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QUENCH CALORIMETER

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FIG. 1.

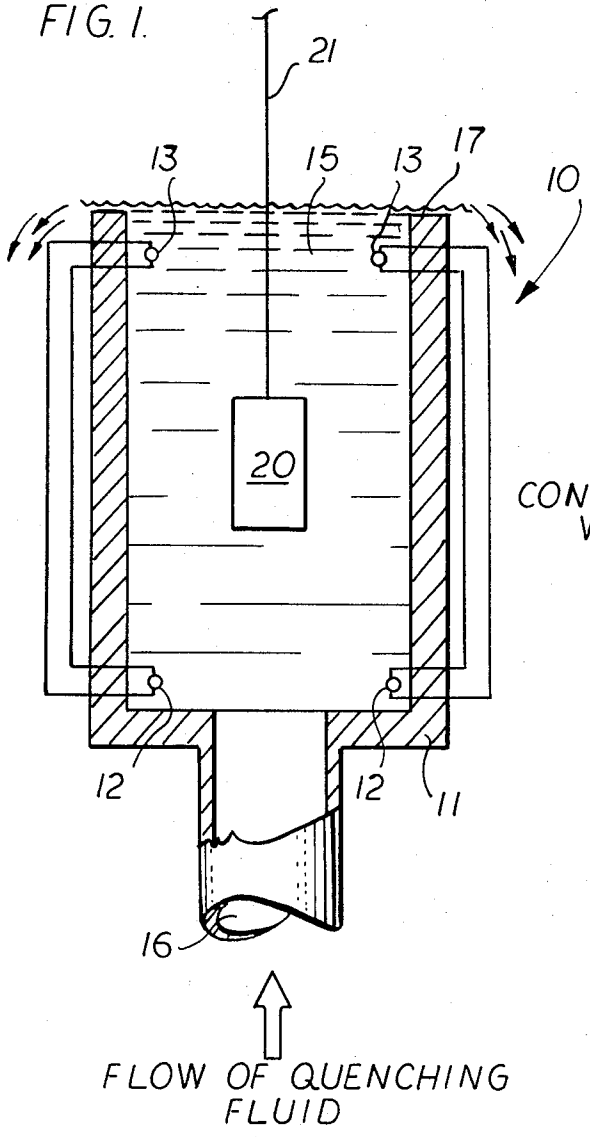
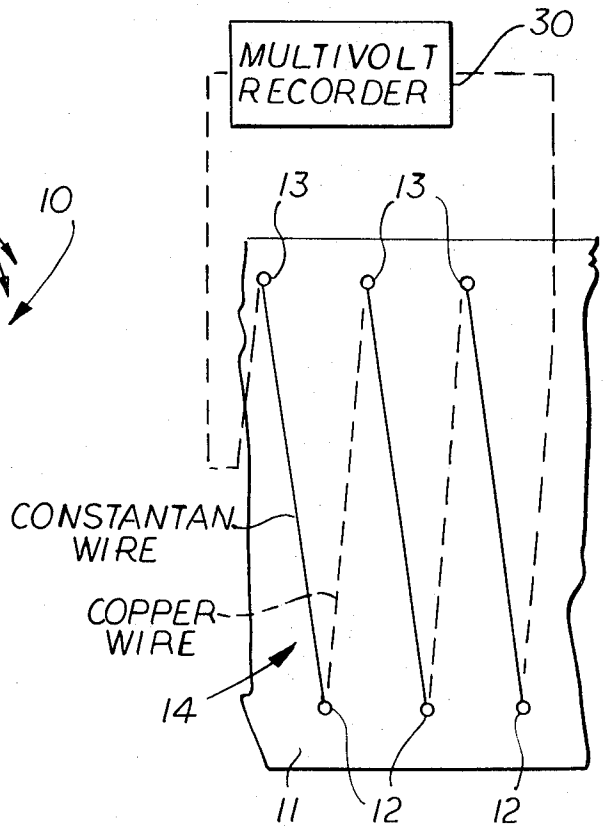


FIG. 2.



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QUENCH CALORIMETER

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ABSTRACT OF THE DISCLOSURE

An instrument to measure and record the change in temperature of a quenching fluid during a quench cycle for a metal specimen. The instrument includes a quench tank filled with a quenching fluid into which the specimen is immersed and a plurality of thermocouples connected in series to form a thermopile which is connected to an electrical recorder. The quenching fluid is circulated into the tank at its bottom and out its top. The opposing junctions of the thermocouples are suitably located to be sensitive to the temperature of the inflowing and outflowing fluid, respectively.

BACKGROUND OF THE INVENTION

This invention relates to testing apparatus, and more particularly to a method and apparatus for measuring and recording the rate of change of thermal conditions within a quenching fluid during the quench cycle for a metallic specimen.

Metallurgists and heat treaters long ago found that steels of various grades require different speeds of cooling during the hardening process if their maximum properties are to be attained without severe distortion or cracking. Oil, water, brine solutions and air were used traditionally, providing some variety from which to choose the most useful cooling rate for a particular steel. In more recent years researchers have found that these fluids, as well as most other fluids, not only have quite different average heat extracting ability, but usually exhibit their own characteristic cooling ability at every different level of temperature of the work-piece as it progresses through the quenching cycle. Efforts heretofore have been made to record the progressive rates of heat dissipation to the quenching fluid in order to evaluate—

(1) the efficiency of the quenching fluid,
(2) the severity of the quenching effect upon the steel specimen, or
(3) the effectiveness of the mechanics of the quenching fixture.

These efforts have centered around placement of temperature or magnetic measuring devices in or around a specially prepared specimen. Alternative procedures involved the destructive examination of a steel specimen or workpiece to determine the response of that steel to the quenching action. The former of the above procedures requires repeated use of the same specimen and the accompanying progressive deterioration and/or contamination of it which seriously affects its reliability, while the latter involves costly specimen preparation and time consuming examination.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and apparatus to examine the rate of change of thermal conditions in a quenching fluid throughout the history of progressive cooling in quenching the specimen from its high initial temperature, typical in heat treating, to its low final temperature instead of the rate of change of the thermal conditions, or its effects, produced in the metallic specimen being quenched.

It is a particular object of the invention to provide a very simple form of metallic specimen of measured mass, used from the same material proposed to be quenched in practice or from other selected standard material, so that a new clean specimen can economically be used for every test. The metallic specimen can thus be exposed to a very similar history of heating, surface oxidation and environment for each test cycle. It then closely duplicates the heat treating practice being investigated instead of being re-used with a contaminated surface or a cleaned or polished surface with consequent change in mass or surface condition.

It is a more particular object to provide a quench tank of low thermal conductivity material through which a quenching fluid is circulated, a plurality of thermocouples disposed to be sensitive to the inflowing and outflowing fluid, and electrical recording apparatus connected to the thermocouples so as to record the change in temperature of the quenching fluid during a quench cycle.

It is a still more particular object to connect the plurality of thermocouples in the outflowing fluid in series as in a thermopile, so as to measure accurately the average temperature of the outflowing fluid, thus allowing for temperature variations at points within the outflowing stream; as for example, due to turbulent flow. Similarly, a plurality of thermocouples is connected in series in the inflowing fluid as a thermopile of matching characteristics to that in the outflowing fluid.

The thermopile in the outflowing stream, being of matching electrical characteristic to that in the inflowing stream, is connected in reverse polarity so as to produce an E.M.F. proportional to the difference in average temperatures of the inflowing and outflowing fluid at any instant throughout the quenching cycle.

Variations in practice of connecting the temperature sensitive elements are considered, as shown in FIG. 2, toward the end that averaging conditions of measurement prevail and that finally, a temperature difference between the inflow and outflow temperatures is observed as related to time.

The change of temperature of the quenching fluid is normally less by a factor of $\frac{1}{100}$ to $\frac{1}{10}$ than the change of temperature of the specimen. The thermocouples thus are never exposed to excessively high temperatures, are not damaged by the fluid medium, and should last indefinitely in operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional schematic diagram of the quench calorimeter of the present invention; and

FIG. 2 is a schematic diagram of the thermopile used in the calorimeter.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The quench calorimeter of the present invention is designated generally by the numeral **10** and comprises a fluid container or quench tank **11** of low thermal conductivity material, and a plurality of thermocouples **12** and **13** connected in series to form a thermopile **14**. The container **11** is adapted to contain a quenching fluid **15** and is formed with a fluid inlet port **16**, and a fluid overflow or outlet port **17**. The quenching fluid **15** is caused to circulate, at a constant controlled rate, through the tank **11** by way of the ports **16** and **17** by suitable means (not shown).

A metal specimen **20**, of predetermined shape and mass, heated to a predetermined temperature in a suitable furnace or other heating device (not shown), is immersed into the fluid **15**, which normally is a liquid but may also be air or other gas, and may be supported by a string or wire **21** (as shown). It is not critical, however, for the

purposes of this invention that the specimen **20** be suspended.

The thermocouples **12** and **13** may be formed of junctures of copper and constantan wire in a conventional fashion. The thermocouples **12** are positioned within the container **11** adjacent the fluid inlet port **16** so as to be sensitive to the temperature of the inflowing fluid. The thermocouples **13** are positioned within the container **11** adjacent the top of the container or near the outlet port **17** so as to be sensitive to the temperature of the outflowing fluid. The exact positioning of the thermocouples **12** and **13** is not criitcal for an understanding of the invention, although they preferably are so located so as not interfere with the insertion and removal of the specimen **20**. The thermocouples **12** and **13** are connected in series to form the thermopile **14**, as shown in FIG. 2, which is connected to a suitable voltmeter or electrical recorder **30**.

The operation of the quench calorimeter **10** is as follows:

The quenching liquid **15** is circulated through the container **11** at some pre-determined flow rate, R. The mass of fluid M_q circulated in a given time equals the product of R times the time *t*, or $M_q=R\times t$.

The specimen **20** has a mass M_s which is determined by weighing. The specimen **20** is heated to a relatively high initial temperature T_{is} in an electric furnace or by other suitable means. (For a steel sample, this temperature may be approximately 1550° F.) The specimen **20** is then immersed in the quenching liquid **15** where it is cooled to a final temperature T_{fs}. The change in temperature of the specimen **20** is DT_s and is equal to the initial temperature T_{is} minus the final temperature T_{fs}, or $DT_s=T_{is}-T_{fs}$. With a specific heat C_{ps} for the specimen **20**, the total heat Q given up to the fluid by the specimen **20** is: $Q=(M_s)(C_{ps})(DT_s)$.

The heat Q transfererd from the specimen **20** to the flowing quenching liquid **15** produces a rise in the temperature of the liquid, depending of course upon the selected flow rate of the fluid R and its specific heat C_{pg}, since, in practice, all of the heat lost from the specimen must be absorbed by the fluid. This may be described as: The heat transferred, $Q=M_sC_{ps}DT_s=M_qC_{pq}DT_q$.

This equality will hold whether taken over the total time of the quenching cycle, or taken over any intermediate increment of time.

In multiple experiments where the mass of the specimen **20** and the specific heat of the specimen **20** remain the same, the factor in parentheses may be treated as a constant. This will be the usual case where a large number of identical parts are manufactured in mass production, and are all quenched in the same quench tank **11**.

It should be noted that any selected quench tank, even in a large scale production facility, may be calibrated to measure, and thereby control the quality of, the quenching operation.

The stated purpose of the present invention was to examine the rate of change of thermal conditions during the quenching operation by indirection, that is by measuring the change in temperature of the quenching fluid, rather than of the specimen itself.

It is a further purpose of this invention as stated above, to enable the examination of the change of rate of heat transfer at any and several increments of time throughout the quenching cycle. These changes reflect the progressive interaction of the changing surface conditions of the metal specimen due to accumulation of contaminants and the changing conditions of vapor phase, nucleate boiling phase and convection phase, or deterioration of the quenching fluid with respect to momentary temperature of the specimen and time of exposure to these physical environment.

It is recognized that an idealized quenching medium would produce a smooth asimtotic curve of temperature differences, diminishing to zero, when plotted against time of duration of the quenching cycle, if the medium (or the specimen) experienced no unusual thermal disturbances. While the system could undoubtedly be calibrated to plot the temperature differences in absolute thermodynamic values, its greatest usefulness will derive from using it as a comparative device to show how curves made from the fluid under test deviate from curves made from a standard fluid such as water.

In an experimental set-up, constructed according to the teachings of this invention, twenty thermocouple pairs **12** and **13** were employed in a small container **11** through which water **15** was circulated at the rate of approximately ⅔ pints per minute. A specimen **20** made from ¾" cold rolled steel bar stock cut to ¾" length and weighing about 40 grams was heated in an electric furnace to about 1550° F. The specimen **20** was quickly transferred to the container **11** where it is was immersed below the surface of the quenching fluid **15** until it cooled. The thermopile **14** was made up of the twenty thermocouple pairs **12** and **13** was found to produce a maximum signal of about 10 millivolts in response to the change in temperature of the water **15**.

Before the immersion of the specimen **20**, the temperature of the inflowing and outflowing fluid **15** was the same and no signal was transmitted to the recorder **30**. After immersion, the voltage generated due to the difference in temperatures of the inflowing and outflowing fluids **15** produced a signal proportional to this difference. For comparison purposes, the signals produced preferably are recorded on a strip chart over the entire quenching cycle. Thus, the apparatus described above including the quench calorimeter **10** does in fact record the average rate at which units of heat are being transferred from the metal specimen **20** to the liquid **15** at any point in time. In other words, the calorimeter **10** and its recorder **30** plots the temperature difference of input to output liquid **15** under conditions of constant flow, which represents average B.t.u. heat transfer at specific points of time. The temperature difference reading or recording at any point in time during the cycle is indicative of the average rate of heat transfer taking place at that precise point in time.

The rate of heat transfer as measured by the quench calorimeter **10** in using this method, provides a means of detecting remotely the rate of heat transfer occurring through boundary conductance on the surface of the steel specimen **20**, as an average over the surface area.

The method and quench calorimeter apparatus **10** described herein has several advantages over existing art in the following particulars:

(1) The heated specimen is free from the encumbrance of thermocouples, and permits a simple shape of low-cost steel to be used, making it feasible to replace the specimen with a new one for every test and thereby include the effect of surface scaling and contamination by the quenching fluid in the same manner as would occur in practice when quenching a freshly machined workpiece.

(2) The temperature range to which the thermopile is exposed is anticipated to be so low that it should last and retain its calibration indefinitely.

(3) The use of many thermocouples positioned at many points in the fluid stream and connected in series should average out local variations in temperature and provide a measurement that is quite precise.

(4) Since the quenching fluid is not damaging to the thermocouples, they can be made of very fine gauge wire with negligible mass, providing rapid response to small temperature changes of the fluid, which is highly desirable.

(5) The method described can be adapted to any selected quench tank which would be calibrated for the precise average temperature of the fluid leaving the top of the tank and the temperature of the fluid entering the bottom of the tank under steady measured flow conditions. The conditions established for a particular, weighed specimen can thus be maintained for subsequent specimens,

thereby providing a degree of control over the quenching operation not heretofore obtainable.

While a preferred embodiment of the invention has been specifically disclosed, it is to be understood that the invention is not limited thereto as other variations will be apparent to those skilled in the art and the invention is to be given its fullest possible interpretation within the terms of the following claims.

We claim:

1. Means for determining the rate of change of thermal conditions within a metal specimen of predetermined mass heated to a predetermined temperature during a quenching operation thereof comprising:

a quench tank adapted to hold a quenching fluid and formed with fluid inlet and outlet ports;

means for supporting the heated metal specimen within said quench tank;

means for circulating the quenching fluid through said ports at a predetermined rate;

temperature sensing means continually responsive to the difference in temperature existing between the quenching fluid entering said quench tank through said inlet port and the quench fluid leaving said quench tank through said outlet port throughout the quenching operation, said means continually generating signals porportional to said fluid temperature differences; and

indicating means coupled to said temperature sensing means for displaying said generated signals.

2. The combination of claim 1 wherein

said temperature sensing means comprises a plurality of thermocouple pairs positioned in the quenching fluid adjacent said inlet and outlet ports.

3. The combination of claim 2 wherein

said thermocouple pairs are connected in series to form a thermopile which provides an output signal that is proportional to a true average of the temperature difference between the inflowing and outflowing quenching fluid.

4. The combination of claim 3 wherein said indicating means includes an electrical strip recorder connected to said thermopile so as to continually record the rate at which the temperature difference between the quenching fluid entering and leaving said tank varies throughout the entire quench cycle to thus indicate the rate of heat transfer from the specimen to the quenching fluid being taking place throughout the entire quench cycle.

5. A quench calorimeter for measuring the rate of heat transfer from a heated metal specimen to a quenching fluid by measuring the change in temperature of the quenching fluid as it is circulated through the calorimeter at some predetermined rate and comprising:

a tank including means for supporting the heated specimen within said tank, said tank having inlet and outlet ports;

means for causing quenching fluid to flow from said inlet port to said outlet port at a predetermined flow rate, thermocouple means positioned to be responsive to the temperature of the inflowing fluid and capable of generating an electrical signal proportional to the temperature of the inflowing fluid;

thermocouple means positioned to be responsive to the temperature of the outflowing fluid and capable of generating an electrical signal proportional to the temperature of the outflowing fluid; and

recording means electrically coupled to both of said thermocouple means for receiving said electrical signals and displaying indications proportional to the temperature differences existing between the inflowing and outflowing fluid.

6. The quench calorimeter of claim 5 wherein

said thermocouple means comprise a plurality of pairs of dissimilar metal wire junctures positioned to be immersed within and to contact the quenching fluid at a plurality of points in the fluid stream.

7. The quench calorimeter of claim 6 wherein

said thermocouple pairs are connected in series so as to generate an electrical signal proportional to the average temperature difference between the inflowing fluid and said outflowing fluid.

8. The method of determining the rate of change of thermal conditions within a heated metal specimen during a quenching operation comprising the steps of:

circulating a quenching fluid through a quench tank at a known predetermined and constant rate;

immersing a specimen of a predetermined mass and heated to a predetermined temperature in the quenching fluid;

measuring and recording the temperature difference between the inflowing fluid and the outflowing fluid periodically and after each of a multitude of increments of time of a predetermined length throughout the entire quenching operation.

References Cited

UNITED STATES PATENTS

1,218,717	3/1917	Thomas	73—204
1,265,775	3/1918	Hadaway, Jr.	73—204
2,587,622	3/1952	Jaffee	73—15
3,142,170	7/1964	Calhoun	73—204 X
3,167,956	2/1965	Grey	73—190
3,464,267	9/1969	Ehrlich et al.	73—190
2,717,515	9/1955	Pesante	73—15

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