carried out at HKB, which in themselves represent a turn towards practice-oriented research. Adrian von Steiger outlines the issues, research, results and consequences of the above-mentioned project on internal

1 For more information and the programme, see www.hkb-interpretation.ch/cimcim (all URLs in this text last accessed 27 July 2022).

2 For more information on the project, see www.hkb-interpretation.ch/projekte/korrosion.

DOI: 10.26045/kp64-6179-001

corrosion in brass instruments. The research carried out for this project was by necessity multidisciplinary in nature and is presented here by means of contributions from different disciplines. Martin Ledergerber, Emilie Cornet and Erwin Hildbrand carried out a preliminary study to investigate the behaviour of moisture inside brass instruments that are played. Bernhard Elsener, Tiziana Lombardo, Federica Cocco, Marzia Fantauzzi, Marie Wörle and Antonella Rossi used electrochemical measurements to monitor instruments that were played during an experiment that lasted fourteen months. The results generated are evaluated in greater depth in the contribution by Federica Cocco, Marzia Fantauzzi, Bernhard Elsener and Antonella Rossi. David Mannes and Eberhard Lehmann used neutron imaging to visualise internal corrosion within the framework of the study; and finally, Martin Ledergerber used endoscopy to carry out optical measurements and documentation of the progression of corrosion in the aforementioned instruments over the fourteen months in question. The reports on the research project are rounded off by Daniel Allenbach's essay on Igor Stravinsky's ballet *Le Sacre du Printemps*, which provided the musical background to the project.

Both the keynote papers from the Congress set out fundamental issues: Arnold Myers emphasises that museums do not just have to conserve objects, but also their inherent information; and Robert L. Barclay presents the complex context in which the conservation, restoration and reproduction of historical instruments are situated. The latter topic is exemplified by two case studies: Sabine K. Klaus discusses a non-invasive means of predicting the playing behaviour of brass instruments without actually playing them, while Marie Martens presents the research history of the bronze lurs in the National Museum of Denmark, which also included playing the instruments on a test basis.

The editors would like to thank all the authors for their contributions and the organisations already mentioned above for making possible both the research project and the Congress.

Adrian von Steiger
Daniel Allenbach
Martin Skamletz

Martin Skamletz

"Practice-Oriented Research". Fifteen Years of Brass Projects at the Hochschule der Künste Bern

When the Hochschule der Künste Bern HKB initially embarked on research in the middle of the first decade of the twenty-first century, no one could have foreseen that research into historical brass instruments would prove particularly successful in the long term, nor that this would soon develop into a whole series of research projects that would continue to this day. The brief retrospective that we offer here can only provide an interim snapshot, given that activities in this field remain ongoing. We shall trace the development of this project series, explain its results and its accompanying activities, and hope thereby to provide insights into the specific framework on which it is based and that has itself influenced the overall conception of the series.

New organisational forms and their legal foundations Research is a relatively recent phenomenon at universities of art, and especially at universities of music. In Switzerland, the rise of research at these institutions is closely related to a transformation that took place at the turn of the new millennium, when the traditional conservatories were made departments of the newly established universities of applied sciences and arts.[1] The Swiss music conservatories had previously been devoted mostly to instrumental and vocal teaching and had been financed by the cantons, but the *Fachhochschulgesetz* (FHSG, "Law on Universities of Applied Sciences") that came into force in 1996 meant that they were no longer to provide exclusively artistic training, but were instead obliged to fulfil a 'fourfold performance mandate'. This meant that they had to engage in "practice-oriented research and development"[2] in addition to teaching, further training and services. The

1 For the history of the Swiss universities of applied sciences and arts, see Hans-Kaspar von Matt: *Die Schweizerischen Fachhochschulen: eine Biografie. Geschichte und Geschichten über die Bildung eines neuen Hochschultypus*, Bielefeld 2022.

2 The German original runs "anwendungsorientierte Forschungs- und Entwicklungsarbeiten", *Fachhochschulgesetz* FHSG *vom 6. Oktober 1995 (Stand am 1. Januar 2013)*, art. 3, para. 3, www.admin.ch/opc/de/classified-compilation/19950279/201301010000/414.71.pdf (all URLs in this text last accessed 28 July 2022). "Den FH wird somit eine Aufgabe übertragen, die für einige unter ihnen neu ist: die Forschung." ("The universities of applied sciences are thus given a task that is new to some of them: research.") *Aktion* DORE *– Kompetenzförderung in anwendungsorientierter Forschung an den kantonalen Fachhochschulen, Tätigkeitsbericht vom 19. August 1999 bis zum 31. Dezember 2001*, Bern 2002, p. 6. The FHSG was replaced on 1 January 2015 by the "Hochschulförderungs- und -koordinationsgesetz" (HFKG, "Law for the promotion and coordination of the universities") of 30 September 2011, which came into force on

DOI: 10.26045/kp64-6179-002

transformation into tertiary institutions that could meet these requirements, and whose curricula had to be redesigned according to the Bologna System, went hand in hand with the merging of smaller educational institutions into larger units. In Canton Bern, for example, the conservatories of Biel and Bern and the Swiss Jazz School Bern, which had hitherto existed independently as vocational colleges, were merged in 1999 to form the Hochschule für Musik und Theater and were separated from their respective general music schools (i.e. the music schools primarily for those of pre-university age). In 2003, this Hochschule für Musik und Theater was integrated in the newly created Hochschule der Künste Bern HKB, where it was divided into separate divisions for music and theatre.[3] As Switzerland's first integrated university of the arts, which is itself a department of the Bern University of Applied Sciences BFH, it also includes divisions for design, art, conservation and restoration, literature, and a transdisciplinary 'Y Institute'.

Roman Brotbeck was initially the Director of the Biel Conservatory, then of the Hochschule für Musik und Theater, and ultimately the Head of the Music Division of HKB. Since he is a musicologist, the new task of integrating research into a tertiary music institution in Bern was taken seriously from the outset and never had to take a back seat thereafter. Already before its integration in HKB, the Hochschule für Musik und Theater set up a forward-looking "research and development institute for our own practice-oriented research" that was called the "Freie Akademie".[4] Other departments at BFH, such as the School of Engineering and Computer Science, already had a long tradition of applied research. This helped to facilitate the establishment of an interdepartmental research culture that to this day continues to search for appropriate forms of interdisciplinary collaboration.

Musicians become researchers Research support infrastructure was subsequently set up at HKB at a central site. It is independent of the different artistic divisions, and in many instances its tasks mean that it has more in common with its umbrella institution BFH. The research competences that were now required were by no means merely bought in from outside, despite most of the teaching staff having been kept on from the predecessor institutions. Instead, a serious attempt was undertaken to introduce the staff to their new

1 January 2015 (current status as of 1 January 2020), www.admin.ch/opc/de/classified-compilation/20070429/202001010000/414.20.pdf.

3 The study area "Opera" was originally part of the Opera/Theatre Division, but was removed from it in 2018 and integrated in the Music Division.

4 "Eine wichtige Neuheit der Hochschule ist unser Forschungs- und Entwicklungsinstitut, die so genannte 'Freie Akademie', wo wir neue Wege im veranstalterischen Bereich und eine ganz eigene, praxisorientierte Forschung betreiben können". Hugo Schaller: Auf dem Weg zur Musikhochschule. [Interview with Roman Brotbeck], in: *Freiburger Nachrichten*, 12 July 2002, p. 3.

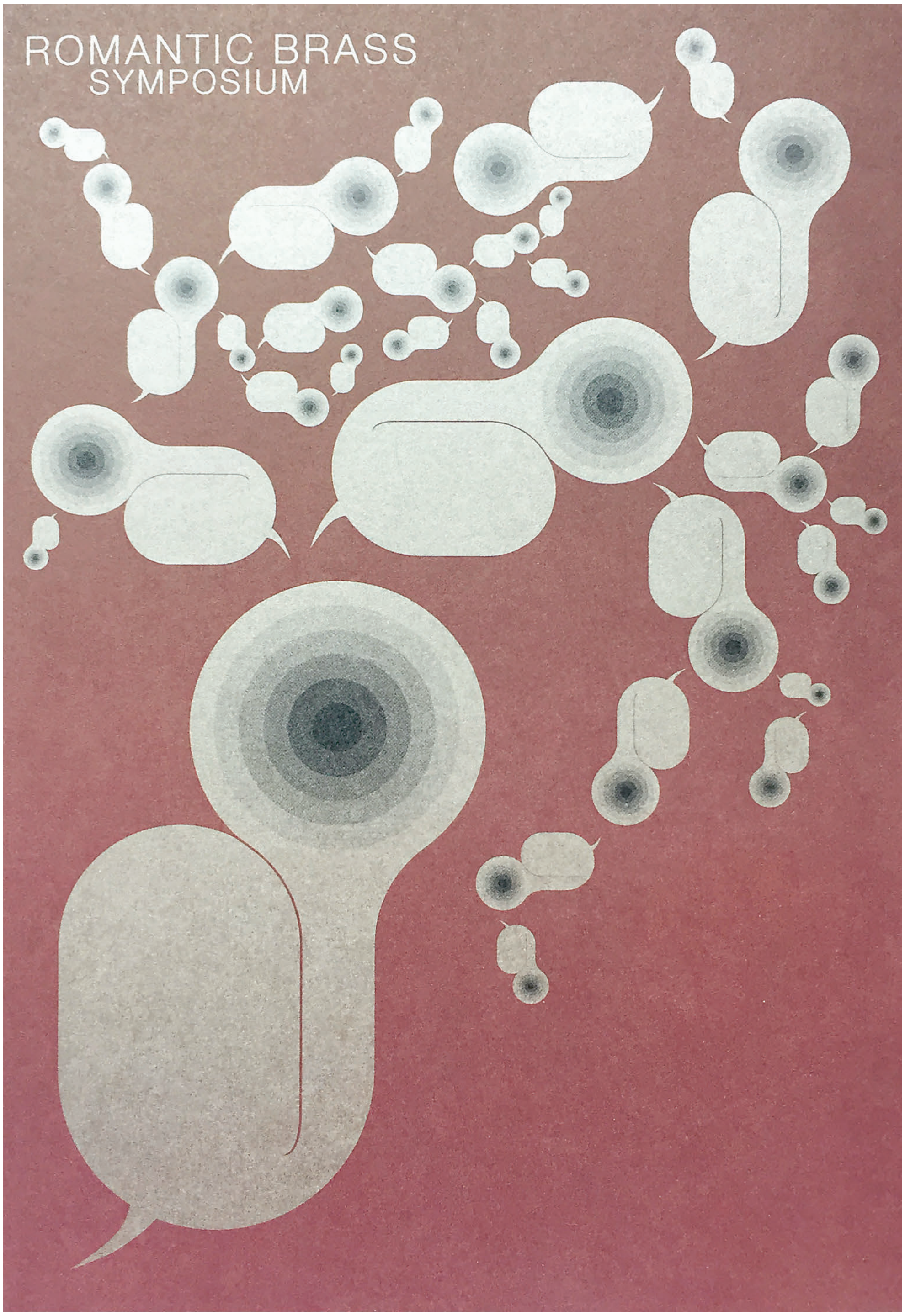


FIGURE 1 Flyer for the first Romantic Brass Symposium (2009).
Design & photo: Viola Zimmermann

task of conducting research, and to further qualify them to embark on such activities. Initial, preparatory research projects emerged when these lecturers were confronted with their new challenges. For example, the process of "de-standardising"[5] the core Romantic repertoire of a conservatory was also important for establishing the strategic position and profile of the Music Division of HKB, and this was undertaken under the banner of "Interpretation practice in the nineteenth and early twentieth centuries".[6] In a subsequent step, greater attention was focused on performance practice on string instruments.[7] Both these preparatory projects, which were financed by BFH, concluded with exemplary symposia[8] and their results were published in a series of books that was set up especially for this purpose by HKB (the same series in which the present volume is being published).[9] A spirit of close cooperation already existed at this early stage with the Institute of Musicology at the University of Bern – which is a cantonal institution, like HKB itself – and led a few years later to the founding of a joint doctoral school: the "Graduate School of the Arts" GSA, which since 2019 has been known as the doctoral programme "Studies in the Arts", SINTA.[10] However, the researchers involved in these early projects were initially artistic lecturers or assistants at HKB's Department of Music. They had not previously been much involved in research, and were supported throughout

5 Regarding the German term "Entstandardisierung", see Roman Brotbeck: Das Forschungsfeld "Interpretationspraxis des 19. Jahrhunderts" an der Hochschule der Künste Bern, in: *Zwischen schöpferischer Individualität und künstlerischer Selbstverleugnung. Zur musikalischen Aufführungspraxis im 19. Jahrhundert*, ed. by Claudio Bacciagaluppi, Roman Brotbeck and Anselm Gerhard, Schliengen 2009 (Musikforschung der Hochschule der Künste Bern, Vol. 2), pp. 189–200, here p. 197. All volumes and articles in this series are available on open access at www.hkb-interpretation.ch/musikforschung-der-hkb.

6 "Interpretationspraxis des 19. und frühen 20. Jahrhunderts", BFH project 5004PT.HKB (2005), applicant: Roman Brotbeck, research staff: Claudio Bacciagaluppi, Manuel Bärtsch, Hans Peter Blochwitz, Carsten Eckert, Tomasz Herbut, Andreas Stahl, www.hkb-interpretation.ch/projekte/interpretationspraxis.

7 "Aufführungspraxis und Instrumentenbau der Saiteninstrumente im 19. und frühen 20. Jahrhundert", BFH project 6003PT.HKB (2006), applicant: Roman Brotbeck, research staff: Claudio Bacciagaluppi, Elena Càsoli, Barbara Doll, Carsten Eckert, www.hkb-interpretation.ch/projekte/aspekte-der-streicherpraxis-in-der-romantik.

8 "Zwischen schöpferischer Individualität und künstlerischer Selbstverleugnung. Zur musikalischen Aufführungspraxis im 19. Jahrhundert" (14–16 December 2005), www.hkb-interpretation.ch/interpretationspraxis; "Aspekte der Streicherpraxis in der Romantik" (18/19 November 2006), www.hkb-interpretation.ch/streicherpraxis.

9 *Zwischen schöpferischer Individualität und künstlerischer Selbstverleugnung*; *Spielpraxis der Saiteninstrumente in der Romantik. Bericht des Symposiums in Bern, 18.–19. November 2006*, ed. by Claudio Bacciagaluppi, Roman Brotbeck and Anselm Gerhard, Schliengen 2011 (Musikforschung der Hochschule der Künste Bern, Vol. 3).

10 www.sinta.unibe.ch/index_eng.html.

by HKB's in-house musicologist Claudio Bacciagaluppi. Their number was expanded at the symposia to include international experts in the fields in question.

Research funding Although the brass players had not yet been involved in these very first research activities at HKB, it is notable that it was they who, in the long run, proved to be the instrumental lecturers in HKB's Music Department who were the most eager to experiment and the most adept at research. This was already evident when it became necessary to seek external, third-party research funding (at first, research funding had been provided by BFH – it was awarded competitively, to be sure, but nevertheless within the university of applied sciences itself). Just as it had never been questioned at HKB that universities of the arts could and should engage in research, so it was also clear from the start that such research activities would be organised as time-limited projects, and that the funds necessary to undertake them should be acquired externally in order to ensure quality control by funding institutions acting in line with the benchmarks of the international research community.

Parallel to the new research mandate given to the universities of applied sciences, Switzerland's two most important national funding institutions, the Swiss National Science Foundation SNSF and the Commission for Technology and Innovation CTI, launched a joint funding programme in 1999 whose specific aim was to build up the necessary skills in the non-technological disciplines of social work, business, health and the arts, all of which were situated at the universities of applied sciences and were consequently rather new to research. Its name was DORE (short for "DO REsearch!").[11] The special feature of this programme was that the university engaging in research projects was supposed to work together with external implementation partners. The goal of the first DORE project, initiated by the composer and organist Daniel Glaus while the Hochschule für Musik und Theater was still in existence, was to develop a wind-dynamic organ together with two organ-building companies.[12] The DORE funding programme had

11 "Um den Erwerb von Kompetenzen in anwendungsorientierter Forschung an den kantonalen FH zu unterstützen, hat das Parlament und der Bundesrat den Schweizerischen Nationalfonds (SNF) und die Kommission für Technologie und Innovation (KTI) mit einem entsprechenden Mandat betraut. Zur Erfüllung dieses Mandates haben die beiden Institutionen die Initiative 'DO-REsearch!' geschaffen". *Aktion DORE – Kompetenzförderung in anwendungsorientierter Forschung an den kantonalen Fachhochschulen, Tätigkeitsbericht 2000–2003*, Bern 2004, p. 3. Cf. *KTI und DORE: Gute Forschung findet starke Förderer*, undated document, www.snf.ch/SiteCollectionDocuments/spe_dor_kti_d.pdf.

12 "INNOV-ORGAN-UM – Innovationen in der Kunst des Orgelbaus und -spiels", SNSF DORE project 101162 (2003–2005), applicant: Daniel Glaus, implementation partner: Orgelbau Peter Kraul, Johannes Röhrig, https://data.snf.ch/grants/grant/101162.

meanwhile become the sole responsibility of the SNSF,[13] and on a hunt for music lecturers who might be willing to take on limited-duration research tasks in addition to their teaching load, the Hochschule found the people it needed among the brass staff. At the same time, there were instrument builders in Switzerland who were keen to get involved in just such practice-oriented research projects as 'implementation partners'.

Historical wind instruments as an object of research and reconstruction To some extent, the practice-oriented nature of this research naturally tended to focus on instrument-building. What's more, the brass section of the classical orchestra was the group whose instruments had undergone the greatest structural changes during the nineteenth century, and where there was still much to be discovered that had hitherto remained unknown or forgotten. Starting with this instrument group promised to provide the greatest possible benefit in the shortest possible time by establishing a new perspective on the core Romantic repertoire of the traditional conservatory. Above and beyond this, it offered the prospect of taking the principle of historically informed performance practice – already a subject of international interest for the music of the Baroque and Classical eras – and extending it into the music of the nineteenth and early twentieth centuries. This would in turn enable HKB to contribute to the international research discourse.

The choice of topic for HKB's first DORE project on brass instruments fell on representatives of their bass register that were in functional terms the precursors of the later tuba, but had fallen into disuse over the course of the nineteenth century. The main focus was on the ophicleide. The project was intended to include reconstructing the instrument itself so that it might be played more widely in historically informed orchestras.[14] Guy Michel and Thomas Rüedi, HKB's lecturers for tuba and euphonium, took part as HKB's own contribution to the project. The actual research that was financed by the project was initially assigned to a HKB graduate, the tuba player Daniel Schädeli. But he won the audition for the tuba position in the Bern Symphony Orchestra at the same time that the

13 "Seit 2004 wird DORE vom SNF allein weitergeführt". DO REsearch (DORE) – *Förderungsinstrument für praxisorientierte Forschung an Fachhochschulen und Pädagogischen Hochschulen, Tätigkeitsbericht 2004–2006*, Bern 2006, p. 4.

14 "Rekonstruktion, Nachbau und Spielmethodik der originalen tiefen Blasinstrumente im 19. Jahrhundert am Beispiel von Cimbasso und Ophikleide", SNSF DORE project 112469 (2006–2008), applicant: Roman Brotbeck, research staff: Roland Fröscher, Guy Michel, Thomas Rüedi, Daniel Schädeli, implementation partner: Instrumentenbau Konrad Burri, https://data.snf.ch/grants/grant/112469. It was originally planned to include the cimbasso in the project, but this proved too ambitious for the two years planned for the project. This was instead postponed and intended for inclusion in a putative later project that up to now has not been realised.

DORE project was approved in 2006, so he had to reduce his research workload from the very start.

The work quota that had been freed up by Schädeli's reduction in research time was assigned to the euphonium player and HKB assistant Roland Fröscher. The resultant teamwork proved ultimately beneficial to the project and furthermore constituted a welcome boost to a member of the non-professorial teaching staff. Daniel Schädeli remained in charge of the core task of developing a replica of the ophicleide together with the instrument builder Konrad Burri, while Roland Fröscher worked on integrating the ophicleide as a variant instrument for tuba and euphonium students at HKB. He himself also embarked on extensive concert activities on the replica instrument. Ultimately, the results of such a project ought always to have practical, professional applications and should also have an impact on the professional training offered by the Music Division of HKB. Since Roman Brotbeck was both Head of the Music Division and Head of the Research Area Interpretation[15] at HKB, he was able to plan appropriately and implement the results of the project, also using HKB's investment budget to purchase the reconstructed instruments upon their completion.

While the ophicleide project was still ongoing, HKB's second DORE project was already approved. It began in summer 2007 and was dedicated to reproducing the keyed trumpet.[16] The primary implementation partner was once more Konrad Burri, though this project also marked the beginning of HKB's collaboration with the Egger company in Basel that continues to this day. This time, Markus Würsch, HKB's own trumpet lecturer, took on the research part of the project that was financed by the SNSF.

The results of these two DORE projects were presented at the first Romantic Brass Symposium in February 2009.[17] Music research at HKB continued to grow, and in late 2010 a further symposium day was held to offer a larger-scale presentation of research at HKB that collectively took a "look back at the nineteenth century".[18] After this, the discussion specifically on the topic of the keyed trumpet – a discussion that continues to this

15 The Research Area Interpretation was renamed the "Institute Interpretation" in 2019.

16 "Klappentrompeten – Rekonstruktion, Spielmethodik und Nachwirkungen der klassischen und frühromantischen Solotrompeten", SNSF DORE project 116291 (2007–2009), applicant: Roman Brotbeck, research staff: Markus Würsch, implementation partners: Instrumentenbau Konrad Burri, Egger Blasinstrumentenbau, Orchestergesellschaft Biel, https://data.snf.ch/grants/grant/116291.

17 "Romantic Brass Symposium [1]" (17–19 February 2009), www.hkb-interpretation.ch/rbs. See Fig. 1 for the flyer of the first Romantic Brass Symposium, and Fig. 2 for the programmes of the first four.

18 Symposium "Ein Blick zurück ins 19. Jahrhundert" (2–4 October 2010), section "Die Klappentrompete von Anton Weidinger: neue Quellen und Theorien", www.hkb-interpretation.ch/blick-zurueck.

Berner Fachhochschule
Haute école spécialisée bernoise
Hochschule der Künste Bern
Haute école des arts de Berne

Forschungsschwerpunkt Interpretation an der Hochschule der Künste Bern
http://www.hkb.bfh.ch/interpretation.html
Kontakt: claudio.bacciagaluppi@hkb.bfh.ch

Romantic Brass Symposium

Donnerstag, 12. bis Samstag, 14. Februar 2009
Bern, Papiermühlestrasse 13a/13d/13h

Instrumentenausstellung
12.-14.2.2009, Papiermühlestrasse 13h
Egger, Historischer Blasinstrumentenbau, Basel (Sandor Veress-Saal)
Konrad Burri, Zimmerwald (Raum 119)
Die Instrumentenausstellung bleibt während der ganzen Dauer der Tagung offen.
Die genauen Präsenzzeiten werden von den Ausstellern selbst organisiert.

Donnerstag, 12. Februar 2009

Papiermühlestrasse 13a, Kammermusiksaal 001
18.00 Uhr HKB-Forschungsapéro und Eröffnung der Instrumentenausstellung
Präsentation der DORE-Projekte zu Ophikleide und Klappentrompete
durch Daniel Schädeli, Roland Fröscher und Markus Würsch (HKB)

Grosser Konzertsaal, Papiermühlestrasse 13d
20.00 Uhr Edward H. Tarr (Hochschule für Musik Karlsruhe)
„Der göttliche Hugo, oder Hugo Türpe (1859-91), ein zu Unrecht
vergessener Kornettsolist des 19. Jahrhunderts"
(unter freundlicher Mitwirkung von Markus Würsch
und Anna De Capitani)

Oper / Opéra • Theater / Théâtre • Kunst / Arts visuels • Visuelle Kommunikation / Communication visuelle • Musik / Musique • Musik und Medienkunst / Musique et arts médiatiques • Jazz • Konservierung und Restaurierung / Conservation et restauration • Bildnerisches Gestalten / Enseignement des arts visuels • Y (Institut für Transdisziplinarität) / Y (Institut de transdisciplinarité) • Rhythmik / Rythmique

Berner Fachhochschule
Haute école spécialisée bernoise
Hochschule der Künste Bern
Haute école des arts de Berne

Romantic Brass Symposium
Aktuelle Forschungsprojekte des Forschungsschwerpunkts
Interpretation der Hochschule der Künste Bern
Mit einem Tagungsbeitrag des Schweizerischen Nationalfonds

7.–10. November 2012
Hochschule der Künste Bern, Papiermühlestrasse 13a

Programm

Cor omnitonique Henri Chaussier
Aus: Constant Pierre: *La facture instrumentale à l'Exposition de 1889. Notes d'un musicien sur les instruments à souffle humain nouveaux et perfectionnés*. Paris, 1890.

FNSNF
Schweizerischer Nationalfonds
zur Förderung der wissenschaftlichen Forschung

Gestaltung und Kunst | Arts visuels et design • Konservierung und Restaurierung | Conservation et restauration • Musik | Musique • Oper/Theater | Opéra/ Théâtre • Schweizerisches Literaturinstitut | Institut littéraire suisse • Y Institut | Institut Y • Forschung | Recherche • Weiterbildung | Formation continue

HKB HEAB BUA
Hochschule der Künste Bern
Haute école des arts de Berne
Bern University of the Arts

Third International Romantic Brass Symposium Bern

Adolphe Sax and his Saxhorns

Tuesday/Wednesday, February 4th and 5th, 2014
Bern University of the Arts, Kammermusiksaal
Papiermühlestrasse 13a

Programme

Concert given at Sax's own concert hall in presence of the Emir Abd-el-Kader (1865)

FNSNF
Schweizerischer Nationalfonds
zur Förderung der wissenschaftlichen Forschung

Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

HBS
HISTORIC BRASS SOCIETY

CIMCIM Annual Congress 2017 and
Fourth International Romantic Brass Symposium

Presentation, Preservation and Interpretation

The Challenges of Musical Instrument Collections in the 21st Century

Wednesday to Saturday, 22–25 February 2017
Basel/Bern

Programme

Organised by CIMCIM, the Bern University of the Arts and the Museum für Musik Basel in collaboration with Schola Cantorum Basiliensis and Klingende Sammlung, Bern, supported by the Swiss National Science Foundation

www.hkb-interpretation.ch/cimcim

FIGURE 2 The title pages of the programmes of the first four Romantic Brass Symposia, 2009–2017 day – had reached a point at which we felt able to embark on publishing the contributions to these symposia.[19]

The goals of the DORE projects These first two projects – on the ophicleide and the keyed trumpet – allow us to observe in exemplary form certain aspects that proved characteristic of both these projects and their successors.

Core repertoire Our starting point was always a work from music history that was as well-known as possible; the aim of each project was to place its interpretation on a new footing and to bring about a long-lasting shift in how it is performed. For the ophicleide, we chose several important works from the early Romantic orchestral repertoire: the *Symphonie fantastique* (1830) by Hector Berlioz, and the Overture and incidental music to Shakespeare's *A Midsummer Night's Dream* (1826–1843) and the oratorio *Elijah* (1846) by Felix Mendelssohn. For the keyed trumpet, we decided upon the two most important trumpet concertos of the Viennese Classical period: those by Joseph Haydn (1796) and Johann Nepomuk Hummel (1803). Later projects focused on the *Morceau de concert* op. 94 by Camille Saint-Saëns (1887), which is renowned among horn players, and Igor Stravinsky's ballet *Le Sacre du Printemps* (1913). Another project took a close look at the repertoire of the on-stage band at the Paris Opéra in circa 1860 – though in this case, the main attraction was the man who directed the ensemble in question: Adolphe Sax. He was responsible not just for developing today's ubiquitous saxophone, but also the family of saxhorns that were our prime focus of interest in this particular research project. In retrospect, this seemingly superficial feature of the HKB research projects – focusing on a concrete musical work – was in fact decisive in demonstrating their relevance and legitimacy: both to practical musicians who were hitherto unfamiliar with such research, to other researchers who were interested in collaborating with us, and – last but not least – to the peer-reviewers and decision-makers of the research funding institutions.

Original instruments Before we could replicate a historical instrument, we had to identify an appropriate model. What kind of instrument was actually used to play the work we had selected? Which original instrument was best suited in technical terms to being replicated, and which original was of the necessary quality and was sufficiently well preserved for our purposes? What new developments might open up a potential business field for our implementation partner, also after the end of the project? What instrument could also be used for a broader repertoire and be played by modern musicians as an

19 *Romantic Brass. Ein Blick zurück ins 19. Jahrhundert. Symposium 1*, ed. by Claudio Bacciagaluppi and Martin Skamletz, Schliengen 2015 (Musikforschung der Hochschule der Künste Bern, Vol. 4).

alternative instrument without any problems? Sometimes there were no open questions to discuss in this regard, and the instrument to be reconstructed had already been identified before the project began. As a rule, however, it was first necessary to engage in travel-intensive research to visit international instrument collections. In certain cases, our search for the one, right instrument remained unsuccessful, which meant that we had to make the best possible decisions based on various second-best options that were all equally valid. For example, we simply do not know on what kind of "organised trumpet" ("organisierte Trompete") Anton Weidinger played when he gave the first performances of the trumpet concertos by Haydn and Hummel, because his own instruments have not survived.[20]

This preparatory search process allowed us to put to an initial test the proposed collaboration between the instrument builder, the HKB's artistic expert and the historical researchers who were also working on the project. The respective interests of the individual participants were in some cases very far removed from each other, so a consensus had to be established among them.

Reconstruction The decisive reasons for situating such research projects at a university of the arts were provided by the actual process of developing the replica instrument, because this could never be reduced to a mere act of 'copying' the original. It was in fact a result of an intensive collaboration between the instrument builders and the practising musicians. New prototypes were made at regular intervals, tried out in practice, discussed, discarded or improved, and rebuilt again. The participants worked so intensively together and with such a high degree of intrinsic motivation that the funds originally earmarked in the project budget for items such as travel expenses proved quite inadequate. In retrospect, we are very grateful that it was thanks to a great deal of extra, private dedication and investment that these reconstruction projects were nevertheless always able to be completed by producing a finished instrument. Such replicas can be based on very different premises, for which the arguments in each case might be completely justifiable. In the initial projects, there was a kind of consensus among both the instrument builders and the practical musicians that their replicas should 'improve' on certain characteristics of the original, or 'optimise' them – such as in matters of intonation, volume and playability. In other words, they endeavoured to adapt the instrument to modern customs, since it was intended for use by today's musicians – both students and professionals. Discussions about how close a replica should remain to the original were later conducted

20 In this regard, see the various contributions to *Romantic Brass. Ein Blick zurück ins 19. Jahrhundert. Symposium 1.*

at a symposium[21] for a bassoon replica project[22] that had run in similar fashion to the brass projects, and whose papers were subsequently published.[23]

Expansion of the repertoire The search for instruments to replicate was accompanied by research into accompanying documents and a hunt for more works in the instrument's repertoire. Besides the standard works that served as the thematic anchor of the project, we also searched for other pieces and for tutors about how to play the instrument. In this field of activity, the collaboration between the musicians and the musicologists supporting them proved crucial. The most important result of this process probably lay in broadening the horizons of the musicians with regard to the musical demands that had once been made on the original instrument – demands that had to be met by the replica they were constructing together with the instrument builders.

Edition The initial plan was for the participating musicians to use historical textbooks to write a modern tutor for the replica of the historical instrument. This was never realised, though historical tutors and other such sources were published in modern editions. Particularly worthy of note are the facsimile edition of Hummel's Trumpet Concerto,[24] edited with a commentary by Edward H. Tarr, and the instructional works for the keyed trumpet that were collected and edited by Adrian von Steiger.[25] It is difficult to imagine today, but ten years ago, not all sources had been digitised and made available online, which is why such editions were commendable undertakings at the time. Above all, however, this scholarly collaboration on the keyed trumpet project marked Adrian von Steiger's introduction to the HKB's research into historical brass instruments. Over

21 See the symposium "Exakte Kopie oder 'im Sinne' historischer Vorbilder – Tendenzen des Nachbaus von Holzblasinstrumenten" (24–26 February 2012), www.hkb-interpretation.ch/exakte-kopie.

22 "Le Basson Savary. Studien an Originalinstrumenten, Nachbau für die historisch informierte Aufführungspraxis, Umsetzung im Konzert, Entwicklung eines Lehrwerks", SNSF DORE project 129909 (2010–2012), applicant: Martin Skamletz, research staff: Lyndon Watts, Sebastian Werr, Marc Kilchenmann, implementation partner: Walter Bassetto Blasinstrumentenbau, https://data.snf.ch/grants/grant/129909.

23 *Le Basson Savary. Bericht des Symposiums "Exakte Kopie" in Bern 2012*, ed. by Sebastian Werr and Lyndon Watts, Schliengen 2017 (Musikforschung der Hochschule der Künste Bern, Vol. 8).

24 Johann Nepomuk Hummel: *Concerto a tromba principale* (1803), *Faksimile in Farbe*, ed. by Adrian von Steiger; supplementary volume with an introduction by Edward H. Tarr, Vuarmarens 2012 (HKB Historic Brass Series, Vol. 4).

25 Eugène Roy: *Méthode de trompette sans clef et avec clefs. Faksimile* (1824) *mit historischer Einführung*, ed. by Adrian von Steiger, Vuarmarens 2009 (HKB Historic Brass Series, Vol. 1). For further editions, see www.hkb-interpretation.ch/publikationen.

the years that followed, he made a significant contribution to the further development of this field.

Integration in university operations One of the core aims of a university of music is to offer its students the necessary additional skills in historically informed performance practice to help them adapt to a music market that is undergoing fundamental changes. Right from the start, HKB endeavoured to realise this aim and to ensure that the results of its research were implemented in the teaching sphere. After the research projects were completed, HKB's Music Division purchased the replica instruments that had been constructed in order to place them at the disposal of its students. To this day, for example, a tuba or euphonium player at HKB can choose the ophicleide as an alternative instrument. And HKB's trumpet students regularly play individual pieces on the keyed trumpet in their final examinations.

Use in professional concerts Also right from the start, Roland Fröscher embarked on intensive concert activities on our replica ophicleide. Given its repertoire, he was more often engaged as an 'extra' for performances by historically informed orchestras than as a soloist. The primary goal of Markus Würsch, however, was always to be able to play the solo concertos by Haydn and Hummel on the new keyed trumpet, accompanied by an orchestra. To this end, a concert was planned with the Orchestergesellschaft Biel from the outset of the DORE project. This also marked the beginning of a collaboration that has continued to the present day (since 2013, the orchestra has been known as the Sinfonie Orchester Biel Solothurn). The performance of the Haydn Concerto with Markus Würsch as soloist, playing the keyed trumpet recreated by Konrad Burri, took place in June 2010 under the baton of Biel's then chief conductor Thomas Rösner. In the autumn of that same year, Würsch also performed the concerto in Austria and in Bern with the Baroque orchestra Concerto Stella Matutina, proving that the replica instrument functioned both with a modern orchestra and with an ensemble devoted to historical performance practice – in other words, when tuned to different pitches and with a different sound balance.

Recordings Rounding off such productions with a CD recording might seem an obvious route to take, but funding issues posed an initial problem. It was just about possible to fund rehearsals for individual performances, but additional recording sessions would have required substantial, extra third-party funding. We also had to realise that as a research institute at a university of the arts, we just did not have the necessary profile or connections that would have enabled us to fill concert halls with audiences. Meanwhile, it has become obligatory to publish all research results on Open Access, and the channels available for this have been professionalised to such an extent that commercial audio or video productions are simply no longer planned. Nevertheless, a somewhat belated CD production for the keyed trumpet project was released in 2018, though the personnel involved were different from those originally engaged in the research project.[26]

Symposia Above and beyond creating replicas of instruments and using them in concerts, a practice-oriented research project also has to deliver scholarly results. In order to create a forum to discuss those results, we continued the practice of inviting as many people as possible who were involved in the project to participate in a symposium of several days where they could present their research findings and discuss them with invited international experts. Such a practice was still unusual for a university of the arts at that time.

Publications In addition to scholarly papers, we were also keen to include as many other symposium contributions as possible in the resulting volumes of conference papers – thus also explicitly including the workshop reports of the instrument builders and the musicians' reflections on how they engaged with the original, historical instruments and on their collaborations with students and instrument builders. Numerous other publications in scholarly journals and other periodicals helped to disseminate the research results of each project.

It is thus clear that we had wide-ranging ambitions, even as early as our initial research projects on historical brass instruments. Most of the related activities presented completely new challenges for the staff of a university of the arts, which may excuse the fact that work did not immediately proceed with the same speed or sophistication in every one of the fields involved. In particular, the final step of publishing the research results often took us a disproportionately long time.

We should not forget, however, that our project acquisition and implementation activities as described above went hand in hand with the development and permanent expansion of the infrastructure for research administration at HKB – indeed, this was a prerequisite for being able to initiate and run the projects in the first place. When the present writer assumed the headship of the Research Area Interpretation in the summer of 2007 (because Roman Brotbeck was concentrating increasingly on his position as head of the Department of Music), HKB was still far from having a functioning administrative support system for its researchers. It was not until 2011 that a back office was properly established and adequately staffed with a stable team possessing the necessary expertise.

26 The Trumpet Concerto by J. N. Hummel can be found on the CD *Cherubini in Wien*, FraBernardo FB 1811678 (2018), https://frabernardo.com/portfolio-item/cherubini-in-wien-concerto-stella-matutina/.

It proceeded to support and manage the research projects and left sufficient resources to develop the project series on a consistent basis and to engage in long-term staff development for the projects, positioning the different projects within HKB and with external partners, and anticipating developments at the funding institutions that were in a constant state of flux at the time.

New partnerships The next DORE project was on the Cor Chaussier,[27] and at first glance it looks similar to the first two. In fact, however, it was based on completely different premises. Only one specific instrument existed that we might replicate, namely the sole specimen of the omnitonic horn developed by Henri Chaussier (1854–1914) and built by the Millereau company in the 1880s that is held today by the Brussels Musical Instruments Museum MIM. The Egger workshop in Basel was obliged to produce "a perfect copy" of the original – far more 'perfect' than had been the case in the previous projects. This was also in the interest of the holding museum.[28] For once, the impetus for this project did not come from lecturers at HKB, but from the horn player Martin Mürner, who lived in Bern but was not attached to HKB, and in fact worked in the period instrument orchestra Anima Eterna in Belgium. For this, he joined forces with Daniel Allenbach, a musicology graduate who had begun horn studies at HKB back in 2007. Daniel Allenbach accordingly worked in this DORE project in parallel with his studies at HKB. When both his degree course and the project were completed in 2012, he was given a permanent position at HKB. Since then, he has become an indispensable pillar of the Institute's work, especially with regard to publishing the volumes of papers resulting from the research projects.

In this case, the collaboration with the HKB Music Department involved one of its students, not its lecturers. Martin Mürner's orchestral colleague Ulrich Hübner was then engaged for the final concerts on the reconstructed instrument. A performance at the Kultur-Casino in Bern in November 2012 with the HKB Symphony Orchestra under guest conductor Jos van Immerseel was followed by a concert with the Sinfonie Orchester Biel Solothurn in April 2013 under the baton of Julien Masmondet. Each concert featured Saint-Saëns's *Morceau de concert* op. 94, which was written in 1887 for Henri Chaussier and

27 "Le Cor Chaussier. Dokumentation, Nachbau und Aspekte der solistischen und orchestralen Aufführungspraxis auf französischen Hörnern zwischen Natur- und Ventilinstrument in der 2. Hälfte des 19. Jahrhunderts", SNSF DORE project 124640 (2009–2012), applicant: Martin Skamletz, project management: Daniel Allenbach, Martin Mürner, further researchers: Cyrille Grenot, Claude Maury, implementation partner: Blechblas-Instrumentenbau Egger, https://data.snf.ch/grants/grant/124640.

28 "The objective of the research […] was to make a perfect copy of the original and then to perform the repertoire on the new instrument". Communication of MIM Brussels, no longer available online.

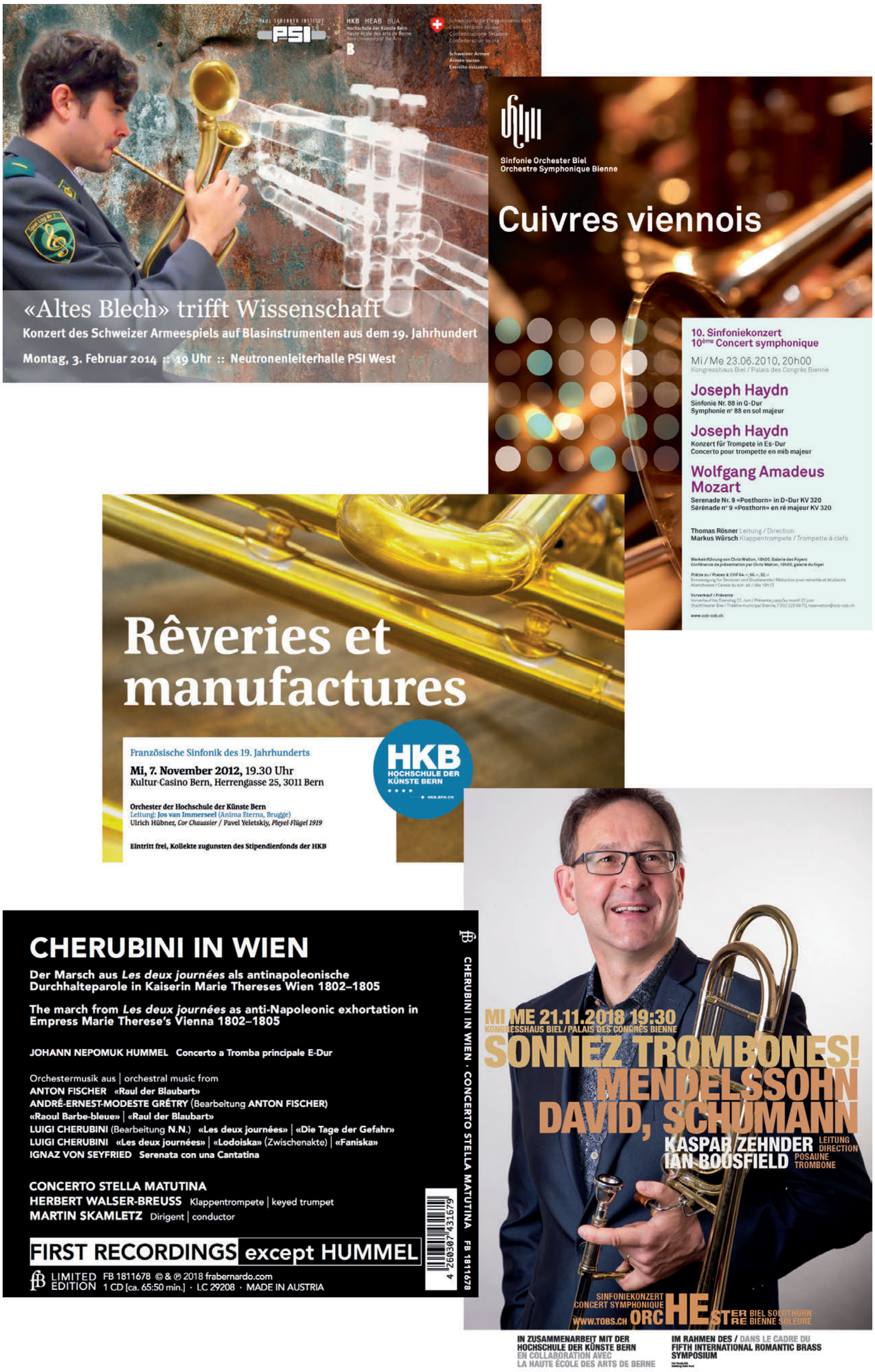


Figure 3 Selected flyers and a CD inlay, 2010–2018

his horn. Ulrich Hübner had already given a recital with piano accompaniment on our replica Cor Chaussier at the MIM in Brussels in October 2012.[29]

New funding formats The 2013 concert in Biel both presented the Cor Chaussier as a solo instrument and equipped the entire brass section of the Sinfonie Orchester Biel Solothurn with either original French instruments of the nineteenth-century or instrument copies by Egger. This concert signified the conclusion of the DORE project and of our first CTI project that had run in parallel, and whose goal was to replicate historical instruments using historical materials and historical working techniques. This had been a core desideratum on the part of Egger, our implementation partner.[30] This new requirement meant that we had to expand our research partnerships to include scientists from the Swiss Federal Laboratories for Materials Science and Technology Empa and the Paul Scherrer Institute. We selected them entirely according to Egger's requirements. This was because the difference between CTI and DORE projects lay in the fact that our implementation partner now had to provide concrete proof of his own funding for the project, with research funds for the participating research institutions being allocated on a matching basis.

The researchers investigated a predefined group of fifty predominantly French brass instruments of the nineteenth century to determine the nature of their brass alloy and to measure their wall thickness. They also hunted for sources on historical manufacturing techniques. They identified a typical brass alloy that differed considerably from those used today, and subsequently manufactured it exclusively for use by Egger. This was a demanding process, not least because the mechanical properties of the alloy made completely different demands during processing.[31] However, the process was overall successful, and to this day Egger is still building historical instruments on request using "MCM

29 www.hkb-interpretation.ch/cor-chaussier-bruessel. See Figure 3 for selected publicity material related to the projects, symposia, concerts and publications.

30 "Research on the Brass-Instruments of the 19th Century: Historic Alloys and Working Techniques in the Historically Informed Production of Musical Instruments", CTI project 10903.1 PFES-ES (2010–2012), applicant: Martin Skamletz, research partners: Swiss Federal Laboratories for Materials Science and Technology (Empa), Paul Scherrer Institute (PSI), project management: Adrian von Steiger, research staff: Hans J. Leber (PSI), Eberhard Lehmann and David Mannes (PSI), Marianne Senn and Martin Tuchschmid (Empa), implementation partners: Blechblas-Instrumentenbau Egger, Sinfonie Orchester Biel Solothurn, www.aramis.admin.ch/Grunddaten/?ProjectID=27505.

31 See Adrian von Steiger/Marianne Senn/Martin Tuchschmid/Hans J. Leber/Eberhard Lehmann/David Mannes: Can We Look over the Shoulders of Historical Brasswind Instrument Makers? – Aspects of the Materiality of Nineteenth-century Brass Instruments in France, in: *Historic Brass Society Journal* 25 (2013), pp. 21–38.

– French sheet metal of the 19th century".[32] The results of the DORE project on the Cor Chaussier and of the CTI project on historical manufacturing technologies were both presented in late 2012 at the second Romantic Brass Symposium[33] and were published together afterwards.[34]

This search for new funding opportunities for our research into brass instruments was also necessary because the SNSF had already gained the impression in 2011 that there was no longer any need for special "start-up funding for […] artistic research at universities of arts and applied sciences". This is why it "integrated the funding for practice-oriented research at universities of arts, applied sciences and pedagogy in its general project funding, and phased out DORE".[35] Projects to be organised with implementation partners would thus have to be financed in future via the CTI. When the universities of the arts wanted to apply for SNSF funding for basic research, they would now be required to compete with the traditional universities in the normal funding process, and would have to label their funding applications "practice-oriented".

The next DORE project on brass instruments was thus also the last. When it began in 2011, it was HKB's first research project that did not focus on a single historical instrument, but on an entire family of instruments, namely the saxhorns. Their inventor, Adolphe Sax (1814–1894), was the director of the stage band at the Paris Opera, and his activities there meant that his saxhorns played a role in a truly core repertoire in the second half of the nineteenth century.[36] Another aspect of this project that was new was that it no longer focused on replicating historical instruments, but rather on playing the

32 "On request, we manufacture the instrument from MCM material, a special alloy similar to that found in French romantic brass instruments." https://eggerinstruments.ch/en/historic/trumpets/trumpets-for-classical-romantic/.

33 "Romantic Brass Symposium [2]" (7–10 November 2012), www.hkb-interpretation.ch/rb2.

34 *Romantic Brass. Französische Hornpraxis und historisch informierter Blechblasinstrumentenbau. Symposium 2*, ed. by Daniel Allenbach, Adrian von Steiger and Martin Skamletz, Schliengen 2016 (Musikforschung der Hochschule der Künste Bern, Vol. 6).

35 "Als Starthilfe für die sozialwissenschaftliche und künstlerische Forschung an Fachhochschulen (FH) und Pädagogischen Hochschulen (PH) hat der SNF gemeinsam mit der KTI im Jahr 2000 das Programm DORE (DO-REsearch) lanciert. […] Der SNF sieht für die kommenden Jahre eine breitere Förderung der anwendungsorientierten Grundlagenforschung vor, die auch die Förderungsbereiche von DORE betrifft. Daher hat er 2011 die Förderung der praxisorientierten Forschung an FH und PH in die allgemeine Projektförderung integriert und DORE auslaufen lassen". [Anon.]: DORE – ein erfolgreiches Förderungsprogramm geht zu Ende, in: SNF *Jahresbericht* 2011, Bern 2012, www.snf.ch/SiteCollectionDocuments/inb_jb_11_d.pdf, p. 18.

36 "'Agilité, homogénéité et beauté' – Das Saxhorn in Oper und Militärmusik", SNSF DORE project 136957 (2011–2014), applicant: Martin Skamletz, project management: Adrian von Steiger, research staff: Martin Mürner, Krisztián Kováts, Reimar Walthert; implementation partner: Swiss Army Band, https://data.snf.ch/grants/grant/136957.

original saxhorns themselves. The many different sizes of saxhorn that were needed – from contrabass to soprano – meant that the energy and expense could not be justified that replicating them would have entailed. Moreover, sufficient original instruments existed in the necessary quality for our purposes, and there is even still a market for them. We were able to draw on the Burri Collection in Bern and on other private collections, especially in France, to assemble the required number of instruments. We also made several individual purchases. Our choice of ensemble to play in the final concerts fell on the Swiss Army Band under the direction of Colonel Philipp Wagner. Its musicians were coached by experts in playing historical instruments, namely Martin Mürner, Krisztián Kováts, Reimar Walthert and Koen Plaetinck. The results of the project were presented at the third Romantic Brass Symposium, which was organised in collaboration with the Historic Brass Society,[37] and published in the associated book series.[38] The Swiss Army Band was also invited to play at the opening of the exhibition celebrating Adolphe Sax's 200th birthday at the Musical Instruments Museum MIM in Brussels.[39]

New subject areas The decisive insight provided by this saxhorn project was the need to apply aspects of conservation and restoration to those historical instruments that are in practical use today. To this end, the first SNSF project outside DORE was carried out, using an interdisciplinary funding format that no longer exists in that form[40] (it also overlapped chronologically with the saxhorn project). We were able to win the Collection Centre of the Swiss National Museum as our partner for the conservation aspects of the project. After long-term trials on the process of corrosion in instruments that are played, the Centre developed a procedure for drying them after use.[41] The original aim of the

37 "Third International Romantic Brass Symposium: Adolphe Sax and his Saxhorns" (4–5 February 2014), www.hkb-interpretation.ch/rb3.

38 *Das Saxhorn. Adolphe Sax' Blechblasinstrumente im Kontext seiner Zeit. Romantic Brass Symposium 3*, ed. by Adrian von Steiger, Daniel Allenbach and Martin Skamletz, Schliengen 2020 (Musikforschung der Hochschule der Künste Bern, Vol. 13).

39 There were further Saxhorn Concerts in Switzerland and Brussels in February 2014, www.hkb-interpretation.ch/saxhorn-konzert.

40 "Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice", SNF CORE project 146330 (2013–2017), applicant: Martin Skamletz, research partners: Marie Wörle (Collection Centre, Swiss National Museum), Eberhard Lehmann (Paul Scherrer Institut), Bernhard Elsener (ETH Zurich), project management: Adrian von Steiger, research staff: Daniel Allenbach, Marion Alter, Emilie Cornet, Florian Kergourlay, Martin Ledergerber, Tiziana Lombardo, David Mannes, Martin Mürner, https://data.snf.ch/grants/grant/146330.

41 See Adrian von Steiger/Daniel Allenbach/Martin Ledergerber/Bernhard Elsener/David Mannes/Federica Cocco/Marzia Fantauzzi/Antonella Rossi/Martin Skamletz/Martin Mürner/Marie Wörle/Emilie Cornet/Eberhard Lehmann: New Insights into the Conservation of Brass Instruments. Brass

project was to reconstruct the brass section of the orchestra that had played in the Théâtre des Champs-Élysées in Paris in 1913, in order to use those instruments in a concert to commemorate the 100th anniversary of the world premiere of Stravinsky's *Le Sacre du Printemps*. While we were able to commemorate the 200th birthday of Adolphe Sax in 2014 as described above, our plans to commemorate Stravinsky in 2013 did not come to fruition. We made several unsuccessful attempts to enter into a cooperation with an orchestra. It was not until 2017 that an ensemble of HKB students was able to give a concert with the instruments, though it constituted only excerpts from *Le Sacre* for brass alone. This concert took place at the fourth Romantic Brass Symposium, which was organised jointly with the Museum für Musik Basel and the Schola Cantorum Basiliensis, and also featured the 2017 Annual Congress of the International Committee of Museums and Collections of Instruments and Music CIMCIM.[42]

A new generation of lecturers While our funding formats have been in a constant state of flux, requiring us to develop new strategies for the acquisition of third-party funding on a constant basis, an almost complete generational change has also taken place within the teaching body of the HKB's Music Division since the beginning of our research activities fifteen years ago. New lecturers have brought new ideas and new needs – and in some cases, they play instruments that have not previously been represented in our research projects.

The trombonist Ian Bousfield acted as an expert in the context of a further CTI project. Egger wanted to develop a trombone that would be suitable for the symphonic repertoire of the second half of the nineteenth century, and to this end we initiated a project that covered the whole spectrum of research activities as described above. We had to find suitable models in museums and private collections, try them out, measure them (both their external dimensions and the composition of their alloy and other aspects), and then replicate them with repeated feedback from Ian Bousfield.[43] The replica instru-

Instruments Between Preventive Conservation and Use in Historically Informed Performance, in: *Historic Brass Society Journal* 30 (2018), pp. 85–101.

42 "CIMCIM Annual Congress 2017 and Fourth International Romantic Brass Symposium: Presentation, Preservation and Interpretation. The Challenges of Musical Instrument Collections in the 21st Century" (22–25 February 2017), www.hkb-interpretation.ch/cimcim. The present volume is based on papers held at that symposium.

43 "The Sound of Brass. The materiality, acoustics and history of brass instruments as exemplified by the trombone", CTI project 17974.1 PFES-ES (2015–2018), applicant: Martin Skamletz, project management: Adrian von Steiger, research partner: Armin Zemp (Empa Materials Science and Technology), research staff: Ian Bousfield, Martin Tuchschmid, implementation partner: Blechblas-Instrumentenbau Egger, Sinfonie Orchester Biel Solothurn, www.aramis.admin.ch/Grunddaten/?ProjectID=37465.

ment was subjected to public appraisal in November 2018 – in line with the practice established since the beginning of our series of projects – in a concert[44] at the fifth Romantic Brass Symposium.[45] Ian Bousfield played the *Concertino* by Ferdinand David, accompanied by the Sinfonie Orchester Biel Solothurn conducted by Kaspar Zehnder. Since the beginning of the project series, HKB students had also steadily become more involved. The HKB trombone class attended a full, intensive week on research into brass instruments at the time of the symposium, and they joined their professor in the final orchestral chorale of the David *Concertino* (see the music example below).

Music example **Ferdinand David: *Concertino for trombone and orchestra* Op. 4, bars 340–343: solo part with the first entrance of the trombone chorale towards the end of the work (reduced scoring, extracted here from the printed parts, Leipzig: Kistner, circa 1838)**

What was new about this project was how it investigated aspects of instrumental sound using empirical methods, in collaboration with a research unit of the Swiss Federal Laboratories for Materials Science and Technology Empa under the direction of Armin Zemp (this was also what prompted the name of the project, namely "The Sound of Brass", which otherwise might seem at first somewhat unprepossessing). This meant that even hitherto sacred cows were subjected to analysis, such as the shibboleth that the material of a brass instrument allegedly has a negligeable influence on its acoustic properties.[46]

There is another new thematic area in our research on brass instruments that has thus far been explored in a preparatory project funded by BFH itself, but which has not

44 www.hkb-interpretation.ch/tromboniade.

45 "The Sound of Brass. Fifth International Romantic Brass Symposium" (20–22 November 2018), www.hkb-interpretation.ch/romanticbrass5. Proceedings in preparation.

46 Armin Zemp/Gwenael Hannema/Bart Van Damme/Adrian von Steiger/Martin Skamletz/Rainer Egger: Determination of Vibro-Acoustic Properties of Brass Instruments, in: *Historic Brass Society Journal* 31 (2019), pp. 77–91.

yet resulted in any large research project funded by an outside body, namely the relationship between the human body and the instrument, player ergonomics and – ultimately – human health. This field was the subject of a study by HKB in collaboration with the BFH School of Health Professions.[47]

This ergonomics project extended our research activities to encompass an instrument that we had not previously studied. A new tuba lecturer at HKB, Rex Martin, brought to bear his decades of experience as a player and made himself available as a test subject for the development of posture exercises.

A dialogue with a broader public In the years 2018–2020, we took the opportunity to present a general audience with the results of the whole project series as described above, using an SNSF AGORA grant (see Table).[48]

2006–2008 DORE Ophicleide
2007–2009 DORE Keyed trumpet
2009–2012 DORE Cor Chaussier
2010–2012 CTI Historically Informed Instrument Production
2010–2012 OPET Burri Instrument Collection
2011–2014 DORE Saxhorn
2013–2017 CORE Corrosion
2015–2018 CTI Trombone
2018–2020 AGORA Fresh Wind
2019 BFH Tuba Ergonomics

TABLE Synopsis of the HKB series of research projects on brass instruments

To this end, we developed a website and an interactive touring exhibition that has already been shown in Bern in the "Klingendes Museum", on the premises of HKB, in the Music Instrument Museum in Willisau and in the Trumpet Museum Bad Säckingen.[49] This presentation of the entire development of our research thus far into wind instruments, including the wind dynamic organ, the Savary bassoon and the CLEX double bass clarinet, is closely connected to a project that has been running in parallel for many years: the

47 "Tuba Ergonomie", BFH project 1964PT_HKB (2019), applicant: Adrian von Steiger, research staff: Rex Martin, Lorenz Radlinger and team BFH School of Health Professions, www.hkb-interpretation.ch/projekte/tuba-ergonomie.

48 "Fresh Wind – Communicating research on musical instruments", SNF AGORA grant 178522 (2018–2020), applicant: Martin Skamletz, project management: Adrian von Steiger, staff: Daniel Allenbach, Jimmy Schmid, https://data.snf.ch/grants/grant/178522.

49 See www.fresh-wind.ch/en/, www.hkb-interpretation.ch/projekte/fresh-wind.

acquisition of the instrument collection of the Bernese instrument maker and dealer Karl Burri (1921–2003) and its preservation as a whole by setting up a foundation with the participation of HKB.

From the very beginning of our research, instruments from the Burri Collection had been a starting point for individual projects. We also worked together with Karl Burri's son Konrad, an instrument builder, as an implementation partner in DORE projects. We began the systematic cataloguing of the Burri Collection in 2010, financed initially by funds from the then Federal Office for Professional Education and Technology OPET that were intended to foster the development of research at arts departments of the universities of the applied sciences (OPET is today part of the State Secretariat for Education, Research and Innovation SERI). When Burri's heirs decided to part with his Collection, we helped to create the legal and financial structure necessary to set up the aforementioned foundation in 2014. This culminated in 2017 in the opening of the "Klingende Sammlung" (literally the "Sounding Collection") in the heart of the city of Bern. The "Collection" was renamed the "Klingendes Museum" ("Sounding Museum") in 2019. In 2021, the Basel collector Ulrich Halder died unexpectedly; his flute collection was subsequently also deposited in the Klingendes Museum that same year.

The central figure in setting this up successfully was Adrian von Steiger. He was in fact responsible for the conception of all the above-mentioned projects and was the project manager in charge of their implementation. It was largely thanks to him that the Klingendes Museum was created, and he was also appointed its first director. From the scholarly appraisal and cataloguing of the collection in his doctoral thesis[50] to the smallest practical questions, he gave complete commitment to his appointed task. Expanding our research interests to encompass the conservation of historical instruments in use today, linking up with the International Committee for Museums and Collections of Instruments and Music (CIMCIM), and hosting the CIMCIM congress in 2017 – all this was relevant and topical precisely because a museum was being set up in Bern at that same time, one whose prime concern was to make its holdings accessible for practical use by musicians as far as would be possible and justifiable. These issues have since become a topic of everyday concern and discussion in the Music Division of HKB. The number of interested students and lecturers has been increasing steadily, along with the number of teaching and performance projects using historical instruments.

To close, we shall turn away from these concrete issues of implementing our research results and consider once again the general framework of our research, which remains in a constant state of evolution, as we have elucidated above. For example, it is clear that CTI projects of the kind described here are moving increasingly out of our reach. This is

50 Adrian von Steiger: *Die Instrumentensammlung Burri. Hintergründe und Herausforderungen*, Bern 2013.

because the transition of the erstwhile Commission for Technology and Innovation into the Swiss Innovation Agency Innosuisse has meant it is giving more emphasis to the economic impact of projects than to their artistic or scholarly relevance.

Cultural production has always been subject to a dynamic, unstable environment. By contrast, the world of research and research funding has traditionally appeared to be very stable, as it essentially used to be limited to the traditional universities, excluding the pedagogical universities, conservatories, academies and engineering colleges.

The Swiss Higher Education Act, which was drafted in the 1990s, initiated a fundamental shift. Not only did the newly established tertiary institutions have to embark on structural and staff development and open up entirely new fields of research – one only has to think of 'artistic research', which has since become a broad topic of international discussion – but the funding agencies also had to react to the new requirements and have in turn been subject to a constant process of internal change. This has obliged them, for example, to follow international criteria – such as the paradigm shift towards open-access publication, which has now largely been implemented.

This long-term process of negotiation within a complex network of stakeholders is probably a specifically Swiss feature of the research scene – and one to which we hope to continue making a contribution with our own research projects.

Adrian von Steiger

The Preservation of Historical Brass Instruments. Developing Guidelines for Their Preventive Conservation

> *"[W]hen one looks beyond the simplistic 'us and them' of museum conservation versus practically the rest of the world, a whole new picture emerges. Dissecting the rationales that underlie and drive the actions results in conclusions of a very different complexion."*[1]

Brass instruments have a relatively short lifespan, mainly due to corrosion, and so wear out and have to be replaced after several decades (or even after several years). In consequence, it is mostly impermissible to play historical brass instruments belonging to collections or museums. As part of our cultural heritage, these instruments have to be preserved in the best possible way. But by playing them, we can gain more information on the instruments and on their historical and musical background. This information itself enriches our cultural heritage, it can help us to understand other aspects of historically informed performance practice, and might also help us to produce replicas. Thus, the fundamental dilemma 'to play versus to display' of historical instruments emerges (see below).

So, if we nevertheless decide to play historical brass instruments – for whatever reason – then we should do our best to protect them. Wearing gloves is a well-established means of protecting the outer surface, but there have been only rare discussions about how to protect the interior of the instrument. This system of tunnels, that can be up to over ten metres in length (tuba), with a number of crossings and sections that are normally closed (the valve tubes), is sort of a black box to conservators. This situation is unique, as research has been conducted on all the other musical instruments, some of which are much more challenging than brass instruments (for example keyboard and woodwind instruments).[2]

We evidently need to conduct research in order to acquire greater knowledge of the interior surface of brass instruments, and so that we might better protect our cultural heritage. Before a museum or collection decides whether to allow someone to play a historical brass instrument, we simply ought to know the impact that playing it can have.

1 Robert Barclay: *The Preservation and Use of Historic Musical Instruments*, London 2004, p. XI.

2 e.g. Ilona Stein: Blasfeuchte in Holzblasinstrumenten, in: *Studien zur Erhaltung von Musikinstrumenten. 1: Holzblasinstrumente, Firnisse*, ed. by Friedemann Hellwig, Munich 2004 (Kölner Beiträge zur Restaurierung und Konservierung von Kunst- und Kulturgut, Vol. 16), pp. 9–121).

DOI: 10.26045/kp64-6179-003

– How do brass instruments corrode on the inside?
– What are the phenomena of interior corrosion? And how do they affect the instrument?
– Can we protect the inside of brass instruments?
– Are there concepts for preventive conservation of the inside of brass instruments, and if so, can they be optimised?

These questions were among those that provided the motivation for our research project. It was conducted by four leading Swiss research institutions, and its full name is "Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice".[3] Our aim was to better understand corrosion phenomena on brass and its application to musical instruments in general, and to develop concepts for preventive conservation when playing historical brass instruments in particular. Our work and our results are presented in detail in this book as well as in specialised journals.[4]

To play versus to display This short formula refers to the basic dilemma of all historical instruments (and in fact, of all functional historical objects). If we play them continuously, or if we take them out of museums and play them again after a non-playing period, then there will be wear and tear, their movable parts will wear out and have to be replaced, and they risk being damaged or lost. Wind instruments suffer the most, as the moisture in the breath blown through them affects the wood and corrodes the brass. This is the reason for the relatively short lifetime of wind instruments. So it is understandable that museums and collections either do not allow anyone to play their wind instruments, or at least minimise their playing time (though in fact minimal playing results in questionable insights due to the short experience time, while the risk due to humidity is almost the same as if one were to play the instrument for a longer period).

3 See www.hkb-interpretation.ch/projekte/korrosion (all links in this article last consulted 28 July 2022). This project was funded by the Swiss National Science Foundation, interdisciplinary department CoRe.

4 Articles giving an overview of the project and its results have been published in the HBS *Journal* and in *Glareana*: Adrian von Steiger/Daniel Allenbach/Martin Ledergerber/Bernhard Elsener/David Mannes/Tiziana Lombardo/Federica Cocco/Marzia Fantauzzi/Antonella Rossi/Martin Skamletz/Martin Mürner/Marie Wörle/Emilie Cornet/Eberhard Lehmann: New Insights into the Conservation of Brass Instruments: Brass Instruments Between Preventive Conservation and Use in Historically Informed Performance, in: *Historic Brass Society Journal* 30 (2018), pp. 85–101, https://doi.org/10.2153/0120180077005; Adrian von Steiger/Daniel Allenbach/Bernhard Elsener/Martin Ledergerber/Tiziana Lombardi/David Mannes/Martin Mürner/Martin Skamletz/Marie Wörle: *To play versus to display*. Historische Blasinstrumente aus Messing im Spannungsfeld zwischen Konservierung und Nutzung, in: *Glareana* 64/2 (2015), pp. 4–18 (in German).

If we do not play historical instruments, however, they are reduced to just one facet of their identity: they are mere objects, a testimony of craftsmanship. We could investigate them by conducting metrical measurements, tomography and material analyses, and we could determine their manufacturing techniques. But they would lose another aspect of their identity, namely their purpose as a tool for sounds, for music. If we play them on a regular basis, however, sooner or later we will lose their material identity.

Concerts on period instruments have been successful for many years, and the early music scene is growing (regardless of whether one considers this movement to be innovative and modern, or authentic and historical[5]). In consequence, there has been a growing demand over recent decades to be allowed to play historical instruments, and the conservational aspect has become more acute than is the case for other object types in collections and museums. Furthermore, historically informed performance practice is today focussing more and more on the music of the nineteenth and twentieth centuries, so specialised musicians are demanding to be able to play period instruments from that time too. Their aim may be research, to gain experience, or to acquire the knowledge necessary to be able to build replicas. But often, these instruments are also hunted out so that they may be played 'normally' in projects or orchestras for the music of certain periods and/or regions. And as wind instruments of that time vary greatly according to their period and region of construction, it is neither worthwhile to instrument builders to produce replicas of all of them, nor would these be affordable to musicians or orchestras. So, many musicians prefer to play on originals. This situation today has only further intensified the dilemma of how to conserve our cultural heritage.

These facts should be well known to all those involved – to museums, conservators, researchers, musicians and conductors. But still we note the antagonism "'us and them' of museum conservation versus practically the rest of the world" (see the initial quote). This dilemma is by its nature impossible to solve for a single instrument, though solutions have been proposed for the entirety of our musical heritage.[6] Aspects such as rarity,

5 These contradictions were discussed in the so-called 'authenticity debate' during the pioneering phase of the early music movement. See e.g. Richard Taruskin: "The Authenticity Movement Can Become a Positivistic Purgatory, Literalistic and Dehumanizing", in: *Early Music* 12/1 (1984), pp. 3–12; id.: *Text and Act. Essays on Music and Performance*, New York 1995; Daniel Leech-Wilkinson: "What We Are Doing with Early Music Is Genuinely Authentic to Such a Small Degree That the Word Loses Most of Its Intended Meaning", in: *Early Music* 12/1 (1984), pp. 13–16; and *Authenticity and Early Music*, ed. by Nicholas Kenyon, Oxford 1988.

6 See Robert Barclay: *The Preservation and Use of Historic Musical Instruments*, London 2004; Jeremy Montagu: Should Museum Instruments be Used?, in: *FoMRHI Quarterly* 26/1 (1982), pp. 11–12; id.: The Availability of Instruments in Museums, in: *Per una carta europea del restauro. Conservazione, restauro e riuso degli strumenti musicali antichi. Atti del convegno internazionale (Venezia, 16–19 ottobre 1985)*, ed. by Elena Ferrari Barassi and Marinella Laini, Florence 1987, pp. 369–380; and Arnold Myers: The Con-

fragility and the original state of an instrument can lead to a ban on playing, or at least to restricted use by a more or less restricted group of musicians. The goal remains the conservation of a representative selection of objects of our cultural heritage in museums. But by having these instruments played by a specialist, inherent information might be gained. Thus, we come to the issue of the scientific value of the object.

To have a selection of instruments, preserved to the best of our ability in public institutions and supplemented by the greatest possible amount of information on them (including their playing characteristics), would be an exciting goal to achieve in preserving our cultural heritage. By gaining information from playing instruments in good condition, and with the help of specialists in period instruments, documented by means of video and written reports, we can enhance and preserve our knowledge of both identities of a historical instrument – the object and the tool for music. It is important in this process to carry out research to find information on appropriate interfaces (i.e. mouthpieces). This is a key issue to which up to now insufficient attention is paid. With the help of databases such as MIMO,[7] this information might also be disseminated throughout the wider community. Thus, it seems it might be possible to overcome the dilemma of 'to play versus to display', and instead end up in a situation of 'to play and to display'.

The research project The present research project was thus engaging with a new field (the interior of brass instruments) within a known landscape (the fundamental dilemma of whether or not to play historical musical instruments). I shall here name just a few of the major challenges we faced:

– How can we apply conservation measures before and after playing, so as to ensure a long life for the object?
– How can we produce replicas appropriate to today's musical and technical demands?
– What are we to do with all the special, rare models of brass instruments from the nineteenth and twentieth centuries from different cultural traditions in Germany, Austria, France, Britain, the USA, Russia and elsewhere – those models that are not considered economically interesting of being reproduced today?
– What is the best practice for recording and conserving the inherent information of the instruments?

servation of Wind Instruments, in: ibid., pp. 221–233; id.: Cataloguing Standards for Instrument Collections, in: CIMCIM *Newsletter* 14 (1989), pp. 14–28, see www.euchmi.ed.ac.uk/itnXIVc.html. See also the articles of Arnold Myers and Robert Barclay in the present volume.

7 Musical Instrument Museums Online, the searchable platform of many museums and collections and many thousands of instruments, www.mimo-international.com.

- How can we conserve and communicate the playing characteristics of an instrument, such as mouthpieces, its variety, timbre and dynamic potential, its playing pitch and the possible range of pitch variations? (Players on one and the same instrument can differ substantially in their playing pitch on account of differences in individual embouchure and technique.)
- How can we achieve a respectful, reversible restoration to 'soundability' or even to playability?
- Interfaces such as mouthpieces, reeds, sticks, strings, hammers or bows are essential parts of an instrument. We must focus on these, both from a research and a performance approach.
- We need research on musical contexts: Were the instruments played in a teaching, orchestral or military context?

Such questions have often arisen among musicians in historical performance practice and also in the course of earlier HKB research projects that have involved playing and copying historical brass instruments. We set up our research team with all these questions in mind. The variety of aspects involved meant the team had to be multidisciplinary, bringing together historians, practical musicians, conservators and natural scientists specialised in surface analysis and corrosion as well as in imaging technologies. The contributions of all the team members are presented in the present volume. Our goal was to look beyond the "'us and them' of museum conservation versus practically the rest of the world" and to leave 'to play versus to display' behind us in a search for a third way to deal with historical brass instruments.

Preliminary research on humidity inside brass instruments led us to the fundamental insight that corrosion is the main reason for their relatively short lifetime. This then led to the basic hypothesis of our research: Drying the inside of the instruments after every playing session can contribute to significantly reducing the corrosion processes in the interior of historical instruments (this also applies to modern brass instruments). Taking this hypothesis as our starting point, the project searched for solutions to drying the instrument, for means of doing this that would be practicable for musicians, and for ways of measuring its impact.

For this field test, we were on the lookout for a score that demands interesting brass instruments from a historical point of view – one that would entail playing historical instruments that are still available on the instrument market. We chose Stravinsky's *Le Sacre du Printemps*, for which our brass section would play on period instruments.

Sacre was composed in 1913 for a Parisian orchestra, so twenty-one French instruments of that period in playable condition were required. These instruments formed the main focus of our research, under the auspices of Martin Mürner. The musicological research on the first performance of *Sacre* and its instruments was carried out by Daniel Allenbach. Our partners in the department of conservation and research at the Swiss National Museum were Marie Wörle and Tiziana Lombardo, both of whom are chemists, and Martin Ledergerber, who is a specialist in preventive conservation. They proposed electrochemistry as the most promising analytical method for monitoring the progress of corrosion. At that point, the corrosion specialist Bernhard Elsener from ETH Zurich and his colleagues Antonella Rossi and Federica Cocco of the University of Cagliari (Italy), both experts in surface analysis, joined the team. Neutron tomography is the speciality of Eberhard Lehmann and David Mannes at the Paul Scherrer Institute, and this was chosen as our second monitoring method. It was hoped that a cross-comparison of the results of electrochemistry and tomography could offer new insights into the development of corrosion in brass instruments over time. During the project, a third monitoring method was added: visual examination by endoscopy, performed by Martin Ledergerber.

Some remarks about the project's general design For the research on corrosion phenomena, we chose sixteen of the twenty-one brass instruments needed for the *Sacre* (see Figure 1). All were taken from playing collections, not from museums. The conservator of the National Museum thus had a role in the project to which he was unaccustomed. From a museum's perspective, this project would have been impossible in many ways, not only on account of lending out and playing the instruments.

The instruments used in the project are made of slightly different brass alloys. The chemical composition we measured was brass with a zinc content ranging from 25 to 35 per cent. Most of the alloys include up to one per cent of lead (the turned parts are made of other alloys, but they are not relevant for the interior corrosion). As was known from previous research, this was the normal brass used by French instrument-makers at that time.[8] Preliminary research at ETH showed that this range of difference in the chemical composition of the tubes does not affect the results of the electrochemical analysis of corrosion states and corrosion rates, and can therefore be ignored.

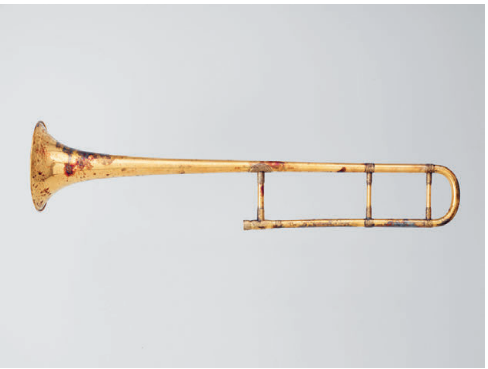
8 See Adrian von Steiger/Marianne Senn/Martin Tuchschmid/Hans J. Leber/Eberhard Lehmann/David Mannes: Can We Look over the Shoulders of Historical Brasswind Instrument Makers? Aspects of the Materiality of Nineteenth-Century Brass Instruments in France, in: *Historic Brass Society Journal* 25 (2013), pp. 21–39, https://doi.org/10.2153/0120130011002; and Marianne Senn/Hans J. Leber/Martin Tuchschmid/Naila Rizvic: Blechblasinstrumentenbau in Frankreich im 19. Jahrhundert. Analysen von Legierung und Struktur des Messings zugunsten eines historisch informierten Instrumentenbaus, in: *Romantic Brass. Französische Hornpraxis und historisch informierter Blechblasinstrumentenbau. Symposium 2*, ed. by Daniel Allenbach, Adrian von Steiger and Martin Skamletz, Schliengen 2016 (Musikforschung der Hochschule der Künste Bern, Vol. 6), pp. 398–419. For information on the project see www.hkb-interpretation.ch/projekte/blechblasinstrumentenbau.

FIGURE 1 The 16 instruments involved in the long-term study: 8 horns, 5 trumpets, 1 Wagner tuba, 1 trombone, 1 tuba (Photos © Schweizerisches Nationalmuseum)










The first phase of the project embraced all the basic research on corrosion and humidity as well as on the instruments to be chosen. In a second phase, a long-term study was carried out whereby the development of interior corrosion phenomena over time was monitored with the help of all three methods, namely electrochemistry, tomography and endoscopy. All the instruments were played every day for at least five minutes over fourteen months. They were investigated at the start, after seven months and at the end. Gloves were used to prevent exterior corrosion. For eight of these sixteen instruments, the players applied a protocol of preventive conservation, emptying all condensed water and drying the inside with the help of a fan after every playing session. For a second group of seven instruments, the players only did what they usually do at the end of playing, simply emptying the condensed water. One reference instrument remained unplayed. The players kept records of their playing time. This gave a total of over two thousand minutes of playing time.

Our three monitoring methods of electrochemistry, tomography and endoscopy differ in their detection size from a few millimetres up to several centimetres. But none of them can examine an entire instrument, let alone sixteen instruments. So specific hotspots were chosen to be measured by all three methods, namely the tuning slide and one valve slide of every instrument, these being areas that never dry without ventilation. For the horns and one trumpet, the crook was measured as a third hotspot. In total, thirty-four parts, slides and crooks of the sixteen instruments were monitored (see Figure 2).

While tomography made an overall 3D examination of these parts, the endoscopy took pictures of its straight tubes, and electrochemistry measured two or three spots of the same straight tubes. For example: the tuning slide and the first valve slide of a tuba were investigated (see Figures 3 and 4). Figure 5 shows photos of the latter through the endoscope. The addition of corrosive layers over time is easily visible. The tomography in Figure 6 shows similar spots of material, and the electrochemistry measured the polarisation resistance at the start, at the mid-point and at the end of the long-term study.

The analysis of the results initially gave the usual cloud of data. Every method found corrosion phenomena and its development over the period of our long-term study at certain spots, and an unclear situation at other points. Finally – in the third and final phase of the project – we found ways of better understanding the results, ranging from visual detection to statistical analysis. A cross-comparison of all three methods gave further insights, both concordances and differences.

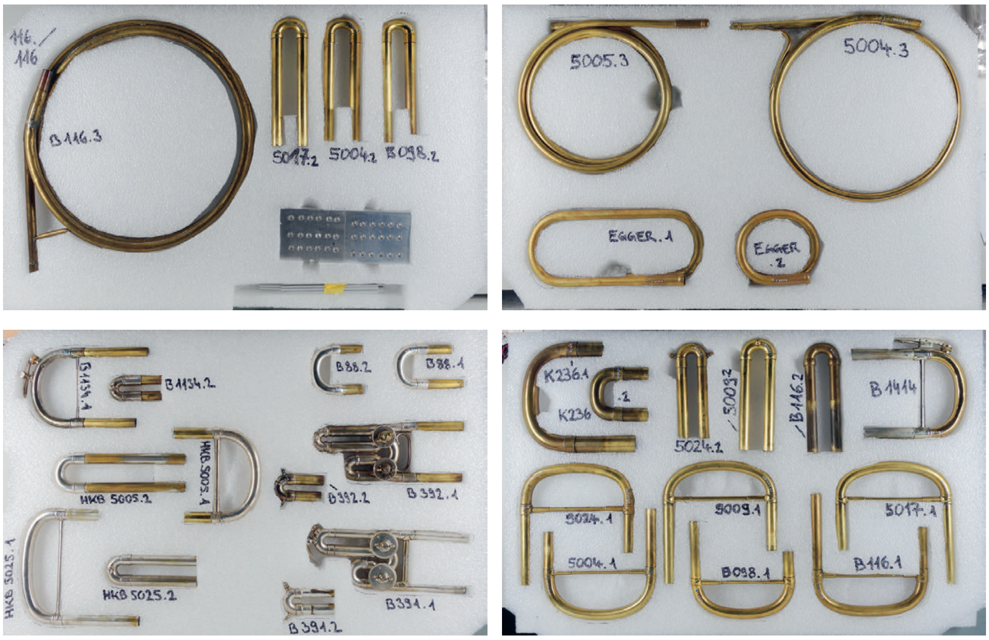


FIGURE 2 **The 34 parts of the 16 instruments examined in detail before, at the project's mid-point, and at the end of the long-term study**

FIGURES 3 AND 4 **The *tuba français à 6 pistons*, made before 1920 by J. Gras in Paris; and its valve slide of the first valve**

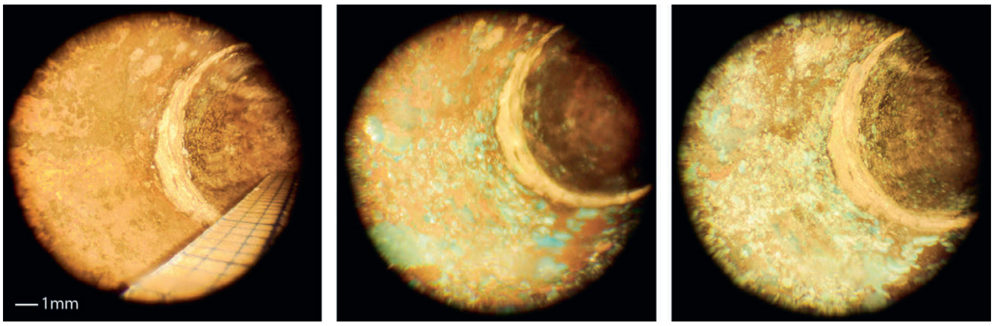


Figure 5 Endoscope photos of the inside of the first valve slide at the point where the straight tube and the bow are soldered together. Left: at the start; middle: at the mid-point of the project; right: at the end of the 14 months of playing

Figure 6 Neutron tomography, made at the end of the long-term study, of one tube of the same valve slide

From scientific results to musician's routine The following focusses on an application of the project's results in the treatment of historical brass instruments that are played.[9] Seen, that every playing situation is different and that individual corrosion phenomena and their development are not generally predictable, this cannot end up in general rules, but in guidelines for better protection of the cultural heritage objects including their inherent information.

For the sixteen 100-years-old brass instruments involved in the long-term corrosion research over fourteen months, the three examination methods electrochemistry, tomography and endoscopy in combination let us statistically conclude that drying of the instrument's inside after use reduces corrosion processes caused by the brought-in moisture. The results of endoscopy and electrochemistry are shown in Figure 7 for the detected parts of instruments with prevention (drying with the help of a fan) and without.[10] In the first group, we find only one instance of significant change in the endoscope test and only two in the electrochemical tests (Rp value much lower). Thus, circa 95 per cent of the tested tubes showed similar or unchanged corrosion phenomena in the endoscope image and similar or identical electrochemical values. In the group of instruments that were treated in accordance with common practice, not using a fan, endoscopy and electrochemistry revealed about 30 per cent of significant changes.

In conclusion, drying the inside of a brass instrument after use statistically reduces interior corrosion processes by a factor of about six, from 30 to 5 per cent. But it cannot

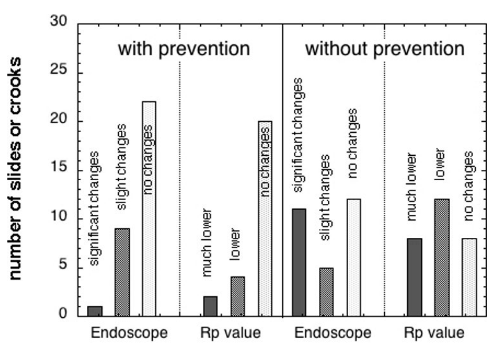


FIGURE 7 **Extent of changes inside the inspected tubes as a result of long-term use as determined by endoscopy (visual examination) and electrochemistry (polarisation resistance Rp)**

9 I am grateful to all project's collaborators for their contributions towards an interpretation of the results with regard of preventive conservation routines as well as the participants of the final discussion of the CIMCIM annual meeting and Fourth Romantic Brass Symposium in Bern in February 2017 for their inputs. The paper has been presented in the international conference "Playing and Operating. Functionality in Museum Objects and Instruments", Paris, February 2020.

10 One single instrument was not played at all. It showed no changes after the 14 months. For all details of procedure and results see the articles by Martin Ledergerber (pp. 92–96) and Bernhard Elsener et al. (pp. 61–72) in this volume.

exclude such processes. In minimum, they are activated during the 'time of wetness', that is, while playing and drying. The statistics only show an average of its preventive conservation effect. Moreover, instruments also wear and tear through use and they even can be damaged by use or transport. All these effects are the reasons for the relatively short lifespan of all wind instruments, compared to string or percussion instruments.

Consequences for instruments in museums The cultural heritage in museums and collections is preserved to maintain objects over generations. In consequence, the playing of wind instruments is not allowed in most institutions. But with the aim of gaining the inherent information such as pitch, intonation characteristics, pitch flexibility by bending the notes, sound characteristics, sound homogeneity over the range, playing characteristics, response, and ease of handling, institutions perform playing tests with experts.

For reliable results of such tests, museum instruments must be prepared to real playing condition.[11] Often, the instruments need to be brought to soundability.[12] Such interventions must not change the object in terms of restoration. Non-corrosive oil and grease must be used.[13] Appropriate period mouthpieces must be found, a challenge also for experts. Then the instrument must be prepared through playing for at least some minutes until the usual film of wetness inside the tubes is built. Even an expert needs much playing time to understand the characteristics of an instrument. The tests must be documented by video, audio and discussion protocol. Finally, all this material must be best conserved together with the instrument[14] and the instrument itself must not only be dried with the help of the fan but treated by the conservator using appropriate long-term conservational measures.

The Hochschule der Künste Bern HKB in collaboration with Klingendes Museum Bern and other collections of historical brass instruments has performed several musical projects playing historical brass instruments. The described guidelines have been

11 The following is based on experiences of the project under discussion as well as of other projects of HKB and other institutions. See e.g. Adrian von Steiger: "Agilité, homogénéité et beauté". The Saxhorn in the Context of the Opéra and Military Music, in: *Das Saxhorn. Adolphe Sax' Blechblasinstrumente im Kontext ihrer Zeit. Romantic Brass Symposium* 3, ed. by Adrian von Steiger, Daniel Allenbach and Martin Skamletz, Schliengen 2020 (Musikforschung der Hochschule der Künste Bern, Vol. 13), pp. 9–17.

12 For the terms of soundability and playability I follow the concept of Robert Barclay, in: *The Care of Historic Musical Instruments*, ed. by Robert Barclay, London 2004, pp. 6 f.

13 See Martin Ledergerber/Emilie Cornet/Erwin Hildbrand: Humidity in Regularly Played Historical Brass Instruments, pp. 48–60 in this volume.

14 See Arnold Myers: Preserving Information Relating to Instruments in Museums, pp. 120–127 in this volume.

followed. The experiences are: none of the instruments got damaged or lost; none had to be restored before use in an unjustifiable way, all were only prepared for soundability; the use of fans prevented almost all corrosion of the inner surface; and historical mouthpieces as well as replicas of such mouthpieces were used.

In conclusion, drying the inside of the instruments after every single playing session seem to be a very important guideline for these situations (beside reversable interventions of restoration, wearing gloves and use of non-corrosive oil and grease). It reduces the 'time of wetness' and therefore the time of activated corrosion to the real playing time. Although that might be many hours over many days, this is a short period compared to the months of activation when an instrument is not dried after playing – maybe after a so-called short playing session, restricted in time in order to a well-intentioned but misunderstood better protection of the instrument.

Musician's routine Beside the instruments in museums, a great number of historical brass instruments in playing condition today is in the hands of the musicians of the historical performance practice scene. A majority was built in the nineteenth and early twentieth centuries. They show a great variety of types according to history, place of origin and musical use. This leads to the variety of sound colours of orchestras and bands which is an important clue for the historical performance practice movement.[15]

In line with the principle that one should use an appropriate instrument for each work, specialised players use a large number of original instruments, changing them constantly. This is also the reason why the production of replica can hardly be affordable for the player and profitable for the maker. Therefore, originals will be used also in future. The trend to play originals will become even more widely followed as the HIP movement expands further into the repertoire of the twentieth century and draws an ever-greater number of performers and listeners into its orbit.

Therefore, it seems to be urgent that the project's insights lead to a new approach in the use especially of these instruments 'in the wild'. An occasional use or an 'only short try', as often done for tests of historical instruments, is the worst possible method. It gives musically unreliable results and ends up in the same long term of many days of humid interior surface and therefore of activated corrosion. In contrast, by drying the inside after every use with the help of the small fan, the time of wetness and thus the corrosion

15 As seen in the research project under discussion, the sound of period French brass instruments for Stravinsky's *Le Sacre du Printemps* differs enormously in immediate comparison to modern instruments. And as seen in a former project, a French military brass band of the 1860s using period saxhorns, cornets, trombones and percussion create an unexpected sound quality, see www.hkb-interpretation.ch/projekte/saxhorn/article-142.

loss can be reduced significantly. Testing and recording these instruments in playing condition, in combination with a careful handling and transport, these historical objects 'in the wild' can even give information which cannot be provided by silent or unplayable instruments in museums and therefore contribute to their safeguard.

Scientific point of view Questions about playing historical brass instruments arise not only from the ethical side of conservation, but from the scientific side: What are the insights of such playing of historical brass instruments? What can end up in misunderstandings?[16]

- Our museum objects are old, they differ, to an unknown extent, from their state when they were new. Therefore, the golden road is the production of faithful replica. Faithfull in terms of material properties as well as of manufacturing techniques, not only in terms of geometry. But, to achieve this, we need in turn to play historical models for comparison, as a compass for replica production.
- Originals may be restored to soundability without any changing or replacing of parts. This intervention differs basically to a restoration to playability in concert. If an instrument does not work properly, only a restorer should be allowed to fix them in line with the ethics of preventive conservation. This is not a solid basis for a public concert, when the instrument must work properly in that very moment.
- We mostly do not know from which context our historical instruments originate. Brass instruments approximately 80 per cent originate from the military context. These are suitable for HIP of military music but in most cases not for the symphonic or operatic repertoire. Here, often other models of brass instruments were in use.[17]
- A good instrument normally is played until it falls apart and get thrown away. It does not end up in a museum. Typical backgrounds of museum's instruments in contrast are, for example, that they were representative instruments, or shelf warmers because they did not work properly, or they were outdated, or they were special instruments such as prototypes that remained in the workshop and ended in the workshop's

16 I concentrate here on the technical side of the instruments, the much broader musical side is known under the term "Authenticity discussion", for a compilation see John Butt: Authenticity, in: *Grove Music Online*, https://doi.org/10.1093/gmo/9781561592630.article.46587.

17 An estimation of a ratio of instruments for military band use vs pedagogical use vs symphonic use has never been properly made. The ratio for the nineteenth century of 80 per cent production for military use is a guess, discussed with participants of the Fourth Romantic Brass Symposium in February 2017. See also Trevor Herbert: Selling Brass Instruments. The Commercial Imaging of Brass Instruments (1830–1930) and Its Cultural Messages, in: *Music in Art* 29/1–2 (2004), pp. 213–226.

museum or depot. In consequence, museum objects often are not the really played instruments, they are not the front side of the coin, but its reverse.[18]

– We must question, who is playing these historical instruments. There are musicians with a great talent to adapt their playing technique to an instrument and therefore to understand historical instruments (not immediately but after a while). They may then understand the features such as which interface to use, what could have been the pitch of an instrument and they are able to adapt their articulation to the instrument not vice versa.

In conclusion: A permission to play an instrument should not be naive, neither from the perspective of ethical standards nor from the scientific point of view. The goal must be the gain of information in a research context or in order to conceive replica. Otherwise it ends up in misunderstandings. But then, acknowledging the questionable points, the gain of playing historical wind instruments in a controlled and research-based framework can be more important than its risks.

18 An estimation of the survival rate of historical musical instruments is possible in rare cases, when the production figures are known. This is the case for the production of the Salvation Army, see Arnold Myers: Instrument Making of the Salvation Army, in: *The Galpin Society Journal* 73 (2020), pp. 30–59; and for Adolphe Sax, see Adrian von Steiger: Sax Figures. Can We Deduce Details of Adolphe Sax's Instrument Production from the Sources?, in: *Revue Belge de Musicologie* 70 (2016), pp. 129–148.

Martin Ledergerber / Emilie Cornet / Erwin Hildbrand

Humidity in Regularly Played Historical Brass Instruments. The Possibilities and Limitations of Preventive Conservation

Abstract Historical brass instruments that are played regularly face a number of risks to their preservation in the long run. Apart from mechanical damage caused by intensive handling and normal wear and tear, one of the major threats is the interior humidity accumulated through and during playing. As far as brass instruments are concerned, no investigations have yet been undertaken to measure the amount of humidity accumulated during playing and its damage potential. With the aid of climate measurements and complementary tests, the effective corrosive impact of regular playing on the interior surfaces of brass instruments was assessed over a period of several months. Based on the insights gained there, potential preventive conservation strategies were evaluated, and maintenance measures suggested that musicians could implement in situ and with ease.

Introduction In the context of historically informed performance practice, musicians increasingly rely on original instruments dating from the period in question. When performing works of early music, original brass instruments are rarely used, for the simple reason that they have become very rare; instead, people rely on modern replicas. But as far as works of the nineteenth and early twentieth centuries are concerned, players like to use original instruments, chiefly because there are still enough original instruments to be found on the market and in musical collections, and because it is deemed justifiable to use them in the context of historically informed performances. To judge whether it is permissible to rely on a certain historical instrument, conservators revert to the assessment procedure developed by Robert Barclay, which relies on the standards "rarity", "fragility" and "state", and offers a valuable decision-making protocol.[1]

Apart from the normal risk of mechanical damage, using historical wind instruments above all involves the danger of humidity accumulating inside the instrument through and during play; this poses a threat to their long-term conservation. The potential damage impact varies greatly, depending on the material. While the humidity fluctuations caused by playing have been investigated as far as woodwind instruments are concerned, this has

1 Robert Barclay: *The Preservation and Use of Historic Musical Instruments. Display Case and Concert Hall*, London 2004, pp. 233–244.

DOI: 10.26045/kp64-6179-004

yet to be done for brass instruments.[2] The present investigation set itself the task of examining the climatic changes caused by playing in order to shed light on the changes to the interior surface textures brought on by moisture in regularly played, historical brass instruments. In addition, our aim was to put forward measures to reduce the risk of humidity-related damage caused by frequent playing. This investigation was conducted in the context of the interdisciplinary research project "Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice", funded by the Swiss National Science Foundation.[3] Brass instruments dating from the nineteenth and early twentieth centuries were lent to musicians with the intention that they should play them regularly over a period of several months. At the end of the project, a performance of Igor Stravinsky's original, 1913 version of *Le Sacre du Printemps* was scheduled. The instruments under examination came from private and public collections whose collection concepts explicitly made provision for playing their instruments.

In the context of this project, the Conservation Department of the Swiss National Museum was given the task of assessing possible approaches to preventive conservation and of coming up with easily implementable maintenance measures that the musicians could apply regularly over an extended period of time. The measures proposed thus had to be viable outside a normal conservatory setting and generally accessible, primarily to musicians who do not necessarily have in-depth specialist knowledge of conservation. In other words, these measures had to be different from the procedures normally utilised by conservators in a laboratory setting.

Brass is an alloy of copper (Cu) and zinc (Zn).[4] From a conservation perspective, instruments made of this material are regarded as being not particularly problematic. This is because brass is a stable material when kept in a dry, pollutant-free environment.[5] The investigations in this study were restricted to damage occurring inside brass instruments through regular playing. There is a comprehensive literature on the changes and damage to the outer surfaces of brass instruments that are played regularly, and on the

2 Ilona Stein: Blasfeuchte in Holzblasinstrumenten, in: *Studien zur Erhaltung von Musikinstrumenten. 1: Holzblasinstrumente, Firnisse*, ed. by Friedemann Hellwig, München 2004 (Kölner Beiträge zur Restaurierung und Konservierung von Kunst- und Kulturgut, Vol. 16), pp. 9–121.

3 See www.hkb-interpretation.ch/projekte/korrosion (all links in this article last consulted 18 October 2022).

4 Hannes W. Vereecke/Bernadette Frühmann/Manfred Schreiner: The Chemical Composition of Brass in Nuremberg Trombones of the Sixteenth Century, in: *Historic Brass Society Journal* 24 (2012), pp. 61–75.

5 Lyndsie Selwyn: *Metals and Corrosion. A Handbook for the Conservation Professional*, Ottawa 2004, pp. 62–71.

problems stemming from normal wear and tear. Robert Barclay makes frequent reference to various conservatory concerns caused by regular playing.[6] For an overview of the range of possible damage to brass instruments, see Panagiotis Poulopoulos and Arnold Myers.[7]

Preventive conservation method The aim of preventive conservation is to avoid, or at least reduce as best as possible, the risks involved during the storage and use of cultural items, in order to ensure their long-term preservation. This requires proactively identifying potential risks and damage to both individual objects and entire collections, and taking measures to protect these items from harm. A successful preventive conservation strategy will thus entail registering and understanding an object in terms of its materiality and present condition, while at the same time recognising all the risks and damage factors that an object or group of objects could be subject to in a specific usage context. Playing brass instruments regularly comes with a multitude of risks. In contrast to displaying instruments in an exhibition or holding them in storage, these playing risks are often difficult to determine and assess.

Since we are well aware of the many risks that come with lending out and playing instruments over a period of several months, we relied on a wide range of preventive approaches. First and foremost in this respect, we wanted to raise the users' awareness about the concept and aims of preventive conservation. After carefully selecting the musicians, and before handing them their instruments, they were instructed about the basics of preventive conservation and asked to handle the instruments carefully and ensure their correct maintenance. The terms of use and the maintenance instructions were given in writing (see Appendix). The products to be used were specified, as were the measures required for the correct maintenance of the tuning slides and valves. During the entire project, the musicians were supported and monitored by a trained conservator. Halfway through the project and at its end, the musicians and all the specialists involved in the project met up to compare and discuss the usage and maintenance practices adopted.

Evaluation of products To ensure reliable functioning, the movable parts of the instruments must be treated on a regular basis. The oils and greases applied to the various valves and tuning slides must be absolutely safe in conservation terms, given that they

6 Robert Barclay: *The Preservation and Use of Historic Musical Instruments. Display Case and Concert Hall*, London 2004; and *The Care of Historic Musical Instruments*, ed. by Robert Barclay, Edinburgh 1997.

7 Panagiotis Poulopoulos/Arnold Myers: Investigating and Preventing the Deterioration of Historic Brass Instruments in EUCHMI, in: *Diagnostic and Imaging on Musical Instruments. Selected Proceedings of the 1st and 2nd International Workshop, Ravenna 2010/2011*, ed. by Emanuele Marconi, Florence 2016, pp. 55–58.

come into direct contact with the instrument. Various commercial products were tested as to their stability and chemical inertness. For this purpose, a simple test series was devised in which small plates of different brass alloys were exposed to different oil and grease samples in small, closed glass jars covered with a foil for a period of several months (see Figure 1). The samples were arranged so that a third of each formerly polished and degreased brass plate was submerged in the product to be tested, while the upper two thirds were exposed to its gaseous components. In a second test set-up, brass powder was mixed with the different products in porcelain vessels, and exposed to 120° Celsius in an oven for a period of twenty-four hours. The musicians were subsequently instructed to use those products that had produced no corrosive effect on the samples in the two tests.[8]

Assessment of instrument cases and covers With regard to the transport and storage of the instruments during the project, various instrument cases and covers were discussed and assessed. The problem of keeping instruments in cases and covers made of non-age-resistant materials is known, as these materials often tend to be chemically unstable and emit pollutants.[9] Careful assessment is therefore required, not least because the materials are in direct contact with the instruments and because the concentration of pollutants tends to rise quite quickly within closed cases and covers, and can damage the instruments. The materials used in the cases and covers were systematically assessed by means of an accelerated aging test regarding their stability and chemical inertness.[10] For the project, only such cases and covers were used that the test results showed were suitable for long-term usage.

Climate tests In order to ascertain the climatic conditions in the interior of regularly played brass instruments, temperature and humidity were measured in multiple test series before, midway through, and after playing, with the aid of electronic data loggers (Figure 2). Through sensors measuring merely 6 mm in diameter and connected by cable with the loggers over a distance of up to 100 cm, we were able to measure the climatic conditions within the instruments at different points over an extended period of time.[11] Measuring was carried out in storage spaces under very stable climatic conditions (T 18–20 °C, 50 % RH); the room climate was recorded as a reference value.

8 The key oils and tuning slide greases selected were La Tromba Cork Grease, Denis Wick Advanced Formula Valve Oil with PTFE, Hetman Synthetic Lubricant 17 Key Oil MEDIUM KEY, and Hetman Tuning Slide Grease 8 TSG.

9 See Klaus Martius/Markus Raquet: Instrumentenkästen. Schutz und Sicherheit?, in: VDR *Beiträge zur Erhaltung von Kunst- und Kulturgut* 2005/1, pp. 123–128.

10 See Lorna R. Lee/David Thickett: *Selection of Materials for the Storage or Display of Museum Objects*, London 1996 (British Museum Occasional Papers, Vol. 111).

11 MSR145 data logger with humidity (RH) and temperature (t) sensor, working between -20 and +65 °C

Figure 1 Test set-up using small brass plates to assess the corrosiveness of different oils and greases

Figure 2 Test arrangement using data loggers for climate testing on a trumpet

In a first phase, we tested the interior climatic changes generated by playing on modern brass instruments. Then, after determining the test parameters, we carried out systematic climate measurements on all 16 instruments involved in the project (5 trumpets, 8 horns, 1 trombone, 1 Wagner tuba, 1 tuba). Relying on a wide scope of instruments ensured that the insights gained were valid for different instrument types featuring varying tube lengths and diameters, and thus diverse forms and volumes.

The test series showed that the climatic effects caused by playing are comparable for all instrument types we examined.[12] Figure 3 shows a typical curve progression during playing. Within the first minutes of playing, the humidity scores within the instruments

and between 0 and 100% relative humidity, with an accuracy of ±2% (MSR Electronics GmbH, Mettlenstrasse 6, 8472 Seuzach, Switzerland, www.msr.ch).

12 Emilie Cornet: *Approches pour la conservation préventive des instruments de musique en cuivre de la collection Burri à Berne*, unpublished report, Swiss National Museum, Affoltern am Albis 2013, pp. 6–9.

rise to over 90 % of relative humidity (RH). The moisture-saturated air condenses on the inside walls, forming droplets and local patches of water, to the effect that the relative humidity values remain exceedingly high over several days. Even when the valve and tuning slides are emptied after use and left out to dry, relative humidity within the instruments does not recede below 70 % RH within 24 hours. One surprising finding was that, even after the maximum recording period of 20 days, relative humidity within the instruments did not recede below 60 % RH (Figure 4).

As far as the temperature is concerned, the tests showed that the temperature rises moderately during playing as expected, owing to the musician's body and breath temperatures. However, these temperature changes due to playing present no problem for the preservation of the instruments.

Methods of drying The high humidity, far above the values measured for the ambient air, suggests that corrosion within the instruments is highly probable. From a conservation perspective, our first priority must be to dry the instruments rapidly after use in order to avoid corrosion damage. The use of moisture absorbers, solvents, heated air and compressed air was tested, but the special project requirements meant that these were deemed inappropriate, since they could not be applied by the musicians independently, on a daily basis, and in separate locations. However, active drying with the help of fans meets all requirements; it is easy and poses no risk to either the instrument or the musician. Climate tests have shown that the use of fans is a highly efficient drying method.[13]

For this project, we used fans especially designed for drying instruments that were powered through a USB port (Figure 5)[14] next to commercial mini-fans. After playing, the tuning slides and valves were emptied and then reinserted. With the help of Velcro straps, the valves were fixed in a position in which all slides were open, allowing an unhindered airflow through all parts of the instrument. Then the fan was attached to the leadpipe (horns: two fans, one to the crook, one to the bell) and turned on. Complete drying was achieved through the continuous stream of air, so that values matching the ambient climate were reached within a matter of 1.5 to 3 hours at most. This marks the end of the drying process.

Figure 6 shows the typical process of active drying with the help of a fan. In this specific case, a humidity sensor was placed 40 cm away from the bell, and a second sensor

13 See also the three videos, produced in the project by the Paul Scherrer Institute (PSI), making visible the humidity in a cornet: https://youtube.com/playlist?list=PL5J-BZoNMhGKj5-u_KKuy7lIKGuFcL2bo.

14 Produced by Stephan Berger, CH-2336 Les Bois (www.serpents.ch).

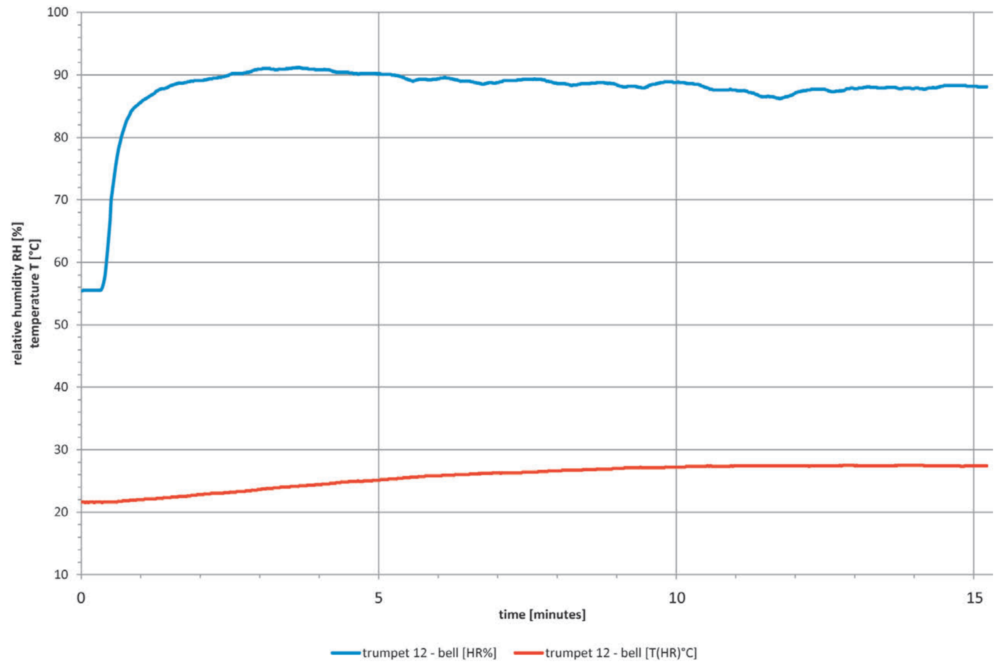


FIGURE 3 Typical climate diagram showing the changes to relative humidity (RH) and temperature (T) during the use of a brass instrument over a period of 15 minutes

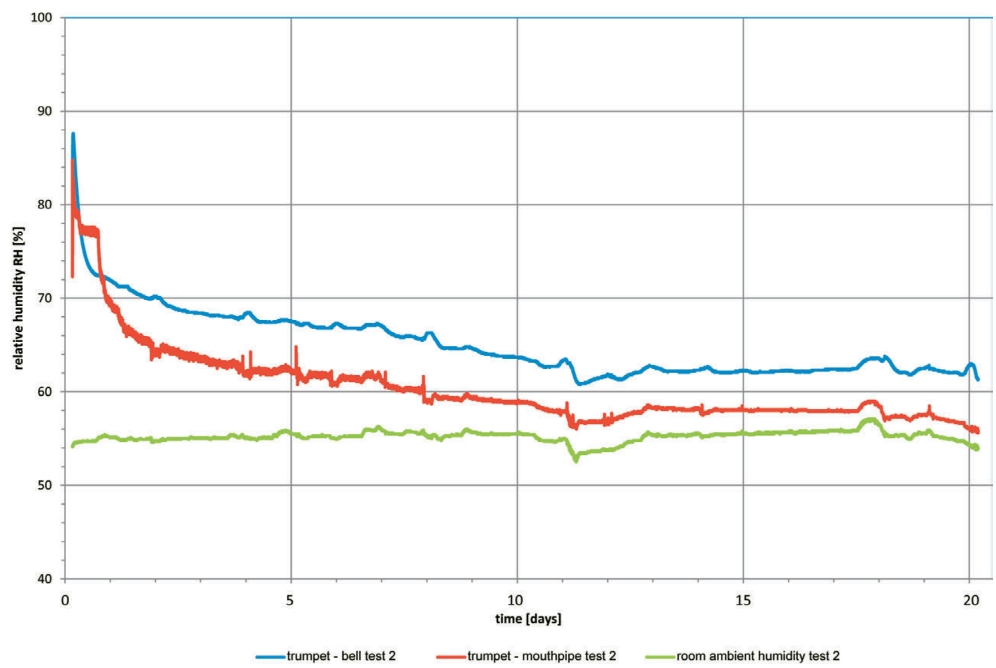


FIGURE 4 Typical climate diagram showing the changes to relative humidity (RH) at two separate points within a brass instrument over a period of 20 days if the instrument is not specially treated and simply left to air dry. The green curve indicating the relative humidity of the ambient air

FIGURE 5 Fans used to dry the instruments efficiently

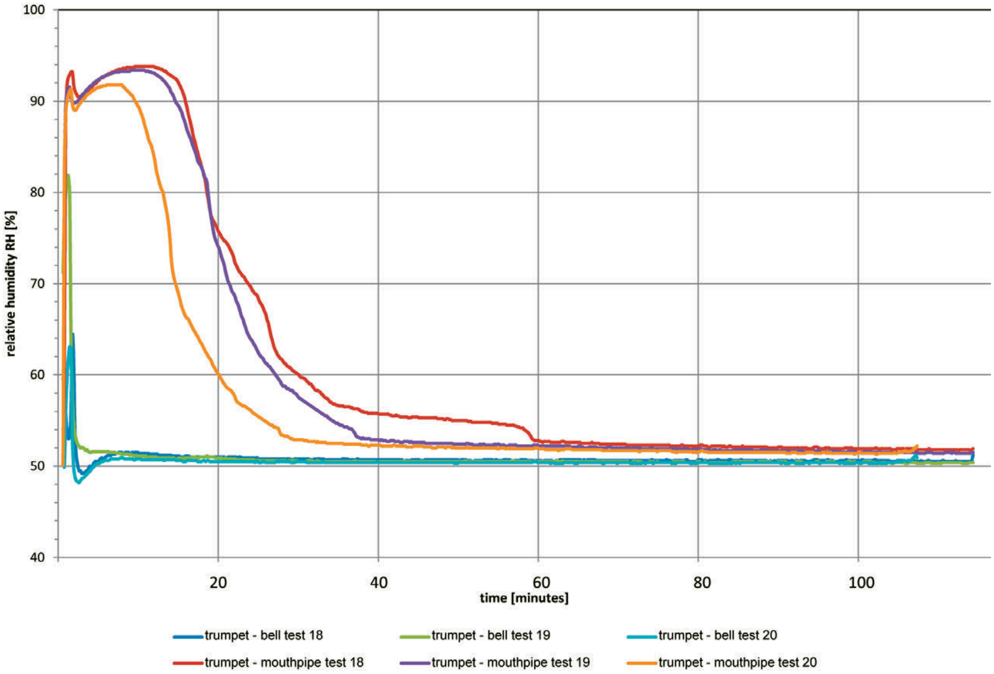


FIGURE 6 Typical climate diagram showing the decrease of relative humidity over time inside a trumpet in different places, using a fan as a drying device

inside the mouthpipe, 20 cm away from the opening. The diagram shows three measurement sequences, with all three producing very similar results. The area around the bell was dry within a few minutes, the section within the narrow mouthpipe after roughly 60 minutes.

In order to test the efficacy of the preventive care measures proposed, two groups were defined for the subsequent period of playing. In the first group, the musicians treated the instruments according to the newly developed maintenance concept, relying on active drying for at least ninety minutes after each period of playing as a prime measure. The instruments of the second group served as a control; here the musicians treated them in the habitual way, that is, the tuning slides and valves were merely emptied and put out to dry after use, without reverting to active drying.

According to the research set-up, the musicians of both groups were asked to play their instruments over a period of 14 months for at least 5 minutes a day. In order to correlate any changes found in the instruments according to the mode and duration of playing, the musicians were also asked to keep a written protocol specifying the playing duration each day, and the care measures applied. On average, the instruments were played 275 times for 6.19 minutes, resulting in an average playing time of 28.3 hours. Three testing methods (electrochemistry, neutron tomography and endoscopy) were applied before the start of the project, after 7 months, and at the end of the fourteen-month period, to ascertain whether the instruments had undergone any changes and to assess the effectiveness of the preventive conservation measures.[15]

Findings and discussion The regular use of historical brass instruments is hardly compatible with the aims of long-term conservation. However, in the context of historically informed performance practice, the use of certain instruments from collections with a corresponding utilisation concept is acceptable. In such cases, even more attention should be given to preventive conservation measures, considering the aims of long-term preservation.

The climate tests we conducted provided clear evidence that brass instruments played regularly remain permanently humid inside if they are only treated conventionally, but not actively dried. In the instruments tested, the humidity scores remained at over 60 % RH for several days. Under these circumstances, corrosion processes are likely to set in, that is, parts of the basic brass material are transformed into corrosion products, leading to a loss of original substance. Active drying with the aid of fans that provide a

15 See the articles by David Mannes/Eberhard Lehmann (pp. 83–91); Bernhard Elsener/Tiziana Lombardo/Federica Cocco/Marzia Fantauzzi/Marie Wörle/Antonella Rossi (pp. 61–72) and Martin Ledergerber (pp. 92–96) in this volume.

flow of air inside the instrument and evacuate the humidity is a highly efficient, easy-to-implement method of drying. The humidity scores in the different types of instruments tested were reduced to values matching the ambient climate within a matter of hours, thus significantly reducing the risk of corrosion. Based on the findings of this study, we would certainly advise musicians to use fans for drying their brass instruments. After the period of play, and before the instrument is returned to storage, further conservation treatments are required. These, however, should be conducted by a qualified conservator.[16]

Apart from active drying as a measure of preventive conservation against corrosive humidity, the use of corrosion inhibitors, chemical passivation or the application of a protective coating inside regularly played period brass instruments are further possible damage-avoiding strategies. However, these approaches were not further pursued in this study, as it would have meant making irreversible changes to areas within the instrument that are difficult to access. Moreover, the efficacy of such measures over time can only be tested to a limited extent. Last but not least, the effect on the acoustic quality of deposits and overlays inside brass instruments needs further investigation.[17]

Although the focus of this study was primarily on the prevention of humidity-related damage inside brass instruments, the protection of the instruments' outside metal surfaces was also an aspect of the preventive conservation measures. Despite daily use and handling, corrosion damage and stains to the instruments' outer surface caused by sweaty hands were largely avoided, as the musicians were asked to wear gloves. All in all, sensitising the participating musicians to the goals of preventive conservation was key to the project's success. By fully and correctly adhering to the maintenance protocol, mechanical damage was avoided almost completely, despite the long, intensive period of use.

16 See Marie-Anne Loeper-Attia: L'impact des restaurations sur la conservation des instruments de musique de la famille des cuivres, in: *Paris – un laboratoire d'idées. Facture et répertoire des cuivres entre 1840 et 1930. Actes du colloque*, Paris 2010, pp. 58–69, here p. 69.

17 John P. Chick/Murray D. Campbell/Arnold Myers: *The effects of the internal condition of the bore on the acoustic properties of brass instruments.* Paper presented at Musical Acoustics Network Summer Meeting, Edinburgh, July 2009.

Appendix **Terms of use and the maintenance instructions**

HKB HEAB BUA
Hochschule der Künste Bern
Haute école des arts de Berne
Bern University of the Arts

Merkblatt zur Handhabung von historischen Blechblasinstrumenten

Das Instrument ist mit grosser Sorgfalt zu behandeln, das Handling ist auf ein Minimum zu beschränken und nur Projektmitarbeitern gestattet.

Ein historisches Instrument ist immer mit Handschuhen zu spielen (Baumwolle, besser geeignet sind Nitril- oder Latexhandschuhe).

Nach jedem Bespielen in allen Stimmzügen und im Korpus das Kondenswasser entleeren.

Pistons regelmässig ölen, allerdings nach Möglichkeit nicht aufschrauben, sondern Öl nur durch Pistonstimmzüge eintropfen lassen. Zum Unterhalt und zur Pflege sind ausschliesslich die von der HKB abgegebenen Produkte zu verwenden.

Bei längerem Nicht-Bespielen des Instrumentes alle Stimmzüge entfernen und an einem sicheren Ort offen lagern. Ablageflächen sollen sauber und gepolstert sein.

Es dürfen keine Veränderungen am Instrument vorgenommen werden.
Bei entstandenen Schäden immer den verantwortlichen Restaurator (Martin Mürner) benachrichtigen und Reparaturen nur durch ihn ausführen lassen.

Transporte nur im zugehörigen Instrumentenkoffer.

Beim Verlust des Instrumentes oder bei irreparablen Schäden ist grundsätzlich die Privathaftpflichtversicherung des Bläsers verantwortlich. Bei Nichtverschulden des Bläsers übernimmt das Projekt einen allfälligen Selbstbehalt.

Jedem Instrument ist ein persönliches Bespielungskonzept zugeordnet, das dieses Merkblatt ergänzt.

Martin Mürner HKB
Verantwortlicher Restaurator

Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Sammlungszentrum.

SNF-Projekt _Korrosion an gespielten Blechblasinstrumenten CR12I1_146330 / 1
"Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice"

Bespielungskonzept

- tägliche Bespielung, Spieldauer mindestens 5 Minuten
- Entleeren und übliche Pflege nach jedem Bespielen (Gruppe A und B)
- Gruppe A: zusätzliche Trocknung mit Ventilator während mindestens 1.5 Stunden nach jedem Bespielen

Wir bitten Sie das Protokoll unmittelbar nach dem Bespielen auszufüllen und folgende Richtlinien einzuhalten:
Grösste Sorgfalt im Umgang mit den historischen Musikinstrumenten, Handschuhe tragen, nur die im Rahmen des Projektes getesteten und von Martin Mürner vorgegebenen Pflegemittel verwenden (Öl: Denis Wick Advanced Formula Valve Oil With PTFE, Fett: La Tromba Cork Grease)

Inv.Nr	Instrumente	Jahrgang	Gruppe	Pflegemassnahmen	erweitertes Pflegekonzept
B1134.	Trompete	1900-1930	B	Entleeren der Stimmzüge, übliche Pflege	
B392./556	Trompete	1900-1920	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator
B391./189	Trompete	1930-1940	B	Entleeren der Stimmzüge, übliche Pflege	
HKB 5027	Trompete	2012	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator
B088.	Trompete	1869	B	Entleeren der Stimmzüge, übliche Pflege	
B116./116	Horn	1930	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator
HKB5004	Horn	1922	B	Entleeren der Stimmzüge, übliche Pflege	
HKB5024	Horn	1932	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator
HKB5009	Horn	1900	B	Entleeren der Stimmzüge, übliche Pflege	
HKB5005	Horn	1920-30	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator
HKB5017	Horn	1900	B	Entleeren der Stimmzüge, übliche Pflege	
HKB5025	Horn	1910	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator
B098./761	Horn	1900	B	Entleeren der Stimmzüge, übliche Pflege	
HKB5020	Posaune	1902	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator
B1414./974	Wagnertuba	1936	B	Entleeren der Stimmzüge, übliche Pflege	
K236	Tuba	1920	A	Entleeren der Stimmzüge, übliche Pflege	Trocknung mit Ventilator

Schweizerisches Nationalmuseum. | Sammlungszentrum. | Lindenmoosstrasse 1, 8910 Affoltern am Albis |
T. +41 (0)58 480 13 13 | F. +41 (0)58 480 13 41 | sammlungszentrum@snm.admin.ch | www.sammlungszentrum.ch

Sammlungszentrum.

SNF-Projekt _Korrosion an gespielten Blechblasinstrumenten CR12I1_146330 / 1
"Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice"

Bespielungsprotokoll

Instrument Nr.	
Name Musiker	
Gruppe	

Spieldauer **mindestens 5Minuten**
Entleeren und normale Pflege immer (Gruppe A und B)
Zusätzliche Trocknung mit Ventilator (Gruppe A) **mindestens 1.5 Stunden**
Öl: Denis Wick Advanced Formula Valve Oil With PTFE
Fett: La Tromba Cork Grease
Handschuhe tragen

Datum	Spieldauer	Entleeren	Ventilator	Bemerkungen

Schweizerisches Nationalmuseum. | Sammlungszentrum. | Lindenmoosstrasse 1, 8910 Affoltern am Albis |
T. +41 (0)58 480 13 13 | F. +41 (0)58 480 13 41 | sammlungszentrum@snm.admin.ch | www.sammlungszentrum.ch

Bernhard Elsener / Tiziana Lombardo / Federica Cocco /
Marzia Fantauzzi / Marie Wörle / Antonella Rossi

Breathing New Life into Historical Instruments. How to Monitor Corrosion[1]

Abstract 'To play or to display' is the dilemma that museums have to face, given the increasing trend towards historically informed performance. Brass instruments can suffer corrosion both during and after playing due to the high humidity inside them. To forestall or at least reduce corrosion, drying with a fan has been chosen as a preventive measure. The state of corrosion inside the tuning slides of the instruments was determined with a specially developed electrochemical sensor. The results of the project show that drying with a fan indeed reduces ongoing corrosion, when compared to a group of instruments played without preventive measures that showed an increasing corrosion rate over time.

Introduction Brass, a copper-zinc alloy, has been used to make wind instruments since the 16th century, mainly due to its very good acoustic properties, the ease of manufacturing instruments with it, and its good resistance to corrosion. Historical brass instruments are conserved in museums or collections such as the Burri collection in Bern,[2] which has more than a thousand instruments. The increasing importance of historically informed performance practice (HIP)[3] has resulted in these original instruments being played in concerts. Private and public instrument collections and museums are being forced to confront the issues that can be summarised as 'to play or to display' – should instruments be displayed only in museum cases, or should they be subjected to 'normal' concert use ? The overall goal of the project "Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance

1 The Swiss National Science Foundation (SNSF) is acknowledged for financing the project "Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice" CR12I1_146330/1. The Italian Ministry of University and Research (MIUR) is thanked for financing the PRIN project prot. 2010329WPF_005 "Sustainability in cultural heritage: from diagnosis to the development of innovative systems for consolidation, cleaning and protection". The Sardinian Regional Government is gratefully acknowledged for financial support (P.O.R. Sardegna F.S.E. Operational Program of the Regione Autonoma della Sardegna, European Social Fund 2007–2013 – Axis IV Human Resources, Objective 1.3, Line of Activity 1.3.1 "Avviso di chiamata per il finanziamento di Assegni di Ricerca").

2 Today part of the Klingendes Museum Bern, www.klingendes-museum-bern.ch (all links in this article last consulted 18 October 2022).

3 See e.g. John Butt: *Playing with History. The Historical Approach to Musical Performance*, Cambridge 2002.

DOI: 10.26045/kp64-6179-005

practice"[4] is to examine the corrosion phenomena in historical instruments currently being used, and to present an appropriate set of recommendations for their conservation and usage.

The main concern on the part of museums and conservators is corrosion in historical brass instruments due to the high humidity inside the instruments caused by playing.[5] Indeed, measurements made during this project have shown that after five minutes of playing, the relative humidity (RH) inside brass instruments exceeds 90 %. It takes several days to reach ambient RH again afterwards.[6] This means that when instruments are played regularly, a thin film of water can be present inside them for quite a long time, meaning that long-term corrosion damage can occur. It is well known that in outdoor atmospheric corrosion, the 'time of wetness' (the time during which a water film is present on the metal surface) controls corrosion intensity. The working hypothesis for preventive conservation of these instruments was thus to reduce the time of wetness by drying them with a fan.

Any preventive conservation measure aiming to control the conditions inside historical brass instruments must, however, be tested and monitored for its efficiency. Conservators need a tool for obtaining the relevant information on the corrosion rate inside the instruments in a rapid, non-destructive way. As corrosion is an electrochemical process,[7] electrochemical techniques are our methods of choice. We shall here present an electrochemical in-situ sensor for corrosion rate measurement inside the tuning slides that is intended to help us monitor the effectiveness of preventive conservation. Parts of this summary paper have already been published in scientific journals.[8]

4 For details, see www.hkb-interpretation.ch/projekte/korrosion and the text by Adrian von Steiger in this volume, pp. 32–47.

5 Einar Mattsson/Rolf Holm: Atmospheric Corrosion of Copper and Its Alloys, in: *Atmospheric Corrosion*, ed. by William H. Ailor, New York a. o. 1982, pp. 365–392.

6 See the article by Martin Ledergerber, Emilie Cornet and Erwin Hildbrand in this volume (pp. 48–60).

7 See R. Winston Revie/Herbert Henry Uhlig: *Corrosion and Corrosion Control. An Introduction to Corrosion Science and Engineering*, New York a. o. 2008, pp. 9–19.

8 Bernhard Elsener/Federica Cocco/Marzia Fantauzzi/Silvia Palomba/Antonella Rossi: Determination of Corrosion Rate Inside Historical Brass Wind Instruments. Proof of Concept, in: *Materials and Corrosion* 67 (2016), pp. 1336–1343, https://doi.org/10.1002/maco.201608996; Bernhard Elsener/Marion Alter/Tiziana Lombardo/Martin Ledergerber/Marie Wörle/Federica Cocco/Marzia Fantauzzi/Silvia Palomba/Antonella Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion Inside Historical Brass Wind Instruments, in: *Microchemical Journal* 124 (2016), pp. 757–764, https://doi.org/10.1016/j.microc.2015.10.027; Federica Cocco/Marzia Fantauzzi/Bernhard Elsener/Antonella Rossi: Dissolution of Brass Alloys Naturally Aged in Neutral Solutions. An Electrochemical and Surface Analytical Study, in: *RSC Advances* 6 (2016), pp. 90654–90665, https://doi.org/10.1039/c6ra18200c.

Corrosion basics In general, copper and brass alloys are quite resistant to atmospheric corrosion due to the formation of protective layers of corrosion products, which greatly reduce the rate of attack.[9] If we wish to monitor the efficiency of a preventive action to reduce corrosion, electrochemical measurements are best suited to determining the corrosion state and the instantaneous corrosion rate of an alloy in a given environment.

Rather like a battery, corrosion reactions are redox reactions composed of oxidation (anode) and a reduction reaction (cathode):

Oxidation: $2\,Zn \rightarrow 2\,Zn^{2+} + 4\,e^-$ (1a)

Reduction: $O_2 + 2\,H_2O + 4\,e^- \rightarrow 4\,OH^-$ (1b)

The electrons released at the anode have to be consumed immediately by the cathodic reaction to maintain electro-neutrality, thus the anodic dissolution current and the cathodic current must be equal (Figure 1) and correspond to the corrosion current.

Of the information contained in Figure 1, only the corrosion potential ϵ_{corr} can be measured experimentally. The corresponding corrosion current density i_{corr} flowing in the system is short-circuited, thus the current measured from external I = 0. However, i_{corr} can be indirectly determined by measuring the polarisation resistance Rp, the inverse of the current versus potential curve close to the corrosion potential ϵ_{corr} (insert in Figure 1).

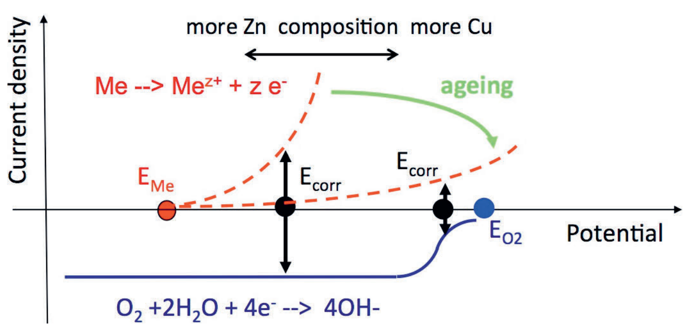


FIGURE 1 Schematic current density – potential curves for brass in neutral solutions. With time of immersion (ageing) the corrosion rate decreases and ϵ_{corr} moves to more positive potentials. ϵ_{corr} establishes at the point of electro-neutrality.

From the measured polarisation resistance Rp, the corrosion current density i_{corr} can be calculated with the Stern-Geary relation[10] that holds for uniform corrosion.

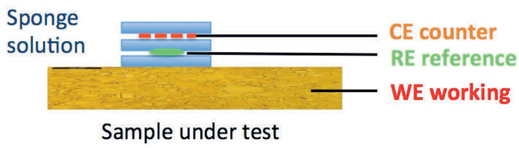
$i_{corr} = B/Rp$ (2)

The constant B in equation (2) depends on the specific system under test; a value of 26 mV for B has been assumed in this work.

9 Mattsson/Holm: Atmospheric Corrosion of Copper and Its Alloys.
10 Revie/Uhlig: *Corrosion and Corrosion Control*, pp. 53–82.

Finally, the loss in thickness or the corrosion rate v_{corr} (in µm/year) can be calculated using Faraday's law. The resulting conversion factor for pure copper is 12, thus 1 µA/cm^2 corresponds to 12 µm/year. This procedure is valid for general corrosion as it occurs on brass alloys in neutral electrolytes.

The electrochemical sensor A dedicated electrochemical sensor was developed to perform the electrochemical measurements inside the historical brass instruments, open circuit potential and polarisation resistance. The sensor combined an Ag/AgCl solid-state reference electrode and a small platinum grid as counter electrode, both embedded in a thin sponge (Figure 2a). The first prototype of the sensor had a surface of about 2 cm^2 (1.5 × 1.5 cm) and was used in the proof of concept for flat samples only (Figure 2b).[11] A further development consisted of a tubular sensor mounted on a thin plastic tube to insert the sensor in the brass instruments.[12]



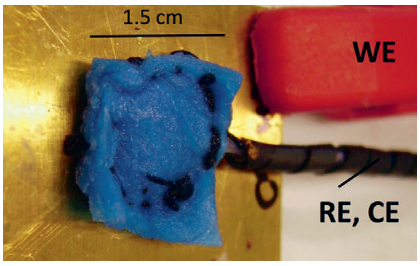


Figure 2 a) Schematic drawing of the sensor for electrochemical measurements on flat samples. The sponge is circa 1.5 × 1.5 cm (area 2 cm^2). Thickness circa 2 mm. b) Photograph of the sensor used on flat brass samples

This tube allowed us to slightly inflate a small balloon mounted at its end and to press the sensor gently against the inside of the tuning slide. When the measurement at one point was completed, the air pressure was released and the sensor was moved to the next measuring position without scratching the inside of the instrument part.

The flat sensor was tested on two model brass alloys (CuZn18 and CuZn37) in different surface states. In order not to alter the surface being tested, a non-aggressive phosphate buffer solution (pH 7) with a small amount of NaCl was used. The results of corrosion potential E_{corr} and polarisation resistance Rp measured with the sensor were comparable to the results obtained in the traditional electrochemical cell as is shown in Figure 3. Freshly polished samples show the lowest Rp values (10–20 kΩcm^2) corres-

11 Elsener/Cocco/Fantauzzi/Palomba/Rossi: Determination of Corrosion Rate.

12 Elsener/Alter/Lombardo/Ledergerber/Wörle/Cocco/Palomba/Fantauzzi/Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion.

ponding to the highest corrosion rate of about 30 µm/year; the 'as received' Cu18Zn brass alloy showed Rp values of around 80 kΩcm^2, corresponding to a corrosion rate of 4 µm/year. On an old mouthpiece, the corrosion rate was found to be 0.4 µm/year. Note that these are the initial corrosion rates. After longer contact with the solution, the values decrease by about a factor of 10.[13] Overall, despite some scatter in the individual results, a linear correlation with a slope of about 0.95 was found between the corrosion rate measured with the sensor and in the electrochemical cell, indicating that the sensor was working properly and reproduced the exposure situation of a traditional electrochemical cell. The accuracy is good and can be estimated to be about ±20 % over two orders of magnitude.[14]

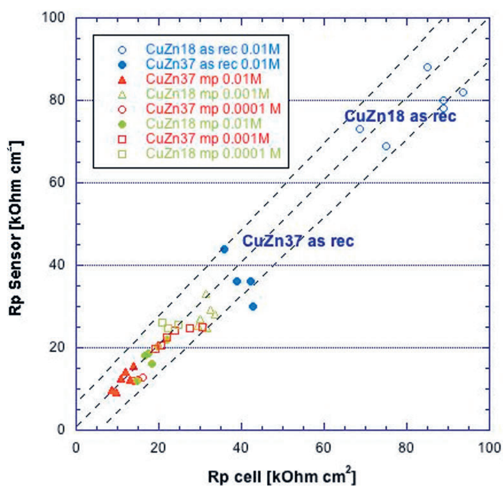


Figure 3 Correlation of the specific polarisation resistance, Rp, measured by the sensor, versus the specific Rp measured using the electrochemical cell. Phosphate buffer solution pH 7 with chloride concentrations from 10^{-4} to 10^{-2} M NaCl. Materials CuZn37 and CuZn18, surface condition 'as received' and mechanically polished[15]

Results from historical instruments In order to assess the preventive conservation (using a fan to dry the instruments after playing), measurements with the sensor were performed before, halfway through and at the end of the testing period of 14 months, in all the 34 tuning slides of the 16 instruments. In total, this came to 102 individual measurement positions. We present here the results of four selected horns (Table 1) from two different manufacturers, Raoux-Millereau, Paris (F) and Couesnon, Paris (F).[16]

Description of the brass instruments (horns) These instruments were manufactured between 1900 and 1932. In a previous project it was found that manufacturers used

13 Cocco/Fantauzzi/Elsener/Rossi: Dissolution of Brass Alloys, p. 90662.
14 Elsener/Cocco/Fantauzzi/Palomba/Rossi: Determination of Corrosion Rate, p. 1341.
15 Ibid, p. 1342.
16 See also Elsener / Alter / Lombardo / Ledergerber / Wörle / Cocco / Palomba / Fantauzzi / Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion, p. 758.

different alloys for different parts of the instruments, for reasons that might be related to the different quality of the sound and also according to alloy availability.[17] So the overall variation of the composition (Table 1) is quite large. All these instruments were bought between 2011 and 2013 and have been stored at the Burri collection since then. With the exception of 5024, they were cleaned at a workshop shortly after purchase by immersing the instruments in a citric acid bath (Cuproten) accompanied by fine brushing with a nylon brush, followed by neutralisation in a sodium carbonate (Na_2CO_3) solution. The inside of instrument 5024 has not been cleaned in the past 30–50 years. Only exterior stains were removed, and the pistons were cleaned mechanically.

TABLE 1 The four instruments (horns) used in the investigation. The range of compositions (wt%) determined by XRF is provided.[18]

Instrument	Manufacturer	Year	Condition	XRF composition (wt%)
HKB 5004	Couesnon, Paris	1922	Cleaned in 2011/2012	Cu: 60–76 Zn: 22–37
HKB 5009	Raoux-Millereau, Paris	1900	Cleaned in Dec 2012	Cu: 64–69 Zn: 30–35
HKB 5024	Couesnon, Paris	1932	no cleaning	Cu: 61–74 Zn: 22–38
HKB 5025	Couesnon, Paris	1910	Cleaned in 2013/2014	Cu: 62–73 Zn: 26–38

Condition assessment with the sensor before playing Measurements of corrosion potential were made in-situ with the tubular sensor (Figure 4), and readings were taken every 1 cm from the entrance on both sides of the tuning slide. After the sensor was pressed against the tube with the small balloon and electrolytic contact had been established, readings of the corrosion potential were taken after 0.5, 1 and 2 minutes at each point. Examples of the results obtained on three different tuning slides are shown in Figure 5. No systematic variations of the corrosion potential were found except the clearly lower ϵ_{corr} values at points of soldering.

The points for polarisation resistance (Rp) measurements were selected on the basis of the corrosion potential recorded previously. Rp measurements were performed in areas with quite homogeneous corrosion potential over several centimetres and were begun 2–5 minutes after contact with the sensor.

17 See Marianne Senn/Hans J. Leber/Martin Tuchschmid/Naila Rizvic: Blechblasinstrumentenbau in Frankreich im 19. Jahrhundert. Analysen von Legierung und Struktur des Messings zugunsten eines historisch informierten Instrumentenbaus, in: *Romantic Brass. Französische Hornpraxis und historisch informierter Blechblasinstrumentenbau. Symposium 2*, ed. by Daniel Allenbach, Adrian von Steiger and Martin Skamletz, Schliengen 2016, pp. 398–419.

18 See also Elsener/Alter/Lombardo/Ledergerber/Wörle/Cocco/Palomba/Fantauzzi/Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion, p. 760.

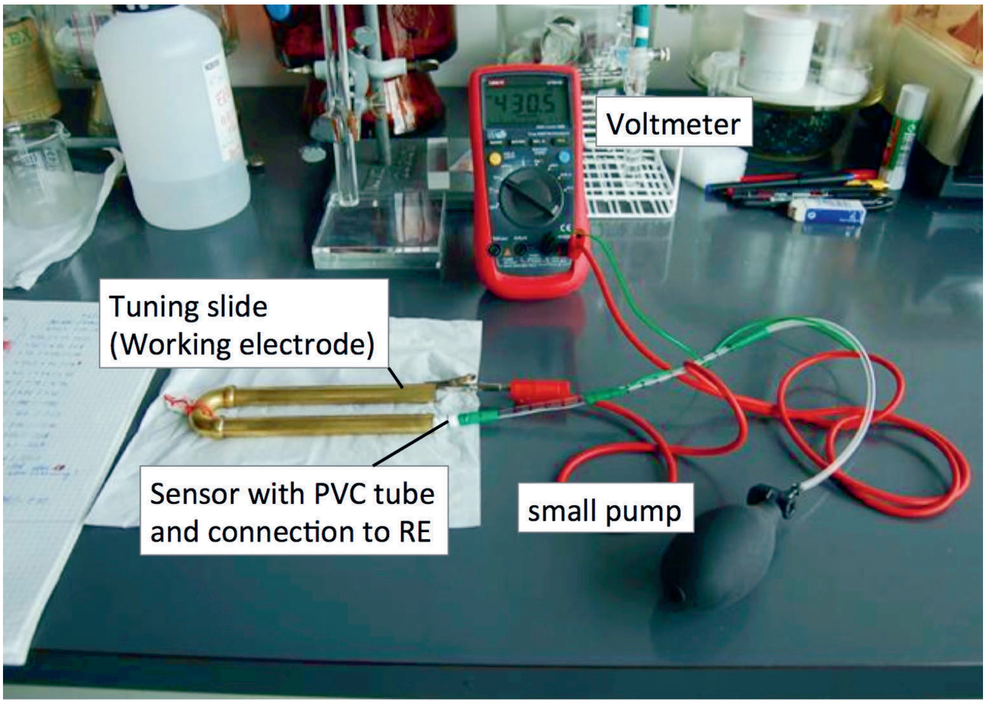


FIGURE 4 Experimental arrangement for the in-situ measurements of corrosion potential and polarisation resistance, using the tubular sensor

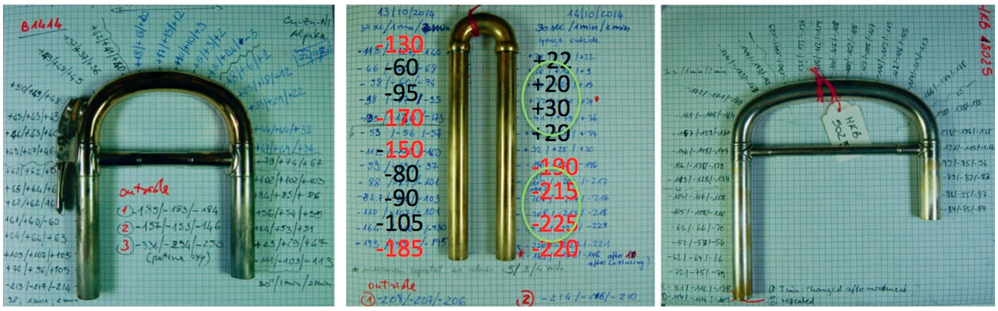


FIGURE 5 Results of corrosion potential measurements performed with the sensor inside the tuning slides. The numbers here indicate the potential measured at a given position after 30 seconds, 1 and 2 minutes. Measurements were taken at a distance of 1 cm in the left and right arm of the tuning slide. Potential of the sensor vs Ag/AgCl sat = -170 ±10 mV.
a) HKB 5004.2 – b) HKB 5009.2 – c) HKB 5025.1

The results of the Rp measurements of the nine tuning slides from the four different instruments show great variations, both within individual tuning slides, and even more among different tuning slides.[19] Overall, no influence by the composition or cleaning procedure can be observed. The polarisation resistance thus allows us to determine the instantaneous corrosion rate at the point of measurement. However, no precise indication of the corrosion state (the reason why Rp is higher or lower) is possible.

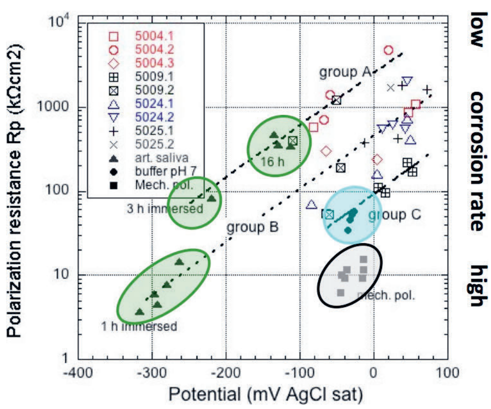


FIGURE 6 **Diagnostic plot of the specific polarisation resistance Rp versus corrosion potential E_{corr} of nine different tuning slides (25 measurement points) of the four horns measured before playing the instruments. Included in the plot are data obtained on the Cu37Zn model alloy immersed for 1, 3 and 16 hours in artificial saliva (▲),[20] data from all the model alloys in a mechanically polished surface state (■), and data from all the model alloys immersed for one hour in the buffer solution pH 7 without chlorides (●).[21]**

Diagnostic plot log Rp versus E_{corr} All the individual pairs E_{corr}/Rp measured at different positions in the tuning slides of the four horns (Table 1) are plotted in a log Rp versus E_{corr} diagram (Figure 6); combining the information from the corrosion potential and the corrosion rate allows us to rationalise the data. Indeed, three different groups of data (indicated by a diagonal line) can be found: *group* A with high to very high Rp values over the whole potential range are found for tuning slide HKB 5004.2, but also single points of HKB 5009.2 and HKB 5004.1 fall into this group. This group of data reflects situations with very high Rp values/very low corrosion rates inside the tuning slides. A much larger group (indicated as *group* B) shows Rp values about a factor of 10 lower than group A (with a corrosion rate a factor of 10 higher). The tuning slides HKB 5024.1 and 5024.2 and HKB 5025.1 belong to this group, as do two points of HKB 5004.1 and one of HKB 5004.3. A third group (*group* C) can be found in the range of 50–200 kΩcm^2, thus at quite low values of Rp. The tuning slides of HKB 5009.1 belong to this group.

19 See ibid, p. 761.

20 Federica Cocco: *Comportamento elettrochimico e analisi XPS e XAES di leghe di ottone per la produzione di strumenti musicali del XIX secolo* [Electrochemical and XPS/XAES Surface Analytical Investigation of Brass Alloys of Musical Instruments of the 19th Century], Master Thesis, University of Cagliari, 2013.

21 Silvia Palomba: *Indagine elettroanalitica del rame, dello zinco e di leghe di Ottone* [Electrochemical Investigation of Copper, Zinc and Brass Alloys], Master Thesis, University of Cagliari, 2015.

The three groups A, B and C can be described each with a diagonal line with slope circa 160 mV per decade Rp. For a given (constant) environment characterised by pH value and oxygen content (in the sensor sponge), the surface state and the alloy composition give rise to systematic and correlated variations of both ϵ_{corr} and Rp, showing that Rp increases (corrosion rate i_{corr} decreases) with increasing potential. However, the data from inside the tuning slides lack any information on the surface composition.

Correlation to the surface state The comparison with data from well-controlled laboratory experiments where the surface state is known substantiates the ϵ_{corr}/Rp results obtained inside the tuning slides. Three sets of data have been included in Figure 6.

The *first set of data* refers to the mechanically polished CuZn37 model alloy exposed to artificial saliva.[22] One can note that after 1 hour of immersion, the data points fall on the line of group B, after 3 and 16 hours respectively of immersion the ϵ_{corr}/Rp data points instead fall on the line of group A. XPS surface analysis performed on the samples after 16 hours of immersion in artificial saliva documented the formation of a surface film composed of CuSCN and $Zn_3(PO_4)_2$.[23] This surface film has protective properties and increases Rp, thus strongly lowers the corrosion rate.

The *second data set* refers to mechanically polished brass alloys exposed for 1 hour in the buffer solution pH 7 (no chloride ions).[24] One can note that these ϵ_{corr}/Rp data fall on the line of group C; we may assume the formation of a non-protective surface film.

The *third set of data* refers to measurements with the sensor on mechanically polished brass alloys. The Rp values are very low (circa 10 kΩcm^2), indicating a very high corrosion rate of these freshly polished samples where practically the bare alloy is exposed to the solution.

Combining data from well-controlled laboratory experiments where XPS surface analysis was performed[25] with the ϵ_{corr}/Rp results obtained inside the tuning slides (Figure 6) allows for the following tentative interpretation: The surface condition of samples lying on *line* A can be assumed to show a protective surface film similar (or much more protective) to that formed upon immersion in artificial saliva for 16 hours. The Rp values are generally high to very high and the corrosion rates correspondingly low to very low. The surface condition of samples lying on *line* B can be assumed to present a more or less thick oxy-hydroxide film, formed after prolonged air exposure or in the initial

22 Cocco: *Comportamento elettrochimico.*

23 See Cocco/Fantauzzi/Elsener/Rossi: Dissolution of Brass Alloys; Cocco: *Comportamento elettrochimico.*

24 Palomba: *Indagine elettroanalitica.*

25 Cocco/Fantauzzi/Elsener/Rossi: Dissolution of Brass Alloys; Cocco: *Comportamento elettrochimico*; Palomba: *Indagine elettroanalitica.*

phases of immersion in artificial saliva.[26] Rp values compared to *line* A are clearly lower, thus the corrosion rates are higher. Samples lying on *line* C could be points where a nearly bare surface is present. A mechanistic interpretation based on the effect of surface composition on the rate of the oxygen reduction reaction has been proposed.[27]

Efficiency of preventive conservation The tuning slides of 16 brass instruments of different age, conservation conditions and state of cleaning[28] were characterised with corrosion potential and polarisation resistance (Rp) measurements before the playing period began, and after 7 and 14 months (for the procedure, see above). During the playing period, the instruments were played daily for at least 5 minutes (with some exceptions) in order to increase the humidity inside the instrument. One group of musicians used only conventional measures (emptying valves to drain condensed water), while the second group used a fan to ventilate the instrument with air in order to dry it out (preventive conservation).

The results of the measurements constitute a huge amount of data and are presented here as a cumulative probability plot, a statistical analysis for any distributed values. Note that a normal Gaussian distribution in a histogram results in a straight line in the cumulative probability plot. The following groups have been created:

- instruments before playing started
- instruments without preventive conservation, after 7 months and after 14 months
- instruments with preventive conservation, after 7 months and after 14 months

Instruments without preventive conservation The statistical analysis in the cumulative probability plot of the instruments (tuning slides) without preventative conservation measures is presented in Figure 7a. It can be noted that the average of polarisation resistance after 14 months of playing is slightly lower (shifted to the left) compared to the average Rp before. This indicates that the *average* corrosion rate measured (which value can be read at the 50 % level) was about a factor two higher after a 14-month playing period than could be expected by the high humidity inside the instruments. The lines at the three measuring times (0, 7, 14 months) are nearly parallel, indicating that the standard deviation remained the same.

26 Cocco: *Comportamento elettrochimico.*

27 Elsener/Alter/Lombardo/Ledergerber/Wörle/Cocco/Palomba/Fantauzzi/Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion.

28 See the article by Adrian von Steiger in this volume, pp. 32–47.

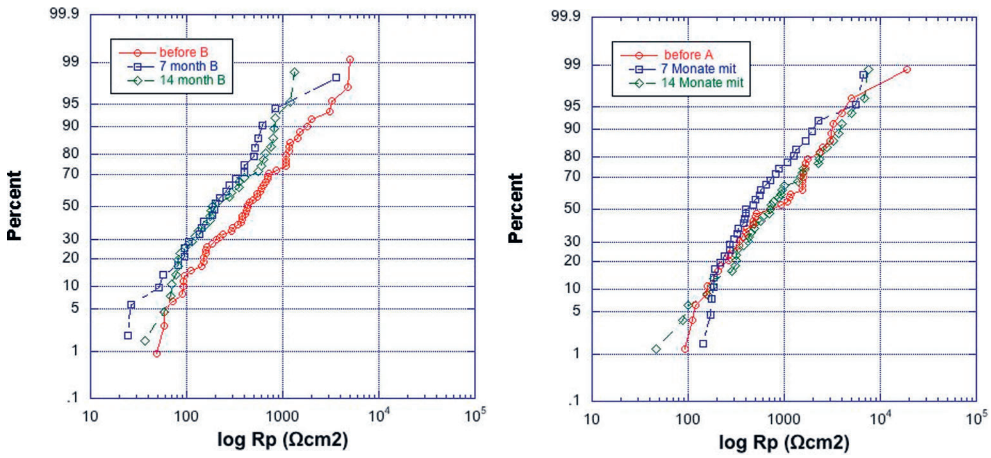


FIGURE 7 Statistical analysis (cumulative probability plot) of the polarisation resistance Rp measured in the different tuning slides of the brass instruments before, after 7 months and after 14 months of playing. Left: without preventive conservation; right: with preventive conservation (drying with a fan)

Instruments with preventive conservation When we compare the Rp measurements in the tuning slides of instruments with prevention conservation before, after 7 months and after 14 months (Figure 7b), we see that the average of the Rp values remained approximately constant (the green curve, 14 months, is identical to the red curve, 0 months). This indicates that the average corrosion rate measured in the tuning slides did not change with time; drying with the fan as a preventive conservation measure was thus effective in preventing the onset of more rapid corrosion such as was observed in the tuning slides without preventive conservation (Figure 7a).

To evaluate a change in the polarisation resistance value at the *individual* measuring points in the tuning slides of the different instruments, a simpler analysis procedure was used ("traffic light"), similar to the evaluation of the endoscope measurements:[29]

- "green" – Rp values are constant (within ±20%)
- "orange" – no clear trend in the Rp values over time
- "red" – the Rp values decrease over playing time

Based on this analysis, instruments with preventive conservation showed 70% of the values "green" and 20% "orange". Instruments without prevention instead showed 70% of the values "red" and 20% "orange". Thus, also based on an analysis of the individual tuning slides, it can be clearly shown that the preventive measure of drying the instrument with a fan after playing is effective.

29 See the article on endoscopy by Martin Ledergerber in this volume, pp. 92–96.

Conclusions The non-destructive electrochemical sensor for in-situ measurements inside the tuning slides of historical brass instruments worked well; the same results were obtained on model alloys as with conventional electrochemical measurements.

The results of the measurements before the playing period showed a great variation in the rate and state of corrosion inside the tuning slides and among the instruments; for this reason, statistical analysis (cumulative probability plots) had to be used.

After 14 months of playing, the two groups of instruments ‘without prevention’ and ‘with prevention’ could clearly be distinguished: inside the tuning slides of instruments where the drying procedure had been applied, the corrosion rate was the same as before, or increased only slightly. On the contrary, inside the tuning slides of instruments without this preventative procedure, the corrosion rate increased over time, on average by a factor of two.

As a scientific result, the diagnostic plot ‘log Rp versus ϵ_{corr}’ allows us to group the individual measurement points and to allocate them to very low, low and medium-high corrosion rates. The reason why individual measurement points belong to which group can be found in the thickness and composition of the surface film inside the brass instruments.

Federica Cocco / Marzia Fantauzzi / Bernhard Elsener / Antonella Rossi

How Surface Analysis Can Contribute to an Understanding of the Preventive Conservation of Brass Instruments[1]

Abstract Historical brass instruments can suffer corrosion during and after playing due to the high degree of humidity inside – but the surface chemistry inside the tuning slides remains essentially unknown. Based on a series of previously published works of the present authors, this paper describes in a comprehensive way how ex-situ XPS surface analytical measurements can shed light on this topic. On freshly polished brass samples exposed to model solutions such as artificial saliva, a thick, polycrystalline surface film composed of copper-thiocyanate and zinc phosphate is formed, whereas in a phosphate buffer solution only a thin film composed of copper and zinc oxy-hydroxide and zinc phosphate is present. 'As received' brass samples from old instruments showed quite a thick surface film of copper and zinc oxy-hydroxide that protects the alloy beneath from corrosion. In combination with the in-situ electrochemical results, a first, tentative identification of the surface film inside the tuning slides can be offered.

Introduction Brass instruments of the nineteenth and early twentieth centuries are being played more and more often for purposes of historically informed performance practice. In the case of a brass instrument, a musician's hot, wet breath could worsen the instrument's interior corrosion, but little is known about this danger. The corrosion state inside these historical brass instruments before and after being played has been monitored using electrochemical methods in order to check the efficiency of preventive conservation protocols.[2] The measurements inside the tuning slides, however, lack any

1 The Swiss National Science Foundation (SNSF) is acknowledged for financing the project "Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice" CR12I1_146330/1. The Italian Ministry of University and Research (MIUR) is thanked for financing the PRIN project prot. 2010329WPF_005 "Sustainability in cultural heritage: from diagnosis to the development of innovative systems for consolidation, cleaning and protection". The Regional Government of Sardinia is gratefully acknowledged for financial support (P.O.R. Sardegna F.S.E. Operational Program of the Regione Autonoma della Sardegna, European Social Fund 2007–2013 – Axis IV Human Resources, Objective 1.3, Line of Activity 1.3.1 "Avviso di chiamata per il finanziamento di Assegni di Ricerca").

2 Bernhard Elsener / Marion Alter / Tiziana Lombardo / Martin Ledergerber / Marie Wörle / Federica Cocco/Marzia Fantauzzi/Silvia Palomba/Antonella Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion Inside Historical Brass Wind Instruments, in: *Microchemical Journal* 124 (2016), pp. 757–764, https://doi.org/10.1016/j.microc.2015.10.027; Bernhard Elsener / Federica Cocco / Marzia Fantauzzi/Silvia Palomba/Antonella Rossi: Determination of Corrosion Rate Inside Historical Brass

DOI: 10.26045/kp64-6179-006

information on the surface state and composition at the point of measurement (except for endoscope images). In order to correlate the results of electrochemical measurements with the surface state and composition, information from surface analytical experiments on model alloys in controlled environments is required.

In this chapter, we report on the results of an x-ray photoelectron spectroscopy (XPS/XAES) surface investigation of brass (Cu-Zn alloy) model samples that have been exposed both to a mild environment (phosphate buffer pH 7) and to a quite aggressive solution (artificial saliva) that represent the two extremes of liquids that can be present in the tuning slides after playing. Brass alloys exposed to the phosphate buffer solution show a rapid formation of a thin film composed of copper and zinc oxide that limits the corrosion rate but is not protective. With the artificial saliva solution, the corrosion rate of brass is initially very high, but decreases rapidly to values below 1 μm/year. XPS surface analysis has shown the formation of a thick protective film of CuSCN (thiocyanate) and zinc phosphate.[3]

Combining electrochemical and surface analytical data obtained on model brass alloys allows us to rationalise the different corrosion behaviour found in the tuning slides of the brass instruments.[4] We here investigate the link between electrochemical behaviour and the surface composition of brass alloys exposed to the atmosphere or to the environment present in the tuning slides.

XPS surface analysis X-ray photoelectron spectroscopy (XPS) has its roots in nuclear physics research and attracted major interest in 1964 when it was first demonstrated that chemical-state information could be obtained by measuring the kinetic energy of electrons emitted by a sample irradiated with soft x-rays. Since then, enormous progress has been made to improve the quality of spectrometers, standards of operation, and procedures for quantification. XPS is a non-destructive technique that combines high sensitivity with chemical-state identification. This technique is well suited for obtaining the quantitative composition of nanometre thick surface films.

The principle X-ray photoelectron spectroscopy (XPS) is based on the photoelectric effect: photons of an adequate energy hν ionise atoms in the sample, resulting in the

Wind Instruments. Proof of Concept, in: *Materials and Corrosion* 67 (2016), pp. 1336–1343, https://doi.org/10.1002/maco.201608996; and the article by Bernhard Elsener et al. in this volume, pp. 61–72.

3 Federica Cocco/Marzia Fantauzzi/Bernhard Elsener/Antonella Rossi: Dissolution of Brass Alloys Naturally Aged in Neutral Solutions. An Electrochemical and Surface Analytical Study, in: RSC *Advances* 6 (2016), pp. 90654–90665, https://doi.org/10.1039/c6ra18200c.

4 See the article by Bernhard Elsener et al. in this volume, pp. 61–72.

emission of core-level electrons. Photo-ionisation comprises (Figure 1): (1) photon absorption, (2) electron emission, (3) move of the electron within the solid toward the surface, and (4) escape of the electron from the solid into the vacuum of the spectrometer.

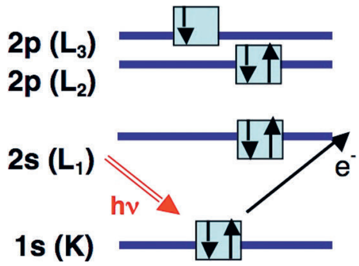


FIGURE 1 Schematic of the photoemission process. The X-radiation of energy, hν, ejects a photoelectron from the K level (XPS notation 1s)

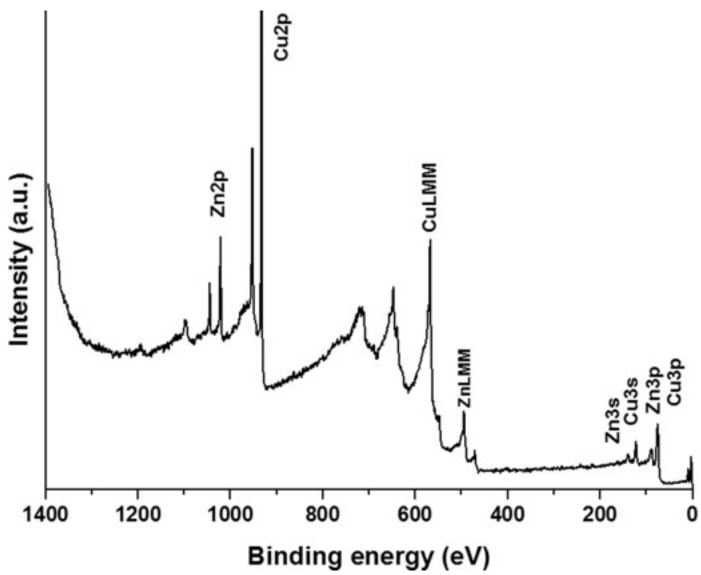


FIGURE 2 Survey spectrum of a CuZn37 brass model alloy after sputtering in UHV. Core levels: copper Cu2p, zinc Zn2p. Outer levels: Zn3p, Zn3s, Cu3p, Cu3s. X-ray excited Auger electrons: CuLMM and ZnLMM (reproduced with permission from the Royal Society of Chemistry)

According to the principle of conservation of energy, the sum of the energy of the initial state E^i plus the photon energy, hν, is equal to the sum of the energy of the final E^f state plus the kinetic energy of the emitted photoelectron, KE. Rearranging this, one obtains the binding energy, BE, of the photoelectron from equation (1) (the difference in energy between the final and the initial state) as the difference between the energy of the incident beam minus the kinetic energy of the emitted photoelectron.

$$BE = h\nu - KE = E^f - E^i \qquad (1)$$

As each element has characteristic core-electron binding energies, it will emit photoelectrons with a characteristic kinetic energy for a given photon energy. Element identification can thus be accomplished by recording the photoelectron energy distribution (spectrum), which will show peaks corresponding to different elements. As an example, the survey spectrum of a CuZn37 brass alloy after ion etching is shown in Figure 2. The spectrum recorded exhibits photoelectron signals attributable to photoemission from core levels of copper (Cu2p), zinc (Zn2p), to photoemission from outer levels (Cu3s, Cu3p, Zn3s, Zn3p), from the valence region (Cu3d and Zn3d with Cu4s and Zn4s) and peaks due to X-ray-excited Auger emission (CuLMM, ZnLMM). Filling the core vacancy with an electron originating from an outer level generates other electrons, known as Auger electrons, that emit no radiation. It should be noted that the photoelectron peaks are narrower and simpler than the Auger signals. The background increases on the low-kinetic-energy side (high-BE side) of the peaks due to the occurrence of inelastic photo-emission. The acronym ESCA (electron spectroscopy for chemical analysis) emphasises the fact that both photoelectron *and* Auger electron peaks appear in the 'XPS' spectrum.

Chemical State Information The difference in binding energy between the same atom, either in two chemically different sites in the same compound or in two different compounds, is referred to as the 'chemical shift'. Many factors can contribute to the chemical shift, and usually its interpretation is accomplished on an empirical basis. A description of chemical shift theory is given in the literature.[5]

From an analytical point of view, it is very useful to compare the measured binding energy for the unknown element with the binding energy of a reference compound, measured under the same experimental conditions. Tables of peak positions may be found in the literature and a database is available from NIST.[6] However, as in the case for copper and zinc, the identification of the chemical state of an element based on binding energy alone is not always possible.[7] Other features of the XPS spectra have to be examined, such as the presence of shake-up satellites or the chemical shift of the X-ray-excited Auger lines combined with that of the correspondent photoelectron peak binding energy in a two-dimensional Wagner plot.[8]

5 See William F. Egelhoff: Core Level Binding Energy Shifts at Surfaces and in Solids, in: *Surface Science Reports* 6/6–8 (1987), pp. 253–415, https://doi.org/10.1016/0167-5729(87)90007-0.

6 Alexander V. Naumkin/Anna Kraut-Vass/Stephen W. Gaarenstroom/Cedric J. Powell: NIST *Standard Reference Database* 20, Version 4.1, https://doi.org/10.18434/T4T88K, accessed August 2019.

7 Federica Cocco/Bernhard Elsener/Marzia Fantauzzi/Davide Atzei/Antonella Rossi: Nanosized Surface Films on Brass Alloys by XPS and XAES, in: RSC *Advances* 6 (2016), pp. 31277–31289, https://doi.org/10.1039/C5RA23135C.

8 Ibid.; see also Giuliano Moretti: Auger Parameter and Wagner Plot in the Characterization of Chemical States by X-Ray Photoelectron Spectroscopy. A Review, in: *Journal of Electron Spectroscopy and Related Phenomena* 95 (1998), pp. 95–144, https://doi.org/10.1016/S0368-2048(98)00249-7.

Instrumentation A basic block diagram of an x-ray photoelectron spectrometer is given in Figure 3. It consists of an ultra-high vacuum chamber equipped with an x-ray source, usually MgKα (1253.6 eV) and/or AlKα (1486.6 eV), which can also be monochromatic, a lens system that collects the photo-ejected electrons, an energy analyser, a detector, and a system suitable for displaying signal intensity as a function of the kinetic or binding energy. The electron-energy analyser is the heart of the system; its task is to measure the electron energy spectrum.

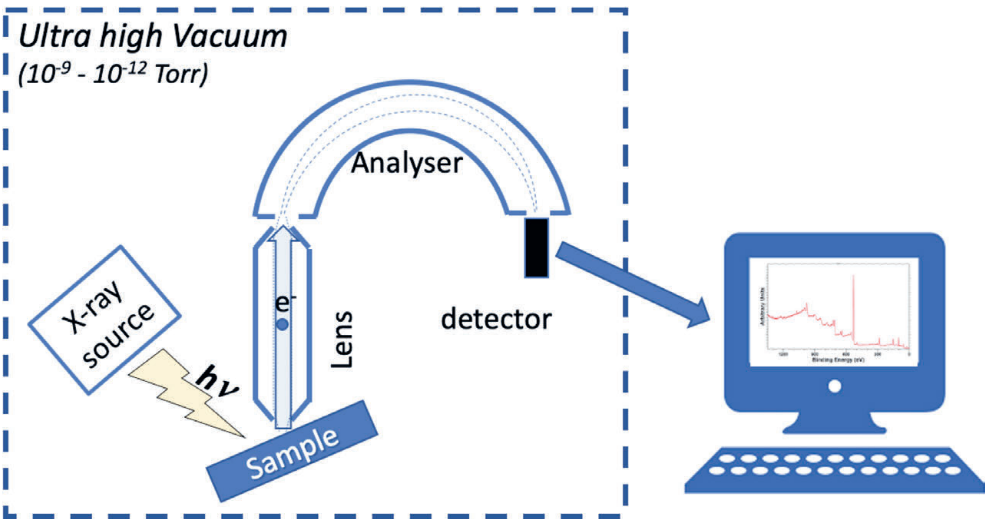


FIGURE 3 Block diagram of a basic XPS instrument

Older spectrometers have poor lateral resolution; however, with recent generation imaging photoelectron spectrometers, lateral resolution down to about 3 μm can be achieved. XPS imaging offers new opportunities compared to existing surface-analysis techniques.

Copper, zinc and brass alloys For copper, zinc and brass alloys, the above outlined approach based on the binding energy to determine the chemical state is very difficult because the chemical shift between the metallic state and the oxidised one is very small.[9] A close inspection of the shape of the x-ray-induced Auger signals $CuL_3M_{4,5}M_{4,5}$ and $ZnL_3M_{4,5}M_{4,5}$, together with the use of the Auger parameter, greatly improves the

9 See Mark C. Biesinger/Leo W. M. Lau/Andrea R. Gerson/Roger St. C. Smart: Resolving Surface Chemical States in XPS Analysis of First Row Transition Metals, Oxides and Hydroxides: Sc, Ti, V, Cu and Zn, in: *Applied Surface Science* 257 (2010), pp. 887–898, https://doi.org/10.1016/j.apsusc.2010.07.086.

assignment of the chemical state for both copper and zinc.[10] A detailed study analysing sputter-cleaned, mechanically polished and 'as received' copper, zinc and Cu37Zn brass alloys[11] provides the basis for the surface analysis of model brass alloy samples and samples from old instruments used in this work.

Auger signals of pure elements copper and zinc (metal and oxide) The Auger signals of metallic copper and copper oxide Cu_2O show a chemical shift of about 1.7 eV and the shape of the spectra are different (Figure 4); the same holds for metallic zinc and zinc oxide ZnO with a chemical shift of 4.0 eV. Thus, based on the Auger signals, it is possible to distinguish and identify metallic and oxidised components on the same sample.

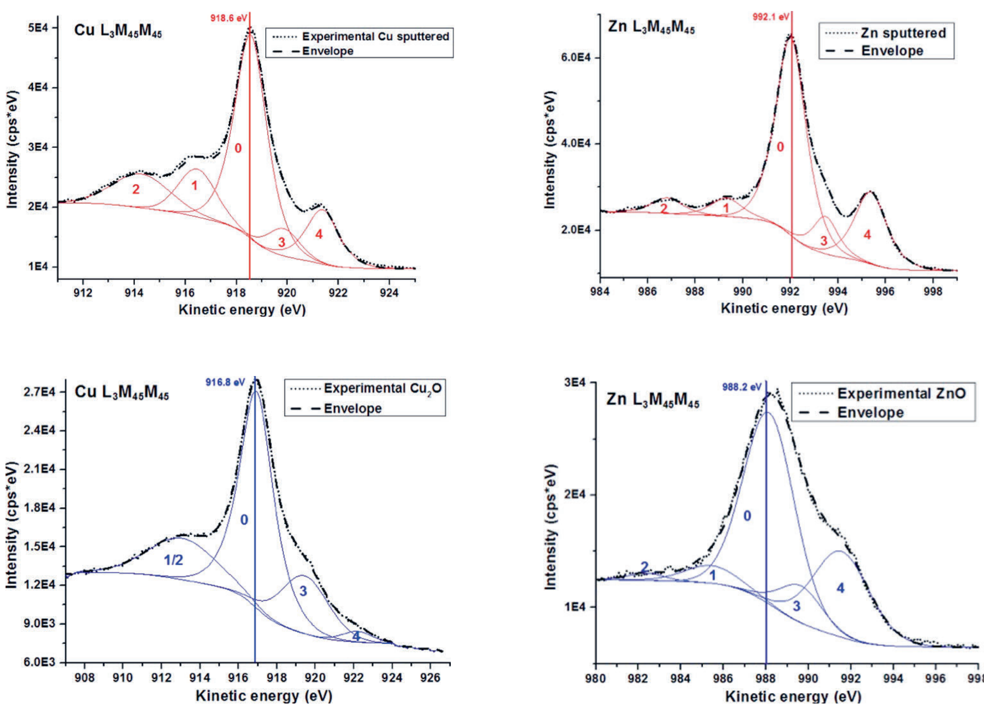


FIGURE 4 Auger spectra $CuL_3M_{4,5}M_{4,5}$ of metallic copper and Cu_2O copper oxide (left) and $ZnL_3M_{4,5}M_{4,5}$ of metallic zinc and ZnO zinc oxide (right)[12]

Brass Cu37Zn model alloy mechanically polished In mechanically polished brass alloys, the signals from copper and zinc are present in the metallic and oxidised state. The most intense photoelectron peaks Cu2p3/2 and Zn2p3/2 showed only one single peak with the

10 Cocco/Elsener/Fantauzzi/Atzei/Rossi: Nanosized Surface Films on Brass Alloys.

11 Ibid.

12 The multicomponent Auger signals are given in detail in ibid.

same binding energy as in pure copper (932.5 eV) and zinc (1021.7 eV), confirming that these signals do not allow for the identification of the chemical state of copper and zinc. The XAES spectra of $CuL_3M_{4,5}M_{4,5}$ (Figure 5a) and $ZnL_3M_{4,5}M_{4,5}$ (Figure 5b) have a clearly different shape with two maxima compared to those of pure metals or pure oxides (Figure 4). This indicates the simultaneous presence of the metal and oxide component due to the presence of a thin oxide layer on the brass surface. The curve fitting of the two Auger peaks (Figure 5) was performed using the envelopes of the metallic state and the oxidised ones (Figure 4). The kinetic energy in the XAES spectrum of metallic and oxidised copper was 918.5 eV and 916.8 eV respectively, of metallic and oxidised zinc 992.3 eV and 988.0 eV respectively.

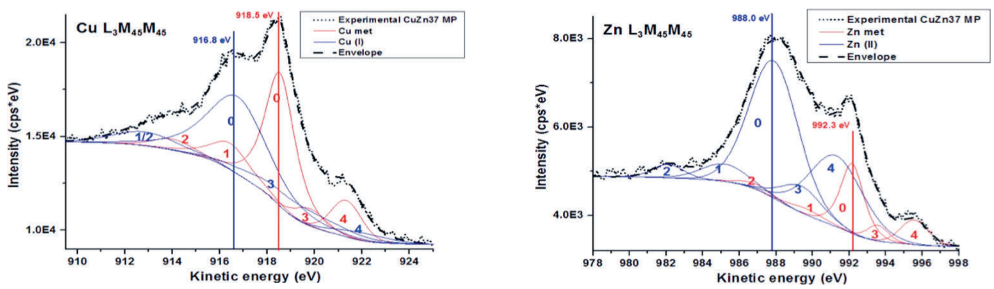


FIGURE 5 High resolution XAES spectra of mechanically polished brass model alloy Cu37Zn, left: copper $CuL_3M_{4,5}M_{4,5}$, right: $ZnL_3M_{4,5}M_{4,5}$

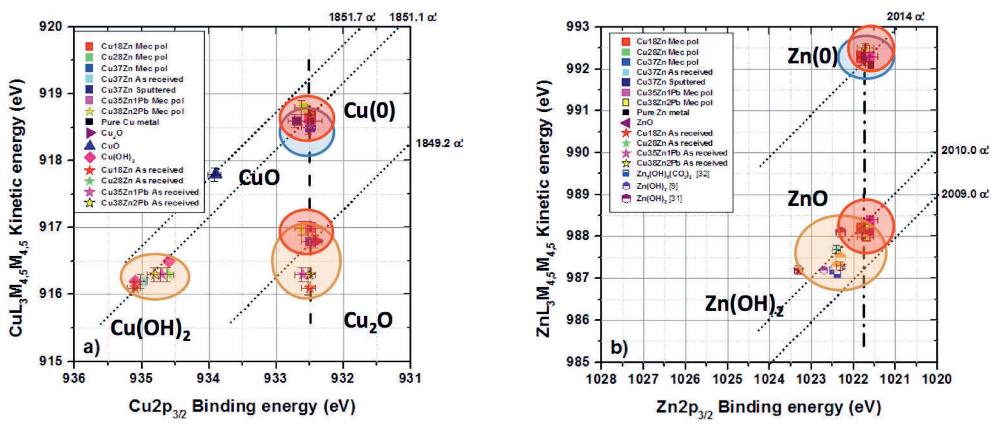


FIGURE 6 Wagner chemical state plot of a) copper compounds and b) zinc compounds (light blue: sputtered alloy, red: mechanically polished alloy, brown: 'as received' alloys)

Wagner chemical state plot The chemical state plot, a two-dimensional plot of XAES kinetic energy, KE, versus photoelectron binding energy, BE, of the same compound, allows for a more accurate assignment of the chemical state, especially in the case of copper and zinc and their alloys.[13]

The chemical state plot for copper compounds (Figure 6a) shows that for sputter-cleaned alloys, only the signal of the metallic copper is revealed for all alloys (BE/KE of 932.6 eV/918.6 eV). By contrast, for 'as received' alloys, no metallic signal is detected due to the thick surface film consisting of $Cu(OH)_2$ and Cu_2O. Mechanically polished alloys show a thin film of Cu_2O, beneath the signal of metallic copper.

The chemical state plot for zinc compounds (Figure 6b) shows for sputter-cleaned alloys only the signal of metallic zinc for all alloys (BE/KE 1021.7 eV/992.3 eV). For the 'as received' alloys studied, a thick surface film composed of ZnO is found and no metallic signal is detected. Mechanically polished alloys show a thin film of ZnO, beneath the metallic signal of zinc.

Brass model alloys exposed to solutions Mechanically polished brass alloys were exposed for up to 16 hours to solutions and the electrochemical and surface analytical data were recorded.[14] In the more aggressive artificial saliva solution,[15] the corrosion rate at the beginning was high but diminished to values <1 µm/year after 16 hours due to the progressive formation of a polycrystalline surface film of copper thiocyanate (CuSCN) and zinc phosphate ($Zn_3(PO_4)_2$). In the phosphate buffer solution, the electrochemical and corrosion behaviour did not change depending on the duration of immersion, and surface analysis revealed a thin surface film composed of copper and zinc oxy-hydroxide.[16]

Applying the technique to samples from old brass instruments After we had elaborated the scientific basis for the XPS/XAES surface analysis using brass model alloys, the XPS surface analytical technique was applied to samples from old brass instruments that were no longer in use. The 'as received' samples showed quite a thick hydrocarbon contamination layer, and after washing in organic solvents a thick surface film com-

13 See Moretti: Auger Parameter and Wagner Plot.

14 Cocco/Fantauzzi/Elsener/Rossi: Dissolution of Brass Alloys; Cocco/Elsener/Fantauzzi/Atzei/Rossi: Nanosized Surface Films on Brass Alloys.

15 Composition according to G. Tani/F. Zucchi: Valutazione elettrochimica della resistenza alla corrosione dei metalli di uso corrente nelle protesi dentarie [Electrochemical Evaluation of the Corrosion Resistance of Commonly Used Metals in Dental Prosthesis], in: *Minerva Stomatologica* 16 (1967), pp. 710–713.

16 Cocco/Fantauzzi/Elsener/Rossi: Dissolution of Brass Alloys; Cocco/Elsener/Fantauzzi/Atzei/Rossi: Nanosized Surface Films on Brass Alloys.

posed of copper oxide (Cu_2O), zinc oxide (ZnO) and hydroxides ($Cu(OH)_2$, $Zn(OH)_2$) was revealed.

On these samples, the same electrochemical tests were performed with the dedicated sensor[17] as inside the tuning slides, and the open circuit potential (corrosion potential) and the polarisation resistance (corrosion rate) were measured.[18] The 'as received' samples from old brass instruments showed a corrosion potential between −50 and 0 mV Ag/AgCl, similar to brass samples after mechanical polishing or after immersion in phosphate buffer solution (Figure 7), the polarisation resistance instead is in the range of 200 kΩcm² to 1 MΩcm², indicating a very low corrosion rate between 1.5 and 0.3 µm/year.

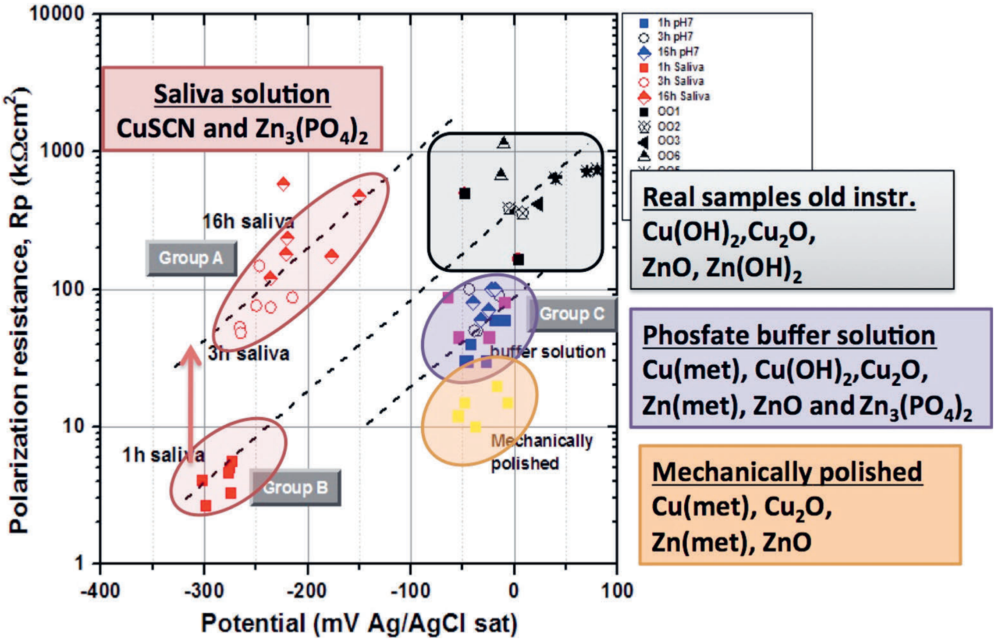


FIGURE 7 **Diagnostic plot combining the electrochemical and surface analytical data obtained on brass samples with different surface conditions**

Combining electrochemical and surface analytical results (Figure 7), it can be concluded that old samples from brass instruments show a very low corrosion rate due to the presence of a thick 'as received' surface film composed of copper oxide (Cu_2O), zinc oxide (ZnO) and hydroxides ($Cu(OH)_2$, $Zn(OH)_2$). By contrast, samples where this native oxide

17 Elsener/Alter/Lombardo/Ledergerber/Wörle/Cocco/Palomba/Fantauzzi/Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion; Elsener/Cocco/Fantauzzi/Palomba/Rossi: Determination of Corrosion Rate.

18 See also the article by Bernhard Elsener et al. in this volume, pp. 61–72.

film has been removed by mechanical polishing (resulting in a brilliant brass surface appearance) show a low polarisation resistance (thus the corrosion rate is very high). Indeed, at the beginning of immersion into the solutions, the corrosion rate is 50–100 times higher than the corrosion rate on real samples with a protective oxide film. This can be explained by the electrochemical mechanism of the oxygen reduction reaction where the redox couple Cu_2O/CuO play a key role.[19]

Based on this information (Figure 7), it is possible to link the electrochemical information obtained from measurements inside the tuning slides[20] with the composition of the surface determined ex-situ on the same materials exposed to different solutions – and thus to make tentative, indirect conclusions regarding the (unknown) surface composition inside the tuning slides.

Conclusions The novel analytical strategy based on a combination of XPS and XAES signals allowed chemical state identification and full quantification of complex systems with copper and zinc such as the brass alloys.

The natural patina formed on old instruments, analysed in the 'as received' condition, was identified as a thick surface film composed of copper and zinc oxides and hydroxides that protects the alloy from corrosion. Freshly polished brass alloys instead showed a thin, non-protective surface film.

Combining the ex-situ surface analytical results with results from electrochemical measurements performed on the same samples allowed for a tentative interpretation of the corrosion behaviour of brass alloys in neutral solutions, which in turn enabled us to get information on the interior of tuning slides of brass instruments.

19 Elsener/Alter/Lombardo/Ledergerber/Wörle/Cocco/Palomba/Fantauzzi/Rossi: A Non-Destructive In-Situ Approach to Monitor Corrosion.

20 Ibid.; see also the article by Bernhard Elsener et al. in this volume, pp. 61–72.

David Mannes / Eberhard Lehmann

Monitoring the Condition of Played Historical Brass Instruments by Means of Neutron Imaging

Abstract Neutron imaging is a non-destructive testing method that functions according to principles similar to x-ray imaging. In contrast to x-rays, neutrons can generally penetrate metals rather well, but at the same time they have a high sensitivity for hydrogen. This makes neutron imaging – which includes radiography (investigations in 2D) as well as tomography (3D) – an ideal method for studying the impact of playing historical brass instruments. Playing a brass instrument creates an accumulation of moisture inside the instrument, which can eventually lead to the generation and expansion of corroded areas inside it. This moisture, along with many other products of corrosion, contains hydrogen, which provides a high degree of contrast for neutron imaging.

This article explains how neutron imaging was used to monitor the condition of historical brass instruments, i.e. the changes in the internal corroded areas, by comparing 3D CT-data sets acquired before and after the instruments had been played on a regular basis over the period of fourteen months.

Introduction Musical instruments reflect the state of knowledge of the period of their conception and manufacture. They are thus subject to constant development and changes in habits. Not only do the manufacturing techniques of a certain instrument type change from one era to the next, but so does the way these instruments are played, and how they sound. Music composed in a certain era for instruments of that period thus sounds different on these instruments than on contemporary instruments. In recent years, historically informed performances have received more and more attention in which an orchestra plays on historical instruments or replicas in order to reproduce the original sound. This has resulted in an increasing demand for more information on historical instruments. Deeper insights on their geometry, structural design and the materials utilised in them have allowed us to manufacture more and more accurate replicas.[1] The pros and cons of playing historical instruments are much debated, because

1 David Mannes/Eberhard Lehmann/Adrian von Steiger: Untersuchung von historischen Blechblasinstrumenten mittels Neutronen-Imaging, in: *Romantic Brass. Französische Hornpraxis und historisch informierter Blechblasinstrumentenbau. Symposium 2*, ed. by Daniel Allenbach, Adrian von Steiger and Martin Skamletz, Schliengen 2016 (Musikforschung der Hochschule der Künste Bern, Vol. 6), pp. 439–445; Adrian von Steiger/Marianne Senn/Martin Tuchschmid/Hans J. Leber/Eberhard Lehmann/David Mannes: Can we Look over the Shoulders of Historical Brasswind Instrument Makers? Aspects of the

DOI: 10.26045/kp64-6179-007

playing an original stands in opposition to the notion that such historical artefacts should be preserved and kept safe.[2] This article shows how neutron imaging can be used to investigate certain aspects of the impact that playing can have on the state of historical brass instruments, with special attention to the development of corrosion. Neutron imaging is a non-destructive testing method that is well suited to investigating historical musical instruments or other objects of our cultural heritage.[3]

Working principle In neutron imaging, neutron radiation is used to probe an object and to generate images. Classical neutron imaging, like x-ray imaging, is based on transmission measurements. An object is placed in front of a detector, and exposed to radiation that is partially attenuated by the object; the beam that is transmitted is then registered by the detector. The attenuation of radiation occurs in a first-order approach according to the Beer-Lambert law:

$$I = I_0 \cdot e^{-\Sigma \cdot z} \qquad (1)$$

where I is the intensity of the transmitted radiation, I_0 is the intensity of the incident radiation, Σ is the attenuation coefficient and z the thickness of the object. The attenuation coefficient is a material parameter which describes to what extent a certain material (that is, the element composition with a specific density) attenuates the radiation. The resultant transmission images provide 2D information on the material, structure and density of the object, integrating the attenuation information along the beam trajectory projected onto the detector.

Materiality of Nineteenth-Century Brass Instruments in France, in: *Historic Brass Society Journal* 25 (2013), pp. 21–38, https://doi.org/10.2153/0120130011002.

2 Adrian von Steiger/Daniel Allenbach/Martin Ledergerber/Bernhard Elsener/David Mannes/Federica Cocco/Marzia Fantauzzi/Antonella Rossi/Martin Skamletz/Martin Mürner/Marie Wörle/Emilie Cornet/Eberhard Lehmann: New Insights into the Conservation of Brass Instruments. Brass Instruments Between Preventive Conservation and Use in Historically Informed Performance, in: *Historic Brass Society Journal* 30 (2018), pp. 85–101, https://doi.org/10.2153/0120180011005.

3 Giulia Festa/Giovanni Tardino/Laura Pontecorvo/David Mannes/Roberto Senesi/Giuseppe Gorini/Carla Andreani: Neutrons and Music. Imaging Investigation of Ancient Wind Musical Instruments, in: *Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms* 336 (2014), pp. 63–69, https://doi.org/10.1016/j.nimb.2014.06.020; Sebastian Kirsch/David Mannes: X-Ray CT and Neutron Imaging for Musical Instruments. A Comparative Study, in: *Wooden Musical Instruments. Different Forms of Knowledge. Book of End of WoodMusICK COST Action FP1302*, ed. by Marco A. Pérez and Emanuele Marconi, Paris 2018, pp. 157–169; David Mannes/Eberhard Lehmann/Alex Masalles/Katharina Schmidt-Ott/Alexandra von Przychowski/Florian Schmid/Steven Peetermans/Katja Hunger: The Study of Cultural Heritage Relevant Objects by Means of Neutron Imaging Techniques, in: *Insight. Non-Destructive Testing and Condition Monitoring* 56/3 (2014), pp. 137–141, https://doi.org/10.1784/insi.2014.56.3.137.

3D information can be generated by performing a computed tomography. For this, the object is rotated between the acquisition steps, resulting in a multitude of projections from different viewing angles. These projections can then be processed by special algorithms to reconstruct tomograms, that is, slices of the investigated object perpendicular to the rotation axes. The stack of reconstructed tomograms represents the three-dimensional information, the volume data set, which can be further processed, evaluated and visualised. Figure 1 shows a schematic of the workflow of such investigations.

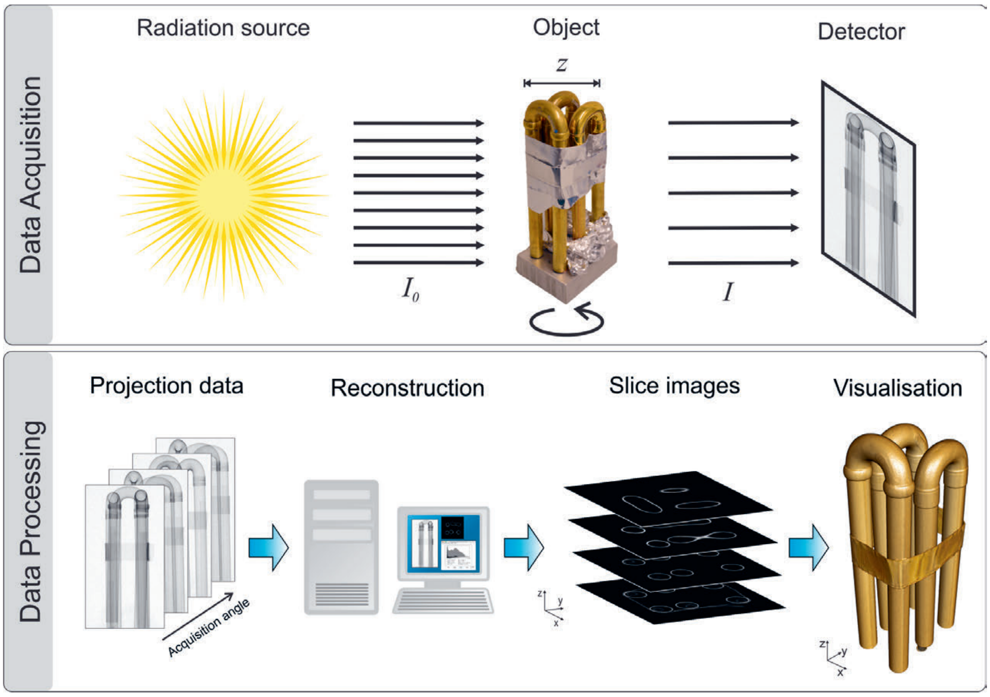


FIGURE 1 Schematic presentation of the workflow of an investigation using computed tomography, from data acquisition to visualisation

The experiment For the investigations presented here,[4] neutron tomography data were obtained on the thermal neutron imaging beamline NEUTRA at the Paul Scherrer Institute in Villigen.[5] The goal of the project was to investigate how playing historical brass instruments regularly impacts on their physical state, with a special focus on corrosion.

4 Carried out within the framework of the project described in this volume and in von Steiger/Allenbach/Ledergerber/Elsener/Mannes/Cocco/Fantauzzi/Rossi/Skamletz/Mürner/Wörle/Cornet/Lehmann: New Insights into the Conservation of Brass Instruments.

5 See Eberhard Lehmann/Peter Vontobel/Luzius Wiezel: Properties of the Radiography Facility NEUTRA at SINQ and Its Potential for Use as European Reference Facility, in: *Nondestructive Testing and Evaluation* 16 (2001), pp. 191–202.

15 tuning slides from the project instruments were inspected at the beginning and end of the project, in order to be able to observe changes that occurred due to playing the instruments on a daily basis over the period of fourteen months. As detector, scintillator-CCD-camera systems were used with an Andor iKon-L and a 100 µm thick $^{6}LiF{:}ZnS$ scintillator, with a field of view of 241 mm × 241 mm and a pixel size of 154 µm for large tuning slides, and field of view of 150 mm × 150 mm and a pixel size of 98 µm for smaller tuning slides. For the tomography, 625 projections were acquired over 360° that were subsequently reconstructed using the Octopus Imaging Software package.

Data evaluation The analysis and evaluation of the volume data were carried out using the software package VG Studio Max. Here, different approaches were used to compare the state of the tuning slides at the beginning and end of the project:

- a variance comparison of the inner surfaces;
- unrolling the tuning slide cylinders to create a virtual plane layer;
- comparison of sections at identical positions.

The variance comparison only takes into account the surface of the object determined by the software algorithm. After the surface determination, the tuning slides are registered, that is, the volume data are aligned in such a way that both data sets are superimposed on each other. Subsequently, the position of every surface point of the tuning slide in its end state is compared to the position of the presumed identical point of the tuning slide in its initial, reference state. The differences are subsequently shown using a colour code for the extent to which the position of the individual surface area varies from the reference state (Figure 2).

In another approach, cylinders were fitted in each leg of the tuning slides and virtually unrolled, allowing us to compare the grey levels (which correspond to a mapping of the attenuation) for every point between the start and the end. In a third step, regions identified by unrolling are examined more closely by specifically positioning section planes in potentially corroded regions.

Results and discussion Variance comparison The variance analysis was carried out under the premise that an increase of corrosion inside the tuning slides would occur along with a displacement of the inner surfaces due to the growth of the corroded areas. In very few regions of the tuning slides inspected, small positive deviations could be found (see the circles in Figure 3). Such increases were very small, only in a range of up to circa 0.25 mm.

In individual spots, a loss in material can be found (see the black arrow in Figure 3). Here, a small piece of solder seems to have fallen off, perhaps due to cleaning the instrument.

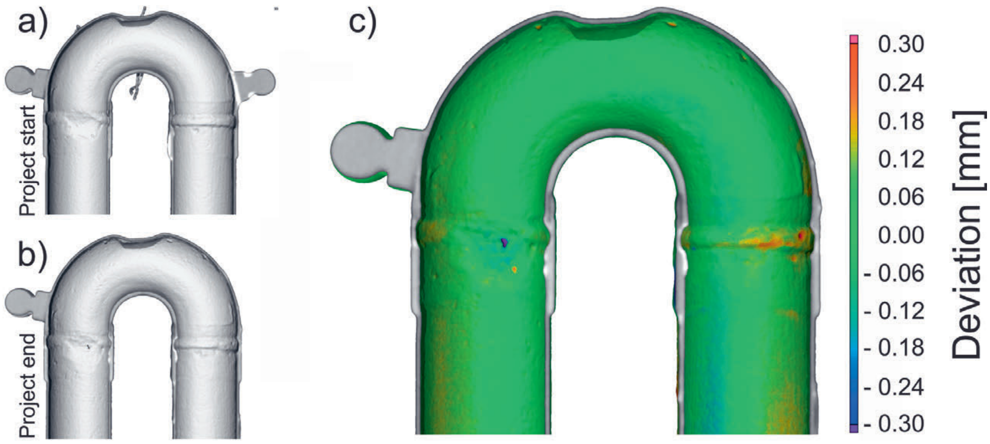


FIGURE 2 Variance comparison of the volume data set of a tuning slide (HKB 5024.2); a) shows a half-section view of the 3D visualisation at the beginning of the project, b) at the project's end; c) shows the differences between the status at the end and the reference state, coded in false colours.

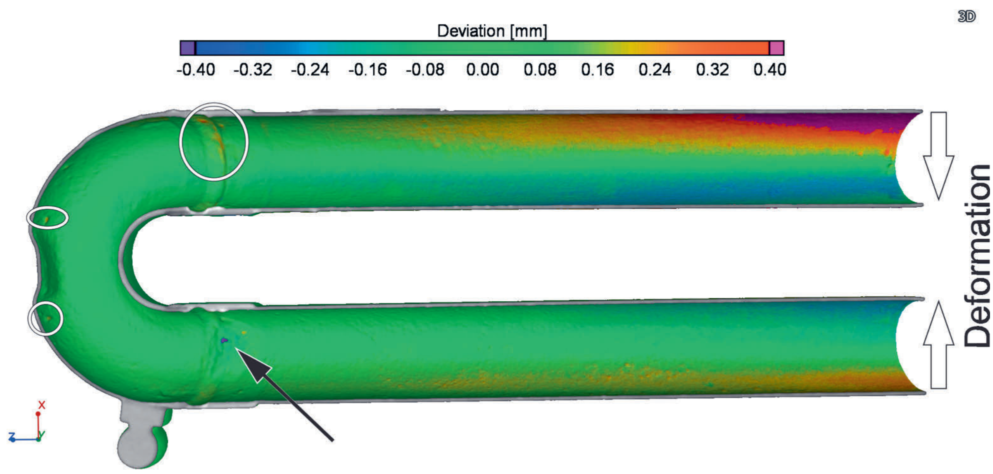


FIGURE 3 3D half-section view of a tuning slide (HKB 5024.2); the colour code shows the deviation of the surface at the end of the project compared to that at the start. The circles show very small regions with a small increase in material, while the black arrow shows a loss of material (perhaps due to cleaning). The colouring at the end of the tuning slide legs shows strong deformation.

One problem that occurred in a large percentage of the tuning slides inspected was deformation of the slide legs. As can be seen in Figure 3, the legs show a relatively pronounced deformation, especially towards their end. These were bent to each other, as is shown by a positive deviation on one side of the leg surface and a negative deformation on the opposite surface. Such deformations might result from the regular removal and reinsertion of the tuning slides in the normal cleaning process. Depending on the individual tuning slide, these deformations are in general clearly below 1 mm, but can still diverge by up to several hundred micrometres. They are hence much larger than might be expected of any growth in a corroded region during the project, and which might have occurred in the same region.

For all tuning slides showing plastic deformation, the variance comparison will not be suitable for showing any growth in corrosion. Here only very small changes can be expected. This is also a drawback when we come to tuning slides in which no deformation has occurred. The pixel size and the resulting voxel size are with circa 100 µm and circa 150 µm rather coarse. Changes smaller than 200 to 300 µm would not be visible with this method.

Unrolling of tuning slide cylinders As the variance comparison analysis could not be used for a large fraction of the tuning slides due to the deformation issue, all of the tuning slide legs were virtually unrolled and the initial and end states compared. For this, a virtual cylinder was fitted into each tuning slide leg using VG Studio Max, and virtually unrolled (see Figure 4a). The grey value of each voxel along the cylinder surface is thus projected onto a 2D plane. The grey values correlate to the mean attenuation that can be found in each voxel, thus giving an indication as to the composition. In regions where the grey values had changed, the attenuation also had to change. If a region on the image is brighter than the grey vale, this means that the attenuation has increased, and this can only be accounted for by an increase in density and/or additional, higher attenuating material. Figure 4b shows a tuning slide leg before, Figure 4c at the end of the project. In the joint, a clear increase can be identified. As an increase in density seems rather unlikely in this case, the change in the attenuation has to have been caused by additional material with higher attenuation coefficients, most likely some hydrogen component. The hydrogen could be part of corrosion products, but could at the same time also be water. Still, at the time of the second inspection at the end of the project, the instruments had not been played for a couple of weeks and the tuning slides had been removed and stored in a special transport container under dry conditions. This makes the existence of any residual water inside the tuning slides rather unlikely.

Comparison of sections at identical positions We examined more closely those regions where we were able to identify changes between the start and the end of the project by means of changes in grey values. To do this, we compared identical positions in different section planes. Figure 5 shows a comparison between the start and the end of the project in two different sections, using the same tuning slide (HKB 5024.2). Section A, a vertical section through the tuning slide, close to the joint of leg and bend, shows a blistered, porous structure on the right side of the joint. This structure, which is possibly a flawed solder joint, appears as a hollow, empty blister at the start of the project, but is filled to a large extent at the end of the project with highly attenuating material. Section B shows

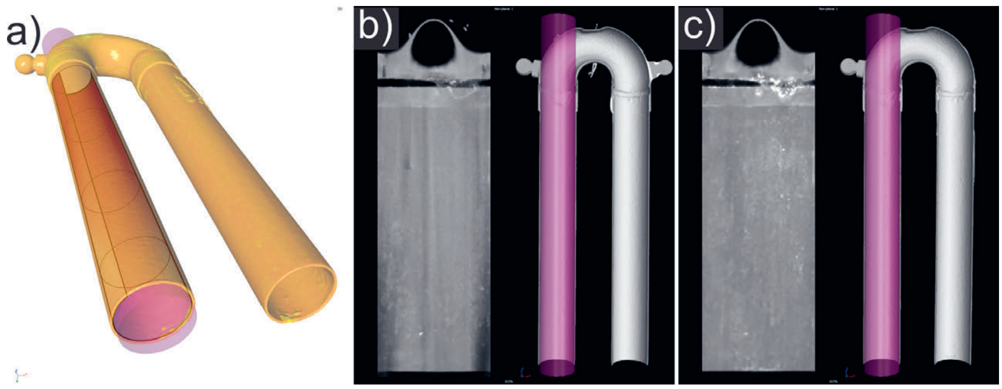


FIGURE 4 Virtual unrolling of the tuning slide legs; a) 3D visualisation of a tuning slide with the cylinder (purple) fitted in one of the legs; b) unfolded tuning slide leg at the start of the project; c) unfolded tuning slide at the end of the project; in the region of the joint a clear increase in higher attenuating voxels is visible.

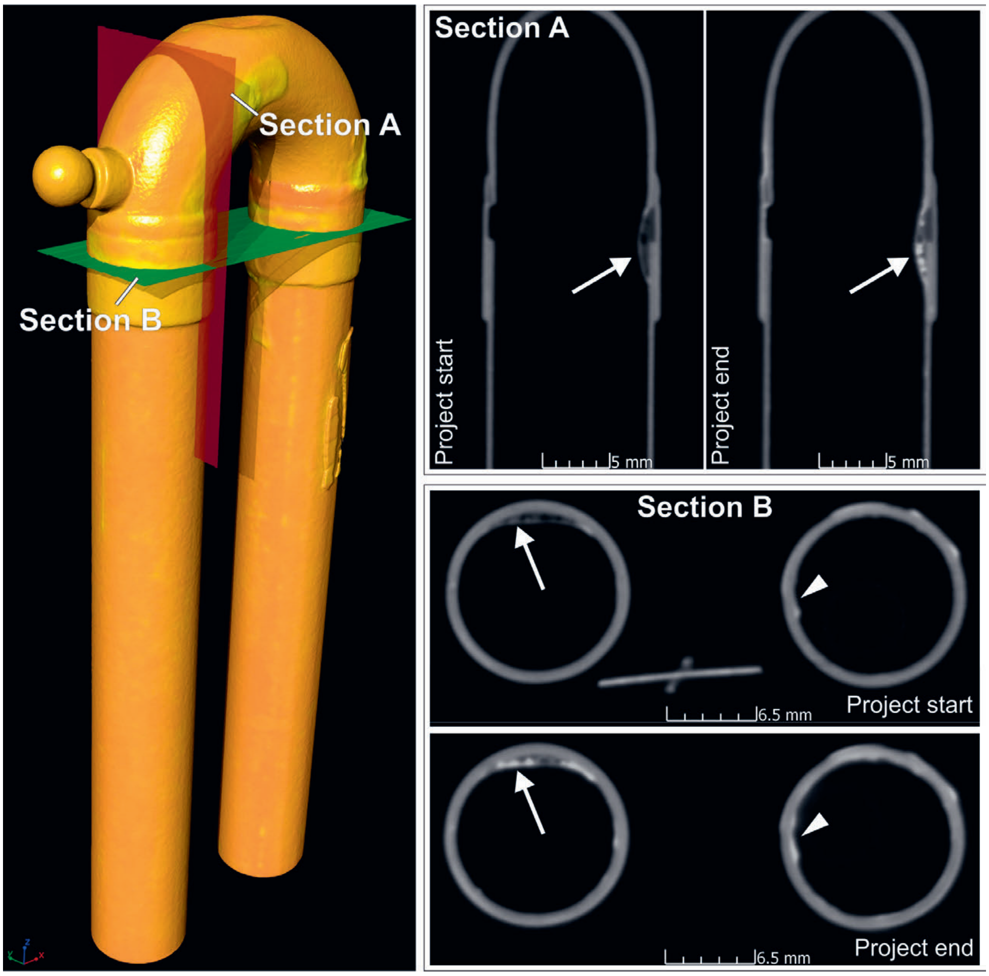


FIGURE 5 Sections of the tuning slide HKB 5024.2; section A shows an empty porous structure (arrows) at the start of the project, which is filled with highly attenuating material by the end of the project. The porous structure can also be seen in section B (arrows); also in section B, we can identify a smaller region with higher attenuation that increased in size between the start and the end of the project (arrow heads).

the same joint in a horizontal section, perpendicular to section A. Here, the blister of solder material appears empty again at the start and partially filled-in at the end of the project. Besides this, there is a small, higher attenuating region in the joint, visible in the other leg. While it is relatively small at the beginning, it is considerably larger by the end of the project. Even though the material in the blister and the joint shows grey values (and hence attenuation coefficients) in the same order of magnitude, it could not be clarified if the materials are identical.

The material in the blister might be some corrosion product containing hydrogen that has accumulated below the surface. Another possibility is residual water that has condensed while playing the instrument. This explanation seems less likely, as all the instruments had been dried and cleaned after the end of the project, and the individual tuning slides were kept in a dry transport container. Another possible explanation is that this highly attenuating material is residual oil or grease that might have been applied after cleaning the instruments.

For the increase in higher attenuating material in the other leg, water seems the least probable candidate. It is more likely that there has been growth in a corroded area, or that there is some residual oil or grease that might have been applied after cleaning. The higher attenuating region increases between the start and the end of the project. This might be accredited to a growth of a corrosion spot that was already present, but whose dimensions were smaller at the first measurement. Another explanation could be that the material represents grease that has been applied after cleaning, and has by chance accumulated in the same spot.

Summary and conclusion Neutron imaging is a non-destructive method that can be used for monitoring long-term experiments on the playability of historical brass instruments, such as the present project. For this, tuning slides from 15 instruments were inspected at the start and the end of the project. It proved difficult to compare changes in the inner surfaces. Many tuning slides showed plastic deformation (bending of the legs of up to 1 mm), which made a clear result in these regions impossible. This was because much smaller changes in dimensions would be expected due to the growth of corrosion layers. The rather coarse voxel sizes of 98 µm and 150 µm respectively allow only for an identification of displacement of the surface due to the growth of corrosion layers in the range from 200 µm to 300 µm upwards. The comparison of the voxel values, which correlate with the attenuation coefficients for the individual voxel, was more successful. In several tuning slides, regions with higher attenuation could be identified whose dimensions increased between the two measurements. Possible explanations are that these spots correspond either to remains of grease or oil applied after cleaning the instrument, or to the presumed growth of already corroded areas.

This project showed that neutron tomography can be used for monitoring long-term changes in cultural heritage objects. By comparing the CT data of several points in time, it is possible to identify and quantify geometrical changes within the range of the spatial resolution (for example plastic deformation, the increase and decrease of wall thicknesses, et cetera) as well as changes in attenuation, which can be attributed to local changes in the elemental composition or density (for example in the formation of different corrosion products, the presence of moisture, the distribution of consolidants, and so on).

Martin Ledergerber

Endoscopy as an Investigative Method

Abstract Endoscopy is a non-destructive, straightforward, optical investigative method that permits one to examine changes inside brass instruments. This article describes the results of repeated endoscopic examinations of sixteen period brass instruments that were played regularly over several months. Moreover, endoscopic assessments were made of the effectiveness of preventive conservation measures that had been developed by researchers of the project and applied by musicians while the instruments were in use.

Introduction Endoscopy is one of three testing methods used in the interdisciplinary research project "Brass instruments of the 19th and early 20th centuries between long-term conservation and use in historically informed performance practice".[1] Historical brass instruments held in public and private collections that explicitly allow the use of their instruments were loaned to musicians to be played daily over a period of fourteen months. Endoscopically accessible parts of sixteen instruments were inspected before the start of the project, after seven months, and at the end of the project, and the findings were documented. These inspections aimed to show the extent of any changes to the internal surfaces or damage that might have occurred in historical brass instruments in regular use.

The aim was also to test the effectiveness of preventive conservation measures suggested in the research project, particularly active drying. To this end, half of the instruments were dealt with in accordance with a preventive conservation protocol, while the remaining served as a control group and were maintained by the musicians in line with common practice.[2]

Method Different types of endoscopic device are used in non-destructive optical examination methods. Those with non-medical applications are called borescopes. The sixteen brass instruments were inspected using a rigid borescope with a viewing angle of 30° and a depth-of-field of 10–15 mm.[3] To document our findings and observations, the borescope was connected to a digital camera, which captured the images in manual mode in order to ensure identical camera settings and image comparability. Endoscopy was

1 See www.hkb-interpretation.ch/projekete/korrosion (last consulted 22 October 2022).

2 See the article by Martin Ledergerber/Emilie Cornet/Erwin Hildbrand in this volume, pp. 48–60.

3 Rigid borescope with cold light projector n° 81482 (Karl Storz GmbH & Co. KG, Tuttlingen, Germany), kindly provided by the Basel Historical Museum.

DOI: 10.26045/kp64-6179-008

one of three different methods used to examine thirty tuning and valve slides from sixteen instruments (5 trumpets, 8 horns, 1 trombone, 1 Wagner tuba, 1 tuba).[4] By means of a rigid borescope, it was possible to conduct a visual inspection of both openings in thirty tuning and valve slides; sixty areas were thus inspected in total. On average, the length of each inspected section was 83 mm, depending on the length of the straight section accessible to the rigid borescope. Starting at the tube opening, an image was taken every 5 mm, with the lens always directed towards the outside wall.

To establish whether any changes occurred in the instruments, and if so, to what extent, all 60 areas were inspected before and after the project and also at the midway stage. This permitted the comparison of identical areas in their initial, intermediate, and final states. At the evaluation stage, some 3,300 borescope images were compared visually. Depending on the changes observed, they were classified into three categories:

- *no change*: no changes were visible in surface texture or appearance;
- *slight change*: slight changes were visible in surface texture and appearance; existing deposits had increased slightly and expanded; random new and localised deposits were visible;
- *significant change*: significant changes were visible in surface texture or appearance; the surface area of existing deposits had increased greatly or significant change was apparent in them; new deposits were present across wide areas. Figures 1–3 show examples of these three categories.

Results The endoscopy confirmed that the initial state inside the tuning slides varies greatly, depending on the history of each instrument. Recently cleaned instruments, for example, showed almost blank inner walls with only a thin and homogeneous layer of copper oxides, whereas other instruments in their initial states presented signs of heavy, irregular corrosion. A large variety of deposits and surface textures was observed inside the different tuning slides, and even in different sections inside the same tuning slide.

During the course of the project, the instruments were played an average of 275 times, for around 6.19 minutes. The average total playing time for each instrument was 28.3 hours. Figure 4 shows changes observed through use, as determined using the method described. In the group of instruments that were actively dried after use, in accordance with the preventive conservation protocol (black), there was only one instance of obvious change in the tuning slides inspected. In the group of instruments that were maintained in accordance with common practice, and which were not actively dried (grey),

4 See the articles by David Mannes/Eberhard Lehmann and Bernhard Elsener et al. in this volume, pp. 83–91 and 61–72.

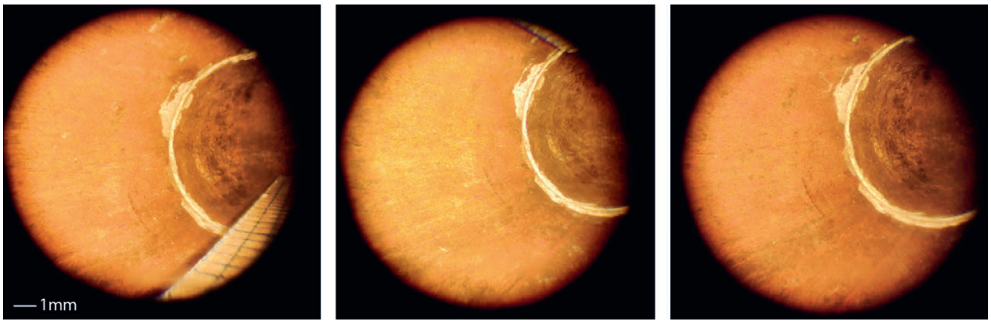


FIGURE 1 Endoscopic image of a tuning slide (horn B098) showing no change (from left to right: initial state; intermediate state after 991 minutes of being played; final state after 1,978 minutes)

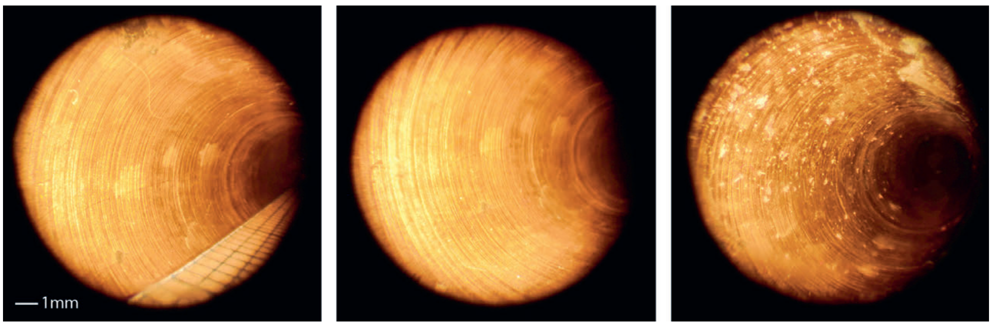


FIGURE 2 Endoscopic image of a tuning slide (trumpet HKB 5027.1_B) in which slight changes have occurred during use (from left to right: initial state; intermediate state after 961 minutes of being played; final state after 1,893 minutes). Whitish spots have appeared.

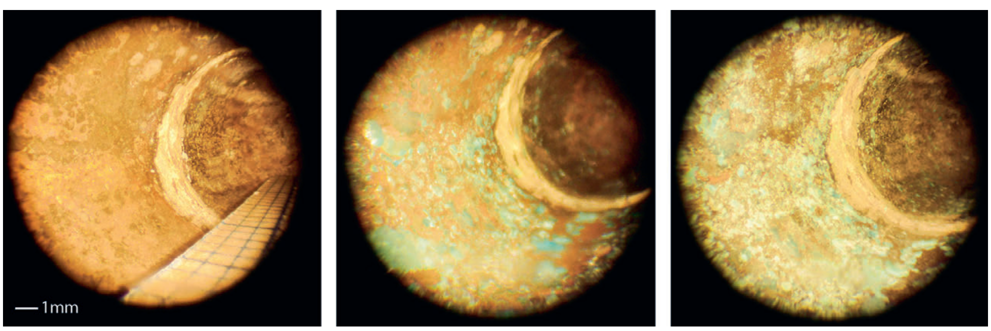


FIGURE 3 Endoscopic image of a tuning slide (trumpet B088.1_B) with significant changes (from left to right: initial state; intermediate state after 1,054 minutes of being played; final state after 2,014 minutes). In this example, green and white deposits have formed over time across almost the entire surface. The green deposits are a clear sign of copper corrosion. Part of the brass, though a small amount, has thus been converted from metal into corrosion products during the period of use. This conversion has led to a loss of original substance.

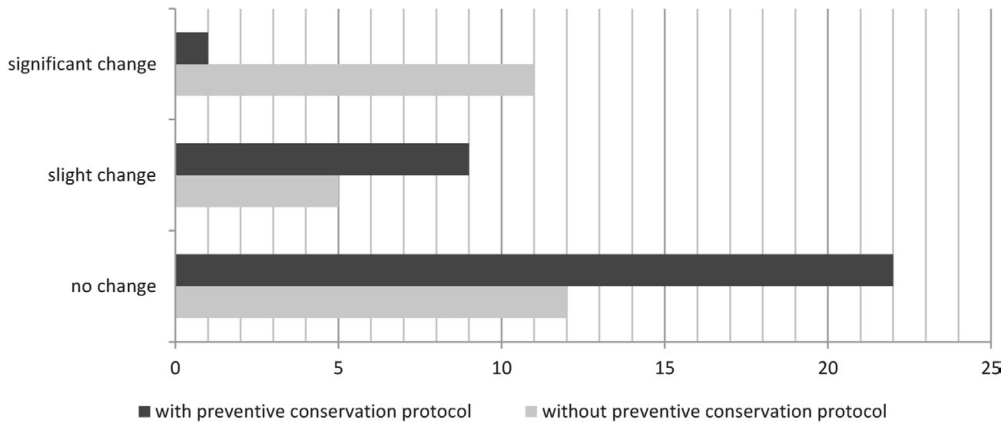


FIGURE 4 Diagram illustrating the frequency and extent of changes inside the tuning slides inspected, as a result of use. The frequency of cases in each category is broken down according to different types of use.

11 instances of obvious change were observed. In the instruments that were actively dried, there were 9 instances of slight change, and 22 instances in which no changes were observed. In contrast, in the instruments that were not actively dried, 5 instances of slight change were observed, and there were 12 instances in which no change was observed.

Conclusions Endoscopy is a method suitable for examining the internal areas of brass instruments. As it is a visual method of inspection, findings are directly observable and accessible. Moreover, an endoscopic examination can be reliably repeated; this means changes happening over time can be documented in photographs.

The use of a rigid borescope is limited to the parts of the instrument with straight access. It is therefore important to point out that the endoscopic examination in this project detected only part of the internal surface of the tuning slides in each instrument. The area under investigation does not necessarily represent the condition of the remaining areas within the instruments which were not accessible to the borescope.

Inside period brass instruments that are played regularly, corrosion can be observed in many cases. Only in a total of three instruments were no changes observed in any of the tuning slides. In all other instruments, we observed areas inside the tuning slides that showed slight or even significant changes.

Whether corrosion develops or not obviously also depends on the initial state of the instrument. It appears that existing corrosion can have a protective function. Overall, the endoscopy shows that there are fewer changes to the tuning slides of the instruments that have been maintained according to the preventive conservation protocol. Our investigation has shown that changes in the interior of regularly played period brass instruments outside a museum context cannot always be prevented by active drying. However, the frequency and extent of the changes can be reduced significantly by means of the preventive conservation method presented in this project.

Daniel Allenbach

A Glimpse into the Orchestra Pit at the Théâtre des Champs-Elysées in Paris on 29 May 1913

When we talk about the world premiere of Stravinsky's *Sacre du Printemps*, we cannot avoid the scandal of its opening night on 29 May 1913, a Thursday, at the Théâtre des Champs-Elysées in Paris. The testimony of several who were present tells of a public out of his senses, screaming, whistling, and even clapping their hands on the bald heads of men sitting in front of them.[1]

Despite all this noise, nobody in our day can be sure just what the uproar was all about. Some claim it was the perceived crudity of the music conducted by Pierre Monteux – for the music is the thing one normally speaks about today when discussing *Le Sacre*. But we must bear in mind that just one year later, on Sunday, 5 April 1914, the first concert performance of *Le Sacre* in Paris, in the Concerts Pierre Monteux at the Salle du Casino, met an enthusiastic reception from a frenetic public.[2] Some are sure that the riot in the Théâtre des Champs-Elysées must have been caused by Vaclav Nijinsky's choreography, which had been very different from classical ballet, using bent-in feet and distorted bodies in line with the primitive scenario and naïve stage sets by Nicholas Roerich. Others believe that the scandal was much less serious than was later claimed – in fact, strong reactions to performances seem to have been quite normal at that time. And, finally, some believe – albeit without concrete evidence, but still with good reason – that the whole incident was pre-planned by the impresario Sergei Diaghilev himself in order to provoke a response to his Ballets russes in the Parisian newspapers: "The greater the controversy, the better his cause was served."[3] None of these explanations wholly excludes the others.

1 See Jean Cocteau: *Le coq et l'arlequin. Notes autour de la musique*, Paris 1918, pp. 67 f. The reviews in the newspapers were less sensational than the reminiscences of Cocteau and others: "*Le Sacre du Printemps* fut hier assez mal accueilli, et le public restait impuissant à retenir son hilarité. Il eût donc été de bon gout à ceux qui pensaient autrement – ils n'étaient pas nombreux – d'épargner aux auteurs une ovation sur la scène dont tout le monde sentit la comique impertinence." Henri Quittard: Théâtre des Champs-Elysées: *Le Sacre du Printemps* […], in: *Le Figaro*, 31 May 1913, p. 5. For a more objective but still fascinating discussion of this evening, see, for example, Esteban Buch: The Scandal at Le Sacre. Games of Distincion and Dreams of Barbarism, in: *Avatar of Modernity. "The Rite of Spring" Reconsidered*, ed. by Hermann Danuser and Heidy Zimmermann, London 2013, pp. 59–79.

2 *Le Sacre* was put on the programme for the Concerts Pierre Monteux (or Société des Concerts populaires) again on 26 April 1914.

3 Charles M. Joseph: *Stravinsky's Ballets*, Yale 2011, p. 97.

DOI: 10.26045/kp64-6179-009

The one thing of which we can be sure is that the story dominated the reception of the premiere, making it difficult for us to discern other aspects of the performance. My task in the HKB's project on corrosion in historic brass instruments[4] was mainly to find out about the brass section present in the orchestra pit on a remarkable evening that not only presented *Le Sacre* to the world, but three other ballets too, namely *Les Sylphides* using music by Frédéric Chopin and choreography by Michel Fokine, *Le Spectre de la rose* with music by Carl Maria von Weber with Vaclav Nijinsky dancing in one of his most famous roles, and the *Polovtsian Dances from Prince Igor* by Alexander Borodin.[5]

But let us now consider the orchestra itself, which was conducted by Pierre Monteux and had undergone no less than seventeen rehearsals, as the conductor testified:

> "Day after day I studied the score with Stravinsky at the piano. I studied it all that winter. In the spring we brought it to the orchestra engaged for the Paris season. We rehearsed the strings first, then woodwinds and brass, each section of the orchestra alone, except for the percussion instruments which were there all the time. The musicians thought it absolutely crazy, but as they were well paid, their discipline was not too bad! When at last I put the whole thing together, it seemed chaotic but Stravinsky was behind me pointing out the little phrases he wished heard. We rehearsed over and over the small difficult parts, and at last were ready for the ballet. We had in all, seventeen rehearsals."[6]

First of all, we know – despite claims to the contrary[7] – that the orchestra in the pit was the "Société des nouveaux concerts", that is, the orchestra of the newly inaugurated Théâtre des Champs-Elysées. In contrast to other years, when Diaghilev and the Ballets russes brought their own orchestra from Russia, in this season they worked with the orchestras on location – also for the performances of *Le Sacre* in London one month later, as Pierre Monteux himself confirmed.[8] Although there is no list of the orchestra

4 See www.hkb-interpretation.ch/projekte/korrosion (all links in this article last accessed 18 November 2022).

5 The case of the *Spectre de la rose* is extraordinary: directly after the chaotic premiere of *Le Sacre* (and an entr'acte), its choreographer Nijinsky himself had to dance on stage – and was hailed unanimously by the audience: "Le *Spectre de la* Rose vint ensuite. La réaction qui devait se produire s'est produite. Karsavina, Nijinsky, et ce bon Weber, qui y est bien pour quelque chose, furent follement et unanimement ovationnés". Gustave Linor: Le Sacre du Printemps, in: *Comoedia*, 30 May 1913, p. 3.

6 Doris Monteux: *It's all in the Music. The Life and Work of Pierre Monteux*, London 1965, p. 91.

7 Tarr implies in the context of trumpeter Pyotr Lyamin that it was still the "Ballet russe" orchestra. See Edward H. Tarr: *East Meets West. The Russian Trumpet Tradition from the Time of Peter the Great to the October Revolution*, Hillsdale, NY 2003 (Bucina. The Historical Brass Society Series, Vol. 4), pp. 117 f. and 185 f. The reason for this is an obituary that Lyamin wrote for his teacher Brandt in 1967: "In that year [1909], still as a conservatory student, I was called to Paris to Diaghilev's troupe as a trumpeter […]. I have kept the contract even to today." Ibid., p. 399.

8 See also letters of Monteux to Stravinsky, held by the Paul Sacher Stiftung Basel, Microfilm 099.1.

Figure 1 Les Adolescentes in *Le Sacre du Printemps*
(Photo Gerschel, in: *Le Théâtre*, 1 July 1913, p. 20)

LES SYLPHIDES
Rêverie romantique en un acte de M. Michel FOKINE
Musique de CHOPIN

LE SACRE DU PRINTEMPS
Tableaux de la Russie païenne en 2 actes, de Igor STRAWINSKY et Nicolas RŒRICH
Musique de Igor STRAWINSKY
Chorégraphie de NIJINSKY
Décors et Costumes de Nicolas RŒRICH

LE SPECTRE DE LA ROSE
Tableau Chorégraphique, Poème de Th. GAUTIER

Danses Polovtsiennes du "Prince Igor"
Musique de BORODINE
Danses composées et réglées par M. FOKINE

Figure 2 Programme (clippings) of the *Sacre* premiere, 29 May 1913 members in the evening programme of the *Sacre* premiere, we can find one in the programme of an opera premiere from that same month (Gabriel Fauré's *Pénélope*).[9]

There is no doubt that the majority of these musicians must have taken part in the premiere of *Le Sacre* as well, as such evidence exists for at least some of the players,[10] and most of them may be found in payrolls from the autumn of that year (Figure 4).[11] Furthermore, the American musicologist Truman Bullard has given us a list with almost all the players that he discovered in "a small black composition tablet which was found in a closet beneath a pile of early financial records of the theatre. In this notebook the list of the musicians in the orchestra for the 1913 Russian Ballet season was written, including a separate page of supplementary players for the Stravinsky ballet".[12] As the scoring of *Le Sacre* requires many more musicians than normally played in the orchestra (and who are listed in the *Pénélope* programme), this source is important. It is therefore a pity that the notebook seems to have disappeared since the 1970s; I have been unable to find any trace

9 This programme can be found, for example, at the Bibliothèque de l'Opéra, Paris, shelfmark Pro B 82.

10 Not for the brass, but for the woodwind section: A business card of the bassoon player Abdon Laus is held in the Stravinsky collection of the Paul Sacher Stiftung in Basel with a handwritten note: "Basson qui joua aux Champs Elysées à Paris pour la 1ère fois le Sacre en 1913" (Microfilm 120.1-000033). Furthermore, the oboe player Louis Speyer is mentioned on various occasions as having participated at the premiere: "Among the members of that orchestra was the oboist Louis Speyer, who had been an extra oboist (that is, not a regular member of the ensemble, but one called in for works requiring more than the normal complement of players) with the Colonne Orchestra and thus had participated in the premieres of the Stravinsky and Ravel ballets with the Ballets Russes. Called for military service in World War I, he came to the United States in 1918 as a member of a French military band and soon became the English horn player of the Boston Symphony Orchestra, a post he held until his retirement in 1964." John Canarina: *Pierre Monteux. Maître*, Cambridge 2003, p. 46. Although Canarina's mention of the Colonne Orchestra initially seems wrong, because Speyer was a regular member of the Champs-Elysées orchestra, it is probably founded in truth, as there is other evidence that Gabriel Astruc, the manager of the Théâtre des Champs-Elysées, often collaborated with the Concerts Colonne when in need of extra players. Through his artists' agency (the Société Musicale), Astruc was already in regular contact with the Concerts Colonne and Concerts Lamoureux; his archives contain budgets for substitutes hired from the Concerts Colonne for performances of (Berlioz's?) *Requiem* on 19 and 24 April 1912. See Archives Nationales, Fonds Gabriel Astruc, Sig. 409 AP26. Furthermore, the conductor Pierre Monteux had been an assistant conductor at the Concerts Colonne, a post from which he resigned when he started working for the Ballets Russes; see Canarina: *Pierre Monteux*, p. 37.

11 We again find the names of Algrin, Champendal, Hoogstoël, Marcerou, Martin, Mériguet, Michel, Mondou, Perret, Rouge, Sazy, Vieulou and Warin as full members, and of Ferret and Lechien as "Supplémentaires (Scène)" on payrolls dated September and October 1913 at the Archives Nationales, Fonds Gabriel Astruc, shelfmark 409 AP39.

12 Truman Campbell Bullard: *The First Performance of Igor Stravinsky's Sacre du Printemps*, Doctoral dissertation, University of Rochester 1971, p. 96.

THÉATRE DES CHAMPS-ÉLYSÉES

SOCIÉTÉ des

NOUVEAUX CONCERTS

Artistes de l'Orchestre

1er Violon solo

M. R. Krettly

1ers Violons

Merkel,
2e *viol. solo.*
Gorsky,
3e *viol. solo.*
Godebsky,
4e *viol. solo:*
Deligat.
Servais.
Celli.
Walther.
Vinson.
Supervielle
Lebot.
Steck.
Bloch.
Bolufer.
Stevens.

2mes Violons

Coréa-Luna.
Fernandez.
Lévêque.
Jumas.
Chaplat.
Couaillet.
Sucher.
Bazin.
Gautier.
Volant.
Pecquet.
Maze.
Dyke.
Glaser.

Altos

Macon,
1er *alto solo.*
Speyer Mus.
2e *alto solo,*
Dejean.
Lavallée.
Jarecki.
Ellis.
Botti.
Picard.
Duvivier.
de Bièvre.

Violoncelles

Audisio,
1er *violle sol.*
Lyon,
2e *violle sol.*
Eysermann.
Bourgeois.
Martin.
Delporte.
Crouzé.
Gablin.
Jamin.

Contrebasses

Dumond,
1er *cont. solo*
Marrain.
2e *cont. solo.*
Ghys.
Girard.
Fortier.
Vassal.
Olive.

Harpes

Mlle Meunier.
Mme Ellie.
Jamet.

Flûtes

Joffroy.
Pascal.
Castagnasso.
Carivenc.

Hautbois

Speyer Lis.
Roucour.
Victor.

Cor anglais

Myrtil Morel.

Clarinettes

Dauwe.
Villetard.
Bâton.

Clarinette-Basse

Lebailly.

Bassons

Laus.
Rogeau.
Dhérin Ch.

Contrebasson

Dhérin Gve.

Cors

Hoogstœl.
Michel.
Algrin.
Warin.
Fabre.
Ferret.

Trompettes et Cornets

Perret.
Champendal.
Mériguet.
Marcerou.
Dubois.
Lechien.

Trombones

Mondou.
Sazy.
Martin.
Dervaux.

Tubas

Rouge.
Vieulou.

Timbales

Lang.

Timbales-Tambours

Pierrot.

Percussion

Drugeon.
Challet.
Dietrich.
Trouillet.

Artistes des Chœurs

Soprani

Mesdames :
Meyril.
Guibert.
Hatt,
Souchon.
Floréal.
Malou.
Coye.
Riellant.
Bourgogne.
Traxel.
Bernier.
Roos.
Varnel.
Jamme.
Lesnards.
Prevost.
Berryer.
Lasserre.

Mesdames :
Mouzin.
Morel.
Thibaut.
Barrault.
Cossi.
Lemercier.
Cathala.

Contralti

Mesdames :
Zuccani.
Rosemai.
Laval.
Maximoff.
Malraison.
Hœffler.
Varney.
Lafontan-Lahor
Teller.
Berthin.
Mesnil.

Mesdames :
Jeanès.
Ticier.
Vignes.
Bresly.
Burgaud.
Raige.
Havet.
Cartier.
De Wuillerz.
Couty.
Bertrand.
Aufrère.

Ténors

Messieurs :
Valette.
Daponte.
Pourville.
Delmas.
Eternod.
Laloye.

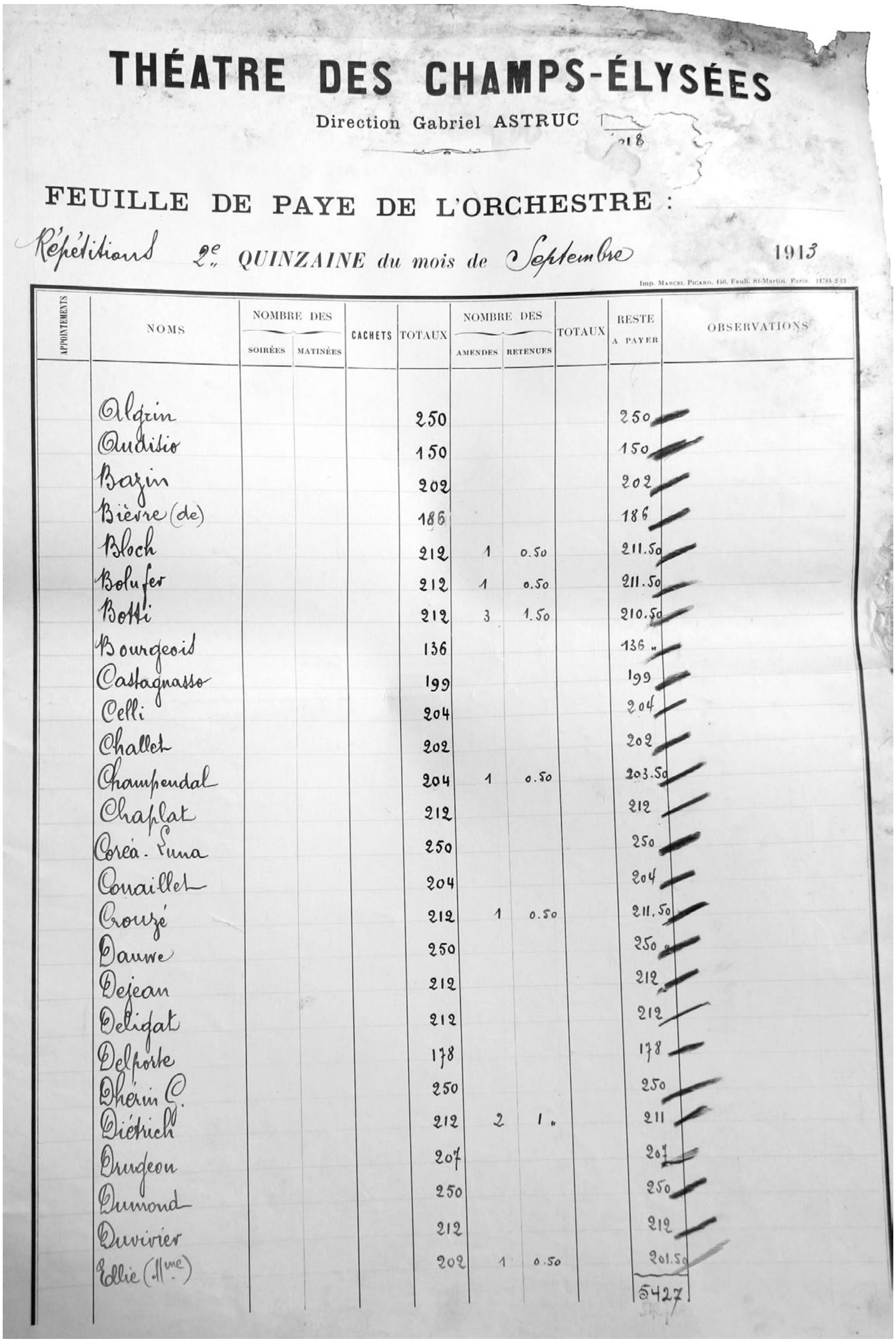
Messieurs :
Saint-Germier.
Payan.
Vilder.
Berryer.
Schlosser.
Cortesi.
Malzac.
Bellanger.
Libert.
Pasquet.
Maire.
Gavarry.
Nagelle.
Darim
Violette.
Sophocle.
Desmarais.

Basses

Messieurs :
Deliano.

Messieurs :
Deschamps.
Car.
Savelli
Delrieu.
Lievain.
Chauchon.
Auer.
Guichard.
Dubois.
Athès.
Richard.
Vallermont.
Mamberti.
Chavanettes.
Euzet.
Moulin.
Wieshaupt.
Barrois.
Fabre-Calixte,
Flotte.

FIGURE 3 **Société des nouveaux concerts (Orchestra of the Théâtre des Champs-Élysées), *Pénélope* programme, 9 May 1913**



THÉATRE DES CHAMPS-ÉLYSÉES

Direction Gabriel ASTRUC

218

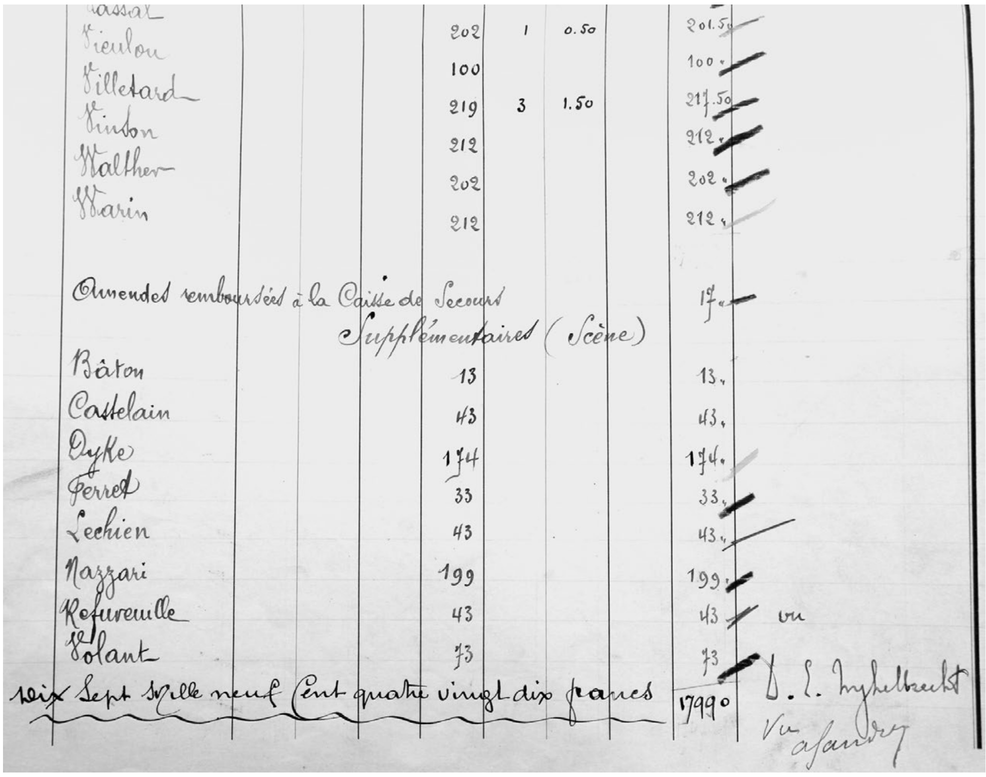
FEUILLE DE PAYE DE L'ORCHESTRE :

Répétitions 2e QUINZAINE du mois de Septembre 1913

Imp. Marcel Picard, 160, Faub. St-Martin, Paris.

APPOINTEMENTS	NOMS	NOMBRE DES SOIRÉES	NOMBRE DES MATINÉES	CACHETS	TOTAUX	NOMBRE DES AMENDES	NOMBRE DES RETENUES	TOTAUX	RESTE A PAYER	OBSERVATIONS
	Algrin				250				250	
	Auditio				150				150	
	Bazin				202				202	
	Bièvre (de)				186				186	
	Bloch				212	1	0.50		211.50	
	Bolufer				212	1	0.50		211.50	
	Botti				212	3	1.50		210.50	
	Bourgeois				136				136 "	
	Castagnasso				199				199	
	Celli				204				204	
	Challet				202				202	
	Champendal				204	1	0.50		203.50	
	Chaplat				212				212	
	Coréa-Luna				250				250	
	Couaillet				204				204	
	Crouzé				212	1	0.50		211.50	
	Dauwe				250				250	
	Dejean				212				212	
	Deligat				212				212	
	Delporte				178				178	
	Dherin G.				250				250	
	Diétrich				212	2	1 "		211	
	Drugeon				207				207	
	Dumond				250				250	
	Duvivier				212				212	
	Ellie (Mme)				202	1	0.50		201.50	
									5427	

Figure 4 First page and excerpt from the last page ("supplémentaires") of the payrolls of September 1913 for the Théâtre des Champs-Élysées (Archives Nationales, Fonds Gabriel Astruc, shelfmark 409 AP39)


...assar
Vieulou 202 1 0.50 201.50
Villetard 100 100.
219 3 1.50 217.50
Vindon 212 212.
Walther 202 202.
Warin 212 212.
Amendes remboursées à la Caisse de Secours 17.
Supplémentaires (Scène)
Bâton 13 13.
Castelain 43 43.
Dyke 174 174.
Ferret 33 33.
Lechien 43 43.
Nazzari 199 199.
Refuveille 43 43 vu
Volant 73 73
Dix Sept Mille neuf Cent quatre vingt dix francs 17990

of it.[13] The list, as communicated via Bullard, is not quite complete, for the ordinary trumpet section is missing, and it only gives the supplementary trumpets.

TABLE 1 Brass players in the orchestra for *Le Sacre*[14]

according to the *Pénélope* programme (9 May 1913)		according to the “small black composition tablet” found by Bullard	
Horns:	Hoogstœl	Horns:	[Paul] Hoogstoel
	Michel		[Jules] Michel
	Algrin		[Joseph] Algrin
	Warin		[Pierre] Warin
	Fabre	S	[Marius-Joseph] Fabre
	Ferret	S	Ferret [= Henri Farré ?]
		S	Vadot
		S	[Ferdinand] Bailleux

13 Nor could any trace of it be found in the Théâtre des Champs-Elysées – and Bullard himself says that he no longer knows the location of the notebook (private communication to the present writer).

14 Programme *Pénélope*; Bullard: *The First Performance*, p. 237 f. First names in square brackets added by Bullard.

Trumpets	Perret	Trumpets	(?)
(& cornets)	Champendal		(?)
	Mériguet	S	[Albert] Dubois
	Marcerou	S	[Georges] Mager
	Dubois		
	Lechien		
Trombones:	Mondou	Trombones:	[Xavier-Marius] Mondou
	Sazy		[Adrien] Sazy
	Martin		[Fernand] Marin
	Dervaux	S	[Jules] Dervaux
Tubas:	Rouge	Tubas:	[Jean] Rouge
	Vieulou		Vieulou

If we combine these lists, we can be relatively sure of knowing most of the names of the brass section on 29 May 1913, at least for the horns and tubas. With the trombones the question remains as to whether Jules Dervaux was a substitute for one of the other trombone players or whether all four of them played (we shall come back to this question below). And for the trumpets we have two names who were certainly part of the *Sacre* orchestra, plus a list of five more players in the *Pénélope* programme from whom the remaining musicians for *Le Sacre* will presumably have been drawn.

Biographies of brass players If we look for all these brass players in the 'concours' lists of the Paris Conservatoire, we can see that most of the musicians in the orchestra were rather young and had either just finished their studies at this time, or were about to do so.[15] Six horn players (1906–1914), six trumpet players and two trombones (and many more woodwinds; we here do not take the strings into account) may be found on these lists. The typically French study system at this institution is the reason for this. At an internal exam in June, students were selected to be given an opportunity to compete in the public 'concours' that always took place in July, at the end of the academic year, and was held for every class (instrumental, theory and composition). Whoever was not selected for this competition within two years after beginning their studies had to leave the Conservatoire, as did those who took part three times without success. Prize-winners were allowed to continue their studies for one year after achieving a Premier Prix. Besides this Premier

15 Unless stated otherwise, all information given here on studies at the Conservatoire is taken from Anne Bongrain: *Le Conservatoire national de musique et de declamation 1900–1930. Documents historiques et administratifs*, Paris 2012, pp. 226–228, 439–445 and appendices.

Prix, a Second Prix, 1er Accessit and 2e Accessit were determined by a secret vote of the jury.[16]

We shall here offer a brief outline of the biographies of all potential brass players in the orchestra pit at the Théâtre des Champs-Elysées in Paris on 29 May 1913, several of whom died at a young age, not long after the premiere of *Le Sacre*, in the battles of the First World War.

PAUL HOOGSTOËL, born in Liévin (Pas-de-Calais) on 7 December 1890, studied with François Brémond at the Conservatoire, achieved his 1er Accessit in 1909, won a Second Prix in 1910 and ended his studies with a Premier Prix in 1911, together with Joseph Algrin. While a report in the newspaper *Le Gaulois* lists only the names of the other prize winners (including the trombonist Jules Dervaux), the two horn players receive a special mention: "MM. Hoogstoël et Algrin, qui tous deux ont une remarquable et poétique sonorité."[17] Hoogstoël was also a member of the Concerts Monteux, the orchestra that gave the first concert performance of *Le Sacre* in April 1914, again under the baton of Pierre Monteux.[18] In later years Hoogstoël played under Sergei Koussevitzky, as did the trumpeter Mériguet.[19]

The first name assigned by Bullard to MICHEL – Jules – might be a mistake, as no such person is listed as having studied at the Conservatoire at that time.[20] Instead, a GUILLAUME JOSEPH MICHEL is mentioned as being a member of the horn class. He was born in Toulouse (Haute-Garonne) on 23 December 1885 and received a 2e Accessit in 1908.

JOSEPH ALGRIN, born in Mèze (Hérault) on 16 (or 18?) November 1887, received a 1er Accessit in 1910 and, as mentioned above, won his Premier Prix alongside Paul Hoogstoël in 1911. He was one of the many victims of the First World War, dying "suite de blessures de guerre" on 23 June 1916.[21]

PIERRE WARIN, born in Valenciennes (Nord) on 1 September 1892, studied with François Brémond and received his 2e Accessit in 1912 and his Second Prix in 1914, though only after the premiere of *Le Sacre*. He was thus still studying while already a full

16 See the regulations in Constant Pierre: *Le Conservatoire national de musique et de déclamation. Documents historiques et administratifs*, Paris 1900, pp. 263, 265 and 267.

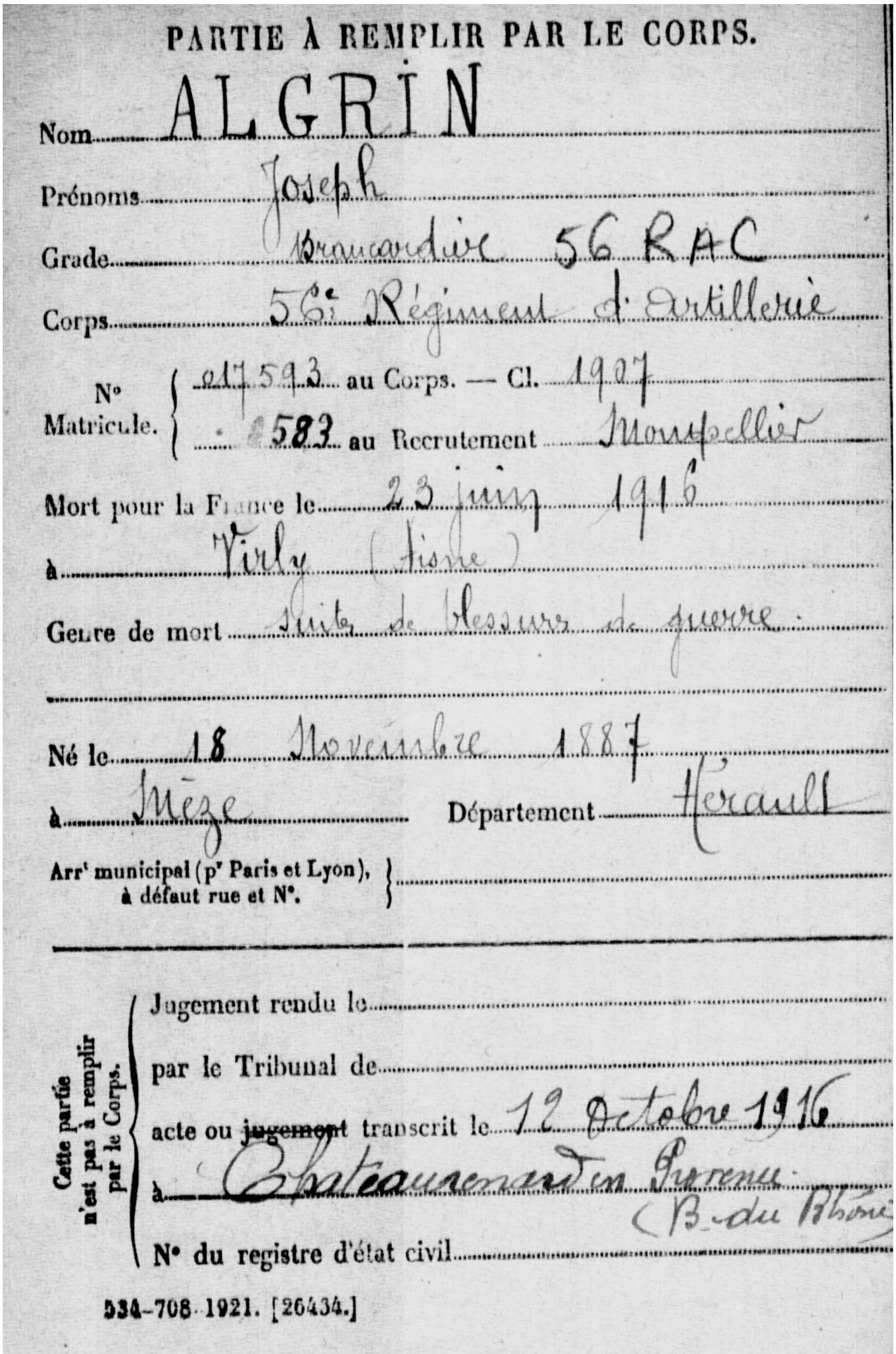
17 Louis Schneider: Conservatoire, in: *Le Gaulois*, 25 June 1911, p. 3.

18 Programme in the Bibliothèque de l'Opéra, Paris.

19 www.classical.net/music/guide/society/krs/programs/1922Mus_1of2.php.

20 We have here also consulted the predecessor of Bongrain's book, namely Pierre: *Le Conservatoire national*.

21 www.memoiredeshommes.sga.defense.gouv.fr/de/ark:/40699/m005239d55e2c4e4/5242bacce7da1.



PARTIE À REMPLIR PAR LE CORPS.

Nom ALGRIN

Prénoms Joseph

Grade brancardier 56 RAC

Corps 56e Régiment d'artillerie

N° Matricule. 017593 au Corps. — Cl. 1907
583 au Recrutement Montpellier

Mort pour la France le 23 juin 1916

à Virly (Aisne)

Genre de mort suite de blessure de guerre.

Né le 18 Novembre 1887

à Mèze Département Hérault

Arr^t municipal (p^r Paris et Lyon), à défaut rue et N°.

Cette partie n'est pas à remplir par le Corps.

Jugement rendu le

par le Tribunal de

acte ou ~~jugement~~ transcrit le 12 Octobre 1916

à Chateaurenard en Provence (B.-du Rhône)

N° du registre d'état civil

534-708 1921. [26434.]

FIGURE 5 Death Certificate of Joseph Algrin (© Ministère des armées – Mémoire des Hommes) member of the orchestra. He was called up into the army in The War, and achieved his Premier Prix ("Prix d'excellence") only in 1919.

MARIUS-JOSEPH FABRE was born at Sète (in these days: Cette, Hérault) on 17 June 1889. After a 2e Accessit in 1908 and a 1er Accessit in 1909, he finished his studies in 1919 with a Second Prix.

We have no details about the horn player FERRET. Bullard suspects that he might have been Henri Farré, who was a horn player at the Opéra comique. Nevertheless, a misspelling seems unlikely, as the name "Ferret" is also found printed in the programme of *Pénélope* and in the programme for the concert premiere of *Le Sacre*, and also written by hand in the aforementioned payrolls.

The next horn player, VADOT, has not been found in any of the sources we have consulted, so it is unlikely that he and Ferret studied at the Conservatoire. Perhaps they were taught at the Garde Républicaine, or had studied in Brussels.

A little more is known about the last horn player. FERDINAND BAILLEUX was born in Valenciennes (Nord) on 17 July 1883, studied at the Conservatoire, and received a 1er Accessit in 1903 and a Second Prix in 1906. He was a member of the Orchestre Colonne officially from 1913 to May 1916, but had probably already joined the army by this latter date, as he was killed in the Somme Valley in 1916. He was awarded the Médaille militaire and the Croix de guerre.[22]

Now to the trumpeters: GUSTAVE JULES PERRET, born in Feyzin (Isère) on 28 October 1886, studied the trumpet with Merri Jean-Baptiste Franquin at the Conservatoire, was awarded a 2e Accessit in 1906, a Médaille for Solfège and 1er Accessit in 1907 and the Premier Prix in 1908. After the war, he continued his career in America, where he played in the trumpet section of the Boston Symphony Orchestra from 1920 to 1933.[23] He later returned to France and was active as a teacher.[24]

LOUIS ÉMILE CHAMPENDAL was born in Paris on 12 April 1888 and also studied with Franquin. After his 2e Accessit in 1908 and his 1er Accessit in 1909, he was awarded the Premier Prix in 1910. He too belongs among the many young men who were lost in the catastrophe of World War I.

AUGUSTE PIERRE LOUIS MÉRIGUET, born in Saint-Junien (Haute-Vienne) on 4 October 1889, studied the cornet à pistons at the Conservatoire with Jean Mellet and Alexandre Petit. He was awarded a 2e Accessit in 1911 and a Premier Prix one year later, in

22 www.memoiredeshommes.sga.defense.gouv.fr/fr/ark:/40699/m005239d6f0d3a4c/5242bbf85ed89.

23 www.stokowski.org/Boston_Symphony_Musicians_List.htm .

24 Jean-Pierre Mathez: Georges Gay [*1922] – Trompeter der leichten Musik, in: *Brass Bulletin* 76 (1991), pp. 50–54, here p. 50.

FIGURE 6 The brass section of the Boston Symphony Orchestra in 1921, with Gustave Perret (standing, right) and Georges Mager (seated, in the middle) (Courtesy of Boston Symphony Orchestra Archives, Douglas Yeo)

1912. He seems not to have been active in the army: "During World War I, René [Voisin, father of Roger] was a freelance musician in many Parisian theaters together with trumpeters Auguste Mériguet and Bailleul (1914–18)".[25] Later, like Hoogstoël, he played in Koussevitzky's Parisian orchestra.[26]

CLÉMENT SILVAIN ALPHONSE ARMAND MARCEROU, born in Elne (Pyrénées-Orientales) on 2 August 1888, studied the trumpet at the Conservatoire: 1er Accessit in 1911, Second Prix in 1912, Premier Prix in 1913. He was also awarded the "Prix Théophile Lisbonne". Nothing seems to be known about his life thereafter.

The next trumpeter might well be a member of a dynasty of trumpeters (though he bears a rather common family name). In the Conservatoire's documents as edited by Constant Pierre, there are four trumpeters named DUBOIS, among them ALBERT DUBOIS, whom Bullard suspects was the supplementary player listed in the abovementioned notebook. However, the 1913 edition of the *Annuaire de l'Association syndicale professionnelle*

25 David Hickman/Michel Laplace/Edward H. Tarr: *Trumpet Greats. A Biographical Dictionary*, Chandler 2013, p. 849.

26 www.classical.net/music/guide/society/krs/programs/1925Mus.php.

et mutuelle de la critique dramatique et musicale lists Albert (residence: Nogent-sur-Marne) as a "pensionnaire",[27] while a fifth Dubois, who is also found in the later documents edited by Bongrain, is mentioned as still being active: ARMAND MARIE DUBOIS, born in Valdahon (Doubs) on 26 July 1885, who received a 2e Accessit in trumpet in 1907.

DÉSIRÉ LECHIEN, born in Champigny (Yonne) on 4 April 1863, studied the cornet à pistons in the class of Jean-Baptiste Arban and finished his studies with a Second Prix in 1885 before many of the other musicians mentioned here had been born.[28] He was thus one of the more established musicians of the orchestra. Lechien is listed only after Dubois in the *Pénélope* programme, and since Bullard states that the latter was a supplementary player, it seems plausible that Lechien was similarly a supplementary trumpeter. His absence in Bullard's list thus suggests that he could not have been in the pit for *Le Sacre*.

Besides Dubois, GEORGES ÉMILE CHARLES DÉSIRÉ MAGER, born in Tourcoing (Nord) on 7 November 1884, is the only trumpeter of whom we can be certain that he played at the premiere of *Le Sacre*. He had studied the cornet à piston at the Conservatoire and received a 2e Accessit in 1904, a Second Prix in 1905 and finally a Premier Prix in 1906. His playing was praised by the newspaper *La Presse* at the time: "MM. Mager et Foveau sont des exécutants impeccables, ils sont l'objet d'une ovation aussi chaude que méritée. [...] Deux premiers prix à l'unanimité à MM. Mager et Foveau."[29] He later made a career in the Boston Symphony Orchestra (see Figure 6). It is interesting that he played a D trumpet by Courtois, at least in his later years. We will return to this matter below.

Now let us proceed to the low brass. XAVIER-MARIUS MONDOU was another established member of the orchestra. Born in Mèze (Hérault) on 27 June 1855, he studied the trombone with Paul Delisse (called Lespagne) and received a Second Prix in 1882 and a Premier Prix in 1883. He became a member of the Orchestre des Folies Dramatiques even before the end of his studies, and in 1882 joined the Opéra orchestra, a post he held for more than twenty years.[30] Later, he became a member of the Monte Carlo Orchestra, and after his retirement he acted several times as an expert for the Conservatoire.

Very little information can be found on ADRIEN SAZY. It seems that he became a member of the musicians' association in 1914.[31]

27 *Annuaire de l'Association syndicale professionnelle et mutuelle de la critique dramatique et musicale*, Paris 1913.

28 Pierre: *Conservatoire national*, p. 792.

29 Robert Mondor: Onzième Journée des Concours du Conservatoire, in: *La Presse*, 29 July 1906, p. 2.

30 Pierre: *Conservatoire national*, p. 815.

31 *Annuaire de l'Association syndicale professionnelle et mutuelle de la critique dramatique et musicale*, Paris 1914.

The identity of the next trombonist is shrouded in uncertainty because the *Pénélope* programme and Bullard differ in their spelling of his name. Bullard opts for FERNAND ÉDOUARD MARIN, born in Pantin (Seine) on 29 March 1887, who received his 2e Accessit in 1907, 1er Accessit in 1909 and a Second Prix in 1910. But there were also two trombone players named Martin who studied at the Conservatoire in the early years of the twentieth century: ADOLPHE MARTIN, born in Valenciennes (Nord) on 1 December 1888, who only achieved a 2e Accessit in 1910, and HENRI JULIEN MARTIN, born in Saméon (Nord) on 19 May 1879, who received a Second Prix in 1900 and a Premier Prix in 1901. We cannot exclude any of these three trombonists from consideration, and it is possible that Bullard's spelling is correct.

The last trombone player is easier to identify, though there is not much information about him. He was JULES DERVAUX, born in Tourcoing (Nord) on 11 May 1887, who first studied solfège and finished his trombone studies with a 2e Accessit in 1908, a 1er Accessit in 1909 and a Premier Prix in 1911.

The tuba players were among the few musicians who did not study at the Conservatoire, for the simple reason that there was no tuba class there at the time. For this reason, they probably studied in the military, though we have been unable to verify this in the case of JEAN ROUGE (or whatever his first name might have been – the *Annuaire de l'Association* also lists an organ and cornet player named FRANÇOIS ROUGE in the years before and after the premiere of *Le Sacre*).

More evidence exists for EUGÈNE-RENÉ VIEULOU, whose name is found several times in the *Journal officiel de la République française*, as in 1910 for example, when he was "directeur de la musique municipale de Gallardon (Eure-et-Loir)" and was made "officier d'académie".[32] Eighteen years later, he received a "médaille militaire" (Garde Républicaine de Paris) as a "musicien de 2e classe, 35 ans de service, 4 campagnes".[33] Various arrangements and marches appear under his name, and in circa 1939 he published a set of études for tuba (*Études caractéristiques pour basse à 4, 5 et 6 pistons*) where he is named as "Tuba Solo à l'Orchestre Symphonique de Paris, Ex-Soliste de la Musique de la Garde Républicaine" and the recipient of several medals (Figure 7).

The instruments Let us now consider the instruments themselves. It is clearly even more difficult to tell what types of horns, trumpets, trombones and tubas were played by the musicians in the pit. But since all of them were French, and France was a rather foreclosed market, it is likely that most of them played French instruments. What is more, in the

32 *Journal officiel de la République française*, 1 January 1910, p. 55.

33 *Journal officiel de la République française*, 11 July 1928, p. 7719.

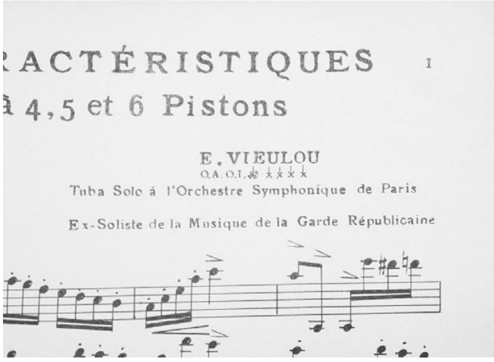


FIGURE 7 Palmarès of Eugène-René Vieulou on the opening page of his *Études caractéristiques pour basse à 4, 5 et 6 pistons* (Copy at the BnF)

early years of the Conservatoire at least, those students awarded a Premier Prix were gifted a (French) instrument:

> "*Nature des premiers Prix*: *Composition*: dix partitions; […] *Piano*: six partitions; *Violon*: un violon; *Violoncelle*: un violoncelle; *Flûte*: une flûte; *Hautbois*: un hautbois; *Clarinette*: deux clarinettes, l'une en *si*, l'autre en *ut*; *Cor*: un cor en tous tons; *Basson*: un basson. […] Les instruments donnés en prix doivent être de facture française."[34]

In later years, however, when the number of students had increased, this tradition seems to have ceased (or at least it is not mentioned anymore): "Art. 67. […] Chaque lauréat reçoit un diplôme. Des médailles en argent sont remises aux premiers et aux seconds prix. Art. 68. L'élève qui a remporté le premier prix peut rester dans sa classe encore une année."[35]

In general, the French manner of building brass instruments entailed using a different bore that was narrower than is normal today, while the construction was also slightly different from that of brass instruments in other European countries. For example, French valve horns often had a detachable crook, whereas the German type was mostly built with a fixed leadpipe. It is also obvious that the playing style and articulation differed from what we are used to today (though this depended on both the instruments and the players themselves).

One can therefore imagine that the horn players at the premiere of *Le Sacre* used horns by firms such as Raoux-Millereau or Courtois-Mille, or perhaps the rather cheaper,

34 Dispositions principales de l'organisation du conservatoire de musique (Germinal an VIII – Mars 1800), quoted as in Pierre: *Le Conservatoire national*, p. 234.

35 Arrêté portant règlement (11 septembre 1878), quoted as in Pierre: *Le Conservatoire national*, p. 264. Already in 1817, horn players seem to have received money (100 francs), while those playing the oboe, clarinet or bassoon received either the money or an instrument: "Un hautbois pour premier prix, s'il est possible, ou 100 francs. […] Un basson, s'il est possible d'en avoir un bon pour 100 francs." And in 1818 it was said that "ces prix sont de trois espèces, savoir: 1° *Des instruments*, pour les classes de violon et violoncelle; 2° *De la musique*, pour toutes les classes de musique; 3° *Des livres*, pour la déclamation." Ibid., pp. 321 f.

mass-produced horns by Couesnon and Gautrot. The tradition of the detachable crook has already been mentioned above. It is furthermore very likely that the higher parts of *Sacre* were played on the ascending valve system that was very common in France. Instead of lowering the instrument by a minor third (as is the case with today's instruments), the third valve in this system raises the instrument by a major second when depressed. This is why it is normally played with a G crook, so that a 'normal' instrument in F results when no valves are depressed. Sometimes, the instruments were also built with a changeable third valve and two different slides – one for an ascending horn for the higher horn parts (with a slide of the same length as for the first valve), and one to change it to a descending model, which the horn section preferred for the lower parts. In any case, these two versions were undoubtedly played side by side in the orchestra pit, rather than the modern double horn in B♭/F that had been developed some years earlier but was not generally employed in those days.

Figure 8 Cor ascendant and cor descendant

The case of the tenor tubas, doubled by horns 7 and 8, is more difficult to determine. There is no doubt that Stravinsky meant two so-called Wagner tubas (where the tenor refers to the tuning in B♭, the instruments in F are called bass tubas).[36] The question remains as to whether such instruments were actually available in Paris, as they were mostly built by German manufacturers at the time, such as Moritz (Berlin) or Alexander

36 "The procession of the sage", played by the tenor tubas und bass tubas, was first intended to be played by muted horns. See Mark DeVoto: *The Rite of Spring. Confronting the Autographs*, in: *The Boston Musical Intelligencer*, 15 February 2021, www.classical-scene.com/2021/02/15/rite-autographs/.

(Mainz). According to the *Encyclopédie musicale* published in 1927 by Lavignac and La Laurencie, these parts were normally played on Saxo-trombas barytons/basses in B♭ when Wagner's *Ring of the Nibelung* was performed at the Opéra.[37] Adolphe Sax Junior is said to have built four instruments with movable bells for this purpose.[38] But since the *Sacre* performances in Paris actually ran at the same time as the *Ring* at the Opéra Garnier,[39] these instruments could not have been used for the former. Another possibility would be the so-called cornophones built by the firm Fontaine-Besson.[40] And, last but not least, the catalogue by Evette & Schaeffer also lists "tubettes", "especially determined for Wagner performances" that were provided with four different mouthpieces so that they might be played by cornet, horn, trombone or tuba players (Figure 9).[41] The question as to the identity of the tenor tuba instrument in the pit for *Le Sacre* remains open, but it is still more likely that the musicians used either some sort of Saxhorn or Saxo-tromba, the abovementioned tubettes or cornophones, rather than actual German Wagner tubas.

EVETTE ET SCHAEFFER, 18-20, PASSAGE DU GRAND-CERF, PARIS — 55 —

Nos	**TUBETTES** Avec le doigté de *la*♮ au 3e piston LIVRÉS AVEC CLÉ D'EAU, UN PUPITRE ET 4 EMBOUCHURES ARGENTÉES	PRIX
—360	**TUBETTE** en *si* ♭, 4 pistons...... **Ces Instruments ont été spécialement établis pour l'exécution des œuvres de RICHARD WAGNER** *Les 4 embouchures livrées avec l'instrument permettent qu'il soit joué indifféremment par un* Cornettiste ou Bugle. Trombone ou Baryton. Corniste ou Alto *mi* ♭. Tuba ou Basse.	**195**

FIGURE 9 Advertisement for "Tubettes" in the catalogue by Evette & Schaeffer (1912), p. 55

Many different sizes and types of tuba existed in France in the late 19th and early 20th centuries: bass and contrabass tubas (sometimes also listed as saxhorns) in C and B♭, with three, four or even six valves. While wind bands normally used tubas in B♭ with three valves, the tuba in C with four or six valves was more common in orchestras.[42]

37 Joseph Brousse: Le tuba, in: Albert Lavignac/Lionel de la Laurencie: *Encyclopédie de la musique. Dictionnaire du Conservatoire. Deuxième partie. Téchnique – Esthétique – Pédagogie*, Paris 1927, pp. 1674–1680, here pp. 1676 f., see also Clifford Bevan: *The Tuba Family*, Winchester ^{2}2000, p. 470.

38 Ibid.

39 On the same Thursday, 29 May 1913, the Opéra gives *Siegfried*, as can be seen in the calendar of events in *Comoedia*, 28 May 1913, p. 6.

40 See John Webb: The Cornophone as Wagner Tuba, in: *The Galpin Society Journal* 51 (1998), pp. 193–195.

41 [Catalogue Evette & Schaeffer] 1912, p. 55.

42 Brousse: Le tuba, p. 1677. See also Bevan: *The Tuba Family*, pp. 345–347.

Given the actual range of the tuba parts – from low E♭$^{\mathrm{I}}$ to G♭^{4} (the first starting on A$^{\mathrm{I}}$, see Figure 10) – the French speciality of the six-valve tuba (with Périnet valves) seems well suited to *Le Sacre*. It is relatively small – more the size of a euphonium today, which gives it a sound that blends somewhat better with the rest of the orchestra than that of the giant contrabass tuba – but is perfectly able to provide the whole range needed by the part in question.

Figure 10 The tuba range in *Le Sacre*

The French trombones of the time differed from modern instruments in their bore and bell in particular. Valve and slide instruments existed alongside each other, with the valve trombone more common in military ensembles and also in the orchestra pit.[43] There is evidence for the existence of the slide trombone in the music, for Stravinsky requires glissandos in all the trombone parts in the "Rondes printanières" (figures 53–54), in the "Glorification de l'Élue" (111–113) and in the "Danse sacrale" (174–186). Nevertheless, Trevor Herbert has been able to prove that Stravinsky was happy enough to have his "glissandos" played by valve trombones, rather than not being played at all.[44] One should therefore at least take into account the possibility that these parts could have been performed with valve trombones. The size of the trombones is also uncertain. Stravinsky does not give any indication as to what he prefers, and the parts – written in tenor and bass clef for all three trombones – seem to exclude an alto instrument at best. Three tenor trombones, or – because the bass clef dominates in the third part, in contrast to the others – two tenor trombones and one bass trombone might have been the actual types played. The instruments built by the various French makers nevertheless exist in rather different bores and forms, while even the makers themselves produced different models that are impossible to list in full, even without considering the problematical question of what mouthpieces were used. Such musical 'interfaces' are both very personal and yet also reflect the period in question, at least to a certain extent. Further research will have to be undertaken here.

With regard to the trumpets, we have evidence that no less than three of our six possible trumpeters participated in an exhibition concert for the firm of Couesnon in 1910:

> "Le 20 décembre 1910, il [Eugène Foveau] participe au concert donné au Grand Palais par l'orchestre Léon Déliance: il fait partie d'un ensemble de 10 cornettistes qui jouent à l'unisson 'Cypris' et 'Fête Militaire' d'A. Petit sur des cornets 'Monopole'; une photo mémorable représentant les 18 solistes de

43 See Trevor Herbert: *The Trombone*, New Haven 2006, p. 191.

44 See Trevor Herbert: Trombone Glissando. A Case Study in Continuity and Change in Brass Instrument Performance Idioms, in: *Historic Brass Society Journal* 22 (2010), pp. 1–18, here p. 13.

> Déliance (tous cornettistes) le montre aux côtés de Lecussant (Opéra), L. Champendal, Lucien Body, G. Delevoye (Club des xx), Gustave Perret (Valette), Lubineau (Colonne), Lucien Jean Robert Gurs, Narcisse Bizet, Arthur Guillet (Lamoureux), Henri Lamouret (Opéra Comique), H. Harscoat, Georges Mager (Concerts Touche), Gaston Petit (Colonne), Noël Laborie, R. Caron et E. Veluard!"[45]

This naturally does not mean that they played only Couesnon trumpets throughout their lives, though it offers further evidence that French instrument makers regarded these musicians as useful partners in promoting their instruments.

There are three different types of trumpet to consider here. Trumpets in B♭ or C were generally the instrument of choice when using a valve trumpet. The trumpet in C was sometimes called trumpet in C alto, because its valves mean it can be constructed shorter than the old natural trumpet in C (basso). The trumpet in D alto, which is a second higher than the trumpet in C, and in which "alto" again refers to Baroque trumpets of double the length, was also in use. Players liked both instruments, in C and D, because of their precision and security in performance.[46] While the trumpet in C – often constructed with a B♭ crook – was regularly used for the normal orchestral repertoire, the shorter trumpet in D was used to interpret the high, risky parts in Baroque pieces by Handel and Bach.[47]

We have a picture of a D trumpet by Courtois that was apparently owned by one of the performers at the premiere of *Le Sacre*: Georges Mager (Figure 11). It bears no serial number, so we do not know when it was built, whether before or after the premiere, though it seems to date from about that time.[48] It is also unclear as to what part Georges Mager played in *Le Sacre*. Nevertheless, we cannot rule out the possibility that this was indeed one of the very instruments played in the pit of the Théâtre des Champs-Élysées on the night of the premiere.

Unanswered questions remain about the trumpet in D alto. Correspondence exists between Stravinsky and Max Steinberg, who was in contact with the company of the instrument salesman Julius Heinrich Zimmermann in St. Petersburg.[49] On 19 December 1912, Stravinsky wrote from Clarens in Switzerland to ask Steinberg what a trumpet in D alto would cost at Zimmermann's.[50] On 11 January 1913, Steinberg wrote back to inform him that none in D was available, but that there was one in E♭ alto with a crook for D.[51]

45 www.thierrycaens.com/efoveau/biographie-deugene-foveau.html.

46 Merri Franquin: La trompette et le cornet, in: Albert Lavignac/Lionel de la Laurencie: *Encyclopédie de la musique. Dictionnaire du Conservatoire. Deuxième partie. Téchnique – Esthétique – Pédagogie*, Paris 1927, pp. 1597–1637, here p. 1611.

47 Ibid., p. 1619.

48 See www.robbstewart.com/courtois-mager.

49 I am grateful to Anselm Gerhard for referring me to these Russian letters.

50 Igor Stravinsky: *Perepiska s russkimi korrespondentami. Materialy k biografij*, ed. by Viktor Pajlakowitsch Varunc (3 volumes), Moscow 1998–2003, Vol. 1, p. 391.

51 Ibid., p. 399.

FIGURE 11 Trumpet in D by Courtois, apparently owned by Georges Mager (© Robb Stewart/Boyde Hood)

There is no letter to confirm that such an instrument was actually ordered, but on 3 May 1913 Stravinsky wrote to insist on being sent the trumpet immediately, which was clearly a more urgent matter for him than procuring the piccolo timpani he had also requested. In this same letter, he wrote about the mutes for the trombones and tubas, which were apparently also to be purchased in Russia:

> "Order at least the *Tromba picc. in Re*. Even if it doesn't work with the *Timpani picc.*, the *Tromba* must arrive *contre tout*! Order from Zimmermann some mutes (made of metal or leather – it doesn't matter) for tuba and trombones – three pieces for trombones and two for tubas. They shall be immediately sent to: *Direction des Ballets russes – chez G. Astruc et C°. Pavillon de Hannover, Rue Louis le Grand, Paris*."[52]

Stravinsky does not seem to be too picky, as it does not matter to him if he is sent copper or leather mutes. Steinberg wrote back to confirm the order four days later: "Trumpet and mutes (5 pieces) are ordered, today they start testing the trumpet, and in a week, they will be sent to Paris; hopefully they will arrive prior to the *Sacre* premiere."[53]

Why Stravinsky decided to import a trumpet from Russia remains unclear. After all, Zimmermann was more of a salesman than an instrument maker himself, and the most expensive (and best?) instruments were purchased by him from Courtois in Paris and others, and then resold.[54] We do not know if the trumpet and all the mutes arrived in time, nor whether the first trumpeter would have been willing to change his instrument to a foreign one, just two or three weeks before the premiere. These too are questions that remain unanswered on our search for the instruments used on 29 May 1913 in Paris.

We do have some information about Georges Mager and his mouthpieces. The Schilke company designed a mouthpiece explicitly for him (Schilke 20D2d),[55] though this was probably many years after the premiere of *Le Sacre*. All the same, its design – with a "large diameter [17.73 mm] for the robust embouchure", which included "a larger 'D' style cup, #2 semi-round rim and larger 'd' backbore [slightly curved out]"[56] – might offer us an indication of his sound preferences (though these might also have changed over the years).

We now come to the last instrument in the brass section of *Le Sacre*, namely the tromba bassa in E♭, played – according to the score – by the fourth trumpet. Today, probably every performance of *Le Sacre* divides up this part, with a trumpet player on a

52 Ibid., Vol. 2, p. 65, translations from the Russian are by the present writer.

53 Ibid., p. 66. The next extant letter is from two days after the premiere, in which Steinberg expressed his hopes that all the instruments had arrived. Ibid, p. 82.

54 See Julius Heinrich Zimmermann: *Musikinstrumente* [catalogue], Leipzig [1899], Reprint ed. by Günter Joppig, Frankfurt 1984, Preface, p. [III].

55 www.thomann.de/de/schilke_20d2d_trompetenmundstueck.htm.

56 *Schilke. Mouthpieces for Brass* [catalogue], [s. l. 2016], p. 12, see also p. 5 for the labelling system.

trumpet in C for the fourth trumpet, and a trombone player on a bass trumpet for the rest of the part (either a bass trumpet in E♭, as written in the score, or even in C or B♭, which were the usual keys for bass trumpets since Richard Wagner invented them). The bass trumpet has valves, though it is more like a trombone in both bore and length, and has normally been played by trombone players. This brings us to the question as to why Stravinsky wrote these two instruments in the same part.

We can find indications as to an answer in Stravinsky's sketchbook, where he states that the part is to be played by a 'trompette contralta in F'.[57] Such low trumpets in F, as well as their counterparts in E♭ (the latter mostly used by the military), can also be found in the abovementioned catalogue of Evette & Schaeffer. This trumpet is narrower in bore than the bass trumpet, and was in fact the instrument on which most trumpet players in older days had to study. This trumpet in F or E♭ might be the reason for Stravinsky having wrote a 'combined' part.

However, if we peruse the performers' list in Bullard again, we see that four trombone players are listed instead of three. If the part could have been played by a low trumpet in F instead of the bass trumpet used nowadays, why would there have been four trombone players?

The solution might be that the old trumpet in F was being increasingly abandoned by trumpet players. In his article on the trumpet for the Lavignac/Lalaurencie *Encyclopédie de musique* of 1927, Merri Franquin tells us that all trumpet players learned the trumpet in F until World War I, with some even doing their exam on that instrument. But he adds that none of them, graduation after 1896, later played it in orchestras because it was assigned more and more to trombone players (its length being the same as that of the alto trombone):

> "La trompette ancienne (dite en *fa*) est dans la même tonalité (même longueur de tube) que le trombone [alto]. C'est une trompette basse jouée, de nos jours, par des trombonistes. […] Sur 43 premiers prix sortis de la classe de trompette, de 1896 à 1914, 15 l'ont obtenu en jouant de la trompette en *fa*, et tous les autres ont appris à en jouer […]. Aucun d'eux n'a jamais joué de la trompette ancienne dans les orchestres."[58]

It remains unclear as to what Stravinsky intended when combining these parts. Was he unaware that the time for combining both instruments in a single part had passed? Or did he have a particular player in mind when he wrote the part? And was that person also the fourth trombonist on the list? Many questions thus remain unanswered.

57 "Tr. c-alta in Fa", see Igor Stravinsky: *The Rite of Spring/Le Sacre du Printemps. Sketches 1911–1913*, London 1969, p. 2.

58 Franquin: La trompette, p. 1614.

In our project, we had to make decisions when planning a workshop concert of brass excerpts from *Le Sacre* using instruments mainly from the Klingendes Museum Bern.[59] Students from the Hochschule der Künste Bern HKB performed several examples at the Fourth Romantic Brass Symposium, using four ascending and four descending horns by Couesnon, Courtois and Raoux-Millereau, trumpets by Couesnon, Pélisson and Halary, an F trumpet by Besson (with a replica by Egger), (slide) trombones by Pihan, Besson and Thibouville-Lamy and finally two six-valve tubas by Gras and Couesnon.[60] These excerpts provided a rough, yet well-balanced brass sound. It was not as rounded (and not as loud) as would have been the case with modern instruments, but had a wide variety of tonal colours. Since the strings, woodwind and percussion were absent for that workshop concert, I here refrain from offering audio examples from it, and instead would like to direct those interested to the live recording of *Le Sacre* by the orchestra Les Siècles under the baton of François-Xavier Roth.[61]

Since the actual sound of the premiere depended on the combination of the instruments and mouthpieces used, the preferences and artistry of the players, the acoustics of the location and the ears of the listeners, we cannot go back in time to recreate the exact soundscape of *Le Sacre* on 29 May 1913 in the Théâtre des Champs-Élysées. But it is clear that there are still many tone colours yet to be discovered when considering historical performances and instruments.

59 www.klingendes-museum-bern.ch.

60 This was combined with the 2017 CIMCIM annual conference: www.hkb-interpretation.ch/cimcim.

61 François-Xavier Roth/Les Siècles: Igor *Stravinsky: Le Sacre Du Printemps/Petrouchka* [CD], Actes Sud, ASM 15 (2014). This recording is available at https://youtu.be/E9evNJu5kBo.

Arnold Myers

Preserving Information Relating to Instruments in Museums

Introduction Museums not only preserve objects, but also information about these objects. Information can be acquired with the object, generated by the museum, or provided by visitors and other external sources. The kinds of information museums preserve and how they do it vary widely, despite professional codes of good practice and the availability of content management systems tailored to museums. In the case of musical instruments, there are specific kinds of information that do not always fit into commercial packages. This article analyses the various kinds of information relating to musical instruments in terms of importance and vulnerability to loss and degradation, suggests priorities for data storage and long-term preservation, examines some of the systems museums have employed for information storage and retrieval, and discusses what museums can learn from digital preservation techniques adopted by research institutions.

Categories of information Musical instruments entering museum collections are re-purposed. As originally produced, they are primarily equipment for music-making with a cultural context, but can also have roles as aesthetic objects for the visual delight of their owner or as status symbols. A museum instrument, however, justifies the deployment of the resources required to curate, conserve and store it by its potential for fulfilling one or more of a variety of purposes in a new cultural context. These can include education, providing evidence of historical music-making practices, and providing models for copying. Performance, museum display and research examination are means to these ends. This re-purposing also often takes place in private ownership. Factual information underlies and valorises most museum activities: display and interpretation, use in performance, security and insurance.

This re-purposing requires a re-prioritising of stored information. A performer's instrument might be accompanied by a stack of sheet music, while museum instruments need conservation, education and research-oriented information. Museum instruments can be interrogated through different disciplines: acoustics, musicology, art history, technology; the future could bring more. We cannot predict future priorities in research or new research techniques. In some cases, it is possible that museum instruments have delivered all they have to teach us, and will never be studied again.

The view is sometimes expressed that *all* information ought to be preserved. This policy has an immediate appeal, but is it practicable? Is there not a danger that we will

doi: 10.26045/kp64-6179-010

devote resources to keeping large quantities of low-quality information? The costs of keeping data may be low, but the costs of evaluating, managing, retrieving and using it are high, since these tasks require skilled human resources.

Much of the content of museum records and catalogues is replaceable. Measurements and transcriptions of inscriptions could be repeated in the event of data being lost. Other information is irreplaceable and justifies considered, planned, and resourced measures for its preservation. The irreplaceable data include ownership provenance, information about who played the instrument and in what musical and social context, and information about its manufacture. The intangible attributes of an instrument contribute significantly to its financial and cultural value, and may need to be validated by research. It is necessary to assess these different kinds of information in terms of their importance and vulnerability to loss and degradation.

Much (but not all) of the information that requires long-term preservation is the data traditionally included in published catalogues. Although printed museum catalogues are long established (some are today available electronically), from the viewpoint of long-term preservation of information, the important criteria may look different from those generally included in a catalogue[1] or aggregation service such as MIMO (which is not primarily a data repository).[2] The kinds of information used in typical catalogues of instruments are listed in Table 1. For collections with large holdings of specific kinds of instrument, additional fields may be needed for measurements and technical description.[3]

The first priority is identifying and naming the instrument. MIMO has a carefully, thoroughly organised thesaurus of instrument names with translations in a number of languages, which is an excellent tool for retrieval by the general public. However, it does not offer details of all the different names used by the various actors in an instrument's history. The inventor, manufacturer, publishers of music scores, players and organologists often used variant names for the same instrument in the one language, and these should perhaps form part of the permanent record together with the sources for the information.

The name of the maker, place and date of production are all data which form part of any catalogue or record display. This information is always subject to revision in the light

1 Arnold Myers: Cataloguing Standards for Instrument Collections, in: CIMCIM *Newsletter* 14 (1989), pp. 14–28, https://cimcim.mini.icom.museum/wp-content/uploads/sites/7/2019/01/Newsletter_14_1989.pdf (all weblinks in this article last consulted 15 February 2022).

2 See https://mimo-international.com/MIMO/.

3 Arnold Myers/Cary Karp: Documentation, in: *The Care of Historic Musical Instruments*, ed. by Robert L. Barclay, Ottawa/London/Edinburgh 1997, pp. 109–123.

of research: if the data is changed, keeping an archive copy of an old file may not be enough without a cogent explanation of the reasons for change.

Museum catalogues often include copious measurements, many of which are without clear purpose and inadequately supported by statements of method and target accuracy. Recording measurements which have no immediate purpose – just in case they are useful to someone some day – is an expensive luxury. If the data were to be lost, one can in most cases recreate much of it through fresh measuring. Measurements should be entirely objective, and in principle are independent of the person doing the measuring, although levels of precision vary. There is a risk that the instrument might be lost, degraded, or that the act of measuring itself risks damage. In the case of brass instruments, for example, some moving parts such as tuning slides can become stuck over a period of time, which means that measurements can no longer be taken. There can be an issue with the volume of measurement data produced by methods such as x-ray, 3D-computed tomography of musical instruments, or even a traditional technical drawing.

The technical description of an instrument can be more a work of art than a science. This is an area where connoisseurship is paramount. Experience of working with similar instruments elsewhere can provide insight and an ability to detect alterations and repairs. Identifying the operation of woodwind fingering systems, for example, is a specialist task. There is no substitute for a trained and experienced eye and keeping one's powers of observation exercised and in good form. A training in museum studies does little to equip one to detect fakes and forgeries.

Describing an instrument is not just a matter of recording facts. The cataloguer has to decide which features are worth recording, and which should be omitted because they are trivial. The guiding principle is to describe distinguishing features in more detail, while indicating the presence of common features as concisely as possible.[4] Since different scholars see different things, there is a strong case for preserving all descriptive information, whether this is the result of systematic documentation or notes made by experts visiting the museum. This is particularly true when it comes to ascertaining the usable pitch of wind instruments. The pitches at which different players find instruments work best vary over tens of cents. There are two aims in pitch measurement: (a) to establish for what pitch standard the maker of the instrument optimised it, which could be an established standard such as *diapason normal*, and (b) to establish at what pitch it actually works best. This is a measurement that should be repeated with as many competent players as possible, whose varying answers should all be recorded. For brass instruments, some objective data can be found by acoustical methods such as the use of

4 Myers: Cataloguing Standards, p. 17.

Table 1 Typical catalogue information relating to musical instruments

Instrument identification
Title(s), keyword(s):
Nominal pitch:
Type or system:

Creation
Maker:
Place:
Date of production:
Serial number:

Measures
Overall size:
Measured sizes including string lengths, sounding lengths, bore profile, weight, etc:
Fitting measurements (such as diameter of mouthpiece receiver):

Description
Technical description:
Inscriptions:
Decorative features:
Faults:
Repair history:
Usable pitch:
Performance characteristics:

Provenance and history
Specific usage history:
Previous ownership:
Current ownership:
Assignment to a named collection:

Curatorial data
Conservation treatment:
Monitoring of condition:
Assignment to a playing/non-playing regime:

BIAS,[5] though even here there is a need for expert judgement over decisions such as the choice of mouthpiece, the settings of tuning slides, and air temperature.

Since actually playing museum instruments is not sustainable in the long-term, if an instrument is played, the experience is definitely unique (for both the player and the audience), probably of lasting value, and certainly vulnerable to neglect and loss. Any findings made by musicians about an instrument's performance characteristics are strong candidates for long-term preservation, along with sound recordings. Information such as which bow or mouthpiece was used in playing an instrument is easily, and probably frequently, lost.

Provenance information is arguably the most precious, and the most vulnerable to degradation and loss. Collectors private and public are often surprisingly uncurious about the past history of their acquisitions. The commercial apparatus of auction houses and dealers often strips instruments of any provenance information they may have had. The intangible attributes of an instrument contribute significantly to its value both financial and cultural.

John Lennon's upright piano, new in 1970 and in itself worth a few hundred pounds, was sold at auction in 2000 for £1.67 million and subsequently placed in the Beatles Story Museum in Liverpool.[6] This may be an extreme example of monetary value deriving from provenance, but scholarly value can also depend on provenance. Statements of provenance and attributions to makers too often rely only on word of mouth. In the case of high value items – whether high financial value or high research value – this is not enough, and the metadata in the form of supporting documentation is crucial. Jeff Nussbaum, Niles Eldredge and Robb Stewart discuss a cornet in a prominent U.S. museum, bought for $ 108,000 and displayed as "the instrument on which Louis Armstrong learned to play when he was just 12 years old". Research into the instrument and the dates when the model was marketed suggest that the claim is false, and that any association with Armstrong is unsubstantiated as far as publicly available knowledge is concerned.[7] The more prominent the association with a particular previous owner or player, the more important it is to obtain and preserve the supporting documentation.

Records of past treatment and condition-monitoring reports need to be kept indefinitely in order to inform future treatments. Conservation treatment reports often

5 See Gregor Widholm: *Brass Instrument Analysis System 7 Handbuch*, Vienna 2015, available under www.artim.at/download/.

6 Georgina Stubbs: George Michael paid £1.67 m for the piano John Lennon wrote Imagine on so people could see it, in: *Independent*, 26 December 2016, www.independent.co.uk/news/people/george-michael-john-lennon-piano-imagine-liverpool-a7496566.html.

7 Jeffrey Nussbaum/Niles Eldredge/Robb Stewart: Louis Armstrong's First Cornet?, in: *Historic Brass Society Journal* 15 (2003), pp. 355–358.

contain valuable original research about the instrument, and copious photography. It can be difficult to integrate the data into other records for the instrument. Information about comparable examples elsewhere may influence decisions about risk-taking when playing instruments, and can be worth recording.

Visiting experts who study instruments are normally required to send a copy of their measurements and observations afterwards, following the CIMCIM *Recommendations for Access.*[8] Museums are able to keep this data and the associated metadata, and, if they do, they can allow other scholars to access them. Some museums keep the data in their files, while others have no policy of storing such data or lack the resources to do so.

Storage The above discussion itemises some of the kinds of information that can be important to keep long-term. Deciding how this is to be done requires one to consider data storage and long-term preservation techniques. Information is most vulnerable to loss when staff changes and inadequate metadata result in degradation of information. Almost inevitably, some metadata has been memorised but not recorded. The time-honoured way to preserve information is to print a catalogue and to place it in libraries around the world. This is often effective, but it can only be part of a solution.

Many musical instrument museums use a commercial content-management system (CMS). Among the many commercially produced content-management systems are: The Museum System (TMS), Vernon Systems, and Axiell's MIMSY. Some are web browser-based and some cloud-based, while others are open-source. They have functions such as storage and retrieval facilities that are difficult to achieve with home-made systems using basic software. However, they can be more popular with museum management than with the staff who have to operate them. They are set up to optimise access by the institution and the general public rather than for storing 'big data'. Some smaller museums have customised existing database management systems and relational database software, such as FileMaker Pro and Microsoft Access, in order to create their own collection-management systems.

Data is entrusted to these systems as an act of faith, since as commercial products no-one knows how long they will last, and whether there will be safe migration to the next generation. Some museums use multiple systems or keep paper printouts of everything as a kind of insurance policy. One solution is to keep data in the most basic, software-independent format available, ASCII plain text, which can at any time be migrated easily into a content management system with no loss of content. The use of a CMS

8 CIMCIM: *Recommendations for Regulating the Access to Musical Instruments in Public Collections,* [s. l.] 1985. Published in English, French, Spanish, German, Italian and Japanese.

has many advantages, but puts data at risk of loss and corruption when the time comes to migrate to the next CMS (even though this might well be a low-level risk).

There can be an issue with the sheer volume of data produced by methods such as X-ray, 3D-computed tomography of musical instruments. Traditional technical drawings can of course be scanned, necessitating a decision about the choice of file format. Similar considerations apply to the circuit diagrams and software which constitute electronic instruments.

The issue of the permanent storage of 'big data' is important to institutions creating research data. There is a significant intersection here with the museum community, and opportunities for knowledge exchange. Major research universities can have a whole department devoted to digital curation that largely works with data from research projects. A large part of the work of such a department involves data appraisal: selecting and setting retention periods. Major research projects have legal requirements and codes of practice that can require making data and research evidence available to other researchers.[9]

However, even well-funded research projects cannot keep everything. Although storage is cheap and getting cheaper,

- data expansion can outstrip storage expansion;
- backup and mirroring are costly;
- retrieval difficulty increases as the volume of data increases;
- creating metadata to preserve context, continuously managing storage, maintaining information integrity through migrations, and ensuring access all require human input and so are expensive.

Retention costs need to be justified; on other hand, selection is a considerable up-front expense.

Archivists need to work closely with data generators and managers. Researchers, who are data generators, can be helped to ensure that their research continues to have an impact when it is in an accessible repository. When archiving research data, the research team needs to provide information on data quality, give guidance on the community who might re-use the data, provide the data in recommended formats, and provide metadata. Meaningful file names can be useful. Formats are a potential issue. Even commonly used formats such as Excel spreadsheets are proprietary and may become unreadable in future if no one intervenes to migrate the data. At the same time, the data repository managers who receive the research data need to make explicit its mission, ensure legal compliance,

9 Digital Curation Centre (DCC): *Curation Reference Manual*, www.dcc.ac.uk/resources/curation-reference-manual.

check and maintain the integrity of data and metadata, create audit trails, and plan long-term preservation.

The criteria for selection can include:

- relevance to the mission of the institution;
- scientific or historical value (assessment of significance, involving projections of future use);
- uniqueness (is the same data preserved elsewhere ?);
- potential for redistribution (assessment of reliability and integrity of data, suitability of format);
- non-replicability (would it be expensive or impossible to repeat the work ?);
- economics (is the expense of managing and preserving the data justified ?);
- full documentation (is the metadata sufficient to allow the data to be used in future ?).

The level of appraisal is not by individual record, but at dataset level or higher. Research data is appraised by archive managers on advice from research teams; peer review can be sought to inform decisions. The rationale for decisions has to be recorded and preserved.

In some cases, a visiting researcher comes from an institution with its own research data management regime, while in other cases a museum might cooperate on a project with a scientific institution. A decision needs to be made here about who keeps the data: the museum or the partner, or both ? Since the museum is already committed to the preservation of objects, it would seem to be the most appropriate institution for preserving related data.

The present generation has opportunities for information preservation that would have been unimaginable before the digital revolution. If managers of musical instrument museums can combine resilient data storage techniques with discerning curatorial connoisseurship, they will maximise the value to future generations of the instruments in their care.

Robert Barclay

Old and New. Mediating Musical Experience

The role of the historic object Since the onset of the early music movement, there has been a strong emphasis on the study of early instruments and restoring them to playing state. There are two components to this trend: recapturing the sounds and sensations of early music, and learning about craft processes, the manner of construction and use of materials. The first of these components is highly subjective and aesthetic, representing a strong desire to recapture the past. As conservator John Watson has observed:

> "Playing Beethoven on an early nineteenth century piano, one cannot help imagining the day when the same instrument took part in the creative process of Beethoven's contemporaries, if not the composer himself. This represents a profound opportunity to step into a dimension of the cultural landscape from which the music originated."[1]

The historic object is a mediator; it helps a spark in our sensibilities cross from the lost past into the experienced present. As such, this use of the historical object is central to the human psyche; it is the driving force behind early music, classic drama, historical fiction, archaeology and the open-ended list of ways in which people of the present culture try to access the past on its own terms.

The second component to the trend is the more pragmatic search for information, often conducted during restoration or conservation treatment. Traces of original craft practices, alterations over the instruments' lifespan, and much other relevant data is derived from instruments during examination. It is true that the bulk of the information we possess concerning the disposition and workings of early instruments has been derived from the processes of either restoration to playing state, or examination with the intent to produce copies. Just to set the record straight upon one point: technicians inform organologists who, in turn, inform musicologists, and not contrariwise. Without craft intervention and organological study, and the technical tools that these two disciplines bring to bear in research, analysis and documentation, the world of early music would be a mere thought structure.

Conservation and restoration Over many centuries of treatment of valuable artistic and technical objects, the restorer has accumulated a history of opprobrium from a twentieth and twenty-first century perspective. Transformations of musical instruments during

1 John Watson: Historical Musical Instruments. A Claim to Use, and Obligation to Preserve, in: *Journal of the American Musical Instrument Society* 17 (1991), pp. 69–82, here p. 75.

DOI: 10.26045/kp64-6179-011

craft intervention have resulted in objects that masquerade as original, yet have acquired accretions as worn parts were replaced, and as musical fashions changed. Classic violins are a case in point. One has only to recall the words of Dom Vincenzo Ascencio, who restored a Stradivari violin for the Spanish Court in 1783:

> "I pierced the centre [patched the belly], replaced the bar by one adjusted to mathematical proportions based on that of Stradivari. I corrected the thicknesses, pieced the four corner-blocks, took the back off and inserted a piece in the centre, as it was too thin. I had to replace the neck, which I did in the most careful manner. I then adjusted the instrument, the tone of which was rendered excellent by all these changes."[2]

The extent and nature of Ascencio's treatment is by no means atypical for the period. Similar transformations have taken place with early keyboards and other instruments. Whenever an object is used it will inevitably change through intervention with tools. Such slow and incremental substitution can lead to a level of unwitting deception, where the desire to recapture the past (mentioned above) comes into conflict with a changed and non-representative object. In essence, the less one knows of the circumstances of an aesthetic experience, the more profound it is likely to be. Gullible scientists have even been co-opted into lending substance to these experiences where the violin is concerned.[3] There is the additional problem of deliberate deception brought about by less scrupulous craftsmen such as Leopoldo Franciolini, whose concoctions grace the storage rooms of many collections.[4]

It has been clearly established that restoration is time-sensitive, in that the processes and results are based upon current knowledge. Restorations considered definitive in previous decades may need to be revisited once new information becomes available. But every re-restoration pushes the historic instrument further from its original state; it does not bring it closer. Thus, returning historical instruments to a functioning state has resulted in a broad understanding of the music in its historical context, but at the expense of the instruments themselves. Conservators, cognisant of these issues, developed the concept of reversibility, all too aware at one level that reversibility of craft processes is impossible.[5] Changes to the historic object during intervention are inevitable. In past decades this realisation resulted in polarised camps where, on the one hand, restoration

2 William Henry Hill/Arthur F. Hill/Alfred E. Hill: *Antonio Stradivari. His Life and Work* (1644–1737), facsimile reprint of 1902 edition, New York 1963, pp. 77 f.

3 Robert L. Barclay: Stradivarius Pseudoscience, in: *Skeptic* 16/2 (2011), pp. 45–50.

4 Edwin M. Ripin: *The Instrument Catalogs of Leopoldo Franciolini*, Hackensack, NJ 1974.

5 Robert Barclay: Reversibility. The Thinking Behind the Word, in: *Reversibility. Does It Exist?*, ed. by Andrew Oddy and Sara Carroll, London 1999 (British Museum Occasional Papers, Vol. 135), pp. 157–160.

to playability was considered axiomatic, and where consignment to a display case or storage room was equated with death; and on the other hand, where restoration was seen as the licensed destruction of historic assets for the purposes of ephemeral delight. The history of this conflict and the strategies to resolve it have been well documented for general musical instrument collections,[6] and more specifically for historic organs.[7]

Two avenues of progress resulted from the reappraisal of restoration to a playable state: restorative conservation, and the making of reproductions. Restorative conservation is a mediated approach to bringing historic instruments into working condition while still protecting their integrity as documents of past practice. This approach has reached a high level of both practical and philosophical maturity, at least in the English-speaking world.[8] The key to this approach lies in documentation and analysis, so any treatment of the object results in a net yield of information. (Translations of these key documents into a number of European languages, at least German and French, would be an excellent service to the profession at large.)

Making copies The early music movement provided a huge stimulus to musical instrument makers in researching and recreating early examples. The industry of producing facsimiles ran parallel to the restoration of extant instruments. Three cases studies – an eighteenth-century horn and two recently-discovered Nuremberg trumpets – illustrate the ways in which musical instrument-making can enhance musical experience while preserving historic documents.

Horn by Christopher Hofmaster, London, circa 1760 This instrument exhibits 'season cracking', a typical deterioration in brass that has been stressed during manufacture. Strain between the grain boundaries in the metal results in vulnerability to attack, particularly by alkalis; cracks appear and propagate, making the metal extremely fragile (Figures 1 and 2). Instruments in this condition cannot be played without great risk, and their acoustic properties are often compromised. In the case of the Hofmaster horn, the fragile state and the lack of a set of crooks and tuning bits made copying the only choice available. Measurements of the corpus of the instrument were used in machining a steel mandrel that conformed exactly to the inside dimensions, and this was used for forming a new bell from sheet brass. A set of crooks based upon the musical requirements of the period was made, each one using a steel mandrel that tapered from the known starting

6 Robert Barclay: *The Preservation and Use of Historic Musical Instruments. Display Case and Concert Hall*, London 2004.

7 John Watson: *Artifacts in Use. The Paradox of Restoration and the Conservation of Organs*, Richmond 2010.

8 Ibid.

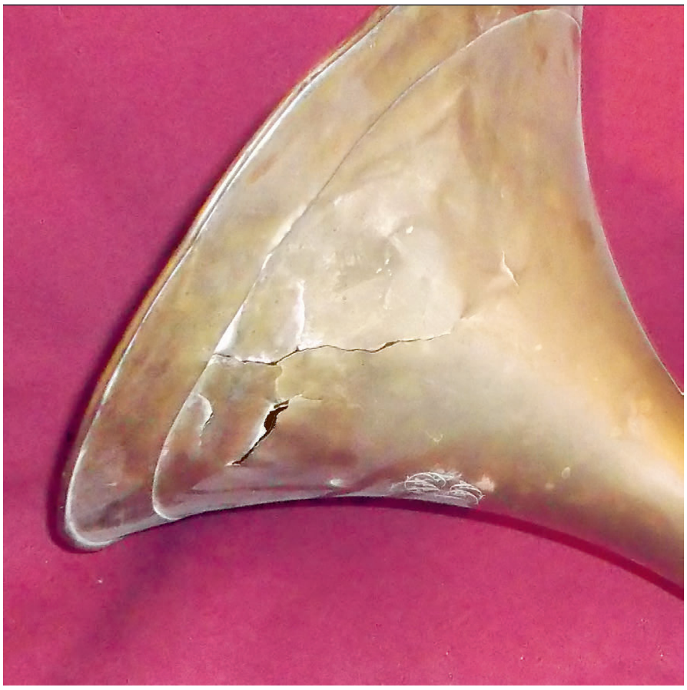


Figure 1 'Season cracking' on the bell of the Christopher Hofmaster horn (photo courtesy of Richard Seraphinoff)

Figure 2 Crumpled tubing due to impact on weakened brass (photo courtesy of Richard Seraphinoff)

Figure 3 Copy of Hofmaster horn with set of crooks (photo courtesy of Richard Seraphinoff)

point in the receiver of the corpus to the known bore of the mouthpiece receiver. The resultant musical instrument is not an 'exact copy' in its entirety, but it is based upon such evidence that the musical results are extremely convincing (Figure 3).[9]

Trumpet by Johann Carl Kodisch, Nuremberg, 1719 This instrument appeared in an estate sale in Indianapolis, Indiana, and little is known of its history. Unlike the horn featured above, this instrument could at least be sounded, although its condition precluded extensive use. It is a good example of the category that has come to be labelled 'soundable' as opposed to 'playable'. For museum objects this is an important distinction, because it means that playing and acoustic qualities of instruments in collections can be assessed under controlled conditions without deleterious use. The decision to make a copy of the trumpet arose from these restrictions in using the original. Basic conservation treatment was applied to the trumpet, including cleaning, stabilisation and filling of a small crack. Dimensions were taken for the production of steel mandrels, and all other parts were documented by drawing and photography. The copy followed the dimensions of the original; the instrument stood in the high pitch of F (~A = 412), and there were reinforcing sleeves on the bell, mouth-pipe and middle yard. It was not possible to determine whether these parts were added in the process of repair, or intentionally in order to alter the pitch after original fabrication. It was decided to retain the present pitch of the original in the copy. The techniques of brass instrument-making have been documented in detail elsewhere.[10] Production of the decorative design on the ferrules could not be done without access to the original rolling mill, so the design was copied and laser-cut into a steel form, which provided the negative mould for pressing new material. The new Kodisch trumpet can be regarded as an 'informed copy' as it follows the original in its present form but, unlike the Hofmaster horn, it makes no conjecture as to the original state (Figures 4 and 5). The finished instrument was assessed against the original and the playing qualities of both were judged identical, but it must be remembered how subjective such impressions are (Figure 6).[11]

Trumpet by Wolfgang Birckholtz, Nuremberg, 1650 This instrument was discovered hanging in the Lutheran church of Belitz in north eastern Germany, where it had remained since 1676 when its owner, Stabstrompeter Jacob Hintze, was killed after an

9 I am indebted to horn-maker Richard Seraphinoff for permission to use this instrument as a case study.

10 Michael Münkwitz/Richard Seraphinoff/Robert Barclay: *Making a Natural Trumpet. Herstellung einer Naturtrompete*, Ottawa 2014.

11 I am indebted to Scott Clements for permission to use this instrument as a case study.

FIGURE 4 Ferrule on Kodisch trumpet (below) and a new ferrule made for the copy (top; photo courtesy of Scott Clements)

FIGURE 5 Engraving of the garland of the Kodisch copy; the supporting plaster of Paris is still in place (photo courtesy of Scott Clements)

FIGURE 6 The old and the new Kodisch instruments side by side (photo courtesy of Scott Clements)

altercation. It was in exactly the state it had been when last used, although its condition had deteriorated.[12] As it stood, the Birckholtz trumpet was a priceless historical document (Figures 7 and 8). Even if it had been playable, the decision to conserve it in its present state and make a copy (or copies) was clear and obvious. As with the other examples above, the instrument yielded dimensions for the production of mandrels and other tooling (Figure 9). In addition to providing a copy, this instrument also provided the additional experience of live concerts in the Belitz church and a commercial recording.[13] The original instrument is now preserved in the collection of the Germanisches Nationalmuseum in Nuremberg, and two copies hang in its place in the church (Figure 10).[14]

Conclusions There has always been conflict between the preservation and the use of historic properties, and this will doubtless continue as long as objects provide the connection – the spark – that crosses the gap between the past and the present. In the museum world we have developed ways of accommodating the demand for authenticity in experience while still maintaining historical and documentary integrity. Careful and structured restoration of originals is the way to achieve this, but it is only valid if the player or auditor requires the 'authentic' aesthetic experience that only the original can provide. The flawed nature of this experience is a separate issue, depending as it does on a lack of information about the actual state of the original object.

Producing copies has been a standard process when supplying musicians with instruments contemporary with the music being played, and it has been the role of museums and private owners to provide access to the originals. Much interpretation has taken place in both conjecturally returning copied instruments to a first-used state, and in providing instruments that modern musicians can use and modern conductors can tolerate. The three case studies here show how degrees of 'copying' are possible and, by extension, how the word 'copy' can be misused. There is an argument to be made for using the term 'informed copy', as is done in the informed performance of early music.

12 State and condition are often confused. See Barclay: *The Preservation and Use of Historic Musical Instruments*, p. 286, fn. 14.

13 Jean-François Madeuf & Ensemble: *Die Birckholtz-Trompete von 1650*, Raumklang RK 1805.

14 I am indebted to Michael Münkwitz for permission to use this instrument as a case study.

Figure 7 The Birckholtz trumpet as found (photo courtesy of Michael Münkwitz)

Figure 8 Close-up of the Birckholtz bell (photo courtesy of Michael Münkwitz)

Figure 9 Close-up of the bell of the Birckholtz copy (photo courtesy of Michael Münkwitz)

Figure 10 Two copies of the Birckholtz trumpet now hang in the church in Belitz, on either side of Jacob Hintze's memorial plaque (photo courtesy of Michael Münkwitz)

Sabine K. Klaus

To Play or Not to Play? How BIAS Can Help

In 2007, the National Music Museum, University of South Dakota, launched a video project to record selected brass instruments in one of its collections: the Joe R. and Joella F. Utley Collection. This project resulted in DVDs to accompany a planned five-volume book series *Trumpets and Other High Brass*,[1] and also provided video clips for future museum displays and online publications. The initial question that arose during the preparation of this project was: how do we choose, from over 600 brass instruments, those that are potentially suitable for recording without testing them beforehand? The aim was to avoid playing historic instruments unnecessarily, only to find that they are not in playing condition.

Selecting instruments for recordings We have found that we can be guided in this selection process by acoustic input impedance diagrams, generated with BIAS (short for non-invasive Brass Instrument Analysis System, developed at the Institut für Wiener Klangstil).[2] Using rubber rings, a self-centring device and a bayonet locking ring, the mouthpiece is given an airtight seal to the BIAS apparatus before the instrument is attached. Acoustic input impedance is the ratio of sound pressure to the oscillating air flow that produces it. In the BIAS apparatus, a microphone in the mouthpiece cup senses the sound pressure there, and a second microphone within the apparatus measures the air flow injected into the instrument. To visualise measurements of acoustic input impedance at a particular frequency, one might imagine an oscillating piston pumping air in and out of the mouthpiece in a pure tone (a sine wave). Either by injecting multiple frequencies simultaneously, or by sweeping the frequency of a sine wave, the BIAS system traces out a curve of the impedance as a function of frequency. For a brass instrument, such an impedance diagram shows a sequence of peaks and valleys. Within the normal playing range of an instrument that plays well, the impedances of the peaks are high (typically in the order of 100 MOhm)[3] and their frequencies fall close

1 So far, four volumes of this series have been published: Sabine Katharina Klaus: *Trumpets and Other High Brass*, Vol. 1: *Instruments of the Single Harmonic Series*, Vol. 2: *Ways to Expand the Harmonic Series*, Vol. 3: *Valves Evolve*, and Vol. 4: *Heyday of the Cornet*, Vermillion 2012, 2013, 2017, and 2022. Each volume is accompanied by a DVD.

2 I want to thank Robert Pyle for his input in interpreting the acoustical analysis below, and for generating the impedance diagrams in the format in which they are presented in this article.

3 The unit of acoustic impedance is the acoustic ohm. Since the acoustic ohm is an inconveniently small unit for use with brass instruments, it is customary instead to use units of millions of ohm, or megohm (abbreviated MΩ).

DOI: 10.26045/kp64-6179-012

to integer multiples of the instrument's pedal frequency. Below I will discuss four categories of impedance diagram that have helped us to decide whether or not to play an instrument.

Example 1: Impedance diagram of an instrument that plays well Figure 1 shows the input impedance diagram of a bugle à pistons in 4½-foot B♭ by Louis Müller in Lyon, made in circa 1835 (NMM 10736), illustrating the position and strength of the natural notes that are playable on this instrument. The player can produce notes whose fundamental frequencies lie on or very near the frequencies of the impedance peaks. The peaks and valleys are regular; the peaks are at a reasonably high level and sharp at the top, suggesting that the natural notes lock in properly. We therefore concluded that this instrument is a good candidate for playing and recorded it with trumpeter Vince DiMartino.[4]

Example 2: An instrument with serious problems that is not fit for recording The most important English contribution to the development of valves was the disc valve.[5] Today, however, conflicting views as to its quality exist; this is due to difficulties in maintaining this complicated valve mechanism. The disc-valve cornopean NMM 7063 by Köhler of London, made after 1851, exemplifies the problems that one may face in keeping this valve type airtight. Figure 3 shows that the impedance peaks and valleys for NMM 7063 without the use of valves, or with the second valve in use, are as regular and well defined as in the Müller bugle à pistons (NMM 10736). However, the first valve displays a very irregular impedance curve that predicts serious problems. Tests with an air-pump device further confirmed that the first valve suffers from a serious leak. We therefore decided not to record the Köhler cornopean, but to leave it well alone.

Example 3: An instrument with plenty of playable notes at a low energy level Figure 5 illustrates the acoustical measurements of the double-piston-valve trumpet NMM 7061 by Joseph Lathrop Allen, made in Norwich, Connecticut, between 1846 and 1849, showing smooth impedance peaks on a low MOhm level. This indicates that the player does not get much support from the instrument and individual natural notes will not lock in very easily. On the other hand, the instrument gives a skilled player more opportunities to manipulate intonation to make up for its faultiness. Despite the predictable problems, we decided to play NMM 7061, mainly because the impedance diagram seemed to confirm a historical assessment about this instrument type. The New York band leader Allen Dodworth described the tonal quality of a family of narrow-bore instruments, to which

4 Klaus: Vol. 3: *Valves Evolve*, DVD track 2.

5 See Frank Tomes/Sabine K. Klaus/Arnold Myers: Shaw, Köhler and the Disc Valve in Britain, in: *Galpin Society Journal* 66 (2013), pp. 99–116.

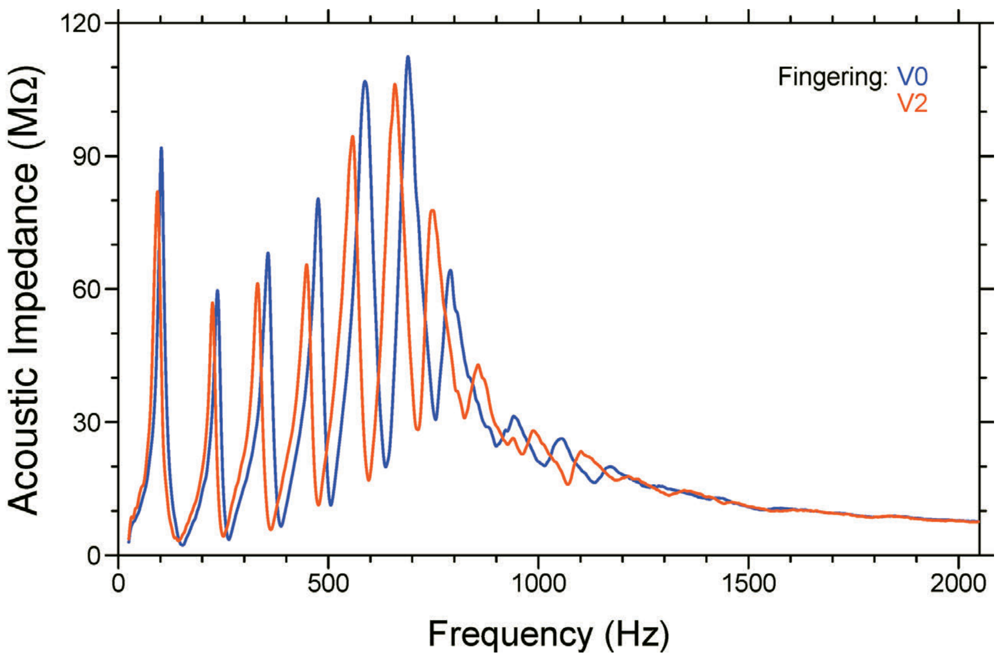


FIGURE 1 Input impedance of a bugle à pistons in 4½-foot B♭ by Louis Müller (NMM 10736). The blue curve shows the instrument without the use of valves, the red curve is generated when the second valve is used.

FIGURE 2 Bugle à pistons in B♭ by Louis Müller, Lyon, circa 1835 (NMM 10736)

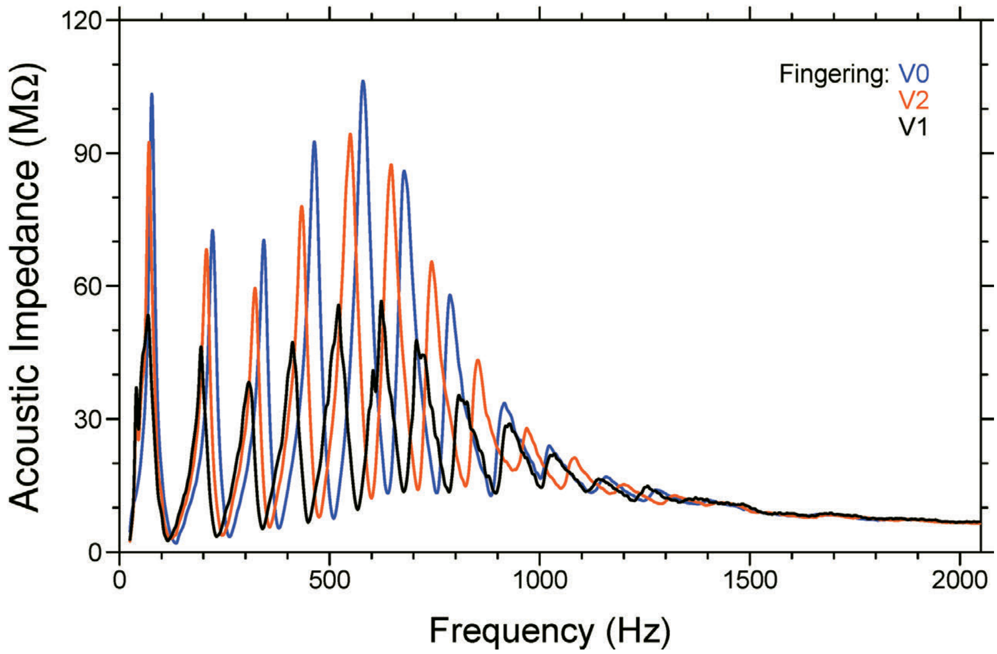


Figure 3 Input impedance of a cornopean by Köhler (NMM 7063). The impedance diagram is regular for the open instrument (blue) and with the second valve in use (red), but very irregular with the first valve due to air-leakage (black).

Figure 4 Cornopean with shanks and crooks for 4½-foot B♭ to 6-foot F by Köhler, London, after 1851 (NMM 7063)

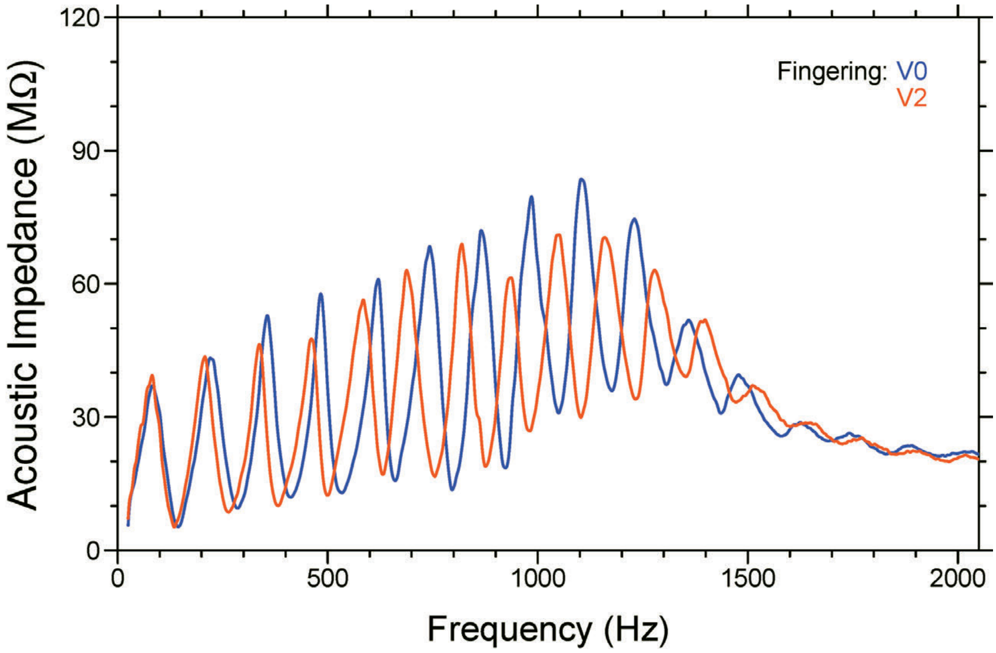


FIGURE 5 Input impedance of the 4½-foot B♭ trumpet (or 'posthorn') by Joseph Lathrop Allen (NMM 7061). The blue curve illustrates the acoustical behaviour of the instrument without valves, while the red curve was measured with the second valve depressed.

FIGURE 6 Trumpet in 4½-foot B♭ by Joseph Lathrop Allen, Norwich, Connecticut, between 1846 and 1849 (NMM 7061)

this trumpet (which he called "Posthorn") belonged, as follows: It is "deficient in power, arising from the smallness of the tubing."[6] Indeed, the playing test with Jeff Stockham showed a subdued tone quality.[7] It can therefore be stated that in this case BIAS helped to validate historical information.

Example 4: Musical instrument or ornament? Input impedance measurements can also help to answer the question as to whether an object was actually conceived as a musical instrument of some sort, or as just an ornament. This question arose in connection with a miniature horn, made in Nuremberg in 1681 by Johann Wilhelm Haas (NMM 7213). Figure 7 shows four distinct input impedance peaks, suggesting that the instrument might be playable, although the natural notes are not well aligned. Note that the impedance at the first peak is so high (167 MOhm) that this plot ranges up to 180 MOhm rather than 120 MOhm as in the other graphs. This little horn was played by Celeste Holler Seraphinoff, who managed to elicit a typical octave leap, as was used for signalling by postmen from the sixteenth to the nineteenth centuries, and entered music history as an idiom, for example in compositions by Johann Sebastian Bach and George Frideric Handel.[8]

Getting instruments ready for recordings Once selected with the help of BIAS, some instruments could be used without further treatment, while others required some preparation. The Haas miniature horn NMM 7213 has its original, integral mouthpiece and could simply be played. Often the initial tubing (mouthpiece receiver) of a historic brass instrument is not totally round anymore and requires some sealing with the mouthpiece; in these instances, wrapping the instrument's initial tubing and the mouthpiece joint with simple cling film may suffice to make an airtight connection. The most drastic and problematic step in the preparation of a valve brass instrument is the use of valve oil, which in most instances is indispensable to make the valves functional and airtight. For a recording session of instruments in the Utley Collection in July 2014 with the trumpeter Vince DiMartino, I therefore decided to allow the use of valve oil, but planned to clean it off thoroughly after the recording session. We used the valve oils, much to my regret, without prior testing. Subsequent concerns were raised during the CIMCIM meeting in Scandinavia in August 2014 about the use of oils in mechanical clocks.[9] This led to an

6 Allen Dodworth: Brass Bands, in: *The Message Bird* (15 June 1850), p. 361.

7 Klaus: Vol. 3: *Valves Evolve*, DVD track 6.

8 Klaus: Vol. 1: *Instruments of the Single Harmonic Series*, DVD chapter 6.

9 Vera de Bruyn: *Material or Sound? Risk-Benefit Analysis in the Recording of Musical Instruments*. Paper presented at the Ringve Museum in Trondheim on 31 August 2014.

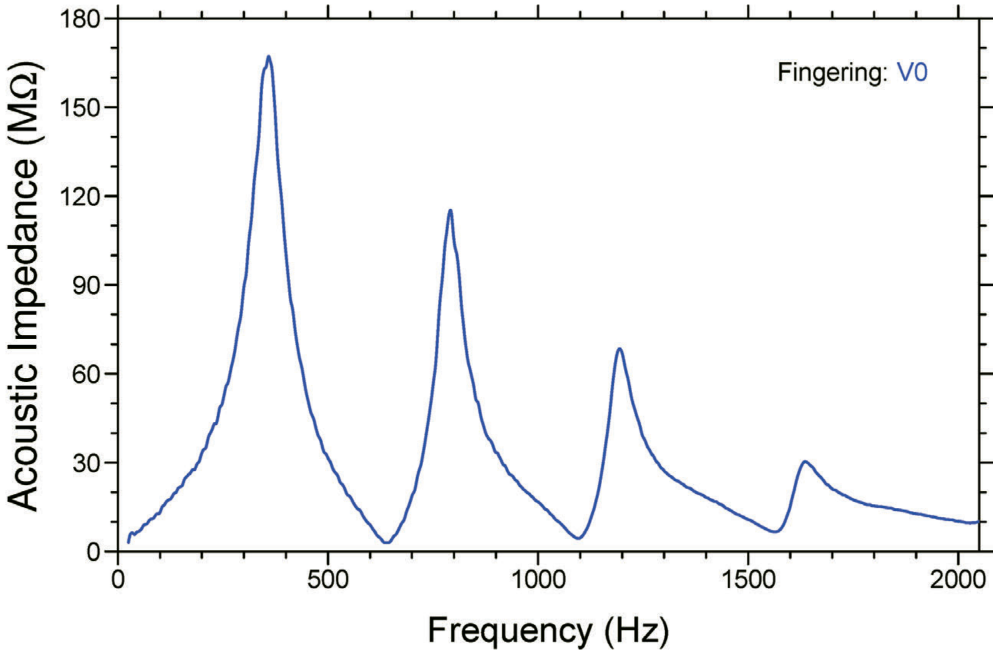


FIGURE 7 Four distinct peaks of input impedance are produced by the miniature horn by Johann Wilhelm Haas (NMM 7213), indicating that it can serve as signal instrument and is not just an ornament.

FIGURE 8 Celeste Holler Seraphinoff testing the miniature horn by Johann Wilhelm Haas, Nuremberg 1681 (NMM 7213)

analysis of the two types of valve oils applied during the recording session the previous month.

Valve oil analysis The two valve oils Vince DiMartino had used were the *Yamaha Synthetic Light Valve Oil* by Yamaha, Japan (P1), and *Synthetic Classic Piston Lubricant* 3 by Hetman, USA (P2). Afterwards, both oils were analysed by the Rathgen-Forschungslabor in Berlin using an Oddy test.[10] The Oddy test, developed by conservation scientist William Andrew Oddy at the British Museum in 1973, is designed to detect harmful materials in display cases, museum environments or packaging in order to prevent damage to museum objects.[11] The Oddy test detects corrosive reactions between the materials to be tested and those present in museum objects.

In this examination, six airtight polyethylene containers were each filled with one of the valve oils to be tested and a 1 cm^2 metal foil of silver, copper or lead. A test tube filled with distilled water was added to each container to ensure constant humidity. The test was conducted over 28 days at 60° Celsius in a drying chamber. The following metal foils by the firm Goodfellow[12] were used in the test:

a) Silver: AG000450/13 silver; thickness: 0.25 mm, purity: 99.95+%, rolled;
b) Copper: CU000591/4 copper, thickness: 0.125 mm, purity: 99.9 %, hard;
c) Lead: PB000280/17 lead, thickness: 0.1 mm, purity: 99.95 %, rolled.

A control test was also conducted in which the metal samples were left in the drying chamber without the addition of the valve oils. Afterwards the metal samples were examined with a digital microscope.[13] Emission of the following compounds is indicated, if corrosion is detected by this test:

Silver:	Emission of sulphur compound;
Copper:	Emission of chloride, oxide and sulphur compounds;
Lead:	Organic acids and aldehydes.

When tested with the valve oil by Hetman (P2), none of the three metal samples showed any corrosion, while the test involving the oil by Yamaha (P1) showed noticeable corrosion of the lead sample. We can therefore conclude that the Yamaha oil should not be used

10 I am grateful to Dr Tom Lerch, Musikinstrumenten-Museum Berlin, for arranging this examination, and to Sabine Schwerdtfeger and Ina Reiche for carrying it out. Rathgen-Forschungslabor, Staatliche Museen zu Berlin, Examination report 88_101414 from 3 December 2014.

11 William Andrew Oddy: An Unsuspected Danger in Display, in: *Museums Journal* 73/1 (1973), pp. 27 f.

12 Goodfellow GmbH, Postfach 1343, Bad Nauheim, Germany, info@goodfellow.com.

13 Microscope VHX-500FD by Keyence.

with museum objects, while the Hetman oil does not raise any concerns when brought into contact with historic valve brass instruments.

Basic treatment after use After the recording session, movable parts such as slides were removed, the instruments and parts rinsed with distilled water, and subsequently dried with a hairdryer. Valves were disassembled as far as possible, although rotors were not removed. Despite efforts to clean off any remaining valve oil, there are areas that are difficult or impossible to access, such as corners in valve cases. When checked in October 2016, some valve oil remains were still found on rotary valves when the bottom valve caps were removed. For this reason, we shall continue to monitor the instruments that we recorded.

Conclusion Once again, we have to conclude that playing our instruments comes with risks attached. We can keep risk factors low, but we cannot eliminate them completely. Acoustical measurements can predict which instruments are potentially suited for recording and which are unplayable, thus protecting the latter from the unwarranted stress of being played with less than satisfying results. The Oddy test showed that it is essential to make sure, prior to playing, that no harmful substances are used in the process of preparing valve brass instruments for recordings, since the reliable removal of oils afterwards is almost impossible.

Marie Martens

Angul Hammerich and the Bronze Lurs. To Play or to Display

Introduction The present article deals with the reception history of the bronze lur from an archival and museum history perspective. However, sources from the nineteenth and twentieth centuries held by the National Museum of Denmark reveal surprisingly little evidence about these characteristic musical instruments and their relatively new life as museum objects.[1]

Even though the bronze lurs from the Bronze Age (circa 1800–500 BC) were investigated during the nineteenth and twentieth centuries, they continue to be a mystery. It is presumed that these instruments from Nordic prehistory were a cult symbol of the Sun, and that they were probably played to worship it. Nevertheless, it is impossible to say anything about how these instruments were played, nor how they sounded 3000 years ago. The bronze lurs are a particularly Nordic phenomenon, and they are likely to have served as status symbols. The first pair of bronze lurs was unearthed in Denmark in the bog of Brudevælte in 1797.[2]

The original name of these ancient instruments remains unknown. In the nineteenth century, the S-shaped natural trumpet with a conical bore was given the name "lur"– a word with roots in the Nordic sagas that was adopted from the wooden lur of the Viking Age (800–1050 AD). This could to some extent explain the great historical confusion between the bronze lurs and the Viking Age, a misinterpretation with roots in the first part of the nineteenth century.[3]

Pioneering survey of the bronze lurs Angul Hammerich (1848–1931), a Danish music historian and the founder and first director of the Musikhistorisk Museum in Copenhagen, was the first to carry out thorough research and an examination of the original

1 This article is partly based on a paper presented at the CIMCIM conference in Switzerland, 22–25 February 2017.

2 I owe my gratitude to Lone Klint Jacobsen and Flemming Kaul, National Museum of Denmark, for access to the archives held by the Department of Nordic Prehistory and for information about the Bronze Age in general.

3 Jørgen Jensen: *Toner fra fortiden*, https://danmarksoldtid.lex.dk/Toner_fra_fortiden (all links last consulted 16 November 2022).

DOI: 10.26045/kp64-6179-013

bronze lurs in the National Museum of Denmark, which he followed up with sound recordings.[4]

According to Hammerich, the earliest description of the bronze lurs was published in a Danish periodical in 1843–45, but in fact we owe the first published description to the second director of the National Museum of Denmark, Christian Jürgensen Thomsen (1788–1865). His three-age system from 1818, which divided the prehistoric periods into Stone, Bronze and Iron Age, was printed in 1836. Jürgensen Thomsen's guideline to Nordic prehistory presented the first illustration of the then so-called *bronze war trombones*. Only one lur with its flat ornamental disc pointing downwards was depicted.[5] Jürgensen Thomsen stated that the bronze lurs in the National Museum at this time were in good condition and that it was possible to play them. Apparently, no further documentation of the bronze lurs was carried out at this point. Hammerich's strongly criticised thesis that the bronze lurs were musical instruments in their own right, published in Danish in 1893, was based largely on his experiments with playing the original bronze lurs in the National Museum of Denmark. Hammerich's thesis was published in German in *Vierteljahrschrift für Musikwissenschaft* the following year.[6]

The passionate critics of Hammerich's methods and results included renowned people from Denmark and abroad, including the Danish philosopher and mathematician Kristian Kroman (1846–1925).[7] Kroman's critical articles from 1902 and 1904 were followed by the German organologist Curt Sachs's (1881–1959) point of view in 1913.[8] Amongst other arguments, published as late as ten and twenty years after Hammerich's thesis, they claimed that Hammerich had supposedly assumed that the people of the Bronze Age were concerned about the shape of the mouthpiece, the quality of tone, the use of overtones, *and* a theory of some kind of polyphony.

4 Angul Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, in: *Aarbøger for nordisk Oldkyndighed og Historie* II/8 (1893), pp. 141–190.

5 [Christian Jürgensen Thomsen]: Kortfattet Udsigt over Mindesmærker og Oldsager fra Nordens Fortid, in: *Ledetraad til Nordisk Oldkyndighed*, ed. by Det kongelige Nordiske Oldskrift-Selskab [Carl Christian Rafn], Copenhagen 1836, pp. 27–87, here p. 48.

6 Angul Hammerich: Studien über die altnordischen Luren im Nationalmuseum zu Kopenhagen, in: *Vierteljahrschrift für Musikwissenschaft* 10 (1894), pp. 1–32.

7 Kristian Kroman: Nogle Bemærkninger om Bronzelurerne i Nationalmusæet i København, in: *Aarbøger for nordisk Oldkyndighed og Historie* II/17 (1902), pp. 79–118; Kristian Kroman: Et Par afsluttende Bemærkninger om Bronzelurerne og hvad de lærer os om de nordiske Bronzealderfolks musikalske Standpunkt, in: *Aarbøger for nordisk Oldkyndighed og Historie* II/19 (1904), pp. 65–88.

8 Curt Sachs: *Real-Lexikon der Musikinstrumente, zugleich ein Polyglossar für das gesamte Instrumentengebiet*, Berlin 1913, pp. 245 f.

However, the question of polyphony in early prehistoric Scandinavian music originated with François-Joseph Fétis (1784–1871), to whose *Histoire générale de la musique* (published in 1869–1876) Hammerich referred a number of times in his own thesis. Most bronze lurs were found in pairs, tuned at more or less the same pitch, but this does not necessarily mean that the instruments were played polyphonically or even in a manner of two-part playing, and Hammerich in fact left open the question of Fétis's theories of polyphony in ancient Scandinavian music.[9]

In an article published in 1903, Hammerich responded to Kroman's criticism and, once again, defended the bronze lurs' value as musical instruments.[10] Hammerich's research methods were also criticised by the Danish organologist Hortense Panum (1856–1933), whose music encyclopaedia, published in 1924, questioned Hammerich's conclusions about the bronze lurs.[11]

In his monograph about Danish music history, published in 1921, Hammerich moderated his arguments, as he did in a manuscript for a series of lectures on music history given at the University of Copenhagen in the period circa 1904–1919.[12] Hammerich was an associate professor of musicology at the University of Copenhagen from 1896 to 1922, and he also gave public speeches on the subject of the bronze lurs. Newspaper advertisements give us an inkling of how popular his lectures must have been at the time of an increasing general interest in the bronze lurs.[13]

In 1931, Godtfred Skjerne (1880–1955), a Danish lawyer and music historian, was appointed director of both the Musikhistorisk Museum and the Carl Claudius Collection after the deaths of Angul Hammerich and Carl Claudius that same year. In 1949, Godtfred Skjerne dealt with the problems of the bronze lurs as musical instruments by adopting a more cautious, scientific approach.[14] In his review of Skjerne's results, Curt Sachs

9 François-Joseph Fétis: *Histoire générale de la musique depuis les temps les plus anciens jusqu'à nos jours*, Vol. 4, Paris 1874, pp. 466 f.; Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, pp. 184–188.

10 Angul Hammerich: Om Bronzelurerne som Musikinstrumenter, in: *Aarbøger for nordisk Oldkyndighed og Historie* II/18 (1903), pp. 62–72.

11 Hortense Panum/William Behrend: Bronzelur, in: *Illustreret Musiklexikon*, Copenhagen 1924, pp. 383–385.

12 See Angul Hammerich: *Dansk Musikhistorie indtil ca. 1700*, Copenhagen 1921, pp. 1–11. Angul Hammerichs Papirer (MMCCS Archive 315), Manuskripter og Optegnelser til Forelæsninger (46 – J, 1a-1b), XXIV. Danmarks Musikhistorie, 1. Oldtid. Middelalder (Danish Music Museum, National Museum of Denmark).

13 See *Adresse Avisen. Upolitisk Handels-Børs-Nyheds og Avertissements-Tidende*, 6 January 1893, p. 1.

14 Hans Christian Broholm/William P. Larsen/Godtfred Skjerne: *The Lures of the Bronze Age. An Archaeological, Technical and Musicological Investigation*, Copenhagen 1949, pp. 73–129.

acknowledged the fact that Skjerne did not jump to conclusions in terms of how the bronze lurs could have been played and how they could have sounded.[15]

In his work on the bronze lurs, it is evident that Hammerich was viewing them from the perspective of his own time and from the viewpoint of Western art music. From his modern standpoint, he failed to consider that the bronze lurs were more likely to have been used for cult purposes, rather than as highly developed musical instruments. Consequently, Hammerich's conclusion that the bronze lurs had a "strong but not sharp tone" seems unlikely, and reflects the modern aesthetic of his own time.[16] In Hammerich's manuscript for his abovementioned lecture on prehistoric music, he pointed out that the sound of the lurs could be *both* soft *and* thunderous. In fact, Hammerich quoted ancient Greek and Latin texts which described the sound of – for example – the cornu as "terribilis", but he initially did not find parallels to the bronze lurs.[17] It would seem that he later paid greater attention to the arguments of his critics.

To play or not to play If one looks at the bronze lurs as mere objects, it is easy to understand the urge to know their sound. Thanks to a different view of museum objects, Hammerich's pioneering sound recordings of the bronze lurs in 1894 provided his own time with an idea of how the original bronze lurs sounded. If we disregard the fact that the bronze lurs had been museum objects for decades, then Hammerich actually applied a modern documentary approach to his research. In his thesis, Hammerich specifically addressed which of the bronze lurs could be played, and which should not be touched under any circumstances. Thus, in his sound documentation of the bronze lurs, Hammerich took seriously the task of preserving the instruments and saving them for posterity.

Today, we must take into account the fact that the times were different back then, and that our attitude towards conservation and preservation has changed over the years. The question of playing or *not* playing original musical instruments in museum collections was an issue neither to Hammerich nor to Carl Claudius (1855–1931), the Danish private collector of musical instruments. Both Hammerich and Claudius arranged historical concerts on more or less original period instruments in their collections, and this was in overall keeping with the practice at the time in musical instrument museums and private collections of musical instruments abroad.

15 Curt Sachs: [Review] H. C. Broholm, W. P. Larsen, G. Skjerne. The Lures of the Bronze Age, in: *Journal of the American Musicological Society* 1 (1950), pp. 46–48.

16 Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, pp. 152–155.

17 Ibid., p. 181.

From the very beginning, Angul Hammerich specifically wanted the instruments in the Musikhistorisk Museum to sound, and he referred to the instruments as "living objects".[18] From as early as 1898, Hammerich invited renowned Danish musicians to participate in the historical concerts given at the museum. Even though the concerts were often accompanied by Hammerich's addresses about music history, the lack of lectures about organology and historical performance practice suggests that these aspects of musicology were not of interest to Hammerich.[19] This fact corresponds to his approach to the investigation of the bronze lurs. Historical concerts also took place in the Carl Claudius Collection, and Claudius referred to the old instruments as "Klangkister" – sound chests – and by that probably meant that their captured sound was only waiting to be released.[20]

Hammerich had found parallels between the mouthpieces of the prehistoric bronze lur and the modern trombone. Even though the mouthpiece of the bronze lur is permanently affixed to the instrument, he applied modern trombone mouthpieces during the recording process. Hammerich must have been aware that this would change the tone and pitch, and that his methods and results would thus be disputed. It is well known that the shape of the mouthpiece, playing technique, time period, geography, and the musician himself are important factors of sound production. We must also assume that Hammerich was indeed aware of the fact that tone production would be much more difficult when using the original bronze lur mouthpieces. In order to further test the tone quality of the bronze lurs, Hammerich also used modern horn and trumpet mouthpieces for his experiments and, obviously, he found that this did in fact alter the tone.[21]

The question of corrosion in relation to the issue of playing or not playing musical instruments from museums must be briefly mentioned. In 1986, a research project was conducted by the National Museum of Denmark. A conservator had the opportunity of doing an endoscopy of one of the bronze lurs from the bog of Brudevælte and, needless to say, corrosion was found. Angul Hammerich concentrated on these particularly well-preserved musical instruments from Brudevælte for both his research and most of his recordings of bronze lurs. Many factors such as production technique, amalgamation, use, soil, climate, air pollution – and the bronze lurs' new life as museum objects – make

18 Anne Ørbæk Jensen: Disse Monumenter ere jo ikke Stene, in: *Musikkens tjenere. Instrument – forsker – musiker*, ed. by Mette Müller and Lisbet Torp, Copenhagen 1998 (Meddelelser fra Musikhistorisk Museum og Carl Claudius' Samling, Vol. 6), pp. 33–69, here p. 61.

19 Ibid., p. 33–45.

20 Carl Claudius: *Carl Claudius' Samling af gamle Musikinstrumenter/Collection Carl Claudius* [descriptive catalogue published by Godtfred Skjerne], København 1931, p. 14. Letter from Carl Claudius to Angul Hammerich, 1 August 1898 (Danish Music Museum, National Museum of Denmark).

21 Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, p. 179.

it impossible to distinguish between corrosion from the Bronze Age and the damage that must have followed by playing the instruments from the 1890s down to our own time. In other words, electrochemistry remains independent of time.[22]

Recordings of the original bronze lurs The archives held by the Department of Nordic Prehistory in the National Museum of Denmark show that the original bronze lurs have been played on surprisingly many occasions since the 1890s, and that many trombone players from Denmark and abroad have applied for permission to play them, even quite recently.

The original bronze lurs have also been recorded a number of times. The recordings from 1894, 1925, and 1966 were authorised and published by the National Museum of Denmark, featuring prominent trombone players. The pioneer recordings from 1894, which followed the year after Hammerich's thesis, are part of the *Ruben Collection* and thus among the oldest sound recordings in the world. As chief representative of *Edisons Fonograph-Compagniet* in Copenhagen, consul-general Gottfried Ruben (1837–1897) had the opportunity of capturing the musicians of the time on wax cylinders. Hence the 1894 recordings of original bronze lurs can still be heard.[23]

In 1925, Hammerich recorded a short speech about the prehistoric bronze lurs in the National Museum, and this was released together with recordings of the original instruments.[24] As the 78-RPM technique had superseded wax cylinders, it was also an opportunity to produce a new, modern recording. At this time, the bronze lurs had become symbols of national importance in Denmark, and Hammerich's work on them had also prompted international interest. In March 1925, bronze lur playing from the town hall of Copenhagen was broadcast on European radio to mark the fact that the original musical instruments would never sound again. The purpose of both events was to raise money for the benefit of the National Museum of Denmark, and Hammerich and the spectacular bronze lurs attracted a lot of attention in the newspapers of the time.[25]

22 The author is grateful to conservators Birthe Gottlieb and Signe Nygaard, National Museum of Denmark, for information about the 1986 endoscopy project and for facts about the bronze lurs and corrosion in general. For a description of corrosion in bronze lurs, see Birthe A. Gottlieb: Lurparret fra Ulvkær i Vendsyssel. Røntgenundersøgelser, in: KUML, *Årbog for Jysk Arkæologisk Selskab* (1990), pp. 31–36

23 The Ruben wax cylinders, circa 1894, recording Nos. 29, 128, and 131. Digitised by the Royal Library – Aarhus, www.kb.dk/en/find-materials/collections/sound-recordings-collections/cylinders-ruben-collection.

24 *Danmarks gamle Lurer – tusindaarige Toner. Foredrag af Professor Dr. Angul Hammerich. Optaget paa Nationalmuseet d. 12. 5. 1925. Udsendt til fordel for Nationalmuseet af Berlingske Tidende & Nordisk Polyphon* [78-RPM], Polyphon X.S. 40657.

25 Original recordings in the Danish Radio archives (Danmarks Radio). See e.g. [Anon.]: Lurblæsning

The museum authorities, among them the previous director of the National Museum, Dr Sophus Müller (1846–1934), had for a long time expressed worries about the state of preservation of the bronze lurs.[26] However, the National Museum was in urgent need of money and it would seem that the public subscription through the "Nationalmuseum-fondet" in 1925/26 was considered more important than the actual instruments. Hammerich referred to Müller's books on Danish prehistory in his thesis, and he and Müller must have exchanged letters about the bronze lurs at the time of Hammerich's survey of the instruments. However, the only solid evidence of a personal connection between the two men seems to be Hammerich's handwritten dedication to Müller on his thesis.

The 1925 recording was supposed to be the last, but in 1966 the National Museum of Denmark released a new recording of the original bronze lurs. On all three occasions, the repertoire played and recorded was Western art music. The 1894 and 1925 recordings were performed by two musicians from the Royal Danish Orchestra who played the national melody *Herlig en Sommernat* by the German-Danish composer Friedrich Kuhlau (1786–1832). The tune is largely based on the natural harmonic series and therefore well suited for natural trumpets without finger holes such as the bronze lurs, though some tones have to be left out or substituted by other tones. Furthermore, the recording included what was considered to be battle signals. However, at the time it was not known that the bronze lurs were unlikely to have been used in battle.

The original bronze lurs were also played on many other occasions. Every year on Midsummer's Day from 1890 to 1910, a pair of bronze lurs was played from the rooftop of the National Museum.[27] It was a very popular tradition, and the public protested when this spectacular ritual was stopped due to the state of preservation of the bronze lurs.[28]

The archives held by the Department of Nordic Prehistory show that both the National Museum of Denmark and the musicians Palmer Traulsen and Georg Wilkenschildt of the Royal Danish Orchestra wished to make a scientific recording of the original bronze lurs once and for all. The Danish archaeologist Hans Christian Broholm (1893–1966), the head curator of the Department of Nordic Prehistory from 1936 to 1965, was displeased with the lack of scientific and musicological results from the existing recordings of the original bronze lurs. However, the funding for a scientific recording could not be raised at the time. In 1947, these two musicians, Traulsen and Wilkenschildt, were appointed to conduct an examination of the bronze lurs in playable condition in the

og Sang pr. Radio, in: *Politiken*, 13 March 1925. [Anon.]: Efter den historiske Lurblæsning, in: *Nationaltidende*, 16 March 1928, p. 1. [Anon.]: De gamle Lurer for sidste gang, in: *Berlingske Politiske og Avertissementstidende, Aften*, 12 May 1925, p. 8.

26 Anton Hansen. *En Kgl. Kapelmusikers erindringer*, ed. by Per Gade, Copenhagen 1996, pp. 48, 242–244.

27 Hans Kjær: *Vor Oldtids Skatte*, ed. by Palle Rosenkrantz, Copenhagen [s. a.], pp. 66 f.

28 J. F.: Den sidste Lurblæsning, in: *Københavns Orkesterforenings Medlemsblad* (1910/11), pp. 141 f.

Figure 1 **Original bronze lurs played on Midsummer's Day, circa 1900 (Department of Nordic Prehistory, National Museum of Denmark)**

National Museum. They very carefully pointed out the various differences between the lur pairs, and stressed the importance of the use of original mouthpieces during the test in order to get a convincing result.[29]

In 1949, Broholm published the monograph *The Lures of the Bronze Age* with William P. Larsen and Godtfred Skjerne. In order to attain the most precise data available at the time for their scientific work, acoustic measurements were performed by the Acoustical Laboratory of the Danish Academy of Technical Sciences in Copenhagen.[30] The recor-

29 *Dokument over Afprøvningen af de intakte Lurer foretaget 1947 af Kgl. Kapelmusikus Palmer Traulsen og Kgl. Kapelmusikus Georg Allin Wilkenschildt* (Department of Nordic Prehistory, National Museum of Denmark).

30 [*Results of acoustical measurements performed on 11 bronze lurs in the National Museum of Denmark by the Acoustical Laboratory of the Danish Academy of Technical Sciences in Copenhagen,*] *Akademiet for de Tekniske Videnskaber – Lydteknisk Laboratorium, Fritz Ingerslev to Godtfred Skjerne, 5 February 1948* (Department of Nordic Prehistory, National Museum of Denmark).

dings seem to be lost, but Godtfred Skjerne's description of the results was published in the book.[31]

However, at the time of the LP recording in 1966, Traulsen and Wilkenschildt, despite all their good intentions, played the same type of Western art music that had been recorded before. This commercial recording included music by Danish composers, for example Carl Nielsen and Hakon Børresen, along with a number of the musicians' own compositions, such as *Bronze Age Rag*.[32] The bronze lurs' original mouthpieces were used for this recording, but the sound quality remains soft and appealing because of the modern playing technique, the embouchure, and the repertoire of these very skilled musicians. Once again, the recording turned out to be a presentation of the ancient musical instruments played in the manner and tradition of modern Western art music. In fact, it would seem that the bronze lurs were played and recorded precisely because this was possible.

Today, permission to play these instruments is unlikely to be granted, but as late as 1984, the Swedish musician, researcher and music archaeologist Cajsa S. Lund was given permission to record original bronze lurs for the Musica Sveciae LP *Fornnordiska klanger*. The recording includes "12000 years of music in 60 minutes" and brings a scientific approach to music from Nordic prehistory. Lund's method is very different from Hammerich's, and gives a theoretical answer as to how the instruments might have sounded in prehistoric times. The recording also offers a plausible answer to how they were used, namely that the bronze lurs were most likely to have been played for cultic purposes.[33]

It does, however, remain a fact that the original bronze lurs have been played and recorded on many occasions in recent times for the sake of sheer entertainment and for commercial purposes. This includes incidental music composed for and played on original bronze lurs by Traulsen and Wilkenschildt on the occasion of the National Museum's 150th anniversary in 1957, Queen Elizabeth II's state visit to Denmark in 1957, a German recording from 1997, and the 1998 recording by the Royal Danish Brass Ensemble which used the lurs from Brudevælte and Folrisdam.[34]

31 Broholm/Larsen/Skjerne: *The Lures of the Bronze Age*, pp. 83–106.

32 *Klange fra Danmark's Bronzealder-Lurer/Music Blown on Lurs from the Danish Bronze Age*, Kgl. Kapelmusici Palmer Traulsen/Georg A. Wilkenschildt, Nationalmuseet/National Museum [LP, 1966]; NM 67-001.

33 *Fornnordiska klanger/The Sounds of Prehistoric Scandinavia*, Musica sveciae: LP 1984, MS 101. CD: 1991, MSCD 101, ed. and annotated by Cajsa Lund [liner notes pp. 18 f., 30 f.].

34 *Lurkomposition af Palmer Traulsen tilegnet Det Danske Nationalmuseum ved 150-års jubilæet d. 15. maj 1957. Uropført på Brudevæltelurerne i C. Solister: Georg Wilkenschildt og Palmer Traulsen, Det Kgl. Kapel* (Department of Nordic Prehistory, National Museum of Denmark), original recordings in the Danish Radio

Exhibiting the bronze lurs No contemporary sources for the bronze lurs exist from the Bronze Age apart from rock carvings, whereas early written descriptions of ancient musical instruments from Greece and Rome have been handed down in the writings of men such as Vergil and Lucan.[35] Angul Hammerich used rock carvings to provide a plausible answer to the question as to how the bronze lurs were held during playing.[36]

Photographs of the bronze lurs on display in the Nordic Prehistory exhibition in the 1880s clearly emphasise the fact that the playing position was still an unanswered question at that time. The lurs were mounted with their flat ornamental disc pointing downwards, and this was also the case with depictions of the bronze lurs in books up to then.[37] Hammerich argued that the end plate should be in an upward position, both because it would otherwise be impossible to play the bronze lurs, and because the instruments would then sound better.[38]

The way the bronze lurs were mounted in the permanent exhibition in the 1930s reflected Hammerich's theory. So did the permanent exhibition from 1992 onwards, which presented the bronze lurs in a story-telling context that made it very clear to museum visitors that the bronze lurs were found in pairs. The current, permanent exhibition, which dates from 2007, is a different matter and stages the bronze lurs in a way that makes them seem like works of art with no reference to their use or history.

Hammered copies When the Musikhistorisk Museum opened in Copenhagen in 1898, the well-known Holmegaard glassworks presented Angul Hammerich's new museum with a copy of a bronze lur made of glass (MMCCS inv.no. F 57). This strongly emphasises the importance of Hammerich's research and the attention it was given.

Hammered copies of the bronze lurs were made from around the turn of the 20th century. The measurements and drawings from Angul Hammerich's work on the bronze lurs were given to the instrument makers I. K. Gottfried, whose company used these materials as the source of their lur Werdegang. These materials were most likely also used during the continuous restoration and conservation of the original bronze lurs – mea-

archives (Danmarks Radio). *Die Luren – Klingende Zeugen der Bronzezeit*, Stephan Maier, Classico Schallplatten, 1997, CR 7020833. *Bronze and Brass, Music from the Danish Past and Present*, Royal Danish Brass Ensemble, Rondo, 1998, RCD 8366.

35 Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, pp. 180 f.

36 Ibid., pp. 158–162. Hammerich: *Dansk Musikhistorie indtil ca. 1700*, pp. 9 f.

37 Well-known examples include Jens Jacob Asmussen Worsaae: *Afbildninger fra Det Kongelige Museum for Nordiske Oldsager i Kjöbenhavn*, Copenhagen 1854, p. 33; id.: *The Industrial Arts of Denmark from the Earliest Times to the Danish Conquest of England*, Covent Garden 1882, pp. 90 f.

38 Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, pp. 158–162.

FIGURE 2 Exhibition of the bronze lurs, Department of Nordic Prehistory, circa 1880 (Department of Nordic Prehistory, National Museum of Denmark)

sures that will have been necessary because of the instruments having been played. The lur Werdegang is now held by the Danish Music Museum.[39]

The private collector Carl Claudius owned a pair of bronze lur copies, and his 1931 catalogue of his collection (published posthumously) showed his fascination with these instruments and the culture that had created them. Claudius also acknowledged the fact that it had proved impossible to copy the casting techniques of the Bronze Age.[40] The bronze lurs probably survived their many years in the bogs because they had been cast, not hammered. They thus bear witness to a highly developed culture capable of an exceptional casting technique – though this does not necessarily mean that the bronze lurs themselves were highly developed musical instruments, such as Angul Hammerich had argued.

The pair of lur copies from the Carl Claudius Collection was made by one of the renowned Danish instrument makers, either I. K. Gottfried or V. Schmidt (the Claudius catalogue and archives offer hardly any information about provenance). Both produced lur copies from plate metal because it had proved impossible to cast a pair of bronze lur

39 I. K. Gottfried: *Bronze lur Werdegang* (Danish Music Museum, National Museum of Denmark, MMCCS Archive 96).

40 Claudius: *Carl Claudius' Samling af gamle Musikinstrumenter/Collection Carl Claudius*, pp. 310–312.

copies that could actually be played.[41] John Petersen, an instrument maker with I. K. Gottfried, explained in an interview that no one had attempted to cast bronze lur copies since the 1930s because the tube turned out thicker on one side, making the instrument impossible to play. Hammered copies have thinner 'walls' than the original bronze lurs which were cast *à cire perdue*, so intonation is easier on the copies, and their tone is more agreeable to the modern ear – a fact that Hammerich also pointed out.[42]

Thanks to modern techniques, a Danish trombone player and a Danish bronze caster recently managed to cast a pair of playable bronze lurs.[43] It is quite thought-provoking that it requires X-rays and 3D-scanning to imitate the casting techniques of Bronze Age people!

Now that we have playable, cast lur copies, it seems unlikely that the original bronze lurs will ever sound again. However, as the bronze lurs continue to fascinate, the question whether 'to play or not to play' historical musical instruments in a museum collection will always remain relevant. A better question to ask would be: When to play and when not to play.

The bronze lurs and the Vikings Little could Hammerich have known that his work would set off a 'bronze lur revival'. The reception history of the bronze lurs from the nineteenth century down to our own time is rather odd, as they have been very much associated with the Viking Age. However, the Vikings played the wooden lur, never the bronze lurs – at the time of the Vikings, the bronze lurs had been in the bogs for a couple of thousand years (something that Hammerich specifically emphasised in his thesis).[44] One might therefore assume that people ought to know better – but associating the bronze lurs with the Vikings proved too popular as a Danish national symbol.

This misinterpretation of the bronze lurs as Viking instruments probably originated with François-Joseph Fétis. The fact that Fétis discussed the bronze lurs in his chapter about Scandinavian music in the Middle Ages – "La musique chez les peuples scandinaves

41 *En musikforretning i 200 år – I. K. Gottfried 1796–1996*, ed. by Klaus Bjerre and Lars Jonasson, Copenhagen 1996, pp. 7–9; Robert Naur: *I. K. Gottfried. 185 år blandt blæseinstrumenter. Skitser af et dansk instrumentmagerværksted gennem 7 slægtled*, Copenhagen [1981], pp. 12 f.

42 Trutter så trommehinderne blafrer, in: *Roskilde Tidende*, 20 October 1984; Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, p. 157.

43 The results of the work by Jens Christian Kloster and Gaute Vikdal can be heard on the recording *Bronselur – Klang av oldtid*, Euridice 2014, EUCD 92 (see also www.bronselur.no). The booklet reads: "The Bronze Lurs for this recording are exact copies of Brudevælte lurs in C at the National Museum in Copenhagen. Copies are made of 'Broncestøberiet A/S' by Peter Jensen by scanning MOEF A/S. The lurs were completed in summer 2013 after years of planning and study of casting technique at various museums in Denmark and Norway".

44 Hammerich: Studier over Bronzelurerne i Nationalmusæet i Kjøbenhavn, p. 187.

FIGURE 3 Undated photo of instrument makers V. Schmidt and R. W. Stepnicka (The Danish Music Museum/ National Museum of Denmark)

au moyen age" – makes one wonder if he was simply lured by the mistaken idea that the Vikings could have played musical instruments from the Bronze Age.[45]

Danish writers, artists, composers and architects in the nineteenth and twentieth centuries used the bronze lurs as national romantic symbols, particularly within the *Skønvirke* movement (circa 1890–1915), which is the Danish equivalent of the Jugendstil/Art Nouveau/Arts and Crafts styles. The bronze lurs and the Vikings were often paired in *Skønvirke* iconography and expressed in a very eclectic, national-Romantic style inspired by Japanese and Arabic art, the Italian Renaissance, the Nordic sagas, and Viking Age ornamentation. Symbolically and artistically, this was in step with the national Romantic notions of the time, and it seems to have been commonly accepted that art did not have to adhere to historical fact. Indeed, it has proved more or less impossible to eliminate the erroneous link between the Vikings and the bronze lurs.

45 Fétis: *Histoire générale de la musique*, pp. 449–469.

The Danish composer Carl Nielsen (1865–1931) unwittingly became involved in the above-mentioned dispute between Hammerich and Kroman. In his article from 1902, Kroman mentioned Carl Nielsen regarding the question of the compass of the lurs.[46] Nielsen was thus most likely aware of the anachronism of the link between the bronze lurs and the Vikings. Nevertheless, Nielsen's incidental music to the play *Hagbarth og Signe* (1910) for the Royal Theatre's open-air performances included two pairs of bronze lur copies.[47] It is possible that Nielsen used these spectacular instruments simply because they were indeed spectacular, because they would sound well and look good on an outdoor stage. Furthermore, the bronze lurs served to emphasise the play's national-Romantic setting as well as its naïve idealisation of the Viking Age.

Unlike other countries, Denmark does not have a national instrument as part of a living tradition. However, at a time of political and national crisis in the course of the nineteenth and twentieth centuries, the need for a national instrument arose, and hence the bronze lurs took on great significance as Danish national symbols.[48] The picture of Vikings playing the bronze lurs is a complete falsification of history, though it remains a popular tool of the tourist industry to this day.

46 Kroman: Nogle Bemærkninger om Bronzelurerne i Nationalmusæet i København, pp. 102–104.

47 Kirsten Flensborg Petersen: Music for Adam Oehlenschläger's Play Hagbarth and Signe, in: *Carl Nielsen. Incidental Music 1*, ed. by Niels Bo Foltmann, Lisbeth Ahlgren Jensen and Kirsten Flensborg Petersen, Copenhagen 2007 (Carl Nielsen Works, Series 1, Stage Music, Vol. 6), pp. XLIV–L.

48 Lisbet Torp: Bliver man skotte af at spille på sækkepibe, in: *Musikkens tjenere. Instrument – forsker – musiker*, ed. by Mette Müller and Lisbet Torp, Copenhagen 1998 (Meddelelser fra Musikhistorisk Museum og Carl Claudius' Samling, Vol. 6), pp. 231–259, here pp. 245–249.

Index

Numbers followed by n. refer to footnotes

Authors

Daniel Allenbach graduated in Musicology, Theater, and Media Studies at the Universities of Bern and Munich. He also did a Performance Master in French Horn with Thomas Müller, Markus Oesch and Raimund Zell at the Hochschule der Künste Bern HKB. Besides orchestral and ensemble playing on modern and historical horns, he writes and corrects programme notes for various concert venues and works as a scientific collaborator in the research department of the HKB.

Robert L. Barclay was born in London, England in 1946. He received a Certificate in Science Laboratory Technology from the City and Guilds of London Institute (1968). After graduating from the University of Toronto with a Bachelor's Degree in Fine Arts (1975), he went on to earn an interdisciplinary PhD at the Open University in England (1999). He worked as a museum object conservator/restorer and musical instrument maker. He instructs at the International Trumpet-making Workshop in Europe and the United States. His publications include *The Care of Historic Musical Instruments* (editor, 1997), *The Preservation and Use of Historic Musical Instruments. Display Case and Concert Hall*, (2004), and *The Art of the Trumpet-Maker* (1992).

Federica Cocco graduated in Chemistry in 2013 at the University of Cagliari. She focused her research within the PhD at the same university on the development of innovative systems for monitoring, cleaning and protection of ancient brass musical instruments. After defending her thesis in March 2017, she had a post-doc position in the surface analytical laboratory of University of Cagliari for two years. In the meantime, she works as a secondary school teacher of mathematics and natural sciences.

Emilie Cornet is a restorer who graduated in conservation-restoration at the University of Applied Sciences in Neuchâtel. After obtaining a Master specialising in scientific, technical and horological objects, she worked for different museums. She also played cornet in the local brass band in her childhood.

Bernhard Elsener is associate professor at University of Cagliari (Italy), Department of Chemical and Geological Science, and former professor at ETH Zurich. He studied materials science at the Department of Chemistry at ETH Zurich and received his PhD from ETH Zurich, Switzerland in 1982. His research interests include corrosion of metals in general, electrochemical techniques, sensors and non-destructive techniques for condition assessment.

Marzia Fantauzzi is associate professor at the University of Cagliari (Italy), Department of Chemical and Geological Sciences. She studied chemistry at the University of Cagliari and received her PhD from University of Cagliari, Italy, in 2005. Her research interests include surface characterisation of materials by X-ray photoelectron spectroscopy.

Erwin Hildbrand is a chemical laboratory assistant specialised in analytical chemistry. Since 2002, he has been working as conservation scientist at the Collection Centre of the Swiss National Museum, where, among other tasks, he is responsible for FTIR analysis on pigments, binders, modern and traditional conservation materials as well as for pollutant tests on different museum materials. He is also responsible for occupational safety and health for the whole Swiss National Museum.

Sabine K. Klaus is the Joe R. and Joella F. Utley Curator of Brass Instruments at the National Music Museum and Professor of Music at the University of South Dakota in Vermillion. Recipient of the American Musical Instrument Society's Frances Densmore Prize (2000) and Nicholas Bessaraboff Prize (2014), and the Historic Brass Society's Christopher Monk Award (2017), she is the author of the book series *Trumpets and Other High Brass* (volumes 1–4 published in 2012, 2013, 2017, and 2022).

Martin Ledergerber studied the conservation of archaeological and ethnographic artefacts at the Haute Ecole Arc Conservation-Restauration Neuchâtel. He was Conservator at the Museum zu Allerheiligen in Schaffhausen, at the Swiss National Museum, and since 2019 at the Museum Rietberg, Zurich. He specialises in preventive conservation and in the conservation of scientific and metal objects.

Eberhard H. Lehmann studied physics at the University of Leipzig before he dealt with the physics and development of the "fast breeder reactor" and finished the PhD at the "academy of science" of the former GDR in 1983. He started as "reactor chief" at the former research reactor SAPHIR at the Paul Scherrer Institute (Switzerland), where he took care for new applications of neutrons, including Neutron Imaging. This know-how was useful enough to build his own research team at the spallation neutron source SINQ. Meanwhile, there are three beam lines under operation for neutron imaging. As president of the "International Society for Neutron Radiology" he was responsible for the 10th World Conference on Neutron Radiography in October 2014 in Grindelwald.

Tiziana Lombardo completed her PhD in 2002 in "Chemistry of Air Pollutants" at the University of Paris Est Créteil on the degradation of glass. In 2002/2003, she studied salt damage in stone materials at the Getty Conservation Institute in Los Angeles. From 2003 to 2013, she worked at the University of Paris Est Créteil, first as assistant researcher and then as an assistant professor, focusing on atmospheric corrosion of medieval and modern architectural glass. Since July 2013, she has been working as Conservation Scientist at the Collection Centre of the Swiss National Museum, where, among other tasks, she conducts research on corrosion of metal and glass artefacts.

David Mannes is a member of the Laboratory for Neutron Scattering and Imaging at the Paul Scherrer Institute, Villigen.

Marie Martens is curator of the Danish Music Museum – Musikhistorisk Museum & The Carl Claudius Collection in Copenhagen. She graduated with a MA in Musicology and Italian from the University of Copenhagen. She has worked at the Danish Music Museum since 2001, and in 2006 she was appointed curator. Since being elected ICOM-CIMCIM Secretary in 2019, she has among other things assisted with CIMCIM's annual meetings.

Arnold Myers is a Senior Research Fellow at the Royal Conservatoire of Scotland and a Professor Emeritus of the University of Edinburgh; he serves as President of the Galpin Society. He read Physics at St Andrews University and received a doctorate from Edinburgh University for investigating acoustically based techniques in the taxonomy of brass instruments. In parallel, he has worked as an information scientist at Heriot-Watt University and as Curator and Director of Edinburgh University Collection of Historic Musical Instruments. He currently researches at the interface of acoustics and the history of brass instruments.

Antonella Rossi, born in Italy, studied at University of Cagliari, obtaining a Laurea degree cum laude in 1981 from the Department of Chemistry in the area of corrosion inhibitors and surface chemistry. She is serving as full Professor of Analytical Chemistry at the University of Cagliari since 2001 and as guest professor at the Department of Materials of the ETH Zurich. Her main research interests are surface functionalisation, characterisation and analysis, development of non-invasive and non-destructive surface analytical strategies for cultural heritage.

Martin Skamletz, born in Austria in 1970, studied music theory and flute in Vienna, traverso in Brussels and composition in Feldkirch. After appointments at Freie Musikschule Basel, Musikhochschule Trossingen and Vorarlberger Landeskonservatorium, he has been teaching music theory since 2007 at Hochschule der Künste Bern HKB, where he is also responsible for the Research Institute Interpretation. www.hkb-inter pretation.ch

Adrian von Steiger is a Swiss musician and musicologist. He received his doctoral degree from the University of Bern with a dissertation on the Burri collection of wind instruments. He conducts research into organology, repertoire, conservation, and the materiality of historic brass instruments at the Institute Interpretation at the Hochschule der Künste Bern HKB, and is the director of the Klingendes Museum Bern.

Marie Wörle is a scientist at the Office for Environmental Protection and Energy, Baselland. Former head of the Laboratory for Research in Conservation at the Swiss National Museum, she has participated in interdisciplinary projects in preventive conservation, and in research in conservation and archaeometry, among others in European projects MUSECORR, CORRLOG and BAHAMAS. She has obtained a PhD in Chemistry at the ETH Zurich.

Hochschule der Künste Bern
Haute école des arts de Berne
Bern Academy of the Arts

Swiss National
Science Foundation

Dieses Buch ist in gedruckter Form im Januar 2023 in erster Auflage in der Edition Argus in Schliengen/Markgräflerland erschienen. Gestaltet und gesetzt wurde es im Verlag aus der *Seria* und der *SeriaSans*, die von Martin Majoor im Jahre 2000 gezeichnet wurden. Gedruckt wurde es auf Eos, einem holzfreien, säurefreien, chlorfreien und alterungsbeständigen Werkdruckpapier der Papierfabrik Salzer im niederösterreichischen Sankt Pölten. Das Vorsatzpapier *Caribic cherry* wurde von Igepa in Hamburg geliefert. *Rives Tradition*, ein Recyclingpapier mit leichter Filznarbung, das für den Bezug des Umschlags verwendet wurde, stellt die Papierfabrik Arjo Wiggins in Issy-les-Moulineaux bei Paris her. Das Kapitalband mit rotschwarzer Raupe lieferte die Firma Dr. Günther Kast aus Sonthofen im Oberallgäu, die auf technische Gewebe und Spezialfasererzeugnisse spezialisiert ist. Gedruckt und gebunden wurde das Buch von der Firma Bookstation im bayerischen Anzing. Im Internet finden Sie Informationen über das gesamte Verlagsprogramm unter www.editionargus.de, zum Institut Interpretation der Hochschule der Künste Bern unter www.hkb.bfh.ch/interpretation und www.hkb-interpretation.ch. Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über www.dnb.de abrufbar.
DOI 10.26045/kp64-6179 ISSN 2700-8681 ISBN 978-3-931264-95-6

Musikforschung der
Hochschule der Künste Bern

ISBN 978-3-931264-95-6