Non-Destructive Testing of materials in ancient Greece

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Abstract

This paper concerns the way that the ancient Greeks applied the quality control for testing materials, goods and commercial products, in far antiquity before 25 centuries, using NDT methods.

As it is well known the materials quality control was developed and was established as scientific method on the middle of last century. Also the way of testing materials using non-destructive methods was introduced after the world war tow.

The aim of the present work is the presentation of the historical and scientific truth, which is that the non-destructive testing was applied for testing materials and constructions, before the appearance of the destructive testing and also that this way of materials testing was known and was applied by the ancient Greeks, in the far antiquity, thousands years ago.

1. Introduction.

Non-destructive testing has been defined as comprising those test methods used to examine an object, material or system without impairing its future usefulness.

Non-destructive testing is a branch of the materials sciences, which incorporates all the technology for detection of discontinuities and measurement of significant properties of materials and has become an increasingly vital factor in the effective conduct of research, development, design and manufacturing programs.

The international community on nondestructive testing adopted a system that classifies the non-destructive methods into six major categories, from which the most important and well-known used worldwide, are: the Visual, the Ultrasonic, the Radiographic, the Liquid Penetrant, the Magnetic Particle, the Eddy Current, the Acoustic Emission, and the Thermography Testing.

Using non-destructive methods in cooperation with Fracture Mechanic, the failure of the materials and constructions can be anticipated or even avoided.

2. Nondestructive Testing in Ancient Greece.

The ancient Greeks were "technological" population. They considered, as it is reported in their Mythology, the Technology (that is to say artistic wisdom) and the Energy (that is to say the fire) as gifts of divine forces to the human gender, immediately afterwards the Creation.

For each marketable good, as for the technological products of ancient Greeks, the production followed the qualitative control.

“Lydia Lithos", e.g., was a black hard stone and it constituted one from the objectives with which ancient Greeks by engraving checked the cleanliness of the golden and silver currencies, jewels and other objects.

Based on historical and scientific information that the archaeological and scientific research has brought in the light, we are led to the conclusion that the ancient Greeks knew and also applied the qualitative control in the materials that they used.

The destructive testing was developed after the 17^{th} century After Christ.

Thus we led to the conclusion, as many ancient Greek inscriptions also confirm it, that the ancient Greeks, 25 centuries ago, applied the non-destructive testing for the qualitative control.

But as the modern technology and also other relative sciences had not been discovered that period, the non-destructive testing must would be applied then by subjective way, that is to say with the help of the five human senses (sight, hearing, touch, smell and taste) with which the mother nature has dowered us. Today, in a lot of cases the non-destructive testing is carried out with similar way that is via the five human senses.

Some from the significant results that the archaeological spade and the scientific research have brought in the light and which constitute regulations that the ancient Greeks used for the qualitative control of materials at the antiquity, are presented in this paper.

These regulations are engraved, mainly, in marble plates, and they have been found in excavations that have become in regions where the ancient Greek culture was developed.

The most important from these inscriptions are:

3. The inscription of Eleusis.

The first of them, the inscription of Eleusis, is presented in Figure 1(a). It was found by archeologist Philios on 1893 in the small town of Eleusis, which is located 15 Km west of Athens city. It has been inscribed on a white marble stele of dimensions 51cm height, 21cm width and 6cm thickness, around 360 Before Christ. At that time this inscription is considered, as the oldest ancient European standard discovered so far and constitutes a standard with very strict technical specifications.

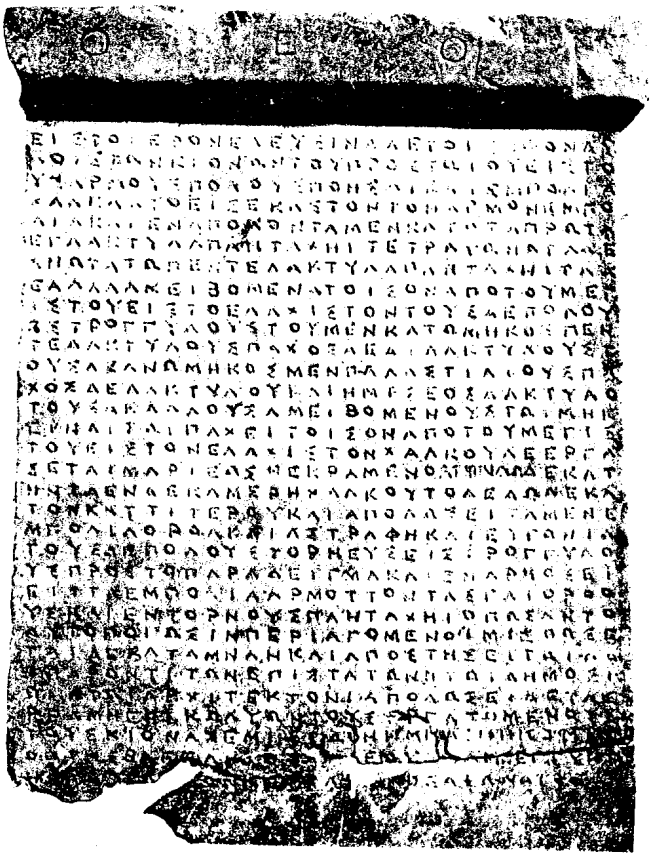
The text of this inscription is appeared in the Figure 2, in original ancient Hellenics (a), in its translation to new Hellenics (b), and in English translation (c).

It concerns the manufacture of bronze fittings, Figure 1(b), known as empolia and poloi, to be used in the erection of the columns of the Philonian Stoa (philonian arcade), a portico placed in front of the much older temple of Eleusis, Figure 1(c), the well-known Telestirion.

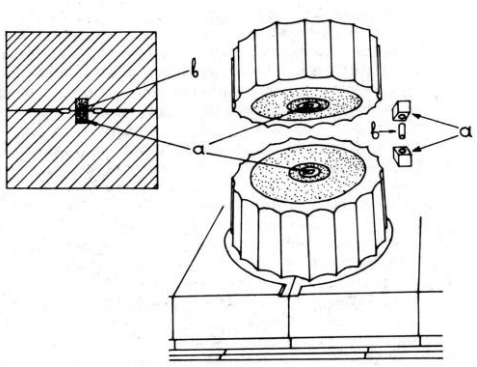
It was given the contractor of the project specific instructions about the origin, the chemical composition of the copper-tin alloy, the shape and the exact sizes of the required fittings, which was to be used.

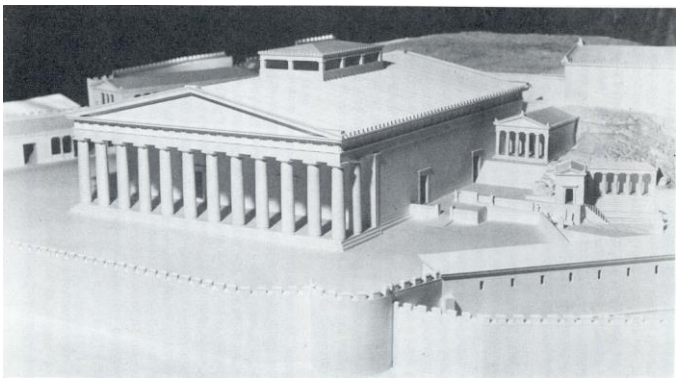
It reports that the bronze and the fittings should be produced in the Marion of Cyprus (today named Arsinoi) and that the 12 parts contain 11 copper and 1 tin.

The message from the distant antiquity is that the ancient Greeks used strict specifications in their orders and also strict quality control of copper alloys, based on non-destructive methods, because, if there was not a control, the specifications would not have any value and the danger for illegitimacy would be serious.



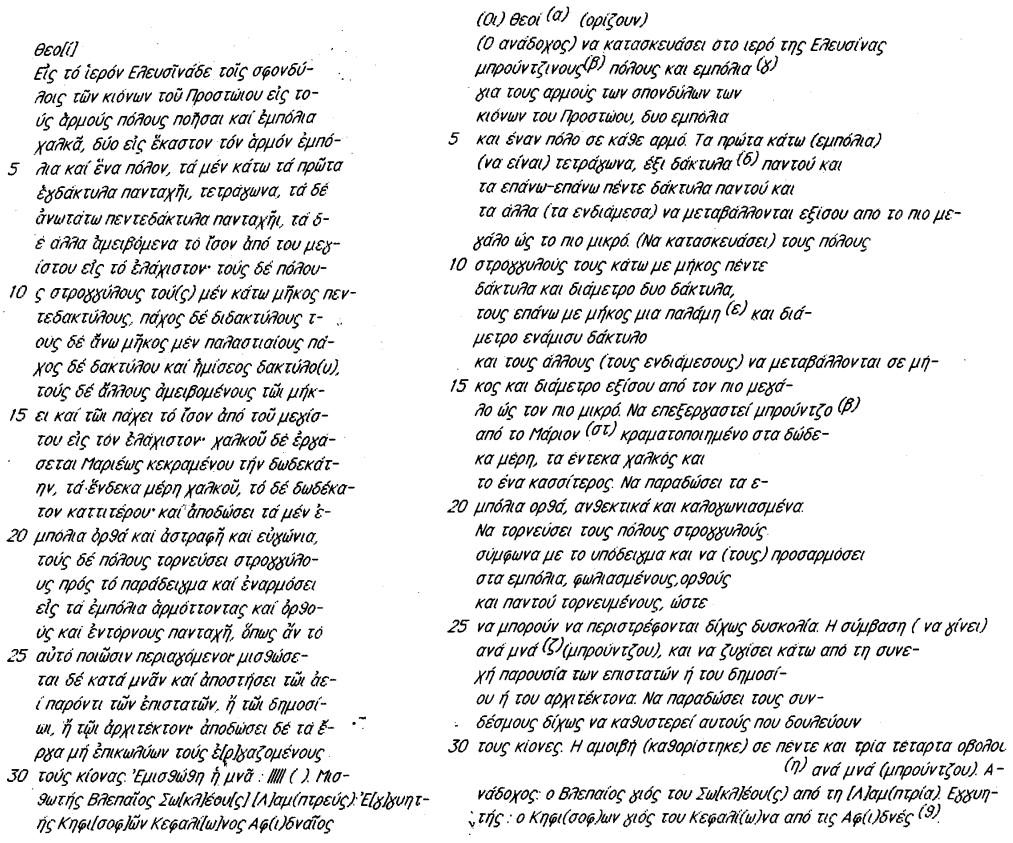
(a)





(b) **(c)**

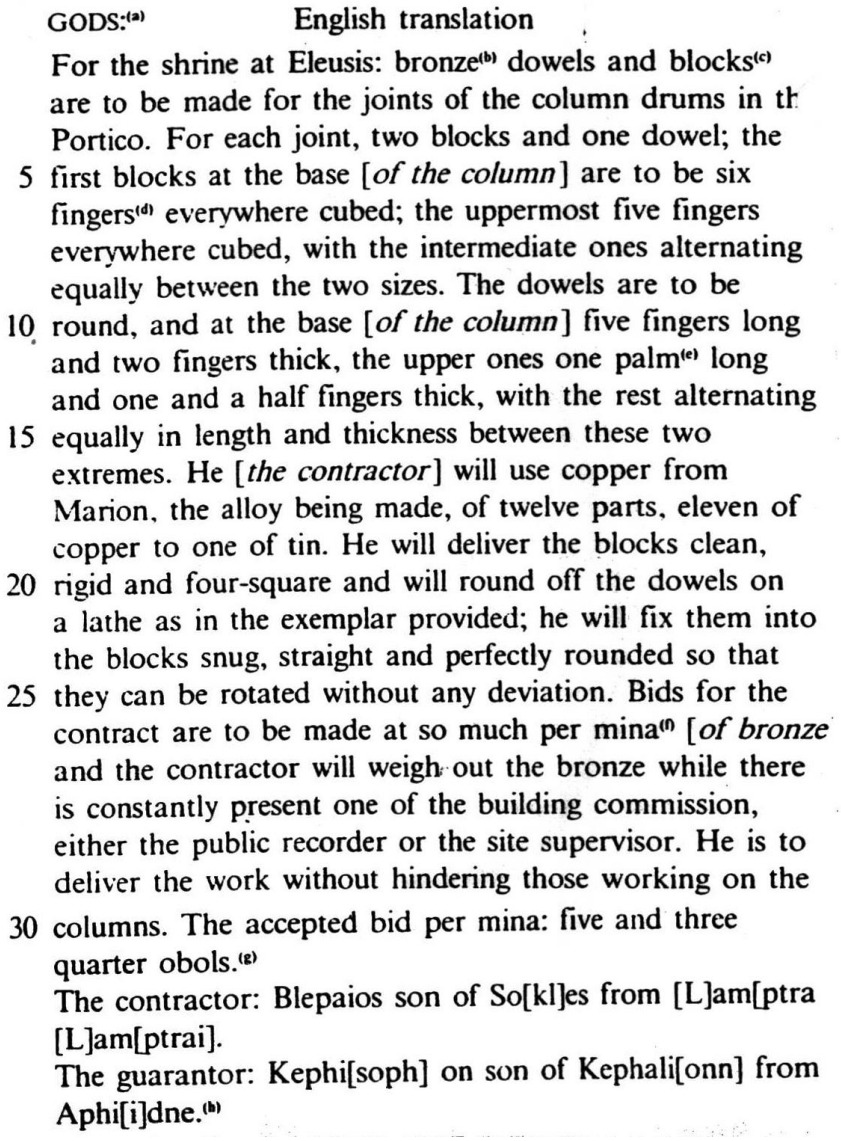
Fig. 1. The marble inscription of Eleusis (a) and the bronze fittings (b) (empolia b(a) and poloi b(b)) and the Philonian Stoa of the Temple of Eleusis (c).



(a) **(b)**

Fig. 2. The original in ancient Hellenics (a) and in the new Hellenics (b) of the Eleusis inscription

(a) Invocation commonly used at the beginning of decrees.
(b) Chalkos can be used to denote "copper" but here must mean "bronze" since the proportions of the alloy are specified below (11. 18-19).
(c) As illustrated in figures 2 and 3.
(d) One dactylos, or finger, was equal to approximately 18 mm.
(e) One palm was equal to four fingers (72 mm).
(f) A mina was equal to 100 drachmae. (Here units of mass, not coinage). J. Swaddling points out that it seems to have been the normal practice in antiquity for the metal worker to be paid according to the mass of metal worked upon. At Eleusis the would-be contractor had to quote his price 'per mina' of bronze.
(g) Left-hand (<) and right-hand (>) "brackets" strokes denoting ½ and ¼ respectively. The price of 5¾ obols per mina, J. Swaddling adds, must refer to labour charges alone and not to the bronze alloy which had probably been purchased under a separate contract.
(h) The names in the last two lines were restored by D. Philios.



GODS:[a] English translation

For the shrine at Eleusis: bronze[b] dowels and blocks[c] are to be made for the joints of the column drums in th Portico. For each joint, two blocks and one dowel; the first blocks at the base [*of the column*] are to be six fingers[d] everywhere cubed; the uppermost five fingers everywhere cubed, with the intermediate ones alternating equally between the two sizes. The dowels are to be round, and at the base [*of the column*] five fingers long and two fingers thick, the upper ones one palm[e] long and one and a half fingers thick, with the rest alternating equally in length and thickness between these two extremes. He [*the contractor*] will use copper from Marion, the alloy being made, of twelve parts, eleven of copper to one of tin. He will deliver the blocks clean, rigid and four-square and will round off the dowels on a lathe as in the exemplar provided; he will fix them into the blocks snug, straight and perfectly rounded so that they can be rotated without any deviation. Bids for the contract are to be made at so much per mina[f] [*of bronze* and the contractor will weigh out the bronze while there is constantly present one of the building commission, either the public recorder or the site supervisor. He is to deliver the work without hindering those working on the columns. The accepted bid per mina: five and three quarter obols.[g]

The contractor: Blepaios son of So[kl]es from [L]am[ptra [L]am[ptrai].

The guarantor: Kephi[soph] on son of Kephali[onn] from Aphi[i]dne.[h]

Fig. 2(c) The English translation of the original inscription of the Eleusis.

4. The Athenian law on silver coinage.

The next inscription is the stele shown in Figure 3(a), which was discovered during the ancient Athens Agora excavations on 1970. This concern the Athenian law on silver coinage, belongs to the beginning of the 4th century Before Christ, and constitutes a "directive" regarding the quality control of silver in general, and more specifically the Athenian silver currency.

In this inscription the following important points are noted:

a) The law required that a skilled public officer should test the silver currency.

b) The testers and the sellers of goods were to be severely punished in case the former were reluctant to test the silver coins brought them, and the latter if then did not accept coins certified to be genuine.

c) The law states that a tester existed in the city of Athens, and one was newly installed in Piraeus city, and

d) The new law in force cancels and replaces existing previous decrees.

In the same figure there is a pure silver Athenian coin of 5th century Before Christ (b), a counterfeit coin of the late archaic period cut across, strengthens this view (c), and a counterfeit coin of the end of the 5th century Before Christ (d).

(a) **(b)**

(c) **(d)**

Fig. 3. The inscription of Athenian law (a), a pure silver Athenian coin of 5th century B.C. (b), a counterfeit Athenian coin of the archaic period cut across of the 6th century B.C. (c) and a copper silver plated Athenian coin of 5th century B.C.(d).

5. The laws (inscriptions) of Thassos.

The next figure 4 presents three inscriptions of the 5th century Before Christ which were found in the island Thassos, a small island of the north Aegean. Their text mentions the following three very important directives, concerning the quality control of wine:

a) The purchase of wine would have been valid, only, if the large jars of wine had been sealed with a quality mark,

b) A heavy penalty should be imposed on those importing foreign wine in the area of the island, and

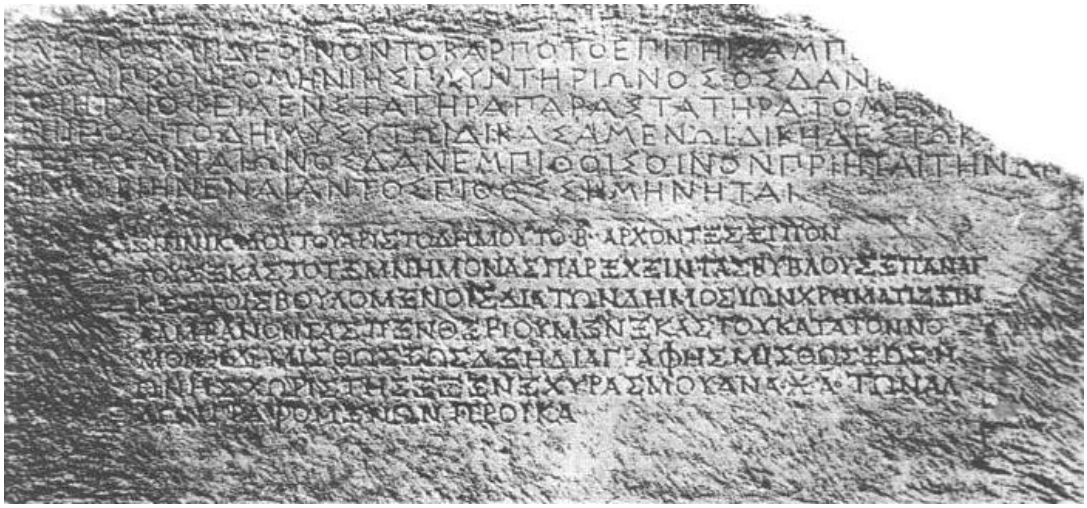
c) The penalties would have been equivalent to those imposed in the case of "watering the wine".

The latter is extremely important since it reveals the existence of another law, unfortunately not yet found, which would have specified the quality control of wine.

These three ancient inscriptions lead to the conclusion that in this time period a very good, well organized, system for the wine quality control must be applied. This test was concerned the water addition and generally its illegitimacy and was based on the non-destructive techniques using the senses of sight and taste or both of them together.

This quality control of wine prove that in ancient Greece, except the metals, were tested and the agricultural products for the protection of the consumer as well as the state from the illegitimacy.

(a)



(b)

(c)

Fig. 4. The three laws of Thasos concern: The first inscription (a) of the 5th B.C. century the testing of wine and vinegar, and the second (b) and third (c) of 420-400 B.C. the commerce of the pure wine and the testing of the illegitimacy with water of the wine.

6. The inscription of Oropou.

Finally the last inscription that I am going to present to you is the inscription of Figure 5, which was found in the Kalamos of Oropou, a small city near to Athens and which constitutes an engraved column of the 3rd Before Christ century.

It concerns the testing of the damaged gold and silver offerings, articles and other objects of the holy temple of Amfiaraou, which could be tested and to be repaired or after their molding to be produced new similar to the original without any looses of gold or silver and of course without any illegitimacy. Also these procedures and tests were based on the non-destructive testing.

7. Possible quality control procedures of testing metals in antiquity.

Contemporary testers, dealing with gold and silver coins consider that the ancients could test the genuineness of silver and gold coins by applying, their three senses: sight, touch and hearing.

First, they observe the coin carefully, then they touch it with their very sensitive fingers, they feel the weight when keeping it in their first, and finally they let it drop on a hard surface and hear the sound of its ringing.

The gold purity and its composition were determined by the common test of the touchstone using the Lydia Stone. It is the oldest colorimetric non-destructive assaying in use since the antiquity. The test is based on the comparison of rubbing a gold object of unknown composition and those left by a series of gold standards of certified composition.

The quality control of copper alloys should be done in a similar way based on the Non-Destructive Testing. Many archeologists and scientists proved that the ancient Greeks should be used a series of standards copper and copper-tin alloys of know composition reference specimens.

The tester of that period with the help of his senses: sight, hearing and with engraving, comparing the unknown content alloy of copper with these standard reference blocks would realize easily the composition of the unknown alloy and consequently the existence of illegitimacy.

Fig. 5. The inscription of Oropou, of the 3rd B.C. century, concerns the testing of the damaged gold and silver objects of the holy temple of Amfiaraou of Oropou.

8. Conclusions.

And finally as conclusions, from the previous mentioned investigations comes out the high level of knowledge and experiences of ancient Greeks in the field of standardization, testing and certification of materials, goods and products.

A well-organized quality control, based on non-destructive methods, was applied to almost all products in those times.

The tests that could have been applied at that remote time would be the use of the five senses: sight, touch, hearing, smell and taste as well the use of the touchstone, the famous Lydian stone.

The ancient Greeks applied standards with strict specifications for all the products and goods as well as non-destructive testing for their quality control.

It confirms the opinion that in well organized with developed civilization societies are observed also developed technology. Culture and technology that is to say keep pace.

Similar information should be existed also in other populations. This work constitutes stimulus so that other scientists seek for similar information from the ancient people of their countries.

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