# Perforated Ceramic Cylinders for Heat-Demanding Crafts

BY ANDERS LINDAHL & PAUL EKLÖV PETTERSSON

Abstract

*Lindahl, Anders and Eklöv Pettersson, Paul. 2011. Perforated Ceramic Cylinders for Heat-demanding Crafts. Lund Archaeological Review 16 (2011), pp. 49–59.*
Perforated vessels in one form or the other are found in ceramic assemblages in most societies from early prehistoric time onwards. They vary greatly in shape and size, indicating a multitude of uses. This paper focuses on a particular type of perforated vessel – the perforated open cylinder, a "vessel" with no base, or rather with rims at both ends. This means that its function as a container is limited and it could only work when standing on a upright surface, e.g. on the ground. Another plausible function could be an extension "pipe", for example, on a permanent furnace. In this paper we refer to experiments on the use of the perforated cylinder for heat-demanding crafts, more specifically what temperatures can be reached without using bellows – natural draught – in perforated cylinders of different size and shape, and which type of fuel is the most appropriate.
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## Introduction

Perforated vessels are ceramic vessels with varying shapes and sizes, There are, for example, small pear-shaped containers interpreted as incense burners (Stilborg 2002; Wood reported by Denison 1998) and large dishes as well as very large barrel-shaped vessels probably used as containers for cereals (Eklöv Pettersson 2008; Scheffer 1982). The size of the perforations varies as well, from 2 mm to a few centimetres. The number of holes and the location of the perforation on the vessel also vary considerably, from a single large hole in the base to vessels practically covered in small holes. This variation in the size of the vessel, the shape, the number of holes and their size implies that these are vessels with a most varied function and as a consequence there are several theories about their function (Stilborg 2002). The interpretation that a perforated vessel is suitable as a strainer has made this the designation for practically all perforated vessels/sherds in the Swedish archaeological vocabulary ("silkärl").

One of the most common interpretations of the function is that these ceramic sieves were used in the manufacture of cheese. This is a marginal function for the perforated vessels (Bratt 1995; Copley *et al.* 2005). Finbar McCormick (1992) refers to early literature mentioning the manufacture of large quantities of cheese being made in Ireland during the Early Christian period AD 0–200), a time when "there is no evidence of perforated vessels" (ibid.). He concludes that "perforated ceramic vessels need not represent cheese making strainers nor are they necessary for cheese making" (ibid.). Referring to ethnographic parallels, Birgitta Hulthén (1995) has given an alternative interpretation of these vessels as being used for steam cooking. The perforated vessel containing, e.g. cereals or vegetables is placed on top of another (ceramic) container with boiling water allowing the steam to enter through the holes. Vessels for this purpose are found from China to North Africa (ibid.).

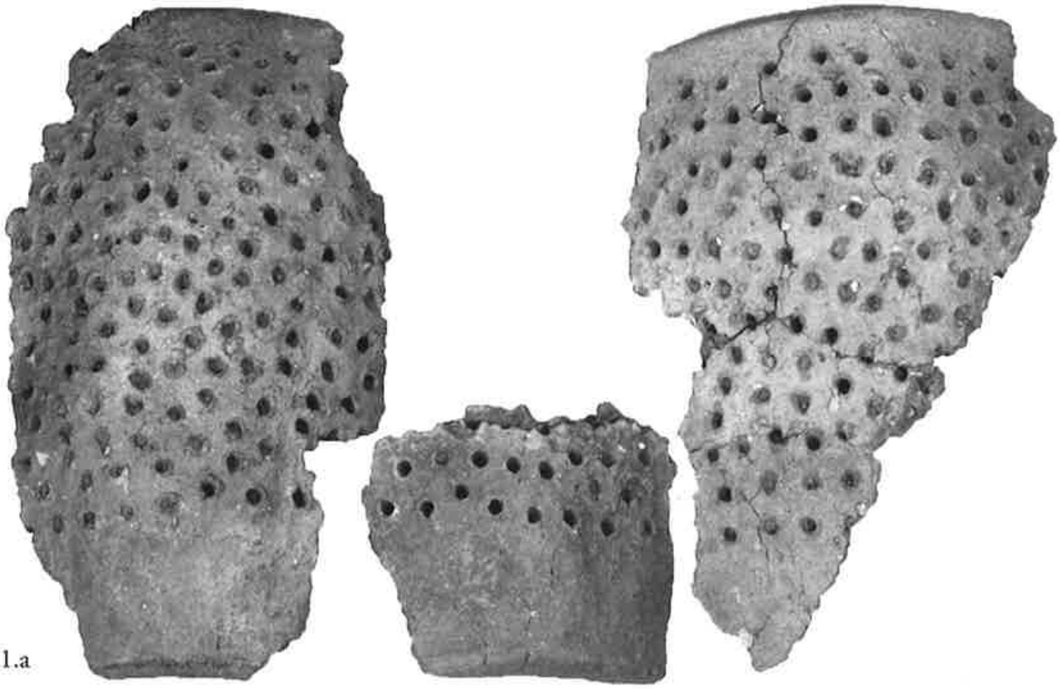
Geographically as well as temporally vessels with perforation are widespread. In the Deccan Neolithic culture, India (Paddayya 1969), there are different types of bowls interpreted with a range of functions such as incense burners, covers when boiling milk, vessels for steam cooking of cereals, and colanders. Paddayya also refers to ethnographic examples where bowls with holes ranging from 5–8 mm diameter are used when making a macaroni-like dish. Dough of cereal paste is pressed through the holes of the perforated vessel into boiling milk (ibid.).

Molly Magee (1967) suggests that vessels perforated with holes found in central Nevada, USA, were not used as colanders, as is the more common description of these finds, but as cages for small rodents e.g. chipmunks. The vessels are very similar to the Roman dolia in which dormice were kept and fattened for eating.

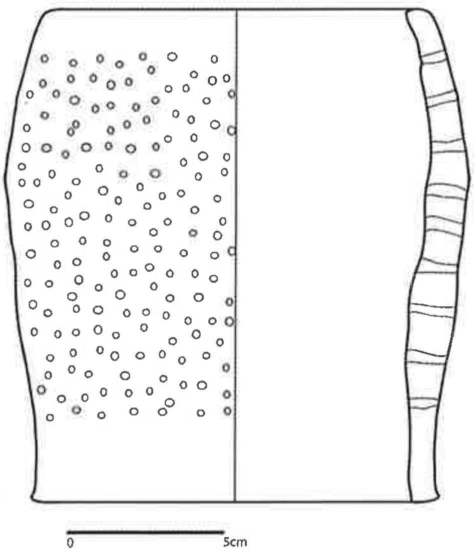
In this work, however, we are particularly interested in the function of the perforated ceramic cylinder. This type of "vessel" that has no base was first noted in Sweden by Nordén (1929) at the archaeological excavation of Boberget hill fort, Östergötland. Excavations at Domprostehagen outside Linköping in Östergötland (1993–1999) disclosed a large number of perforated sherds which have been put into two groups mainly according to the colour of the sherds, black/grey or reddish. The reddish sherds seem to have been exposed to high temperature, and within this sherd group there were two sherds with a rim in both ends that have been reconstructed as perforated cylinders (Hörfors 2001). One end of the cylinders is turned slightly inwards and their size is 14–17 cm in height with a diameter of 12–13 cm (Fig. 1). The finds of perforated cylinders at Domprostehagen are closely related to metalwork (ibid). The cylinders from Östergötland are dated to 400–600 AD, but similar finds from Fosie, Malmö, are found in contexts dated to the Bronze Age (Stilborg 2002). Perforated cylinders are also found on Gotland. One dated to the Roman Iron Age is reconstructed to 18 cm in height with one rim of 6 cm and the other approximately 13 cm in diameter (Fig. 2).

Similar finds are also reported from Harappan sites in India (Paddayya 1969; Vora et al. 2002). These perforated vessels are described as tall and cylindrical and with a large hole in the base. A complete vessel filled with charcoal was found at Firoz Khan-damp, Awan in Pakistan, and these have been interpreted as braziers or heaters. A vessel of the same type from the Harappan site of Bet Dwarka, India, measures 18 cm in height with a diameter of 10 cm (reconstructed) (Vora et al. 2002).

At the Early Bronze Age site of Chrysokamino on Crete, thousands of ceramic fragments perforated with holes 20 mm in diameter and about 50 mm apart have been found in connection with metalwork, most likely copper smelting (Pryce et al. 2007). Experiments with reconstructions of both perforated and unperforated furnaces of the same size and shape indicate that perforated furnaces have several advantages over unperforated ones. Among these are that they reach higher temperatures and that they offer the operator a better control of the process. The size of the reconstructed furnaces is approximately twice that of the finds of perforated cylinders in Sweden (height 30 cm and diameter 20 cm top and 40 cm base). Similar furnaces were used in southern Bolivia in traditional smelting of silver at the time of



1.a




1.b

Fig. 1. (a) A sherd of a cylindrical vessel from Domprosthagen, Östergötland (photo: Lasse Norr, Östergötlands Museum) and (b) a reconstruction of the vessel.

Fig. 2. A refitted cylindrical vessel from Gotland (Roman Iron Age) (photo: Monica Elmshorn, Gotlands Fornsal).

the Spanish conquest, and most likely during the pre Columbian time as well (Proyecto Arqueológico Porco-Potosí). These furnaces are called "Huayrachinas" (translated as "wind furnace") and are perforated on two sides in order to let the wind reach into the furnace. They are also built on hilltops or ridges where the wind is especially strong.

## Aims and objectives

The shape of the perforated cylinder, including the absence of a base, indicates a specialized function different from that of other perforated vessels. Clearly this is not the type of vessel used as strainer or for steam boiling. The association with the braziers from the Harappan period and the furnaces from Crete and Peru are much more interesting in this context. The aim of this study is to investigate whether the perforated cylinders could be used for heat-demanding crafts, different types of metal craft, manufacture of glass beads etc.

The main questions are:

- What temperature can be reached without using bellows?
- Is the shape and size of the container important in order to reach a high temperature?
- How are the perforated cylinders manufactured?
- To what extent is the ceramic ware affected by the heat?
- How can perforated sherds be identified as belonging to a perforated cylinder?
- How functional in the sense of practicality is the perforated cylinder for different types of heat-demanding craft?
- Do different types of fuel give different temperatures?
- The consumption of fuel; which type of fuel is the most economic in the sense of amount used in order to reach and maintain a high temperature?

## Method

### *Manufacture*

To manufacture the cylinders a local, iron-rich, clay tempered with approximately 20% (vol.) crushed granitic rock was used. All the different types of perforated cylinders were hand-made using coiling technique, for the most part the so-called N-technique (Stilborg 2002). The perforation was made with a pointed stick when the cylinders were leather-hard. The holes had a diameter varying from 3-5 mm. To find out whether the manner in which the cylinders were fired would affect their function, the dried cylinders were fired in three different ways. The first was firing in an electric kiln to a temperature of 1000 °C. The second was firing in an open fire for approximately 45 minutes, using twigs and small branches as firewood. The third way was to fire the dried cylinder when it was first used as a furnace.

### *Use*

Perforated cylinders were used as containers for different types of fuel and the temperature reached by the combustion in the centre of the container was measured in three areas: the bottom, the middle and the top (Fig. 3).

As a further study the practical work with different prehistoric crafts was tested to see if the heat containers where suitable for the specific crafts (Lindahl, Eklöv Pettersson, Nilsson and Crantz forthcoming).

Three different types of fuel – dried horse dung, finely chopped firewood and charcoal – were tested and their usability for reaching and sustaining high temperatures was ascertained. After use, the inside of the containers was examined to determine the extent to which the surface of the ware had been affected by the heat, reduction, oxidation, sintering, etc.

Fig. 3. During the experiments the temperature in the cylinders was measured at three different levels.

## Results

### *Fuels*

The types of fuel that were tested were chosen due to their use and appearance in (pre)historic time: horse dung, wood and charcoal.

Since the main purpose of the study was to find out whether or not the perforated cylinders were used for heat-demanding crafts, the different fuels were ranked according to their ability to reach the highest temperature; maximum temperature in the shortest period of time and their ability to keep the temperature stable without too much work by the operator.

Furthermore, the point in the container (bottom, middle or top) where the highest temperature was reached was also noted.

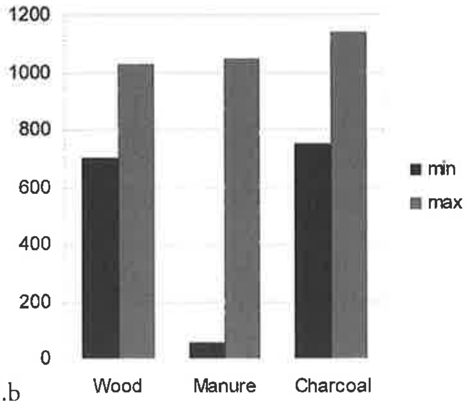
### *Horse dung*

According to the tests, horse dung fluctuated very much in reaching and holding the maximum temperature. It quickly reached as high as 1000 °C, but just as quickly dropped to around 200 °C (Fig. 4). A probable cause of this fluctuation was the large amount of ash that was accumulated when using this fuel. The ash clogged the holes, obstructing the airflow. When the airflow suddenly stopped the temperature dropped rapidly. This emphasizes the importance of the perforation and the location of the holes. The advantage of using horse dung over other types of fuel was that it was easy to collect quite large amounts in a short period of time. However, when looking at function, the unstable temperature must be considered as a considerable disadvantage.

### *Wood*

Finely chopped wood worked surprisingly well, and the temperatures that were reached exceeded that of a normal hearth by at least 200 °C (Fig. 4). The wood also gave a more stable temperature than horse dung and displayed a pattern similar to charcoal, in terms of the maximum temperature and fluctuation. Access to finely chopped pieces of wood during the Bronze/Iron Age, on the other hand, would perhaps have been a problem, as the tools for cutting the wood may have made this work process ineffective and time-consuming. However, the finely cut wood could


4.a




4.b

Fig. 4. The difference in temperature depending on type of fuel (a) over time and (b) the maximum fluctuation measured throughout the duration of the firing.

possibly be replaced by twigs and small tree branches (Eklöv Pettersson 2011).

### *Charcoal*

Charcoal was by far the best fuel. With this kind of fuel the combustion reached the highest temperatures at almost 1200 °C (Fig. 4). Charcoal was also the most stable fuel regarding temperature. Access to charcoal during the Iron Age was probably not a problem (Persson 1994). To produce small lumps of charcoal fitted for this kind of combustion is probably cheaper in work hours since the wood only have to be split but not cut into small pieces before it is transformed into charcoal. Instead it can be broken into small pieces later when it is much more brittle. One may also assume that the small pieces that appear naturally when producing charcoal alongside the large ones would be unfit for e.g. iron production and thus sorted out to be used for other crafts.

Charcoal can be produced in several ways. One way is to simply use the charcoal that is naturally produced in a open fire. Recent experiments show that charcoal can easily be produced out of twigs and smaller branches using a perforated vessel. This is a way to produce charcoal and use it as a furnace at the same time(Eklöv Pettersson 2011).

## Types of perforated cylinders

The conclusion from the fuel tests was that charcoal was the most likely type of fuel to have been used if the perforated cylinders functioned as furnaces for high temperature demanding crafts. Therefore, in the further tests only charcoal was used as fuel.

### *Replicas of Iron Age perforated cylinders*

Four different types of perforated cylinders were chosen, all dated to the Iron Age. Two of them were replicas of finds from Boberget and Domprostehagen in Östergötland, Sweden. They had a slight convex shape and the upper rim turned inwards (height 16.7 and 14.5 cm, diameter 13.7 and 13 cm respectively, Fig. 5).

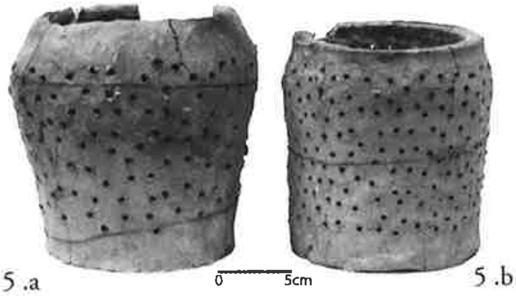



Fig. 5. Two vessels reconstructed from the measurements made on the findings of cylindrical vessels from (a) Boberget and (b) Domprostehagen.


Fig. 6. Reconstruction of a cylindrical vessel found in Fosie, Scania (Pre Roman Iron Age) (photo: Lena Wilhelmsson, Malmö Museer).

The other two were replicas of finds from both Boberget in Östergötland and Fosie in Scania. This type has a conical shape (Fig. 6). The first two turned out to be the most useful in heat-demanding crafts, being able to reach temperatures around 1100 °C, (Fig. 7). The second type could only reach temperatures up to 800 °C. Thus, this second group was excluded in further studies. However, a possible function for these small "furnaces" could have been for burning incense or heating crucibles and moulds. It has also been suggested that they could have been used as a prehistoric type of Bunsen burners (Wood 2006) as well as a complement to a tuyere (Hörfors 2001)

*Perforated cylinders of various sizes*

Is size and shape important for a perforated cylinder to work as an efficient furnace? To test this we made nine more or less straight perforated cylinders in addition to the replicas. These straight cylinders varied from 10 to 20 cm in diameter and from 15 to 25 cm in height and were tested parallel to the replicas. The aim of this experiment was to use cylinders of different sizes in order to find out whether there is an "ultimate" size of cylinder to reach a high temperature.

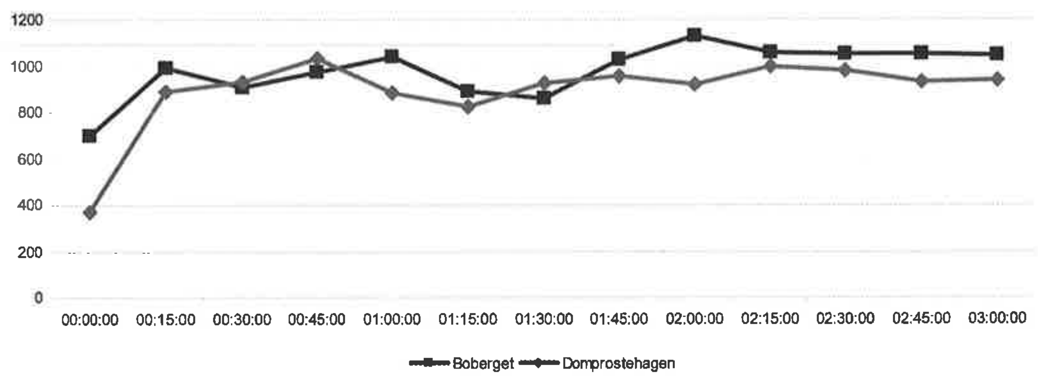



Fig. 7. Temperature measured in replicas made from finds at Boberget and Domprostehagen (Migration period).

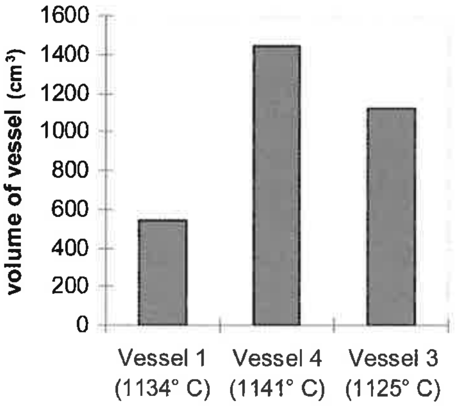



Fig. 8. The volume (in cm³) of the three vessels that reached the highest temperatures during the experiments (Vessel 1, 3 & 4).

Fig. 9. Perforated cylinder, design; Gustavsson, D. 2007, construction Eköv Pettersson, P. 2007.

The two replicas were also reproduced in a smaller and larger version. This was, once again, to test whether the vessels really were designed to reach maximum temperatures and thus had the optimal size.

The overall results from these tests showed no noticeable difference regarding maximum attainable temperature between the smallest and largest cylinder. Furthermore, none of the nine straight cylinders exceeded any of the replicas in maximum temperature.

The conclusions to be drawn from this test are that the size/volume of the container seems to be of less importance since the ratio for volume versus temperature is irregular (Fig. 8). The shape of the perforated cylinder, on the other hand, seems to be more important. The finds from Boberget are, as mentioned earlier, slightly concave with a slightly narrow end at its base and the "upper" rim turned inwards. This could be interpreted as showing that they were indeed designed to reach the highest temperatures.

*Further added models*

To test the necessity of holes for this type of furnace, two additional containers were made. The first had no perforation. The second was designed by David Gustavsson, master's student in engineering, specialized in production design, with no previous knowledge of the perforated cylinder. He was asked to design a portable container for heat-demanding crafts made of clay using charcoal as fuel.

The "furnace" designed by Gustavsson did not look like the prehistoric perforated cylinders. His design was slightly conical with the narrow end in the top, a solid base and perforations only in the area from the base and 5 centimetres up (Fig. 9).

The container without perforation has an advantage in being both easy and quick to make, thus cheap in work hours. However, it has no known parallels in prehistoric or ethnographic materials. During the experiments it displayed very inconsistent results; one test was able to reach temperatures around 1100 °C and in the following test it could not exceed 950 °C.

The modern designed furnace was the least efficient furnace of all the types tested. It could only reach a maximum temperature of 700–800 °C.

## Discussion and conclusions

Both the inside and outside surfaces of the cylinders fired in an open fire (oxidized atmosphere) displayed a more or less reddish colour. However, there are patches with grey to black colour (reduced atmosphere) where the cylinder had been buried in ashes or in contact with larger pieces of firewood especially during the final part of the firing (Fig. 10). The cylinders fired in an electric kiln (oxidized atmosphere) at 1000 °C took on an even brick-red colour on both the inside and outside surfaces. After they had been used as furnaces, the colour of the cylinders fired in the electric kiln did not change, neither on the outside nor on the inside. However, the cylinders fired in an open fire changed colour on the inside. The lower part turned to an even brick-red colouration.

In the experiments we also used unfired cylinders, which took on a buff brick red colour on the inside after use, and slightly brown/red on the outside.

It is interesting to note that, contrary to what was expected, none of the cylinders, not even those that reached maximum temperatures close to 1200 °C and not after repeated use for several hours, show any sign of sintering. The finds of sintered perforated sherds in association with metalwork have been used as an argument that perforated ceramics were used for heat-demanding craft (Stilborg 2006). However, this study clearly shows that sherds/vessels that are not sintered may very well have been used for heat-demanding crafts. The high temperatures that are needed are measured in the centre of the containers, in the burning fuel. The wall of these ceramic furnaces (outside and inside surfaces) is not exposed to the same high temperature from the fire and it is also cooled from the outside by the wind.

One might argue that, since the cylinders are easy to fire by simply using them in a dried state, this would have been the preferred way

Fig. 10. Firing of vessels in an open fire.

of firing. However, there are sherds of perforated cylinders that show clear evidence of being fired in an open fire, such as grey/black patches on the outer surface.

The main argument for the hypotheses that the perforated cylinders were indeed used for heat-demanding crafts would be that they are found in contexts of such crafts (e.g. small-scale iron smithery, bronze, silver and gold casting/smithery, glass bead manufacture).

The finds from Domprostehagen are definitely in a context of metalwork (Hörfors 2001) and the finds of perforated cylinders at hill forts (e.g. Boberget) indicate associations with metalwork. This may sound like very little, but considering the difficulty in identifying these furnaces and the difficulty in identify small-scale metalwork and glass bead manufacture, one find that definitely can be linked to metalwork is substantial under these circumstances. The experiments show that after they have been reheated 5–10 times the perforated cylinders start to crack and can no longer be used as a furnace. When the furnace is broken the (temporary?) workshop is cleared of refuse and the shards are thrown in the local garbage pit. If it is a temporary workshop/area the portable furnace may have been stored in a place that bears no link to the heat-demanding craft. Thus, when it is broken the sherd may be interpreted as having been used for something else.

Since the perforated cylinders, in contrast to "normal" vessels, do not have a base they are very hard to identify unless they can be reconstructed from the top rim to the base rim.

However, according to the experiments, the most characteristic trait of a ceramic perforated cylinder used as a furnace is the oxidized fired inside surface.

Even though the shape of the perforated cylinder resembles a hibachi, the experiments clearly show that they are inadequate for cooking. When a pot is placed on top of the cylinder the airflow almost stops and the temperature drops. In the tests it took more than one hour to reach the boiling temperature of one litre of water, which is not economic in an industrial or domestic context

The two types of vessels that turned out to be most useful for heat-demanding crafts were subjected to further studies and therefore several replicas were made. Three different crafts were tested in connection with using charcoal as fuel, smithing, casting and glass bead production (Lindahl, Pettersson, Nilsson & Crantz forthcoming). The smithing of iron worked perfectly with regard to temperatures, but the vessels did impose a limit on the size of the iron that the craftsman processed. The glass bead production also worked regarding temperature, although we must consider that glass beads, according to current evidence, were only produced in Scandinavia from the 6th and 7th centuries onwards (Lund-Hansen, Näsman & Rasmussen 1995). In a metal-casting context the vessels were probably most useful. Although we actually did not manage to melt bronze in these initial experiments, we did reach the theoretical melting point of bronze (950-1000 °C). The experiments also show that it was easy to melt silver and gold. Furthermore, these portable furnaces are most adequate for preheating the moulds as well as keeping the moulds warm when casting different metals.

In conclusion, the tests are very definitive in that the replicas of the prehistoric perforated cylinders are by far the most efficient in reaching high temperatures, and with the right type of fuel they are also very stable in holding this temperature. All in all, this strengthens the theory that the perforated cylinders were used for heat-demanding crafts

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