Making Sound Present: Re-enactment and Reconstruction in Historical Organ Building Practices

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Introduction

In his treatise *L'art du facteur d'orgues* ('The Art of the Organ-Builder'), French Benedictine monk and organ builder Dom François Bédos de Celles (1709-1779) described what is nowadays seen as the conundrum of organ sound: 'The entire instrument can be very well built, the pipes perfectly well manufactured and conditioned, and still this can be a very bad organ'.[1] Making the pipes 'speak', as Bédos continues to explain, requires careful attention: 'this instrument being made only to be heard, it is essential to give it a good and pleasing harmony'.[2] Many delicate operations, called 'voicing'[3] are necessary to make sure that the wind passes optimally through the sound-producing mechanism. Only after having voiced all the pipes can the organ builder begin to tune them, i.e. to set them to the appropriate pitches.

Today, voicing is held to be the moment at which the organ builder conveys the signature sound quality to the instrument. The tweaking of pipes that are almost ready to play, but do not sound properly yet, seems to conceal the secret of the good organ builder. The particular timbre of the instrument will depend on the skill of the voicers, and it seems that Bédos was the first to utter this. What listeners eventually appreciate in the instrument – whether consciously or not – is in the hands and ears of these experts. When entering contemporary workshops, one often finds the wall decorated with plates from historical treatises such as Bédos's. Especially organ builders with an interest in the long history of organ building – actually a regular feature in the craft – seem to hold him in high esteem. Even though organ builders have adopted new practices, including machinery that was unavailable when Bédos wrote his treatise in the second half of the eighteenth-century, there seems to be a sense of connecting back to this historical moment of making the art of organ building accessible.

The sound of the organ, as the two authors of this chapter contend, has always been the central problem in organ building. Yet, sound means something different to Bédos than to today's organ builders. This problem becomes particularly relevant when today's organ builders try to approximate the historical sound of the instruments. This entails the necessity to question not only materials and operations, but also ways of hearing and listening. Sound's fleeting nature has not changed since the time of Bédos, but the ways in which sound can be reproduced have changed dramatically. This has affected the notion of sound itself. The intent to understand what organs sounded like in the past necessarily implies addressing sound according to one's present notion of it.

How can we then make sense of this additional element – the notion of sound –, if we want to understand practices of re-enactment in organ building? Obviously, recreation, re-enactment and reconstruction will always be guided by today's conditions for learning to hear. This article proposes a framework that involves three chronologically arranged case studies that allow us to reconstruct three approaches to sound's fleeting nature. The first is that of the French monk and organ builder Bédos; the second concerns a shift in the understanding of sound that began during the second half of the nineteenth century; the third focuses on one expert in the reconstruction of historical organs, namely Munetaka Yokota, who was responsible for the casting and voicing of the pipes in several projects of reconstructing historical instruments.

Historical pipe organs are artefacts with a biography. Built for spaces with their own functions and acoustics, they are unique. Their biographies, sometimes spanning hundreds of years, make pipe organs interesting objects of musicological and organological study.[4] As 'mirrors of their time', pipe organs not only reflect the musical and artistic ideals and practices of a certain period, but also the artisanal knowledge and skills of their makers. As such, they offer an important contribution to an epistemic history of musical artefacts that focuses on the persistence of practical knowledge through technologies and materials.

Thus, organ building, in its richness of information, is a fruitful object in the study of re-enactment practices. For disclosing this knowledge, we will introduce a twofold approach to methodologies of reconstruction, re-enactment and replication. We discuss, on the one hand, the replication and reconstruction of the material object, and on the other hand the way in which historically distant concepts of sound and hearing get in the way of the community of organ builders and researchers who also need to make the result accessible to the present concepts of sound and hearing. We follow a chronological order to tease out the differences between the historical settings from which we reconstruct the concepts of sound and their relations to manual and aural practices.

The three parts of this chapter instantiate a different logical order of these two approaches: Bédos naturally begins with casting the metal sheets from which the pipes are made to then take the organ builder through the construction of a pipe and its voicing. Casting is central in this case study, as it epitomises the extent to which the organ builder depended on carrying out the necessary operations in one go. Even though the good sound of the organ is the goal during this moment, it is at the same time very distant from this operation. By contrast, nineteenth-century scientists and organ builders found themselves confronted with a new malleability both of their basic materials and of sound, and accordingly also attempted to free the discourse from the accidental features inherent to craft. We argue that this allegedly independent concept of sound is a necessary precondition for today's organ builders' practices. Today's reconstructing craftspeople don't simply attempt to reverse the logical order of building and listening, but they are in fact very conscious of the very reversal, as we will seek to instantiate using the example of Yokota. Hence our working hypothesis: Organ building has always relied to a certain degree on practices of re-enactment. What has changed is the degree to which the idea of malleability of sound guides the re-enactment process.

Organ building in the eighteenth century – Casting the pipe in one go

Dom François Bédos de Celles

Dom Bédos was a Benedictine monk who became widely known as an organ adviser and organ builder. Born in the Hérault in France, he entered the congregation of St. Maur in the region of Toulouse at the age of seventeen. He later moved to the abbey of Sainte-Croix in Bordeaux, where he became the abbey's secretary. Three years after moving he finished his first organ, which was built for the monastery church. How he had come to learn the craft is not fully known. Very likely he had been apprentice to the Toulouse based Jean-François Lépine, as the congregation was interested in having its own organ builder.[5] Two of the organs Bédos built are still in use. The one for Sainte-Croix was later transferred to another church in Bordeaux, the second is located at the basilica Notre-Dame des Tables in Montpellier.

Already before 1760, Bédos had made himself a name as a savant. He was elected to the *Académie des Sciences* of Bordeaux, and in 1760 went to Paris to finish a treatise on sundials and gnomology. Starting from 1763, he lived in Paris permanently, where he died at the abbey of Saint Denis in 1779. Bédos is best known for the treatise *L'Art du facteur d'orgues.* Published between 1766 and 1778, its four volumes were part of the *Déscriptions des arts et métiers* that were commissioned by *the Académie Royale des Sciences*. Its 113 volumes provided a detailed account of the state of eighteenth-century manufacturing, craftsmanship, and trades. *L'Art du facteur d'orgues* is the most detailed historical document on organ building in the eighteenth century, and it is still used by organ builders as a reference or source of inspiration.

Bédos's treatise is in line with the overarching project of a representation of craftsmanship. The four volumes addressed the insider and, in addition, also attempted to embed organ building in a broader context. The first volume of the treatise set the stage by introducing general mechanical principles, an overview of tools, and an introduction to the various divisions in an organ. The second volume started off from distributing competences. Here, Bédos addressed the commissioners rather than the organ builders themselves, reminding them of what had to be considered once the decision to build a new instrument had been taken. Most often, Bédos insinuated, commissioners were unable to anticipate what the envisaged space would allow them to have. It was therefore crucial to involve the organ builder from the very beginning. In the ensuing chapters, this second volume expounded in great detail the actual building and construction of the various parts of an organ. The third volume addressed the organists, instructing them how to maintain their instrument. The fourth and final volume added descriptions of concert organs and small organs, as well as cylinder organs.

As is characteristic of the volumes of the *Descriptions des arts et metiers*, Bédos's treatise is accompanied by rich illustrations of excellent quality. The plates added to each of its volumes show detailed illustrations of organ parts, tools, and working procedures. In this combination of text and images, the publication shared the same stylistic characteristics of the *Encyclopédie*. While the *Déscriptions* did not have the same reach as the *Encyclopédie* seen on the longer historical perspective, illustrations such as those in the organ treatise can be seen to adhere to the same policy of publicising knowledge. As Charles Kostelnick has argued, visualising knowledge stood at the centre of the *Encyclopédie* project.[6] Existing technical drawing conventions were used, such as perspective, cutaways and exploded views to see the inside of objects, as well as letters and figures as labels for linking image and text.[7]

In addition, the craftsmen were represented as interacting with technology and performing practical tasks in a physical and cultural context such as the manufacturing shop.[8] This points to a shift from knowing entirely through the mind to knowing through experience and sensory perception. As Kostelnick explains, this shift was characteristic of Enlightenment epistemology.[9] Another illustrative convention in the *Encyclopédie* was the use of images to narrate a process: 'Rhetorically, each plate integrates the temporal elements of its story into a coherent narrative over space and time and is often accompanied by numerous drawings of tools and equipment visualized in the narrative.'[10] John R. Pannabecker has examined how the resulting method of uniform representation by Denis Diderot and Louis-Jacques Goussier, highlighting smooth process and lack of obstacles, eventually omits the tacit knowledge, experience and problem-solving that go with the inherent difficulties and failures of actual work.[11] He analyses how contemporary writers like Claude-Henri Watelet and Benoît-Louis Prévost attempted to represent some of the more intuitive, tacit aspects of the arts and reflected more on matters of personal judgment than did either Diderot or Goussier.

[Figures 4.1-4 can be placed either before or after the following sub-chapter
It is also possible to split and put figures 4.1 and 4.2 near here.]

Casting pipes

To give a better idea of how Bédos used text and images to transmit the art of organ building, the process of casting pipe metal serves as a good example. The chapter on this subject has three sections, each divided into numbered paragraphs. Plates are referred to in the text and sometimes also in the margins. Three plates relate to this chapter (see our Figures 4.1, 4.2 and 4.3). The first plate presents a view of the organ builders' workshop with the melting pot on the left, a slanted casting bench and several objects and tools. Two workers operate a sliding box, into which one of them pours the molten alloy. Some of the tools are shown in more detail below, among which, again, some function in a way that resembles an exploded view.

The first, relatively short, section of the chapter explains which tin to use and how to test it: English tin is the best, tin from Hamburg and the Netherlands should not be used. Testing can be done by using a cupped test stone and watching the texture of the surface of the melt – the object in question can be seen in Figure 4, plate LXIV (our Figure 4.1) lying on the floor and labelled ‘G’.[12] The second section explains how the melting pot is constructed; it should be placed in such a way that it does not hinder the workers. This refers to Figures 1 to 3 on the same plate, to end up in the overview of the workshop in Figure 4. Next, the casting bench is described, as well as the remaining tools to be seen on this plate.

A lengthy description ensues of how to construct the casting bench in such a way that it will not warp as a result of the heat of the molten metal. There are two ways to position the casting table: Slanted, which is most common according to Bédos and shown in the overview of the workshop as well as in the less detailed entry of the *Encyclopédie* (our Figure 4.4), and horizontal, which is shown on a different plate and is the one that Bédos himself prefers. That plate (LXVI, our Figure 4.2) also shows the construction of the table. After explaining that the table can be covered with layers of cloth, molton or linen, Bédos describes the construction of the casting box and the rails that guide it along the edge of the table.

The third section is devoted to the actual casting. To establish the temperature of the molten metal, a piece of white paper should be used: If it stays white, the metal should be heated more. This and other details suggest that Bédos knew from his own experience, or from experienced workers, how to cast. The illustration is now referred to, allocating letters to the two collaborating craftsmen. When casting the molten alloy in the casting box, worker C should press the box tightly to the table, whereas worker D should keep the casting spoon low to prevent the metal from flowing over the hands of worker C. A skimmer is used to clean the molten metal, and a stick to stir it. The right moment to start sliding is when the surface becomes ‘grainy’ or ‘sandy’. While walking along the bench, the box has to be pressed tightly, and at the end of the table one should walk faster because the temperature has dropped already, which causes the metal to solidify. Surplus tin is collected in the trough at the end of the table. Bédos makes clear that the goal of the correct casting procedure is to get metal plates that have the right thickness. Plate LXXII shows the design of a double casting box in Figure 4.3. Such a box enables the casters to even more precisely control the thickness of the metal sheet.

Overall, the tools are described and visualised in great detail, including human figures and even objects that seem mundane, such as the broom to clean up spilled tin in the workshop illustration. They present situations – e.g. the casting bench and the box in their relation to the melting furnace – that are assembled for a specific purpose, such as controlling the thickness of the metal plate. The use of paper to establish the temperature or the position of the casting spoon to prevent accidents can be seen as instances of verbalising and visualising tacit knowledge or embodied skills. Yet, the most important purpose of the description is to convey the rationale of this step in manufacturing the pipes. The missing element of this rationale is the sound of the pipes. Any of the steps can eventually result in, and be controlled by, listening to the pipes during voicing. For the organ builder this loudly tacit aspect could not possibly be addressed. The goal – good sound – was always implied, yet without any means to differentiate within this concept according to the required procedure.

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The discussion of sound in L’Art du facteur d’orgues

The description of casting metal is perhaps closest to the general aims of the encyclopaedic projects such as the *Descriptions des arts et metiers*. The aspect of sound, however, makes this craft peculiar, as becomes clear from the passage cited at the beginning. Any gesture or operation that the organ builders carry out is intended to contribute to the sound of the musical instrument. This starts with the very first subjects discussed in Bédos's treatise. The advice that the place for the organ should be chosen carefully and the dimensions of the instrument considered with respect to the architecture and the financial means that are available, in the event, are meant to secure its functioning as a musical instrument. The organ could be too large or placed in the wrong spot, not to speak of architectural problems, such as a structure that would not hold the heavy weight of the pipes or start vibrating with them; any unreasonable decision can eventually spoil the organ. This aim of the craft – to give the instrument a good and pleasing harmony – is explicated in the treatise only when it comes to voicing, yet its implicit presence differs to some extent from notions of tacit knowledge that result in less ephemeral effects than sound.

To understand the peculiar nature of sound as an element of practical knowledge, two aspects in the overarching function of sound must be distinguished. One is conceptual, the other pragmatic. A concept of sound accompanies all the steps in making the organ. Yet, although the experiential knowledge of former generations of organ builders flows into them and is explicated to a great extent in Bédos's treatise, the effect of the operations cannot be controlled directly. Bédos also addresses such a moment of direct control when he discusses voicing. In this operation, actual sound must be heard. Here, sound acts as the effect of the tweaking of the pipes so as to enable them very concretely to function properly – and that means to produce good sound.

Bédos's description of voicing is telling in this respect; it contains the only moment when the sound becomes the subject of the discussion. That is to say, sound is being discussed when it occurs in direct interaction with the material object. By changing the position of the upper or lower lip, for instance, or by raising or lowering the languid, the metal plate that separates the pipe body from the pipe foot and creates the windway.[13] He used terms such as 'soft' or 'sharp' to describe the sound of the pipe in question. Such qualifying descriptions always go hand in hand with concrete actions. If the builder used the right materials, followed the correct scaling of the pipes and the cutups, and assured a good wind pressure from the very beginning, a pipe would speak almost automatically. Voicing thus was understood to be the finishing moment in a process, which in one single proper way prepared harmonious sound.

To find out what an organ sounds like, the organ builder of Bédos's times had to go to an organ and play it. The immensely complex procedure that was needed for materialising this instrument, of course, relied on experience and, by the same token, on the transmission of tacit knowledge. Most of the steps of the procedure had to be done without being able to carry out an immediate test. The casting of the metal, which is crucial for a pipe that is thick and thin, soft and hard at the ideal spots, resulted in a characteristic spectrum of overtones, as we would say in a more contemporary technology. Yet, in the process of making a pipe, the moment of casting was far from the moment when the pipe first resounded. This comes to the fore in the moment of voicing. If the casting went wrong, voicing would not remedy the problem.

Organ building in the nineteenth century – Malleable sound

In 1887, Swiss organist Carl Locher published a booklet in which he describes the organ stops. He also included an entry about voicing. Although badly paid, voicing should be seen as 'the actual *art* in organ building,' he asserted.[14] He considered it one of the most important operations in organ building, since the instrument's sound depends on it. As did Bédos, Locher insisted that an excellent instrument may turn out to sound bad, if it is not properly voiced. He went on to provide criteria for successful voicing. Thus, the result should be 1). a proper definition of the pipes' sound with regard to high and low tones; 2). it should enable the pipes to 'speak' easily and quickly, 3). convey them an appropriate sound quality (*Klangfarbe*), and 4). adjust the volume to the space in which the instrument is located. Finally, Locher included

5). temperament, that is to say the adjustment of tuning to the varied purposes of polyphonic music, in his list.[15]

In this list, the appearance of the term *Klangfarbe* is telling, since it emerges in the German language only during the nineteenth century, most often as the translation of the French *timbre*.[16] Locher provided a separate entry for the term, arguing that it was critical in defining the topic of his publication: the qualities that distinguish one stop from another must be referred to as their *Klangfarbe* or tone colour. The term itself, as he went on to explain, was introduced by Hermann von Helmholtz in his 'classic' book *On the Sensations of Tone as a Physiological Basis for the Theory of Music*.[17] Locher dedicated his brochure to Helmholtz, who, in return provided a friendly note that Locher listed in the beginning together with acclamations from other celebrities in the organ world of his times, such as the Munich-based composer Josef Rheinberger or the Weimar cantor Alexander Wilhelm Gottschalg.[18]

Most importantly, *Klangfarbe* also emerged as an aim in and of itself for the organist, because the very art of using the stops could be seen as directly intervening in sound quality and creating all kinds of shades from the means at hand. Mixture stops combining several high pitched pipes on one note provided prefixed combinations of overtones, a famous example being the organs of Gottfried Silbermann. But in general, the organist was responsible for finding the best combinations or *Registermischungen*. For this art, the organist had to study the *Klangfarbe* of each stop, so as to be rewarded by a beautiful sound in their combination.[19]

The background for this eulogy to tone colour was Helmholtz's research into the frequency components of musical sound. He was first to generate almost pure tones with just one frequency. Combining these into various patterns, he was able to verify whether the ear could distinguish patterns of such components that differed in nothing but the intensity of the frequencies involved. This eventually made the theorem of Jean-Batiste Joseph Fourier about periodic waves being analysable into sinusoidal components accessible for an unambiguous formal description of sounds. As a result, musical intervals changed their status. They could no longer be said to represent mathematical proportions straightforwardly, as had been assumed since the legendary Pythagorean experiments, but they had to be acknowledged as consisting of complex combinations of frequencies that differed according to the concrete composition of each tone involved. In return, physiology was now able to explain how the ear could cope with its complex task. The ear had to be seen as an analogy to a mathematician using the theorem of Fourier, and each distinguishable tone as an equivalent to the solution of an equation in Fourier's terms.[20]

Helmholtz's findings boosted not so much the symbolic description of sounds – which was left to technicians – but they entered the imagination. As media theorist Friedrich Kittler has argued, the moment in which sense data were disconnected from their sources in the world outside of our minds, media history took off.[21] One could now imagine a friend's voice speaking through the telephone and music sounding from the radio, because the electric energy was now understood to pass through the wire, and not the voice or the sound themselves. By the end of the nineteenth century, acousticians went so far as thinking of sound in terms of circuit diagrams.[22] Meanwhile, sound was represented more and more as being malleable in and of itself.

For organ builders, this malleability had a very different and no less important aspect. Parallel to these conceptual reflections in scientific research, the process of organ making changed. At a time when the use of steam power radically altered manufacturing and transportation practices, the organ workshop, 'once the epitome of cutting-edge mechanical expertise, was rapidly becoming an anachronism'.[23] By the second half of the nineteenth century, organ building was dominated by what Barbara Owen has called 'the organ factory'.[24] Phases in the organ building process that were previously dependent on embodied skills, such as the casting and planing of the metal sheets for pipes, were now adapted to the ease of machinery. Bédos would advise organ builders to cast the sheets as closely as possible to the final thickness that was required for the type of pipe in question. This would save the organ builder the time and effort of scraping the metal manually until it had the required thickness and it would prevent material loss. Scraping machines changed the economy. Since the thickness of the sheet no longer mattered because the machine would do the work, organ builders gave up on casting sheets close to the final thickness. Under the new circumstances this proved less efficient.

The question of how to adapt the organ to new scientific insights and technological developments as well as new aesthetic ideals was taken up by organ builders and organ theorists. One of them was Johann Gottlob Töpfer (1791-1870) whose book *Die Orgelbau-Kunst nach einer neuen Theorie dargestellt und auf mathematische und physikalische Grundsätze gestützt*, published in Weimar in 1833, had a strong influence on organ building practices in the following decades.[25] From their theoretical debates and practical experiments, a new organ aesthetic emerged that can be summarised in three rules, as Hans Fidom puts it in his doctoral dissertation on German organ building between 1880 and 1918.[26] These rules aimed at a unity of pitch, timbre and dynamics, thus subjecting organs to a parametrised concept of sound. All individual pipes should sound the same in terms of their potentially independent manipulation according to one of these parameters. This was realised, on the one hand, by referring back to the formula Töpfer had suggested for standardising the scaling of pipes.[27] On the other hand, Helmholtz's insights into the nature of hearing were set to work in a concrete instrument. For instance, his research indicated adding many high overtones to a fundamental frequency would result in a sharper, brighter sound, and vice versa. This insight led to the strategy to have many 8' stops in relation to higher stops. They were seen as representing the reference to the parametrised sound or, in other words, a zero-level for all three parameters.

The practice of voicing also shifted over the course of these developments. From its function as the final stroke to a process that already contained the essence of what was to be achieved, it turned into the actual secret of the craft. Like the casting itself, the finishing of the sound was now considered an act of manipulation, guided by some ideal of sound. Voicers developed new techniques to adjust the character of the 'speech' and the sound of flue pipes. An example is making nicks, i.e. small cuts in the languid bevel that enable the voicer to reduce unwanted noise in the sound. Making nicks to smoothen the pipe sound was not common before the eighteenth century but became more or less a standard procedure in late eighteenth and nineteenth century organ building.

As can be seen from Locher's brochure, the organ building craft was becoming aware of these dramatic changes. The sound of the pipe was now handed over to the voicer, and the conundrum of good sound within a parametrised sound space was placed into their hands, ears, and imagination.

Reconstructing organs

In recent decades, replica's and style copies have become part and parcel in the investigation of historical organ culture. Against the background of historically informed performance practices that emerged in the 1960s, there was a renewed interest in understanding how seventeenth- and eighteenth-century organ builders made their instruments. This led to detailed documentations, comprising organ cases and specifications, wind chests and wind systems, and the characteristics of the pipes. These characteristics include the pipes' dimensions and measurements, their metallurgical composition and the shape of the pipe mouths. Such documentation was essential in carrying out restoration projects aimed at bringing organs back to their original state as much as possible. As the German organist and scholar Harald Vogel has pointed out from the point of view of restoration ethics, however, later additions to the organ cannot simply be taken away. Also, the historical and use values have to be balanced.[28]

This put new emphasis on replica building rather than restoring original instruments. Vogel resumes that '[w]e have actually come to the point now where replicas come closer to the original sound than the surviving originals themselves. Building new instruments in historical styles is the path that we must take in the future'.[29]

The actual building of these replicas or style copies not only required a close reading and interpretation of sources, both archival and material, but also a relearning of historical organ building skills. In the remainder of the chapter, we show that it was crucial in replica projects to understand how the sound quality of historical pipes was related to their production and anatomy. To actually make replicas of pipes, the researcher-builders relied on a variety of written sources, such as church contracts, organ inspection reports, and treatises about organ building and relevant practices, such as metal casting. In addition, they carried out extensive experiments to learn how to make pipes according to the historical information. As we will observe, the ultimate aim of contemporary builders is to recreate the sound of historical instruments, which will eventually bring us back to the question of whether and how sound was made present in these historical sources.

Relearning pipe making skills

Many of the insights and ideals from the paradigm of historicising organ building culminated in the 1990s in the milestone North German Organ Research Project of the Göteborg Organ Art Center (GOArt) at the University of Gothenburg in Sweden.[30] [31] The aim of this project was to construct an organ the way it might have been built by the famous organ builder Arp Schnitger in late seventeenth century Northern Germany.[32] The builders took the case of the 1699 Schnitger organ in the Lübeck Dom, of which only photographs remain after it was destroyed during a bombing raid in 1942, as a reference. The famous Schnitger organ in the Hamburg St. Jacobi church was also destroyed during the Second World War, but because the pipes had been stored, the surviving pipework of the organ could be used as a reference.[33]

A central assumption in the North German Organ Research Project was that recovering the sound of historical organs required relearning artisanal building techniques that were displaced by modern building techniques over a century ago. Hans Davidsson, the initiator of the project and back then affiliated to the School of Music and Musicology of at the University of Gothenburg as organ teacher and musicologist, argued that from an artistic point of view, replicating antique organs became desirable as a reaction against modern organs produced by industrial methods. When organs became subjected to industrial production techniques, he wrote in 1993, 'the main aim was no longer to attain the highest quality possible; instead factors such as capacity and profit became predominant […] piece by piece, the accumulated experience of the skilled craftsmen disappeared. Thus the end result came to be determined more by the production process itself than by aesthetical or stylistic aims'.[34]

How was the understanding of pipe making related to the sound quality of the pipes in the GOArt-project? And what did the researchers learn about these sounds through actually making the pipes? To answer these questions, we follow the work of Munetaka Yokota who was responsible for the pipe making and voicing for the Örgryte church organ.[35] Yokota developed his idea to work according to seventeenth- and eighteenth-century principles when he studied to become an organ builder.[36] Historically, Yokota argues, craftsmen worked with what was at hand.[37] This was true for the materials they used, but also for how they processed them. Instead of using machines to make a thick piece of wood thinner and throw away a lot of the material, they would look at the required strength and the qualities of the wood that was available. Using local materials thus required adaptation to these local circumstances.

This situated focus on how materials were handled and shaped can help to understand why well-made old pipes sound good, Yokota argues:

> "These old pipes have a beautiful balance between the fundamental pitch and overtones, a balance between 'musical' sound and 'noise,' as well as a good sense of balance between the strength, length, and character of the speech and the sustaining tone. (…) Was the old sound partly a product of the aging of the materials, or could we reach this level of quality again in a modern instrument? Essentially I define 'good sound' as sound that has a sense of life."[38]

To give the pipes a good, lively sound, the researchers and builders, including Yokota, had to learn the 'pattern language' of Arp Schnitger, a term they took from Christopher Alexander.[39] Schnitger and his fellow organ builders knew what an organ looked like and sounded like, because they knew the patterns of the language that made up all of the things that it would have to do. 'Reading' historical organs in combination with other primary sources, the researchers at GOArt tried to define and understand what Schnitger's pattern language was. 'Then the ways of working had to be understood, copied, tried out, and finally performed, in a continuous dialectic interplay between theory and practice'.[40] This process reconstruction did not aim at imitating but at learning. Imitating, Yokota argues, would be senseless precisely because one would only copy site-specific solutions that were developed under unique circumstances with local materials and tools.[41] Learning why historical builders developed certain solutions is thus key to making new pipes that sound as good and lively as the surviving old pipes.

One of the processes that was reconstructed at the Göteborg Organ Art Center (GOArt) in the 1990s was the casting of the metal for the pipes. As explained above, sheets were cast by pouring a molten lead-tin alloy into a wooden casting box, which has a narrow opening at the bottom, and then sliding this box over a casting bench. The melt would flow out of the box and spread into a thin layer covering the bench, cool down and solidify into a metal sheet. Important parameters in the historical casting process were the speed with which the metal cools down and the thickness of the sheet. Yokota used what he calls a tap testing method to analyse the material from which a historical pipe was made, its scaling, and wall thickness. Tapping on the metal with his fingernail gave him two tones: The metal tone produced by the pipe body and the air tone produced by the air column inside the pipe. A higher metal tone indicates a harder metal. It turned out that even though the chemical composition of a modern alloy would be almost identical to its historical counterpart, it would be much softer than in the old pipes. Combining this diagnosis with the fact that old pipes are usually thinner, Yokota concluded that it was necessary to know more about how the metal was cast and what the relationships were between the materials, tools and construction method.

Historical documents, such as organ contracts, organ building treatises and secondary sources were studied to gain information about the composition of historical pipe metal.[42] Metal samples of remaining organ pipes were analysed by using spectrometrical methods and the alloys of the pipe metal for the new organ were established.[43] The next step was to actually reconstruct a seventeenth-century practice of casting the metal sheets. In modern organ building traditions, the casting bench is made of stone or wood and covered with a fire retardant cloth. In historical traditions, however, the casting bench was made of stone and covered with a linen cloth or a layer of sand. An important question was whether the material properties of the pipe metal were dependent on using sand or cloth. Yokota and his team established that casting on sand gives the metal a completely different quality than when cast in modern ways. Due to the sand bed beneath the molten metal, the metal cools quickly, causing the pipe metal to become harder than modern pipe metal. The right type of sand, the right proportion of impurities or trace materials in the metal, and the right casting temperature all proved to be of vital importance to the end result.

What role did descriptions and images in historical treatises play in the reconstruction of the casting process? In our interview with Yokota, he underlined that written sources such as Bédos's treatise could provide only part of the information he needed to make and voice the pipes.[44] The voicing through which a pipe gets its final sound character was hardly mentioned at all in the treatises, he said, and the pipe's sound therefore could only be investigated by carefully observing historical pipes. Overall, the treatise *L'Art du facteur d'orgues* by Bédos de Celles proved to be the most systematically written and detailed, he added. Yet, it should be critically assessed because it is not clear if Bédos was a craftsman himself and his book represents French practices from the mid-eighteenth century only.

An inbuilt history of hearing?

For Yokota and his team at Gothenburg University, relearning the skills of Arp Schnitger and the workers in his workshop proved to be arduous. Hundreds of casting experiments were carried out before sheets could be cast that closely resembled the metal from Schnitger's pipes. During the casting experiments that were carried out between 1995 and 1997, practical questions arose: Did Schnitger cast on sand or cloth? If he cast on sand, what sand layer thickness did he use? What type of sand did he use? Did he mix any oil or water into the sand and if so, what type of liquid and how much did he use? Finding the answers required patience; Yokota writes:

> Many times, it is tempting to take modern shortcuts or to find a series of immediate solutions to specific problems; such solutions, however, often overlap and create a domino effect of new problems. Seventeenth-century builders must themselves have sought immediate solutions to problems, but they had many more technical limitations. Therefore they had to solve these problems in terms determined by their practical conditions. In addition, wood and metal have more complicated properties than modern materials such as plastic and steel. Our goal remained that of discovering the so-called simple techniques of the earlier organ builders, where each aspect of the process positively affected the others without creating unnecessary complications.[45]

Yokota's approach to pipe making was far more complex than simply re-enacting historical craftsmanship as it is handed down in treatises from sources such as Bédos. Re-enacting them would have meant to copy situations like the casting procedures that Bédos describes and shows. Instead, Yokota's approach started from the question of how to explain the lively sound of historical pipes, harder and thinner than modern pipes. His strategy was to understand the casting process from its historical context by doing practical experiments based on information that he gathered from a variety of sources, including treatises, but first and foremost the pipes' sound and shape. He aimed at understanding the 'grammar' of pipe making, a certain logic that is local and situated, yet at the same time can still be followed under the conditions of the present. This meant that much of the information that Bédos gives, even the hands-on practical information about determining the right temperature of the alloy or the actual construction of the casting bench, was not relevant. On the other hand, in solving the problem of casting on sand Bédos did not give enough information, but the article on casting lead in the *Encyclopedie* did.[46]

During our interview in August 2018, we discussed with Yokota the issue of sound. As explained above, Bédos does write about the pipe sound in his tenth chapter of the second volume, which focuses on the voicing of the pipes. In fact, Bédos himself calls it the most important chapter of his book, since it is about the sound of the organ. Yokota points out that Bédos's rendering of the voicing is at odds with nineteenth- and twentieth-century ideas about voicing as an 'art' in itself. 'There is no room for human judgment to get into it. It is only in the twentieth-century that voicers get this artist status that they can destroy the organ sound or make it beautiful'.[47] For organ builders like Bédos, the sound of their instruments could not be imagined separately from the material artefact and artisanal knowledge. In his text, sound was built in rather then made explicit as a phenomenon that should or even could be manipulated in and of itself. The approach of Yokota and his team to recreate the sound of historical organs such as those made by Arp Schnitger and others mirrors this attitude in that it started from understanding the apparatus and logics that historical organ builders put in place. The historically informed reconstructions relied on experimenting and understanding rather than copying and re-enacting. Following concrete evidence from a variety of sources and putting preconceived ideas about baroque sound aside, they tried to learn the aesthetics of seventeenth- and eighteenth-century organ sound from what well-built pipes had to say.

Conclusion

If you employ Munetaka Yokota and his team today – whether for reconstruction of a historical instrument or building a new one – you must be aware that his work as a voicer may take a long time – whether the pipes are cast according to present day standards or historical written and material sources and re-learned casting skills. The reason is that you, as his employer, will expect the result to re-enact the sound only. You may not be willing to return to eighteenth-century restrictions of subjecting oneself to getting one chance only for obtaining a desired result. Nor will you necessarily be able to put it in the appropriate location – an eighteenth-century church that is to say –, and thus the very point of departure for Bédos. But this may not be necessary. Today's reconstruction practices in the world of sound nest the 'ancient sound' into today's habits of hearing – producing thereby something unheard of. And for this, we need a skilled voicer.

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Endnotes

[1] Bédos de Celles *L'Art du facteur d'orgues*, p. 425 (our translation).
[2] Bédos de Celles *L'Art du facteur d'orgues*, p. 425 (our translation).
[3] See on this also the contribution by Hans Fidom in this volume.
[4] In musicology, 'organology' refers to the study of musical instruments more generally.

[5] On the biography of Dom François Bédos de Celles see Steinhaus, *Wege zu Dom Bedos*; Steinhaus, 'Bédos de Celles', https://www.mgg-online.com/mgg/stable/47819, checked on December 2nd, 2018.
[6] Kostelnick, 'Visualizing Technology'.
[7] Kostelnick, 'Visualizing Technology', p. 444.
[8] Kostelnick, 'Visualizing Technology', p. 447.
[9] Kostelnick, 'Visualizing Technology', p. 447f.
[10] Kostelnick, 'Visualizing Technology', p. 448.
[11] Pannabecker, 'Representing Mechanical Arts'.
[12] It does not seem logical that the test stone lies on the ground, which means that rather than representing an actual situation, the image is stylised to give room to the various objects mentioned in the text.
[13] The windway is the narrow opening between the lower lip and the languid.
[14] Locher, *Erklärung der Orgel-Register*, p. 26.
[15] Locher, *Erklärung der Orgel-Register*, p. 27.
[16] Locher, *Erklärung der Orgel-Register*, p. 28. On this see Kursell, *Epistemologie des Hörens* and Dolan, *The Orchestral Revolution*.
[17] Locher, *Erklärung der Orgel-Register*, p. 29.
[18] Locher, *Erklärung der Orgel-Register*, p. IX.
[19] Locher, *Erklärung der Orgel-Register*, p. 34ff. (on Mixture stops), p. 36 (on Silbermann) and p. 50ff (on Registermischungen).
[20] See Kursell, *Epistemologie des Hörens*.
[21] Kittler, *Discourse Networks 1800/1900*.
[22] Wittje, *The Age of Electroacustics*.
[23] Owen, 'Technology and the Organ', p. 213.
[24] Owen, 'Technology and the Organ', p. 221.
[25] Töpfer, *Die Orgelbau-Kunst*.
[26] Fidom, *Diversity in Unity*.
[27] Töpfer's 'Normalmensur' is a rank of pipes based on an internal diameter of 155.5mm (6.12in) at 8' C (the lowest note of the modern organ compass) and a mouth width which is one-quarter of the circumference of such a pipe. The scale provides for a reduction in diameter of the pipes by half at every succeeding seventeenth pipe.
[28] Watson, *Artifacts in Use*.
[29] Vogel, 'Organ Restoration', p. 345.
[30] Speerstra, *The North German Organ Research Project*.
[31] Other organ replication projects have been carried out in Germany, the Netherlands, Korea, and the US.
[32] It was built by the Göteborg Organ Art Centre (GOArt) of the University of Gothenburg, and financed by grants from, among others, the Swedish government and the European Union.
[33] The North German Baroque organ was inaugurated in 2000. In the following years, members of the team were involved in two other projects to build replicas of historical organs. One was carried out at the Eastman School of Music in Rochester, designed after specifications of an instrument built by Adam Gottlob Casparini in 1776 in Vilnius, Lithuania. The other project, a new organ for the Anabel Taylor Chapel of Cornell University in the United States, aimed at reconstructing the tonal design of an instrument that Arp Schnitger had built for the Charlottenburg-Schlosskapelle in Berlin in the first decade of the eighteenth century.
[34] Davidsson, 'The North German Organ Research Project', p. 9.
[35] Yokota was also involved in the New Baroque Organ project at the Orgelpark in Amsterdam. Here, a new organ was built after the style of the German organ builder Zacharias Hildebrandt (1688-1757). Peter Peters has done extensive ethnographic research on this project. Some of the interviews with Yokota that were done in the context of this research project were used in this chapter.
[36] The sound of historical organs had fascinated him ever since he was a fourteen year old school boy. He bought an LP recording made by the German organist Fritz Heitmann in 1938 on the Schnitger organ in the chapel of the Charlottenburg Castle in Berlin. Because the organ was destroyed in the Second World War, the recording is the only way we can still know how this instrument sounded. In addition to this document there are photographs and measurements of the pipes. Having listened many times to this and other recordings of historical European organs, Yokota concluded that these 'old organs sounded better than new ones'. See Yearsley, 'The Organ-Building'.
[37] Interview with Munetaka Yokota, May 16th, 2014, Orgelpark in Amsterdam.
[38] Yokota and Ruiter-Feenstra, 'Historical Pipe Metal Casting', p. 165.
[39] Alexander, *The Timeless Way*; Alexander et al., *A Pattern Language*.
[40] Speerstra, 'An Introduction', p. 19.
[41] Interview with Munetaka Yokota, May 16th, 2014, Orgelpark in Amsterdam.
[42] Examples of historical organ building treatises that were used are Johann Phillipp Bendeler, *Organopoeia* (1609); Salomon de Caus, *Les raisons des forces movvantes* (1615); Diderot and d'Alembert, *L'Encyclopédie ou*

dictionnaire raisonné des sciences, des arts et des métiers; and Dom Bedos de Celles, *L'art du facteur d'orgues* (1770). See below, footnote 44.

[43] Yokota, 'Historical Pipe Metal Casting', pp. 165-167.

[44] Interview with Munetaka Yokota, August 27nd, 2018, Orgelpark in Amsterdam. Elsewhere, he indicates five sources: Salomon de Caus's *Les raisons des forces mouvantes* (Frankfurt: 1615), Johann Philipp Bendeler's *Organopoeia* (Merseburg: 1690), Dom Bedos de Celles's *L'Art du facteur d'orgues* (Paris: 1770), Adlung's *Musica Mechanica Organoedi* (Berlin: 1768), and Diderot and d'Alembert's *L'Encyclopédie* (Paris: 1780). See Yokota and Ruiter-Feenstra, 'Historical Pipe Metal Casting', p. 167.

[45] Yokota, 'Historical Pipe Metal Casting', p. 168.

[46] Yokota, 'Historical Pipe Metal Casting', p. 176.

[47] Interview with Munetaka Yokota, August 27nd, 2018, Orgelpark in Amsterdam.