MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1943
We PHILIPS INDUSTRIES LIMITED, a company incorporated under the laws of the State of New South Wales, in the Commonwealth of Australia, manufacturers, of 4th Floor, 79 Clarence Street, Sydney, New South Wales, hereby apply for the grant of a Patent for an invention entitled "METHODS AND APPARATUS FOR CASE HARDENING A WORKPIECE", which is described in the accompanying provisional/complete specification.

Our address for service is Philips Industries Limited 4th Floor, 79 Clarence Street, Sydney, New South Wales.

Dated this 26th day of January, 1971.

PHILIPS INDUSTRIES LIMITED

[Signature]
P.Dawson
Attorney

To: The Commissioner of Patents Commonwealth of Australia.

To: The Commissioner of Patents, Commonwealth of Australia.
COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

DECLARATION IN SUPPORT OF AN APPLICATION FOR A PATENT

In support of the Application made by PHILIPS INDUSTRIES LIMITED, a company incorporated under the laws of the State of New South Wales, in the Commonwealth of Australia, of 4th Floor, 79 Clarence Street, Sydney, in the aforesaid State, for a patent for an invention entitled: "METHODS AND APPARATUS FOR CASE HARDENING A WORKPIECE",

I, PETER DAWSON, Attorney of, care of and on behalf of PHILIPS INDUSTRIES LIMITED, of 4th Floor, 79 Clarence Street, Sydney, N.S.W., do solemnly and sincerely declare as follows:

1. I am authorised by PHILIPS INDUSTRIES LIMITED, the applicant for the patent to make this declaration on its behalf.

2. H. NEAL, of 169 Munro Street, Ringwood, Victoria, is the actual inventor of the invention and the facts upon which I, the Applicant, is entitled to make the application are as follows:

PHILIPS INDUSTRIES LIMITED, is a person who, if a patent were granted to the inventors upon the present application, would be entitled to have the patent assigned to it.

Declared at SYDNEY, this fourteenth day of January 1971

(Signature of Declarant)
P. Dawson

To: THE COMMISSIONER OF PATENTS
Commonwealth of Australia.
SHORT TITLE: 

INT. CI: 21D 1/10; 1/12

CHASSN. 15.8

APPLICATION NUMBER: 38442/72

LODGED: 29/1/71

COMPLETE SPECIFICATION—LODGED: 19/1/72

ACCEPTED:

LAPPED: 30/5/73

PUBLISHED: 8/7/73

PRIORITY:

RELATED ART:

665161 156771 06.7; 15.8

665281 157195 06.7; 15.8

1523747 140570 06.7; 15.8

TO BE COMPLETED BY APPLICANT

NAME OF APPLICANT: PHILIPS INDUSTRIES LIMITED

ADDRESS OF APPLICANT:

ACTUAL INVENTOR: H. NEAL

ADDRESS FOR SERVICE: PHILIPS INDUSTRIES LIMITED

4th FLOOR, 79 CLARENCE ST., SYDNEY.

COMPLETE SPECIFICATION FOR THE INVENTION ENTITLED: METHODS AND APPARATUS FOR CASE HARDENING A WORKPIECE.

THE FOLLOWING STATEMENT IS A FULL DESCRIPTION OF THIS INVENTION, INCLUDING THE BEST METHOD OF PERFORMING IT KNOWN TO ME:

* NOTE: The description is to be typed in double spacing, pica type face, in an area not exceeding 250 mm in depth and 160 mm in width, on tough white paper of good quality and it is to be inserted inside this form.
COMPLETE AFTER PROVISIONAL

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-1969

COMPLETE SPECIFICATION FOR THE INVENTION ENTITLED:

"METHODS AND APPARATUS FOR CASE HARDENING A WORKPIECE".

The following statement is a full description of this invention, including the best method of performing it known to me:-
The present invention relates to methods and apparatus for case hardening a workpiece of the kind in which the workpiece is heated and then quenched, heat being generated in the workpiece by producing a flow of high frequency electric current near the workpiece surface.

The term "high frequency" when used herein refers to a frequency of an alternating electric current at which "skin effect" is significant.

In known methods of case hardening of the kind to which the invention relates, high frequency electric currents are produced in the workpiece by induction or otherwise to heat the workpiece at and near the surface to within a critical temperature range whereupon the workpiece is quenched. To achieve case hardening to a uniform depth, quenching must be carried out under conditions when the temperature of the workpiece at and near the surface is within the critical range to the desired uniform depth. When the workpiece surface has an irregular profile, the desired conditions for obtaining a uniform depth of case hardness may be difficult to obtain. For instance, to achieve a uniform depth of case hardening for a workpiece surface provided with gear teeth (e.g. a workpiece such as a gear wheel or a rack) is recognized as being extremely difficult using methods of the kind to which the invention relates. It has been found that a uniform depth of case hardness
cannot be obtained using high frequency current of a single fixed frequency. By applying high frequency current having a fixed frequency of 10,000 Hz, unless the workpiece is of unusually large dimension the tips of the gear teeth are ineffectually hardened when the desired depth of case hardness is obtained at the surface in the valleys between teeth whereas the reverse is the case applying current having a frequency of 450,000 Hz where the tips of the gear teeth may reach melting point before the surface in the valleys has reached the hardening temperature.

These drawbacks have been overcome to a limited extent by simultaneously or sequentially applying to the workpiece two or more high frequency currents each having a different frequency but such methods have not been found to be completely successful.

In accordance with the invention, a method of case hardening a workpiece in which the workpiece is heated and then quenched, heat being generated in the workpiece by producing a flow of high frequency electric current near the surface is characterized in that during such generation of heat coolant fluid is directed onto one or more selected surface portions so as to influence the temperature distribution.

The method in accordance with the invention may advantageously be employed for case hardening a flat surface to an uneven depth or alternatively for case hardening an irregular surface to a substantially uniform depth. References to depth of case hardness
here are given the meaning discussed in chapter 14 of the publication "Induction hardening and tempering".

A particularly useful application of the method in accordance with the invention is for case hardening a workpiece surface provided with gear teeth, in which instance, the frequency of the electric current produced is chosen so that the tips of the gear teeth are heated to a greater extent than the remainder of the workpiece surface and during the generation of heat coolant fluid is directed on to the tips of the gear teeth so as to influence the temperature distribution at and near the surface whereby a substantially uniform depth of case hardening is achieved.

In most cases water is the most suitable form of coolant fluid but other types of coolant fluid such as air, oil, brine etc. may be more appropriate in particular instances.

In applying the method in accordance with the invention for case hardening a workpiece surface provided with gear teeth, the precise period of time that coolant fluid should be directed onto the tips of the gear teeth to obtain a uniform depth of hardening depends upon a number of factors but is usually for the first three quarters or so of the period during which heat is being generated in the workpiece.

To carry out the method in accordance with the invention many different kinds of apparatus may be devised depending upon the nature of the workpiece. In each case however, the apparatus comprises means for producing high frequency electric current in the work-
piece to heat the workpiece, means for directing coolant fluid onto the workpiece during the generation of heat and quenching means.

The invention will now be described with reference to the accompanying drawings in which:

Figure 1 diagrammatically illustrates known apparatus used in methods for case hardening the toothed surface of a gear wheel.

Figures 2 and 3 illustrate diagrammatically the paths followed in a gear wheel of induced high frequency current.

Figures 4 and 5 diagrammatically illustrate the hardness patterns produced in gear wheels surface case hardened by means of induced high frequency current.

Figure 6 diagrammatically illustrates a desired hardness pattern for a case hardened gear wheel.

Figure 7 diagrammatically illustrates apparatus in accordance with the invention for carrying out a method according to the invention.

Figure 8 diagrammatically illustrates the hardness pattern produced in a workpiece surface hardened by means of apparatus of the kind illustrated in Figure 7.

In Figure 1, the workpiece is in the form of a steel gear wheel provided with teeth 2. In order to heat the toothed surface of the gear wheel 1 for case hardening, the gear wheel 1 is encircled by a work coil 3 supplied with high frequency current from a supply source 4.
As is well known, a current flow in the work coil 3 will induce a flow of current in the gear wheel 1 in the opposite direction. Assuming the flow of current in the work coil 3 to be in the direction indicated by the arrow 5 at a particular instant then the current induced in the gear wheel 1 will flow in the general direction indicated by the arrow 6 at the same instant. Owing to the "skin effect" and the "proximity effect" the induced current will follow a path close to the toothed surface of the gear wheel 1 although the precise path followed depends inter alia upon the frequency of the high frequency current and the teeth dimensions. Owing to the resistance of the material of which the gear wheel is made, the flow of induced current heats the gear wheel near the toothed surface. Accordingly, when the portion of the gear wheel near the toothed surface reaches the desired hardening temperature, the gear wheel is quenched by directing quenching fluid onto the toothed surface desired to be hardened whilst simultaneously switching off the current in the work coil.

The apparatus for carrying out the quenching operation is not shown in the Figure but may take the form of a quenching ring comprising a ring of copper tubing provided with suitably spaced inwardly directed nozzles or parts for spraying or directing jets of the quenching fluid supplied via tubing onto the toothed surface of the gear wheel.

The hardness pattern obtained depends upon the temperature distribution in the workpiece at the time.
of quenching and thus may take different forms depending upon the frequency of the induced current. As indicated earlier, the precise path taken by the induced current flow depends upon its frequency. If the frequency of the induced current is relatively low e.g. 100.000 Hz, the path of the induced current may be somewhat as indicated by the arrows 7 in Figure 2 and if the frequency is relatively high e.g. 450.000 Hz, the path of the induced current may be somewhat as indicated by the arrows 8 in Figure 3. In the case of a 10.000 Hz source being used to induce current for heating, after quenching, the resultant hardness pattern would be somewhat as illustrated in Figure 4 whereas in the case of a 450.000 Hz source being used to induce current for heating, after quenching the resultant hardness pattern would be somewhat as illustrated in Figure 5. The shaded areas in both Figures 4 and 5 indicate the case hardened portions. This is not to say that hardness patterns such as those of Figures 4 and 5 are the only patterns possible. Many different hardness patterns may be achieved by making compromises of one kind or another in the frequency selection, in the particular shape of the work coil and so forth but none of the known methods appear to be completely satisfactory in producing a hardening of the toothed surface of a gear wheel to a uniform depth. However, it is sometimes desirable to obtain a hardness pattern such as that in Figure 6 which indicates surface hardening of a toothed surface to a substantially uniform depth.
When a method in accordance with the invention is employed to case harden the toothed surface of the gear wheel 1, similar apparatus to that of Figure 1 together with quenching apparatus of the kind described is appropriate but additional apparatus for directing coolant fluid on to the tips of the gear wheel teeth is also required. Such additional apparatus may take the form of a coolant fluid supply ring similar in construction to the quenching ring already described but in which the nozzles or parts are spaced and dimensioned so that they direct coolant fluid only on the tips of the teeth of the toothed surface. Other alternatives are possible of course. For instance, a work coil assembly for encircling the workpiece may be constructed which incorporates three hollow channels, one channel to which water is continuously supplied for cooling the work coil assembly itself, the second channel feeding inwardly directed quenching outlets to which water is supplied for the quenching operation and the third channel feeding inwardly directed coolant fluid directing outlets to which water is supplied for cooling selected portions of the workpiece during heating.

Figure 7 is a diagrammatic cross-section of a workpiece and apparatus for producing a flow of high frequency current in the workpiece and for directing coolant fluid onto selected surface positions in accordance with the invention, the workpiece not being a gear wheel but having a surface provided with gear
teeth for which surface hardening of substantially uniform depth is required.

In Figure 7, the workpiece 10 is a piston rack forged from S.A.E. 1045 steel intended to form part of a power steering box for a motor vehicle. The workpiece 10 is provided with gear teeth 11 and it is required to harden the surface of the workpiece 10 on which the teeth 11 are provided to a substantially uniform depth.

The apparatus for surface hardening the desired portion of the workpiece 10 comprises the proximity bar assembly 12 and associated apparatus. The assembly 12 includes the proximity bar 13 made from a solid piece of copper, one surface 14 of the proximity bar being shaped so as to extend parallel to the surface of the adjacent workpiece 10 on which the teeth 11 are provided. Portion of the proximity bar 13 functions as a supply conductor 15 and extends parallel with a separate supply conductor 16, the conductors 15 and 16 being insulated from each other by a block of heat resistant insulating material and the complete assembly being rigidly held together by screws (not shown).

An electrical contact 18 is provided at the extremity of the conductor 16 and a similar electrical contact 19 is provided on the surface of the proximity bar 13 at its end remote from the conductor 16. The conductors 15 and 16 are connected across a source 20 of high frequency current delivering an output at a fixed
frequency of 450,000 Hz. Hollow bores 21 and 22 are provided through the proximity bar 13 and the bores are terminated at the inlet connectors 23 and 24 to which the flexible coolent fluid supplied tubes 25 and 26 are respectively attached. Depending upon the physical size of the proximity bar 13, it may be necessary to provide a cooling system for dissipating heat generated in the bar. The cooling system may take the form of copper tubing running on the surface of the bar, with a coolent fluid being continuously circulated through the tubing.

In operation, the workpiece 10 is mounted in the position indicated so that contact is made between the contacts 18 and 19 and the workpiece 10. With the supply source switched on, current flows along the path generally indicated by the arrows 27 (which indicate the direction of flow at a particular instant), from the source 20, along the conductor 16, viz the contact 18 to the workpiece 10, along the workpiece 10 close to the toothed surface, via the contact 19 to the proximity bar 13, along the proximity bar 13 close to its surface 14 returning to the source 20 via the conductor 15. The proximity effect of the current in the workpiece 10 near the toothed surface in opposite direction to current flow in the proximity bar 13 near the surface 14 results in a tendency for the current in the workpiece to follow a path close to the toothed surface.
During the first two thirds of the period of current flow in the workpiece, coolant fluid in the form of water is supplied from a water supply source (not shown) via the tubes 25 and 26 and the bores 21 and 22 so that the water is directed onto the tips of the teeth 11. If the water was not supplied so, at the frequency of the current concerned the tips of the teeth 11 would be heated to a greater extent than valley surface between teeth since the heat generated at the valley surface is conducted away to other parts of the workpiece more rapidly than is the heat generated along the flanks and at the tips of the teeth 11. Accordingly, the direction of coolant fluid onto the tips of the teeth 11 results in dissipation into the coolant fluid of the heat generated in the teeth 11 whereby the workpiece near the valley surfaces becomes heated to a greater extent than are the flanks and the tips of the teeth 11 for so long as the coolant fluid is supplied. In other words the coolant fluid holds back the heating of the tips of the teeth 11 in relation to the heating of the valley surfaces. Upon cessation of the coolant fluid supply, since the high frequency current continues to be supplied, the valley surfaces continue to be heated to the same extent as before but heating of the tips of the teeth 11 is now no longer held back and the flanks and the tips of the teeth 11 commence to be heated to a greater extent.

It will be appreciated that the precise period of time for which current is supplied and the precise
period of time for which coolant fluid is supplied should be gauged so that when the current supply is switched off the valley surfaces and the flanks and tips of the teeth 11 are all within the required temperature range for hardening.

When the current supply is switched off, quenching fluid is directed onto the whole of the toothed surface of the workpiece 10 in order to affect quenching whereupon the surface hardened workpiece 10 may be removed. The supply apparatus for quenching is not shown in Figure 7 but may take the form of a series of nozzles arranged alongside the proximity bar assembly 12 so as to direct a plentiful supply of quenching fluid at the appropriate time between the assembly 17 and the workpiece 10.

The method and apparatus described in relation to Figure 7 is intended for surface hardening the toothed surface of the workpiece 10 on a mass production scale, so that whilst the basic apparatus only is illustrated, it will be understood that the apparatus in question will, in operation, be associated with apparatus for loading and unloading a constant supply of workpieces 10 into the operative position illustrated.

Steels of grade S.A.E. 1045 of which the workpiece 10 is made, contain 45% to 50% carbon and when raised to the temperature of 850°C - 900°C and then quenched in water, a martensic structure of about 60° Rockwell C is produced. Accordingly, to produce case hardening of the tooth surface of the workpiece 10 to a substantially uniform depth by employing the method
and apparatus according to the invention, it may be necessary to determine by experiment the periods of time for which the high frequency current supply should be switched on and the period of time for which the coolant fluid supply is switched on. Moreover, in setting up the apparatus, it may be necessary to make adjustments to the rate of flow of the coolant fluid or modify the bore sizes of the bores 21 and 22 in order that the appropriate area of the tooth tips is cooled in a manner to achieve the desired results. In most cases, the correct result can only be determined by trial and error methods after study of the hardness patterns actually produced in workpieces that have been subjected to the surface hardening process.

Figure 8 illustrates diagrammatically a desired hardness pattern for the workpiece 10. Such a pattern has been consistently obtained by the applicant in practice.
CLAIMS
CLAIMS RELATING TO THE INVENTION ARE AS FOLLOWS:

CLAIM 1.

A method of case hardening a workpiece in which the workpiece is heated and then quenched, heat being generated in the workpiece by producing a flow of high frequency electric current near the surface thereof characterised in that during such generation of heat coolant fluid is directed onto one or more selected surface portions thereby influencing the temperature distribution.

CLAIM 2.

A method of case hardening a workpiece surface provided with gear teeth in which the workpiece surface is heated and then quenched, heat being generated by producing a flow of high frequency electric current near the surface having a frequency such that the tips of the gear teeth are heated to a greater extent than the remainder of the surface, characterised in that during the generation of heat coolant fluid is directed onto the tips of the gear teeth to reduce the temperature thereof.

CLAIM 3.

A method of case hardening a workpiece surface in accordance with Claim 2 in which coolant fluid is directed onto the said tips of the gear teeth for a period of time shorter than the period during which a flow of high frequency current is produced.
CLAIM 4.

Apparatus for carrying out a method of case hardening in accordance with Claim 1, 2, or 3 comprising means for producing high frequency electric current in the workpiece to heat the workpiece, means for directing coolant fluid onto the workpiece during the generation of heat and quenching means.

CLAIM 5.

A method of case hardening substantially as herein described with reference to Figures 6, 7 or 8 of the accompanying drawings.

CLAIM 6.

Apparatus for carrying out a method of case hardening substantially as described herein with reference to Figures 6, 7 or 8 of the accompanying drawings.

Dated this seventeenth day of January, 1972.

PHILIPS' INDUSTRIES LIMITED.
END