

Publication in the Official Journal Yes / No

File Number: T 494/91 - 3.4.2

Application No.: 87 301 981.4

Publication No.: 0 239 275

Title of invention: Measuring oxide scale on inner surfaces of boiler tubes

Classification: G01N 29/00

**D E C I S I O N**  
of 14 January 1992

Applicant: THE BABCOCK & WILCOX COMPANY

Headword:

EPC Article 56

Keyword: Inventive step: yes, after amendment

**Headnote**



Case Number : T 494/91 - 3.4.2

**D E C I S I O N**  
of the Technical Board of Appeal 3.4.2  
of 14 January 1992

**Appellant :** THE BABCOCK & WILCOX COMPANY  
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**Decision under appeal :** Decision of Examining Division of the European  
Patent Office dated 21.02.1991 refusing European  
patent application No. 87 301 981.4 pursuant to  
Article 97(1) EPC.

**Composition of the Board :**

**Chairman :** E. TURRINI  
**Members :** M. CHOMENTOWSKI  
C.V. PAYRAUDEAU

## Summary of Facts and Submissions

- I. European patent application No. 87 301 981.4 (Publication No. 0 239 275) was refused by the Examining division on the grounds that the subject-matter of the valid Claim 1 lacked an inventive step with regard to  
D1 = Patent Abstracts of Japan, Vol. 9, No. 312 (P-411) (2035), 7 December 1985 & JP-A-60 142 210, and  
D2 = EP-A-0 049 956.
- II. The Appellant (Applicant) lodged an appeal against this decision. He requested that the decision under appeal be set aside and that a patent be granted on the basis of the text of the patent application submitted with the written Statement of the Grounds of Appeal or, auxiliarily, according to a secondary request with an amended text. Auxiliarily, he requested the appointment of oral proceedings.
- III. The Board expressed in a written communication accompanying the invitation to oral proceedings its provisional opinion that the subject-matter of the claims lacked an inventive step having regard to D1 and D2.
- IV. During the oral proceedings, the Board drew the Appellant's attention to the text of the submitted Claim 1, which did not specify that the frequency for energising the transducer to transmit an ultrasonic pulse into the boiler tube is at least 50 MHz; thus, the deletion of this originally claimed feature resulted in additional subject-matter. At the end of the oral proceedings, the Appellant requested that the decision under appeal be set aside and that a patent be granted - as main request, on the basis of the description (pages 1 to 8), Claims 1 to 5 and drawings (2 sheets) filed with the Statement on Grounds of Appeal with

cancellation, in the description, page 2, lines 28 and 29 and in Claim 1, lines 11 and 12 (4 occurrences) of the words "high temperature";

- as first auxiliary request, on the basis of the description, pages 1 and 2a to 8 and drawings (2 sheets) filed with the Statement on Grounds of Appeal and of page 2 and Claims 1 to 5 filed at the oral proceedings as first auxiliary submission;
- as second auxiliary request on the basis of the description, pages 1 and 2a to 8 and drawings (2 sheets) filed with the Statement on Grounds of Appeal and of page 2 and Claims 1 to 5 filed at the oral proceedings as second auxiliary submission.

V. Main request

Claim 1 reads as follows:

"1. A method of ultrasonically measuring oxide scale (12) formed in the presence of steam on a cylindrical inner surface of a boiler tube (10) within a boiler, the method comprising:

establishing a relationship between the thickness of said scale on a cylindrical inner surface of a boiler tube and the time of flight of an ultrasonic pulse within the scale by first subjecting a plurality of samples of the boiler tube including scale of varying thicknesses to ultrasonic pulses to determine the time of flight within the scale, physically measuring the thicknesses of the scale on the respective ones of the samples, and then correlating the physical thickness measurements of the oxide scale with the time of flight of the ultrasonic pulse in the oxide scale;

positioning an ultrasonic transducer (14) in an orientation on the outer surface of an area of a boiler tube (10) at which said scale is formed on the inner

surface for directing transmission of an ultrasonic pulse into the boiler tube so that the centreline of the ultrasonic beam is perpendicular to the inner surface of the boiler tube;  
energising the transducer (14) to transmit an ultrasonic pulse into the boiler tube (10);  
measuring a first time of flight ( $ToF_1$ ) representative of the time for the ultrasonic pulse to be transmitted to and reflected from the tube/scale interface;  
measuring a second time of flight ( $ToF_2$ ) representative of the time for the ultrasonic pulse to be transmitted to and reflected from the scale/tube interior interface;  
determining the difference ( $ToF_2 - ToF_1$ ) between the second time of flight and the first time of flight; and  
determining the scale thickness from said difference and said relationship."

Claims 2 to 5 are dependent claims.

First auxiliary request

Claim 1 reads as follows:

"1. A method of ultrasonically measuring oxide scale (12) formed in the presence of steam on a cylindrical inner surface of a boiler tube (10) within a boiler, the method comprising:  
establishing a relationship between the thickness of said scale on a cylindrical inner surface of a boiler tube and the time of flight of an ultrasonic pulse within the scale by first subjecting a plurality of samples of the boiler tube including scale of varying thicknesses to ultrasonic pulses to determine the time of flight within the scale, physically measuring the thicknesses of the scale on the respective ones of the samples, and then correlating the physical thickness measurements of the

oxide scale with the time of flight of the ultrasonic pulse in the oxide scale;  
positioning an ultrasonic transducer (14) in an orientation on the outer surface of an area of a boiler tube (10) at which said scale is formed on the inner surface for directing transmission of an ultrasonic pulse into the boiler tube so that the centreline of the ultrasonic beam is perpendicular to the inner surface of the boiler tube;  
energising the transducer (14) to transmit an ultrasonic pulse having a frequency of at least 50 MHz into the boiler tube (10);  
measuring a first time of flight ( $ToF_1$ ) representative of the time for the ultrasonic pulse to be transmitted to and reflected from the tube/scale interface;  
measuring a second time of flight ( $ToF_2$ ) representative of the time for the ultrasonic pulse to be transmitted to and reflected from the scale/tube interior interface;  
determining the difference ( $ToF_2 - ToF_1$ ) between the second time of flight and the first time of flight; and  
determining the scale thickness from said difference and said relationship."

Claims 2 to 5 are dependent claims.

Second auxiliary request

Claim 1 is identical with Claim 1 of the main request with the addition of the expression "in situ" after "a boiler tube (10)" in the second line of the claim.  
Claims 2 to 5 according to this request are dependent on Claim 1.

VI. The Appellant submitted the following arguments in support of his requests. The deletion of the originally claimed feature that the frequency for energising the

transducer (14) to transmit an ultrasonic pulse into the boiler tube (10) is at least 50 MHz is based on the values disclosed originally in Table 2, on page 7, which clearly show that frequency values less than 50 MHz can be used.

The actual starting point for the claimed method is the destructive metallurgical method of measuring scale thickness acknowledged in the present application. The person skilled in this particular technique would not be incited to take into consideration the method for measuring the thickness of the inner and outer layers of a tube made of zirconium and a zirconium alloy described in D1 according to which a section of the tube is immersed in a fluid where it is submitted to an ultrasonic measurement because D1 is only concerned with the measurement of the thickness of homogeneous manufactured metallic layers, which are quite different from the non-homogeneous scale oxide, and because said known method cannot be used "in situ" on a tube forming part of an actual boiler but is only applicable on short tube sections. D2, which is not concerned with a thickness measurement but only with the detection of the presence or of the absence of a manufactured inner layer of a tube, does not give any information to the skilled person how to modify the known method of D1 for measuring the thickness of a scale deposit in a boiler tube and does not make any suggestion which could incite the man of the art to modify the method of D1 for effecting such measurements.

Therefore, the skilled person could arrive at the presently claimed method only by hindsight, and this is not allowable when assessing an inventive step.

## Reasons for the Decision

1. The appeal is admissible.
2. Main request
  - 2.1 Allowability of the amendments

The Appellant has submitted that the deletion of the originally claimed feature that the frequency for energising the transducer (14) to transmit an ultrasonic pulse into the boiler tube (10) is at least 50 MHz is in accordance with the frequency values disclosed in Table 2 on page 7 of the original description, which are between 0.5 and 100 MHz. However, it is to be noted that the application as filed (see page 3, lines 27-28) states: "The transducer 14 is a high frequency transducer. As used herein, high frequency is intended to refer to frequencies of 50 MHz or greater". Moreover, the description as filed (see page 7, lines 27-32) specifies that testing has established that frequencies in the region of 5 and 10 MHz cannot be used to measure the thickness of oxide scale, although testing indicated that a highly damped 10 MHz transducer with a laboratory grade pulser/receiver and oscilloscope can detect but not measure the presence of scale on the inner surface of a boiler tube when the thickness of the scale is in a certain range of values. Thus, by deleting the original frequency limit of 50 MHz, a process with a frequency of 5 or 10 MHz, which are values disclosed in Table 2 but which were unambiguously excluded, would be comprised within the range of frequency values of Claim 1. Moreover, although it was not specifically indicated in the description of the patent application as filed whether the frequencies comprised in the range between 10 and 50 MHz could be used to measure the thickness of the



oxide scale, it results clearly, notably from the above cited passages of page 3, lines 27-28 and also from the passage of page 8, lines 5-6 of the application as filed, that only the use of an ultrasonic pulse having a **minimum** frequency of 50 MHz has ever been contemplated by the invention. Therefore, the deletion of said frequency limit results in the European patent application being amended in such a way that it contains subject-matter which extends beyond the content of the application as filed, and thus, the main request is not allowable (Art. 123(2) EPC).

3. First auxiliary request

3.1 Allowability of the amendments

3.1.1 The Board is satisfied that, since Claim 1 comprises the feature that the frequency for energising the transducer (14) to transmit an ultrasonic pulse into the boiler tube is at least 50 MHz, in accordance with the application as filed, the requirement of Article 123(2) EPC is met.

3.2 Novelty

3.2.1 A method for ultrasonically measuring the thickness of a layer (1b) formed on a cylindrical inner surface of a tube (1a) is known from D1 (see the abstract); the method comprises:

positioning an ultrasonic transducer (3) in the vicinity of the outer surface of an area of the tube (1a) at which said layer (1b) is formed on the inner surface in an orientation for directing transmission of an ultrasonic pulse into the tube so that the centreline of the

ultrasonic beam is perpendicular to the inner surface of the tube;

energising the transducer (3) to transmit an ultrasonic pulse having 20 to 100 MHz frequencies into the tube (1a).

3.2.1.1 D1 specifies that the reflected wave is received by the probe (3) and a sending echo (T) is displayed on a cathode-ray tube (5) of an ultrasonic inspector (4); the ultrasonic wave is reflected at the interface between the material (1a) and the medium (2), i.e. at the external interface of the tube (1a), at the interface between the tube (1a) and the layer (1b), and at the interface between the layer (1b) and the medium (2), i.e. at the inner interface of the layer; respective echoes are generated; the thickness of the materials (1a) and (1b) are measured accurately and surely from time intervals between respective echoes.

3.2.1.2 Therefore, in the opinion of the Board, it is also directly and unambiguously derivable from D1 that the following steps of measuring a first time of flight representative of the time for the ultrasonic pulse to be transmitted to and reflected from the tube/layer interface;  
measuring a second time of flight representative of the time for the ultrasonic pulse to be transmitted to and reflected from the layer/tube interior interface;  
determining the difference between the second time of flight and the first time of flight; and  
determining the layer thickness from said difference, are comprised in the method of D1.

3.2.2 However, in the known method, in particular,

- the ultrasonic transducer is not positioned on the outer surface of the tube (1),
- the transducer and tube are immersed in a fluid medium in a tank,
- the frequency of the ultrasonic pulse transmitted by the transducer is not at least 50 MHz, but 20 to 100 MHz, and
- the material of the inner layer in the tube is not an oxide scale, but zirconium.

3.2.3 The other prior art documents are less relevant because they do not relate directly to the ultrasonic measurement of the thickness of a layer formed on the inner surface of a tube. In particular, D2 relates to the detection of flaws in the inner lining of a tube and the prior art metallurgical measuring technique for measuring the scale thickness in a tube acknowledged in the patent application (see page 1, lines 5-22) does not comprise any ultrasonic measuring step.

3.2.4 Therefore, the Board is of the opinion that the subject-matter of Claim 1 is novel in the sense of Article 54 EPC.

### 3.3 Inventive step

3.3.1 In examining for the presence of inventive step, the Board follows, in accordance in particular with the decision T 138/85 of 23 September 1987, unpublished (see in particular point 3.6), its normal practice of first deciding what is the closest prior art. This may or may not correspond to that from which the Applicant developed his invention. In reaching a decision on this issue, it is necessary to compare the technical features of the

method which is the subject-matter of the claim under consideration with those of the prior art methods, as has been done above, without regard to the reasons which motivated the designers of the respective methods. It is only after the closest prior art has been identified in this way that the problem to be solved is determined. This is done objectively by comparing the results achieved by the subject-matter claimed with those achieved by that prior art.

3.3.1.1 D1 pertains to the technical field of methods for ultrasonically measuring the thickness of layers of materials formed on a substrate, for instance a tube, of a different material. The Appellant has submitted (see the written Statement of Grounds of Appeal, paragraph 5; see also the present application, page 1, lines 3-22) that the actual prior art, from which the claimed method was developed, is the metallurgical technique which has typically been employed to measure scale thickness to predict the remaining life of high pressure boiler tubes, which method requires physical removal and replacement of boiler tube sections and analysis of the removed tube sections at laboratory facilities each time a scale thickness measurement is desired. However, the Appellant also acknowledges (see the application as filed, page 1, lines 27-29) that ultrasonic methods were already used for detecting surface and subsurface flaws and for the measurement of the thickness of a material or the distances to a flaw. Thus, the Board is of the opinion that the person skilled in the art of the measurement of scale thickness in boiler tubes would have been aware of the technique of D1.

3.3.1.2 The method of D1 is disclosed only in relation with zirconium and alloys thereof. However, there is no technical information derivable from D1 which could be understood as meaning that the disclosed method can work

only with these materials and could not be used to ultrasonically measure any other type of layers. In particular, oxide scales formed in the presence of steam on a cylindrical inner surface of a boiler tube within a boiler form a layer in contact with the boiler tube but with different properties and thus, in the opinion of the Board, the use of the method of D1 for ultrasonically measuring said layer would have been taken into consideration by the person skilled in the art of the acknowledged metallurgical thickness measurement.

3.3.2 Therefore, the Board is of the opinion that D1 is the closest prior art because it is concerned with a method for ultrasonically measuring the thickness of a layer formed on a cylindrical inner surface of a tube and thus, a person skilled in the art of measuring the thickness of a layer formed on a cylindrical inner surface of a tube, for instance the person skilled in the art of the acknowledged metallurgical method, being aware of this technique, would have started from this prior art and adapted it for measuring the thickness of a scale layer on the inner surface of a tube.

3.3.3 However, there is no information in D1 about measurement of scale thickness. The Appellant has submitted that oxide scale formed in the presence of steam on a cylindrical inner surface of a boiler tube within a boiler is not, contrary to the zirconium of the inner layer of D1, an homogeneous material having definite chemical and physical properties; in particular, the velocity of sound in zirconium can be found in the literature, or is available by measurement, and the thickness of the layer can be calculated easily by the product of said velocity by the difference of time of flight; on the contrary, there is no such information concerning scale oxide (see the present application, page 7, lines 12-14) and the known measurement methods do

not give definite values because of the inhomogeneous structure, as can be seen from Fig. 3 of the present application. In the opinion of the Board, this argument is credible. Additionally, the mentioned drawbacks when measuring the oxide scale thickness by the method of D1 are increased because of the following features of said known method and, therefore, the skilled person would have serious doubts to still try to obtain an effective measurement of the scale thickness based on this method.

3.3.3.1 In the method of D1, the ultrasonic transducer (3) is not positioned on the outer surface of the tube (1), but at some distance of the tube (1), the transducer and the tube being both immersed in a fluid medium (2). The Board is therefore of the opinion that, because of the distance between the ultrasonic transducer and the tube (1), the method of D1 presents the drawbacks that there can be some angular dispersion of the ultrasonic waves which may fall on curved parts of the tube located besides the point of normal incidence thereof with a resulting dispersion of the reflected waves, i.e an inadequate coupling between the transducer and the tubular surface under investigation and thus an increased lack of precision of the measurement.

3.3.3.2 In this respect, it is to be noted that the method of D1 is only usable with dismantled tubes immersed in a fluid whereby the outer layer and the inner layer of the tube are both in contact with said fluid (see paragraph 20 of the written Statement of Grounds of Appeal). Thus, the Board is of the opinion that, by trying to avoid the above-mentioned inadequate coupling between the transducer and the tubular surface under investigation, the modification which would consist in positioning the ultrasonic transducer on the outer surface of the tube,

as suggested in D2 (see page 2, line 24, page 3, line 25; page 4, lines 2-24), would introduce other sources of lack of precision because of the different interface conditions at the inside surface and at the outer surface of the tube, respectively.

3.3.3.3 Incidentally, it is to be noted that D2 (see page 2 lines 5-8; page 2, line 24, page 3, line 25; page 4, lines 2-24), which discloses a ultrasonic method of testing the integrity of the internal lining of a hollow body such as a tube (1), even if it takes into account the local thickness of said lining, does not however specifically disclose a method for measuring a thickness, but for locally detecting the absence of an inner layer on a tube. Therefore, the Board is of the opinion that, even by taking into account its suggestion of using comparison standards, D2 would not incite the person skilled in the art to fabricate thickness comparison standards, as in the present Claim 1.

3.3.3.4 Moreover, D1 specifies that a range of frequencies of 20 to 100 MHz is employed. However, as mentioned in the present application (see page 2a, lines 20-23; page 6, line 19, page 7, line 11), a preferred feature of the claimed method is the use of a frequency of 50 MHz for measuring scale as thin as 0.127 mm; in this respect, it is to be noted that it is specified that, to resolve the interfaces, the scale thickness must be at least one wavelength of the ultrasound and that it is derivable from Table 2 that wavelength for ultrasonic frequencies less than 50 MHz are greater than 0.1188 mm, for instance 0.2376, i.e. more than the above mentioned thickness value, for 25 MHz. Thus, the Board is of the opinion that, for measuring adequately the thickness of current oxide scales, a lower limit of the frequencies of 50 MHz appears to be necessary and that, thus, a further

modification, i.e. a selection from the known frequency values of D1, not suggested in the prior art, was needed to arrive at the presently claimed method.

3.3.4 Therefore, the Board is of the opinion that, taking into account the different properties of zirconium and oxide scale and the predictable unprecise results of thickness measurements of scale oxide, taking also into account the modifications of the method of D1 which are not specifically suggested by the prior art and which should be necessary to arrive at the presently claimed method, the Appellant's argument that such modifications would only be the result of "ex-post facto" reasoning can be accepted.

3.3.5 Moreover, as submitted by the Appellant, there is a result of the measurement according to the claimed method which is unexpected, in particular when taking into account the inhomogeneous structure of scale oxide. Indeed, an equation,

$$\text{"oxide thickness} = (0.1619 \times (\text{ToF}_2 - \text{ToF}_1)) - 1.42\text{"},$$

relates the scale thickness to the difference of time of flight, said relation being also derivable from Fig.3 of the present application (see page 6, lines 10-18) and allowing, by using comparison standard as defined in Claim 1, to measure the thickness of scale oxide with a precision which appears to be sufficient in said technical field.

3.3.6 Therefore, the Board is of the opinion that, having regard to the modifications of D1 necessary to arrive at the method of Claim 1 and to the unexpected resulting measuring relation, the subject-matter of Claim 1 implies an inventive step in the sense of Article 56 EPC.



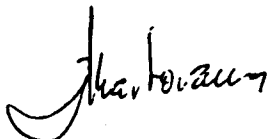
- 3.4 Since the European patent application and the invention to which it relates meet the requirements of the Convention, a patent may be granted.
4. Since the first auxiliary request is allowable, it is not necessary to consider the second auxiliary request of the Appellant.

#### Order

For these reasons, it is decided that:

1. The decision under appeal is set aside.
2. The case is remitted to the first instance with the order to grant a patent on the basis of the first auxiliary request presented by the Appellant at the oral proceedings and including the following documents:  
description: pages 1 and 2a to 8 filed with the Statement on Grounds of Appeal, and  
page 2 filed at the oral proceedings,  
Claims: 1 to 5 filed at the oral proceedings,  
drawings: Fig. 1-3 (2 sheets) filed with the Statement on Grounds of Appeal.

The Registrar:



P. Martorana

The Chairman:



E. Turrini

