Jan. 19, 1971 E. M. WAGNER 3,556,864

THERMOCOUPLE STRUCTURE AND METHOD FOR MAKING SAME

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FIG. 1

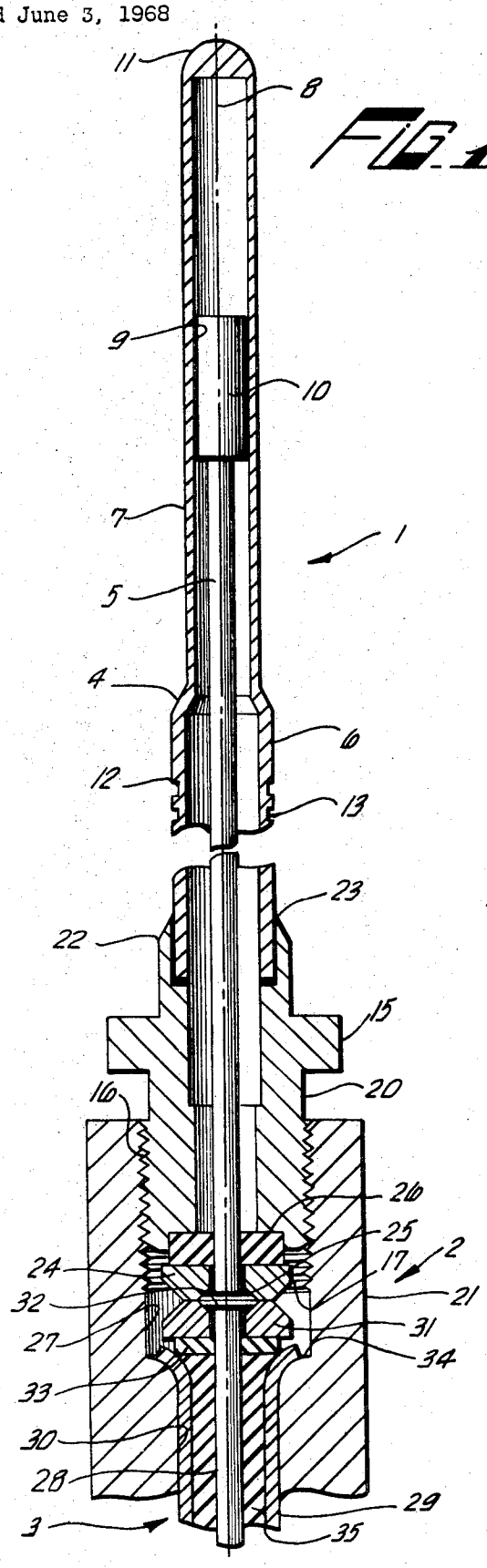


FIG. 2A

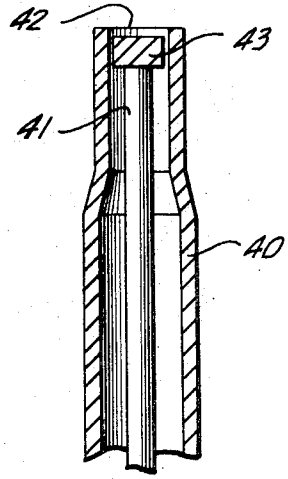
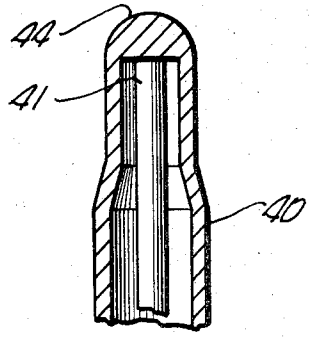


FIG. 2B



INVENTOR.
EDMOND M. WAGNER

BY
Christie, Parker & Hale
ATTORNEYS

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FIG. 3A

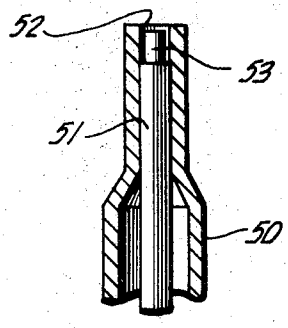


FIG. 3B

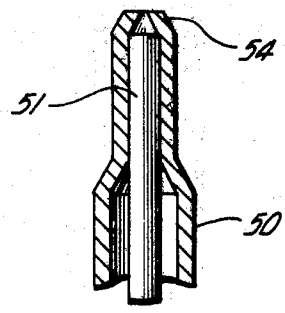


FIG. 3C

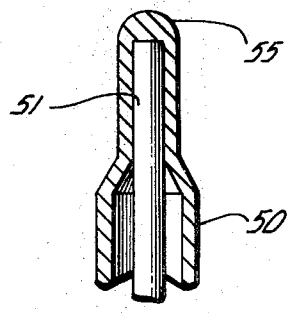


FIG. 4A

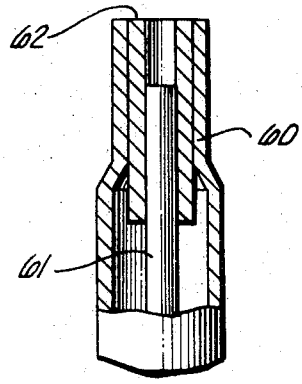


FIG. 4B

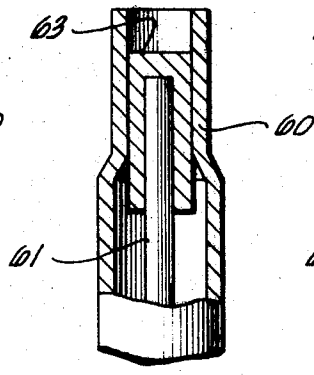


FIG. 4D

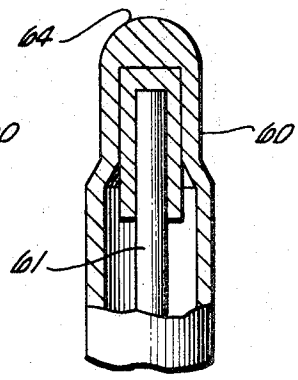


FIG. 4C

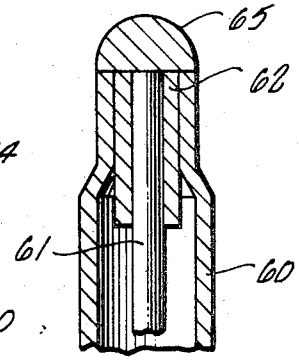


FIG. 5A

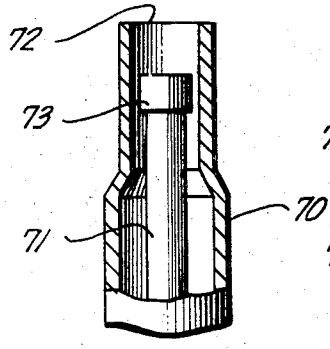
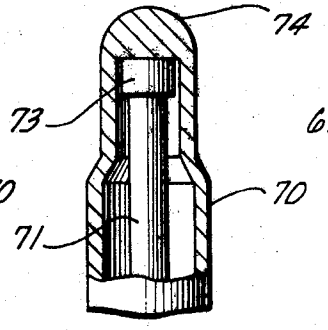


FIG. 5B



INVENTOR.
EDMOND M. WAGNER

BY

Christie, Parker & Hale
ATTORNEYS

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FIG. 6

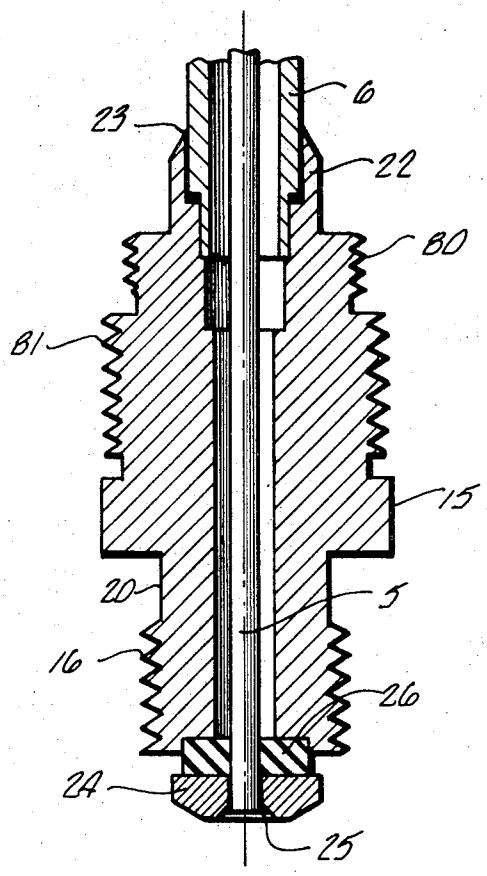


FIG. 1A

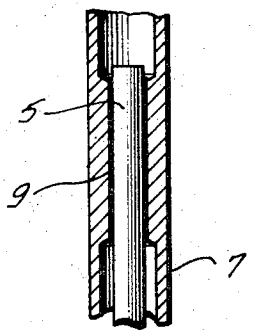
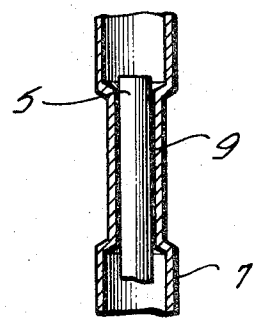


FIG. 1B



INVENTOR.
EDMOND M. WAGNER

BY

Christie, Parker & Hale
ATTORNEYS

United States Patent Office

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THERMOCOUPLE STRUCTURE AND METHOD FOR MAKING SAME

Edmond M. Wagner, Sierra Madre, Calif., assignor to Jade Controls Co., Inc., Montclair, Calif., a corporation of California

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Int. Cl. H01v *1/04*

U.S. Cl. 136—228 17 Claims

ABSTRACT OF THE DISCLOSURE

A length of tube made from one metal has an extremity with a smaller diameter and wall thickness than its base. A length of wire made from a dissimilar metal extends inside the tube in axial alignment therewith from a point spaced from the end of the extremity of the tube to its base. A hot thermocouple junction is formed in a cylindrical area between a portion of the extremity of the tube and the adjacent portion of the length of the wire. A tip is formed integral with the end of the extremity of the tube and is spaced from the adjacent end of the wire so as to seal the end of the tube from the atmosphere without electrical contact with the end of the wire. A connector having a male member and a female member adapted to mate with each other has two mutually insulated electrical paths connecting a pair of leads to the tube and the wire, respectively. At least one cold junction is formed in one of the electrical paths. The formation of the tip is facilitated by reducing the open area at the end of the tube prior to the sealing operation.

BACKGROUND OF THE INVENTION

This invention relates to thermocouples and, more particularly, to thermocouple structures especially suited for use in the pilot burner of a gas heater and to a method for making such thermocouple structures.

Conventionally, the thermocouple used in a target-type pilot burner, of which the pilot burner disclosed in U.S. Patent 3,291,185 issued to Harold A. McIntosh et al. is typical, comprises a length of wire and a length of tube made from dissimilar metals. The length of wire, which has an appreciably smaller diameter than the inside diameter of the tube, lies inside the tube in axial alignment therewith. Preferably, the extremity of the tube against which the flame of the pilot burner impinges has a smaller diameter and wall thickness than the base of the tube so as to promote large heat transfer radially inward through the extremity and small heat transfer axially from the extremity to the base of the tube. A tip is formed on the end of the extremity of the tube to seal its interior from the atmosphere and to form a hot thermocouple junction between the extremity of the tube and the adjacent end of the wire. A pair of leads, permanently joined respectively to the base of the tube and the adjacent end of the wire, connect the thermocouple to an electrical measuring instrument.

The tube is made from a nonoxidizable metal such as stainless steel, but the wire is generally made from an oxidizable metal. If the seal at the extremity of the tube is imperfectly formed by the tip, oxidation of the wire takes place and the hot thermocouple junction deteriorates. The diameter of the wire is appreciably smaller than the inside diameter of the tube to avoid the possibility of a short circuit through contact between the wire and the tube at a point other than the hot junction. As a result, it is difficult to center the end of the wire sufficiently in the open area at the end of the extremity of the tube while the tip is being welded. Eccentricity between the end of the tube and the wire tends to cause an

uneven distribution of the metallic weld bead forming the tip. As a result, stringers of the wire material may be produced in the tip that are eventually oxidized, leaving the tip porous. If more heat is used to form the tip in an attempt to eliminate imperfect seals, the danger exists that too much admixture of the dissimilar metals occurs at the tip to form an efficient hot junction. The problem of imperfect seals at the tip becomes especially acute if the tip forming operation is automated by use of heliarc equipment.

The provision and installation of replacement thermocouples for original equipment also causes some problems. For example, the vertical distance of the flame produced by the pilot burner from the mounting bracket for the thermocouple is not standardized in the industry. Thus, a set of exact adapters to provide exact positioning for each style burner and/or bracket must be provided with replacement thermocouples to enable the thermocouple to be mounted at different heights from the bracket so the flame of the pilot burner impinges upon the extremity of the tube. Further, since the leads of the original thermocouple, usually a coaxial conduit, are permanently joined to the tube and the wire, replacement thermocouples must also include a conduit. The length of conduit extending from the thermocouple makes the installation of the replacement thermocouple more difficult. In many applications and designs, pilot burners are located in hard-to-reach, relatively inaccessible places and have a threaded thermocouple mount so the entire conduit turns as the thermocouple is being installed.

SUMMARY OF THE INVENTION

In one aspect of the invention, a thermocouple structure of the type described above is provided with a tube having a long extremity dimensioned to promote large heat transfer radially inward through the extremity and small heat transfer axially from the extremity to the base of the tube. The end of the wire is set in from the extremity end of the tube so the extremity end of the tube is sealed from the atmosphere by the tip without electrical contact with the end of the wire. The hot thermocouple junction is formed between a portion of the extremity of the tube, preferably in the middle region of the extremity, and the adjacent portion of the wire, preferably covering a cylindrical area. The long extremity of the tube and the location of the hot thermocouple junction in the middle region of this extremity, as distinguished from locating the hot junction at the tip of the thermocouple, allow heating for effective thermocouple operation to take place over a much larger portion of the thermocouple length, i.e. the heating is not confined to the contact area. Consequently, a replacement thermocouple can be installed in pilot burners of different manufacturers without the necessity of such exact adapters to adjust the thermocouple position to the distance of the flame from the mounting bracket. Furthermore, in forming the tip of the thermocouple, sufficient heat can be applied to the weld bead to insure a good seal at the extremity end of the tube without impairing the quality of the hot junction, because the hot junction is spaced from the extremity end of the tube.

In another aspect of the invention, a thermocouple structure of the type described above is provided with a connector having a male member and a female member adapted to mate with each other and to complete two mutually insulated electrical paths between the tube and the wire, respectively, and two leads. Preferably, the members of the connector are threaded and the first and second leads are coaxial. The male member is permanently attached to the thermocouple and the female member is permanently attached to the coaxial conduit, or vice versa. The outer lead of the conduit is flared. The

conduit extends into the female member through a hole in its back that is smaller than the flared end of the outer lead so the flared end is retained within the female member. The female member has a shoulder within its threaded cavity that bears against the flared end of the outer lead to form electrical contact therewith and hold the end of the inner lead in electrical contact with the end of the wire. The female member is rotatable with respect to the leads of the conduit. When it is necessary to replace the thermocouple, the male and female members of the connecttor are separated and the used thermocouple is removed without disturbing the conduit. Thus, considerable expense is avoided because the original conduit is reused with the replacement thermocouple and installation is simplified because the conduit is not disturbed and does not have to be turned to mount the replacement thermocouple.

Another aspect of the invention involves the formation of the tip at the extremity end of the tube. The open area at the extremity end of the tube is reduced prior to the application of heat to form the tip. As a result, the weld bead can more easily bridge the gap at the extremity end of the tube and a more reliable seal is formed, whether the hot thermocouple junction is formed at the tip or elsewhere.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of specific embodiments of the invention are illustrated in the drawings, in which:

FIG. 1 is a side elevation view in section of a thermocouple structure embodying the principles of the invention;

FIGS. 2A and 2B are side elevation views in section of the extremity end of a tube respectively before and after the formation of the tip;

FIGS. 3A and 3B are side elevation views in section of the extremity end of swaged tubes before the formation of the tip, and FIG. 3C is a side elevation view in section of the same tubes after the formation of the tip;

FIGS. 4A and 4B are side elevation views in section of the extremity end of tubes before the formation of the tip, and FIGS. 4C and 4D are side elevation views in section of FIGS. 4A and 4B after the formation of the tip, respectively;

FIGS. 5A and 5B are side elevation views in section of the extremity end of a tube, respectively, before and after the formation of the tip;

FIG. 6 is a side elevation view in section of an alternative embodiment of the male member of the connector shown in FIG. 1; and

FIGS. 7A and 7B are side elevation views in section of alternative embodiments of the hot junction of the thermocouple shown in FIG. 1.

DESCRIPTION OF SPECIFIC EMBODIMENTS

In FIG. 1, a thermocouple structure **1**, a connector **2**, and a coaxial conduit **3** are shown. Thermocouple structure **1** comprises a length of tube **4** made from a non-oxidizable metal such as, for exmaple, Type 446 stainless steel and a length of wire **5** made from a dissimilar metal such as, for example, a 40-percent-nickel-60-percent-copper alloy, copel. The term "metal" as used in this specification means a material that is a good conductor of electricity and the term "dissimilar metals" designates materials that exhibit the Peltier effect when brought into contact with one another. Tube **4** is centered on a longitudinal axis **8**. The length of tube **4** has two regions, namely, a base **6** and an extremity **7**. As depicted in FIG. 1, the wall thickness and diameter of extremity **7** are significantly smaller than the same dimensions of base **6**. The purpose of this is to promote large heat transfer radially inward through extremity **7**, i.e., in a direction perpendicular to axis **8**, and small heat transfer axially from extremity **7** to base **6**, i.e., parallel to axis **8**. Wire **5** is in approximately axial alignment with

tube **4** along axis **8**, and wire **5** has an apreciably smaller diameter than the inside diameter of tube **4**. In other words, the guage of wire **5** is so selected and wire **5** is so positioned within tube **4** that no contact takes place between the surface of wire **5** and the interior surface of tube **4** (except for a hot thermocouple junction) in spite of the tolerance variations that may occur in tube **4** and wire **5** and in spite of the forces to which thermocouple structure **1** may be subjected. One end of wire **5** is set in from the adjacent end of extremity **7** as depicted in FIG. 1. A hot thermocouple junction **9** is formed between a portion of extremity **7** and the adjacent portion of wire **5**. Hot junction **9**, which preferably covers a cylindrical area between extremity **7** and wire **5**, could be formed by spot-welding techniques. In view of the appreciable difference required between the inside diameter of extremity **7** and the diameter of wire **5**, it is preferable to reduce this difference in the area where hot junction **9** is to be formed prior to its formation. In the embodiment of FIG. 1, this is accomplished by upsetting the end of wire **5**. The upset end portion **10** of wire **5** has a diameter almost as large as the inside diameter of extremity **7**. Instead of upsetting the end of wire **5**, the inside diameter of extremity **7** in the area where the hot thermocouple junction is to be formed could be reduced by milling a portion of extremity **7** with a smaller inside diameter than the remainder, as depicted in FIG. 7A, or by swaging extremity **7**, as depicted in FIG. 7B. However, upsettiing the end of wire **5** is preferable because it is a simpler operation and results in a larger area for hot junction **9**. A tip **11** is formed integral with the end of extremity **7** and is spaced from the end of upset portion **10**. Thus, tip **11** seals the end of tube **4** from the atmosphere without electrical contact with the set-in end of wire **5**. Base portion **6** has annular grooves **12** and **13** for receiving a conventional clip used to mount thermocouple structure **1**. Efficient operation of thermocouple structure **1** results as long as the flame of the pilot burner with which it is used impinges upon extremity **7**, which gives substantial leeway in the position of thermocouple structure **1**. In a conventional thermocouple with hot junction at the tip, the flame must impinge substantially on the tip for acceptable performance.

Connector **2** comprises a male member **20** that is permanently attached to thermocouple structure **1** and a female member **21** that is permanently attached to coaxial conduit **3**. A sleeve portion **22** of male member **20**, which is made from a dissimilar metal from tube **4**, surrounds the end of base **6** and is fused thereto by spot-welding or brazing to form a cold thermocouple junction **23**. One end of male member **20** has a flange **15** for mounting purposes. The other end of male member **20** has external threads **16** for mating with female member **21**. A disc-shaped terminal **24**, which could be made, for example, from brass, is attached to the end of wire **5**. This end of wire **5** and disc **24** are silverplated for good conductivity. A button **25** made from a very good conductor such as 60–40 solder is located at the center of terminal **24** and joins the end of wire **5** mechanically and electrically to terminal **24**. A disc-shaped electrical insulator **26** supports the end of wire **5** in spaced relationship from the interior of male member **20** through which wire **5** extends. Thermocouple structure **1** and male member **20** cannot rotate with respect to each other. Female member **21** has a cavity **27** with walls on which internal threads are formed that mate with the threads of male member **20**. Coaxial conduit **3**, which is conventional and made from a metal such as, for example, copper, has an inner lead **28** and an outer lead **29** that are supported in spaced relationship by heat-resistant insulation **35**. Conduit **3** extends through an opening **30** in the back of female member **21** into cavity **27**. The end of outer lead **29** within cavity **27** is flared so its diameter is larger than opening **30**. Thus, the end of conduit **3** is permanently retained within female member **21**. A disc-shaped terminal

31, which could be made, for example, from brass, is attached to the end of inner lead 28. A button 32, which is made from a good conductor such as 60–40 solder, is located at the center of terminal 31 and joins the end of inner lead 28 and terminal 31 mechanically and electrically. A cold thermocouple junction is also formed where wire 5 and inner lead 28 are connected by buttons 25 and 32. Although it is usually desirable in practice to utilize at least two cold thermocouple junctions as in the embodiment of FIG. 1, the invention can be practiced in a thermocouple employing a single cold junction. Inner lead 28 and terminal 31 are held in spaced relationship from outer lead 29 by a disc-shaped electrical insulator 33. The interior surface of female member 21 forming the transition between opening 30 and cavity 27 has an annular shoulder 34 that conforms to the flared end of outer lead 29. Female member 21 is capable of rotating with respect to the flared end of outer lead 29. When members 20 and 21 of connector 2 are mated as illustrated in FIG. 1, shoulder 34 bears against the flared end of outer lead 29 to form a good electrical contact therewith. As shoulder 34 bears against outer lead 29, terminal 31, which is spaced from outer lead 29 by insulator 33, is forced against terminal 24, thereby forming a good electrical contact between wire 5 and inner lead 28. In summary, one electrical path is formed from tube 4 through sleeve 22, male member 20, and female member 21 to outer lead 29. The other electrical path is formed from wire 5 through terminals 24 and 31 to inner lead 28. When thermocouple structure 1 is to be replaced, female member 21 is turned and conduit 3 and male member 20 are held stationary until members 20 and 21 separate, thereby releasing thermocouple structure 1 from conduit 3.

In the construction of thermocouple structure 1, wire 5 is first positioned inside of tube 4 in axial alignment therewith such that its one end is set in from the end of extremity 7. Hot thermocouple junction 9 is then formed between a portion of wire 5 in the vicinity of the set-in end and the adjacent portion of extremity 7. Finally, the end of extremity 7 is sealed without forming an electrical contact with the set-in end of wire 5.

Reference is now made to FIGS. 2 through 5 for a discussion of techniques for improving the seal formed at the end of the extremity of the tube of thermocouple structure. The described techniques are applicable to the formation of tip 11 in the embodiment of FIG. 1, as well as to the formation of a seal that also forms the hot thermocouple junction. The general concept involved in these techniques is that the open area at the end of the tube is reduced prior to the welding operation that forms the seal.

In FIG. 2A are shown a tube 40 and a wire 41 that are made from dissimilar metals. The end of wire 41 is set in slightly from the end of tube 40. The open area 42 at the end of tube 40 is reduced by placing a pellet 43 made from the same metal as tube 40 in the mouth of tube 40 on the end of wire 41. The pellet provides extra weld material of the same composition as tube 7, and also protects wire 41 from direct contact with the welding arc, thereby minimizing alloying of wire material 41 in tip 44. FIG. 2B depicts the same components as FIG. 2A after the end of tube 40 is welded shut. A tip 44 is formed that provides a good seal from the atmosphere and an efficient hot thermocouple junction between tube 40 and wire 41. To employ this technique in forming tip 11 in FIG. 1, pellet 43 is spaced from the end of the wire by an insulator or by swaging a portion of the tube onto the pellet to retain it at the end of the tube in spaced relationship from the end of wire 41.

In FIG. 3A, a tube 50 and a wire 51 are shown. Wire 51 is set in slightly from the end of tube 50 and a portion of tube 50 near its end is swaged onto wire 51. The swaging of tube 50 serves to reduce the open area 52 at the end of tube 50. This eliminates the problem of centering wire 51 within the interior of tube 50. Open area 52 is further reduced by placing a pellet 53 made from the same material as tube 50 in the mouth of tube 50 on the end of wire 51. In FIG. 3B the need for pellet 53 is eliminated by swaging inward the portion of the length of tube 50 that extends beyond the end of wire 51 to form a conical region 54. As illustrated in FIG. 3C, a tip 55 is formed when the end of tube 50 in FIGS. 3A or 3B is welded shut. The hot thermocouple junction could be formed at tip 55 or between the swaged portions of tube 50 and wire 51. In the latter case, wire 51 will be spaced from end of tube 50 so as not to melt and mix in weld 55 when the weld is made.

In FIG. 4A, a tube 60 and a wire 61 are shown. A sleeve 62, which is made from the same metal as tube 60, is spot-welded to wire 61 to form a hot thermocouple junction therebetween. At the same time, the spot-welding operation may establish a good electrical contact between tube 60 and sleeve 62 if spot-welded simultaneously. The end of sleeve 62 extends above the end of wire 61. In FIG. 4B, a cap 63 replaces sleeve 62. Cap 63, which is also made of the same metal as tube 60, is spot-welded to wire 61 to form a hot thermocouple junction therebetween. As illustrated in FIGS. 4C and 4D, tips 64 and 65 are formed on the end of tube 60 when the end of tube 60 is welded shut. The cap 63 is shown in the completed tip of FIG. 4C, tube 60 in FIG. 4D.

In FIG. 5A, a tube 70 and a wire 71 are shown. The open area 72 of tube 70 is reduced by providing wire 71 with an upset end portion 73. As illustrated in FIG. 5B, a tip 74 is formed when the end of tube 70 is welded shut. Tip 74 serves to seal the end of tube 70 and to form the hot thermocouple junction with the end of upset portion 73.

Of course, other ways of reducing the open area of the tube prior to the welding operation are also included within the scope of the invention.

In FIG. 6, an alternative embodiment of male member 20 in FIG. 1 is shown. Threaded portions 80 and 81 adapt thermocouple structure 1 for mounting in brackets of different manufacturers. The formation of the adapters as an integral part of the thermocouple is made practical by the provision of connector 2 between thermocouple structure 1 and conduit 3 so conduit 3 does not turn as thermocouple structure 1 is being screw mounted. Fewer, i.e., less exact, adapters are made possible by the longer portion of the thermocouple length over which heating of the tip for thermocouple generating takes place. Thus, the point at which the flame from the pilot burner impinges on the thermocouple is not so critical as with prior art thermocouple structures.

What is claimed is:

1. A thermocouple structure comprising:

a length of tube made from one metal, the extremity of the tube having dimensions that promote large heat transfer radially inward through the extremity and small heat transfer axially from the extremity to the base of the tube;

a length of wire made from a dissimilar metal, the wire having an appreciably smaller diameter than the inside diameter of the tube and extending inside of the tube in approximate axial alignment therewith from a point spaced from the end of the extremity of the tube to its base;

a hot thermocouple junction formed between a portion of the extremity of the length of tube and the adjacent portion of the length of wire;

a tip integral with the extremity end of the tube and spaced from the adjacent end of the wire to seal the extremity end of the tube from the atmosphere and to isolate the extremity end of the tube from the adjacent end of the wire; and

first and second electrical conductors electrically connected, respectively, with the base of the length of tube and the adjacent length of wire, at least one of the conductors being made from a dissimilar metal

from the length of metal to which it is electrically connected so as to form a cold thermocouple junction therewith.

2. The thermocouple structure of claim 1, in which the difference between the inside diameter of the portion of the extremity of the tube forming the hot thermocouple junction and the diameter of the adjacent portion of the wire is smaller than the difference between the inside diameter of the remainder of the extremity of the tube and the diameter of the remainder of the wire.

3. The thermocouple structure of claim 1, in which the portion of the wire forming the hot thermocouple junction is upset so its diameter is larger than the diameter of the remainder of the wire.

4. The thermocouple structure of claim 1, in which the hot thermocouple junction is formed in a cylindrical area.

5. The thermocouple structure of claim 1, in which the extremity of the tube has a smaller outside diameter and wall thickness than the base of the tube.

6. The thermocouple structure of claim 1, in which each of the conductors is made from a dissimilar metal from the length of metal to which it is electrically connected so as to form a cold thermocouple junction therewith.

7. The thermocouple structure of claim 1, in which the first and second conductors comprise:

first and second leads; and

a connector having a male member and a female member adapted to mate with each other and to complete two mutually insulated electrical paths between the tube and the wire and the first and second leads, respectively,

one member of the connector being electrically connected, respectively, to the base of the length of tube and the adjacent length of wire, and

the other member of the connector being electrically connected, respectively, to the first and second leads.

8. The thermocouple structure of claim 1, in which the portion of the extremity of the tube forming the hot thermocouple junction is swaged onto the portion of the wire forming the hot thermocouple junction.

9. The thermocouple structure of claim 1, in which the portion of the extremity of the tube forming the hot thermocouple junction has a smaller inside diameter than the remainder of the extremity.

10. The thermocouple structure of claim 7, in which the member of the connector connected to the tube and the wire has a first set of male threads adapted to mate with female threads on a mounting bracket.

11. The thermocouple structure of claim 33, in which the member connected to the tube and the wire has a second set of male threads having a smaller diameter than the first set and lying between the first set and the tip, the second set of threads being adapted to mate with female threads on a different mounting bracket.

12. A method for making a thermocouple comprising the steps of:

positioning a length of wire made from one metal inside of a length of tube made from a dissimilar metal such that one end of the wire is set in from the adjacent end of the tube such that the tube and the wire are in approximate axial alignment, the diameter of the wire being appreciably smaller than the inside diameter of the tube, the extremity of the tube having dimensions that promote large heat transfer radially inward through the extremity and small heat transfer axially from the extremity to the base of the tube,

forming a hot thermocouple junction between a portion of the length of wire in the vicinity of the set-in end and the adjacent portion of the extremity of the tube;

sealing the adjacent end of the tube and simultaneously isolating the sealed end of the tube from the set-in end of the wire; and

forming a cold thermocouple junction by electrically connecting first and second electrical conductors, respectively, with the base of the length of tube and the adjacent length of wire, at least one of the conductors being made from a dissimilar metal from the length of metal to which it is electrically connected so as to form said cold thermocouple junction therewith.

13. The method of claim 11, in which the hot thermocouple junction covers a cylindrical area between the wire and the tube.

14. The method of claim 11, in which the difference between the diameter of the portion of the length of wire where the hot thermocouple junction is formed and the inside diameter of the adjacent portion of the length of tube is made smaller than the difference between the diameter of the remainder of the length of wire and the inside diameter of the remainder of the length of tube prior to forming the hot thermocouple junction.

15. The method of claim 14, in which the difference is made smaller by upsetting the portion of the length of wire where the hot thermocouple junction is formed.

16. The method of claim 11, in which:

the extremity of the length of tube is formed with a smaller outside diameter and wall thickness than the base of the length of tube; and

the hot thermocouple junction is formed in the region of the extremity of the length of tube.

17. The method of claim 11, in which the open area of the adjacent end of the tube is reduced prior to sealing the adjacent end of the tube.

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CARL D. QUARFORTH, Primary Examiner

H. E. BEHREND, Assistant Examiner

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,556,864 Dated January 19, 1971

Inventor(s) Edmond M. Wagner

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Patent column 3, line 59, "exmaple" should be --example

Patent column 4, line 1, "apreciably" should be --appreciably--;

line 28, "upsettiing" should be --upsetting--.

Patent column 5, line 44, --a-- should be inserted after "of", third occurrence.

Patent column 7, line 50, "33" should be --10--.

Signed and sealed this 29th day of June 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents