United States Patent [19]

Cooke-Yarborough

[11] **3,894,911**

[45] **July 15, 1975**

[54] **MEMBER FOR CONDUCTING EXCESS HEAT AWAY FROM HEAT SOURCES**

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[22] Filed: **Feb. 26, 1974**

[21] Appl. No.: **445,933**

[30] **Foreign Application Priority Data**

Feb. 28, 1973 United Kingdom................ 9762/73

[52] **U.S. Cl.** **165/86**

[51] **Int. Cl.** **F28d 11/00**

[58] **Field of Search** 165/86, 47, 32

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[57] **ABSTRACT**

Should a radioisotope-powered engine (e.g. a Stirling cycle engine for generating electricity) stop working for any reason, the radioisotope heat source will continue to generate heat. This will result in a rise in temperature which may cause overheating of and possible damage to the engine as well as to the heat source itself.

The invention provides a support/location member for conducting excess heat from the heat source and which, in normal operation of the engine, will impede the conduction of heat away from the heat source and so reduce thermal losses.

The member is of elongated form and comprises a stack of heat-conductive slugs disposed in a tube and in interspaced relationship along the axis of the tube. The tube supports the slugs in axial alignment. Means are provided for attaching an end one of the slugs to the heat source and means operable on overheating of said end one of the slugs are also provided whereby the slugs are able to move into heat-conducting contact with each other so as to conduct the excess heat away from said heat source.

The slugs may be brazed to the tube whereby progressive overheating of the slugs along the stack results in an overheated slug being freed from attachment to the tube so as to allow the overheated slug to move along the stack and engage the next slug in line in heat-conducting contact.

9 Claims, 4 Drawing Figures

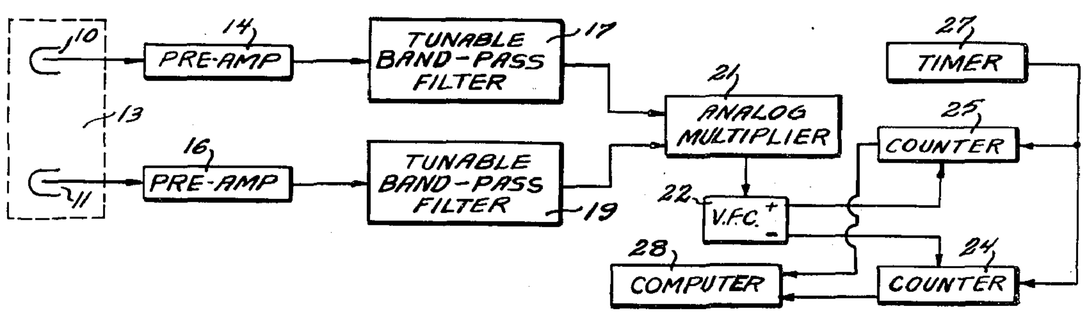
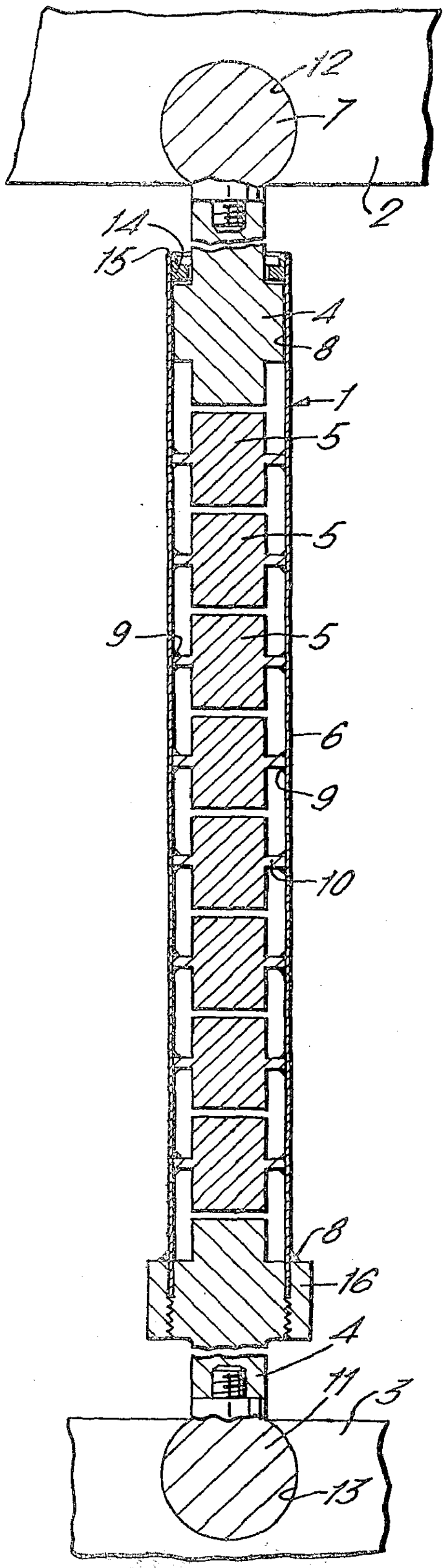


FIG. 1.



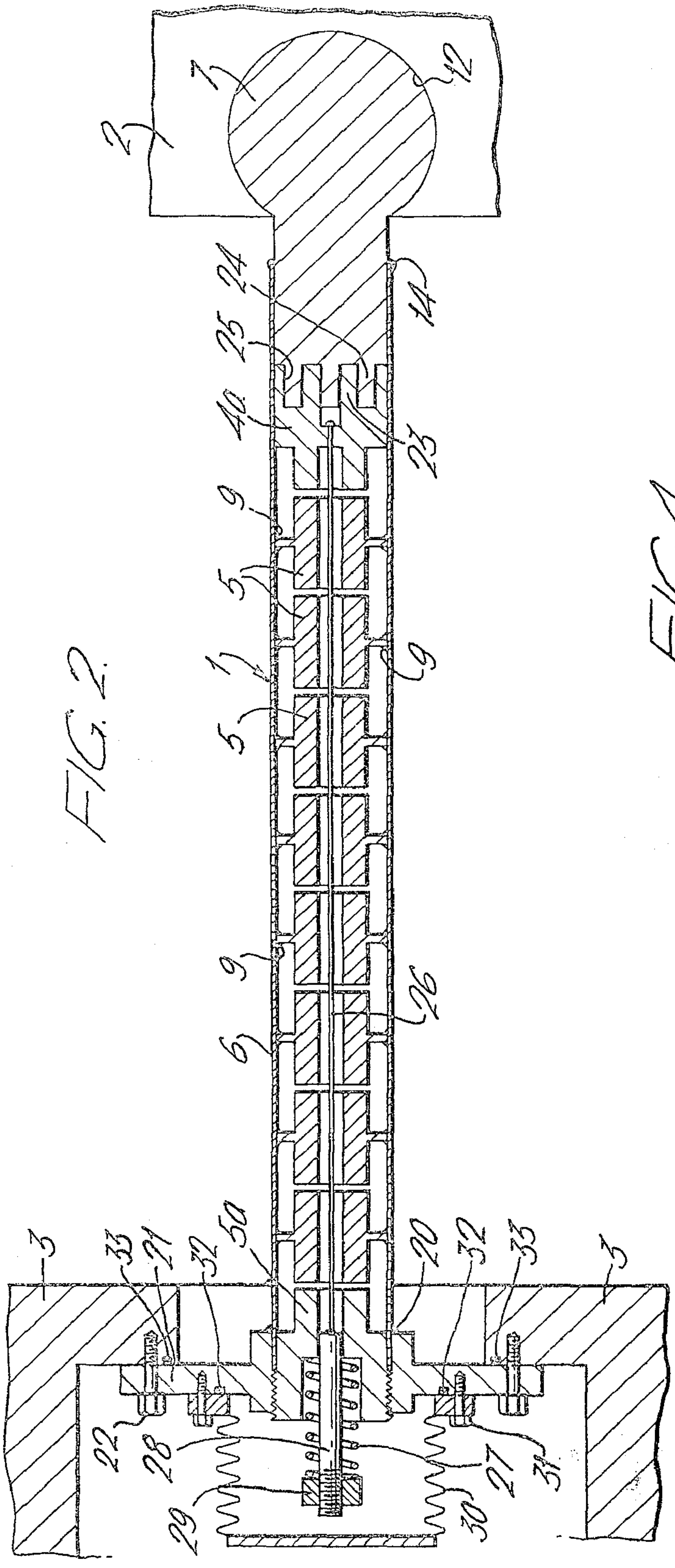

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FIG. 2

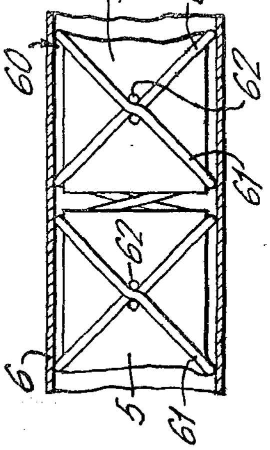
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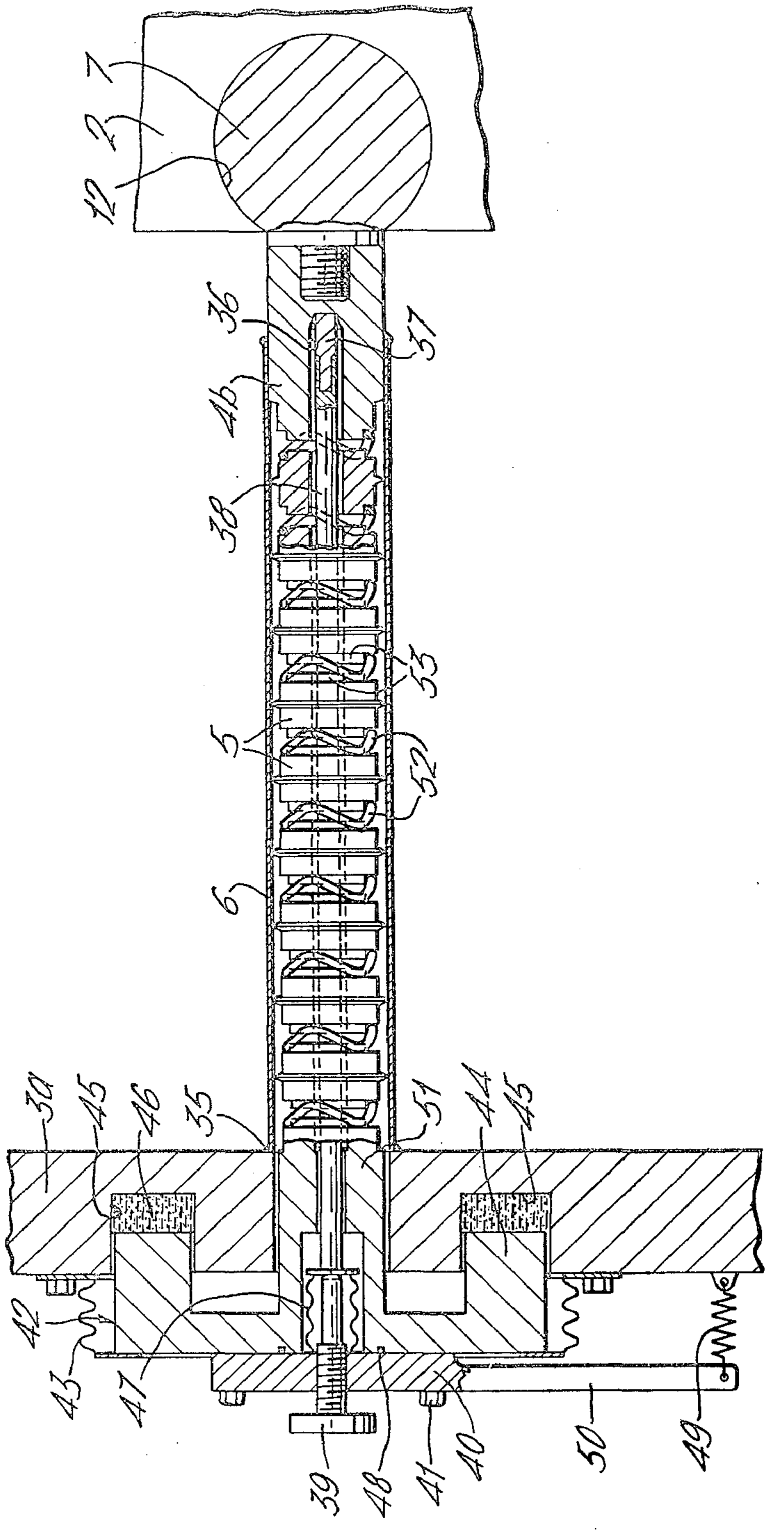
FIG. 4

FIG. 3.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MEMBER FOR CONDUCTING EXCESS HEAT AWAY FROM HEAT SOURCES

BACKGROUND TO THE INVENTION

This invention relates to members for conducting excess heat away from heat sources.

British Patent Specification No. 1,252,258 relates to Stirling cycle heat engines for generating electricity. Such engines use heat sources and it has been proposed to employ a radioisotope heat source for this purpose.

Should a radioisotope powered engine stop working for any reason, the radioisotope heat source will continue to generate heat. This will result in a rise in temperature which may cause overheating of and possible damage to the engine as well as to the heat source itself.

It is an object of the invention to provide such a member for conducting excess heat from the heat source and which, in normal operation of the engine, will impede the conduction of heat away from the heat source and so reduce thermal losses.

The member may be used to support and/or locate the heat source.

SUMMARY OF THE INVENTION

According to the invention, a member for conducting heat from a heat source is of elongated form and comprises a stack of heat-conductive slugs disposed in interspaced relationship along the longitudinal axis of the member, slug support means for locating the slugs in axial alignment, means for attaching an end one of the slugs to the heat source and means operable on overheating of said end one of the slugs whereby the slugs are able to move into heat-conducting contact with each other so as to conduct the excess heat away from said heat source.

The elongated member may have fusible attachment means (for example brazing) attaching the slugs to the slug support means whereby progressive overheating of the slugs along the stack results in an overheated slug being freed from attachment to the attachment means so as to allow the overheated slug to move along the stack and engage the next slug in line in heat-conducting contact.

The elongated member may be provided with means biasing the slugs towards contact with each other.

Alternatively, the elongated member may be provided with means biasing the slugs into contact with each other and counter-acting means biasing the slugs apart whereby the means operable on overheating of the said end one of the slugs allows the first-mentioned means to override the second-mentioned means.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings wherein:

FIGS. **1**, **2** and **3** are side views in medial section of differing arrangements, and

FIG. **4** is a fragmental side view illustrating a modification.

In the figures like reference numerals refer to like components.

DETAILED DESCRIPTION OF THE INVENTION

With reference first to FIG. **1**, a member **1** for conducting excess heat from a radioisotope heat source **2** is of elongated form. The member **1** supports part of the weight of the heat source **2** above a support frame **3** of a Stirling cycle heat engine (not shown) and comprises a stack of heat conductive slugs **4, 5** disposed in interspaced relationship along the longitudinal axis of the member **1,** slug support means in the form of a thin-walled tube **6** for locating the slugs **4** in axial alignment, a ball part **7** of a ball and socket joint for attaching the upper end slug **4** to the heat source **2,** and means operable on overheating of said upper end slug **4** whereby the slugs **4** are able to move progressively into heat conducting contact with each other so as to conduct the excess heat away from the heat source **2.** The last-mentioned means comprise fusible attachment means in the form of brazing **8, 9,** attaching the slugs **4, 5** to the tube **6.** As explained hereinafter, progressive overheating of the slugs **4, 5** along the stack results in an over-heated slug being freed from attachment to the tube by fusing of its brazing so as to allow it to move along the stack and engage the next slug in line in heat-conducting contact.

In further detail, the slugs **4, 5** are of copper and the thin-walled tube **6** is of stainless steel. The slugs **5** have central flanges **10** and the brazings **9** attach the slugs **5** to the inner surface of the tube **6** by way of these flanges. The brazing **8** between upper end slug **4** and the tube **6** is disposed between the inner surface of the tube and the outer surface of the slug. The brazing **8** at the other end of the support member **1** is between the outer surface of the tube and a ring **16** into which the lower end slug **4** is screwed. Since the lower end slug **4** loses heat by way of the engine frame **3,** which acts as a heat sink, this brazing **8** does not melt. The lower end slug **4** carries a ball part **11** of a ball and socket joint. The ball parts **7, 11** are screwed into the upper and lower end slugs **4** and are located by sockets **12, 13** formed in the heat source **2** and engine frame **3.** These ball and socket joints relieve the support member **1** from lateral stresses.

A steel ring **14** is fitted into the upper or hot end of the tube **6** and is secured thereto by a weld joint **15.** The ring **14** has a small axial clearance from the adjacent end slug **4.**

The tube **6** may be filled with a gas (e.g. Xenon) or it may be evacuated. If filled with a gas however, this will increase heat losses along the elongated member **1** occuring under normal operating conditions of the engine.

In practice, several members **1** are required to support the heat source **2.** Some of these may be in tension and others in compression. However, the arrangement is such that whatever the altitude of the heat source **2,** one of the members **1** is in compression so that its slugs **4** can move into contact with each other under gravity, should the brazing **9** melt.

In operation, with the member **1** in compression, the support stresses are transferred by the tube **6** to the support frame **3.** Under these conditions, because heat is constrained to flow along the thin-walled tube **6,** the upper end slug **4** is at a temperature substantially that of the heat source **2** and the lower end slug **4** is at a temperature substantially the same as ambient temperature.

In the event of overheating of the heat source **2,** the brazing **8** around the upper end slug **4** softens so that the slug is free to slide down within the tube **6** to contact the next slug in line, which is the upper slug **5.**

With slugs 4, 5 in contact, excess heat is conducted from the heat source 2 to both slugs and when the temperature of the slug 5 rises until its brazing 9 softens, both slugs 4, 5 slide down within the tube 6 to contact the next slug 5.

This process can continue until there is thermal contact between all of the slugs 4, 5 and heat will then flow from the heat source 2 down through the slugs to the engine frame 3. This can bring the temperature of the heat source 2 down to its normal level, or even below that level. The reduction in temperature will allow the brazings 8, 9 to harden again, leaving the heat source 2 positively located although it may be displaced a little from its original position.

The ring 14 prevents the upper or "hot" end slug 4 from moving outwards if its brazing 8 softens with the tube 6 in tension.

Thermal conductivity between the slugs 4 and 5 may be improved by making their contacting end surfaces conical or spherical rather than flat and/or coating these surfaces with braze material.

In a non-illustrated modification, the slugs 5 and the lower end slug 4 are brazed to a light wire cage. This assembly is then inserted into the tube 6 with the upper end slug 4 already brazed in position. The cold or lower end slug 4 is then secured in position, for example, by adhesive or by low-temperature soldering. In this modification the combination of the wire cage and the tube 6 may be regarded as the "slug support means" of the invention.

FIG. 2 illustrates an arrangement which does not depend on weight-loading for the slugs 4, 5 to move into contact with each other and thus is not required to function as a support. As shown the elongated member 1 is disposed horizontally but it could also be disposed substantially vertically, if desired.

In this arrangement the slugs 5 are hollow and the "cold" end of the tube 6 is brazed at 20 to a load-bearing flange 21 attached to the support frame 3 by bolts 22. An O-ring joint 33 is disposed between the frame 3 and flange 21. The "hot" end plug *4a* has a plurality of fingers 23 which interfit with fingers 24 formed on the ball joint 7. The fingers 23, 24 are brazed together with brazing 25. A tie-member comprising a steel wire 26 extends through the hollow slugs and between the "hot" end slug *4a* and a slug *5a* at the "cold" end of the member 1 and is tensioned by a compression spring 27. The "cold" end of the wire 26 is secured to a rod 28 bearing a screwed nut 29 which abuts the spring 27 and which is rotated to vary tension in the wire.

A bellows-type cover 30 attached to the flange 21 by bolts 31 with an O-ring 32 there between seals off the interior of the tube 6 which may be filled with a gas (e.g. Xenon) or evacuated.

Should the heat source 2 overheat, the brazing 25 securing the fingers 23, 24 together softens and allows tension in the wire 26 to pull the "hot" end slug *4a* into heat-conducting contact with the adjacent slug 5. Heat is now conducted from the heat source 2 to the said slug 5. Should this slug 5 overheat the brazing 9 attaching it to the tube 6 will soften and allow tension in the wire 26 to pull the contacting slugs *4a*, 5, along the tube 6 and into heat-conducting contact with the next slug 5 in line.

This movement of slugs *4a*, 5 along the stack can continue progressively until all the slugs are in heat-conducting contact with each other whereby excess heat is generated from the heat source 2 to the heat sink 3 by way of said slugs.

FIG. 3 illustrates another arrangement which does not depend on weight-loading for the slugs 4, 5 to move into contact with each other, and thus is not required to function as a support.

In the arrangement illustrated by FIG. 3, the "cold" end of the tube 6 is attached to the heat sink/support structure *3a* by brazing 35. The "hot" end slug *4b* is formed with a central recess 36 which houses a fusible plug 37. An elongated compression member comprising a tube 38 extends through the hollows in the slugs 5 to contact the fusible plug 37. Compression is applied to the tube 38 (and hence to the plug 37 it abuts) by a screw 39, which is located by a plate 40 attached by bolts 41 to a spring-loaded extension 42 of the heat sink/support *3a*.

The extension 42 is sealed to the support *3a* by a flexible bellows 43. The extension 42 is formed with a central boss section 51 and a peripheral ring-like portion 44 which is disposed within an annular recess 45 in the support *3a*. The recess 45 is packed with silicon grease 46 of high thermal conductivity, so as to ensure a good transfer of heat from the portion 44 of the extension 42 to the support *3a*. (Heat transfer can also, or alternatively, be achieved by providing the extension 42 with fins so that the extension may be cooled by convection). A bellows seal 47 extends between the plate 40 and the compression tube 38 to enclose that part of the screw 39 projecting from the inner side of the plate 40. An O-ring seal 48 is fitted between the plate 40 and the heat sink/support extension 42. The extension 42 is spring-loaded towards the support *3a* by tension springs 49 disposed between the support *3a* and three equi-spaced "spider" arms 50 extending radially from the plate 40.

In this arrangement the slugs 5 are not brazed to the tube 6 and are separated from each other by thin "zig-zag" springs 52 located by spigots 53 at adjacent end faces of the slugs. The springs 52 bear on each of the slugs 5 at three equi-spaced points.

It will be noted that the compression spring 49 tends to bias the slugs 5 into contact with each other and the springs 52 counteract this tendency by biasing the slugs 5 apart from each other.

In operation, should the heat source 2 overheat, the excess heat in the "hot" end slug *4b* will cause the fusible plug 37 to soften. This will allow the extension 42 and compression tube 38 to move towards the heat source under the action of the spring 49, displacing fused material of the plug 37 as they do so by forcing the material into the bore of the tube 38.

As the extension 42 moves towards the heat source 2, its central boss portion 51 compresses the stack of slugs 5, so as to override the springs 52 until the slugs 5 are actually in thermal contact with each other whereby heat is then conducted away from the heat source 2 to the heat sink/support structure *3a* by way of the slugs *4b*, 5 and extension 42. The plug 37 can be replaced after melting and operation restored to normal whilst the support member remains in place.

Heat-dumping can be performed manually by slackening the screw 39 until the spring 49 can compress the stack of slugs 5 sufficiently to allow thermal contact to take place between the slugs.

The tube **6** may be air or gas (e.g. Xenon) filled, or it may be evacuated.

In a modification of the arrangement illustrated by FIG. **3**, the arms **50** are attached to the heat sink extension **42** instead of to the plate **40**. This modification allows replacement of the plug **37**, (after first removing the plate **40** and tube **38**), without relaxing compression of the slugs **5** by the springs **49**.

This modification reduces the risk of the heat source overheating whilst the plug **37** is being changed.

With reference to FIG. **4**, in a modification of either of the embodiments of FIGS. **2** and **3**, a cylindrical framework **60** of resilient construction may be slidably disposed within the tube **6**. The framework **60** comprises, in effect, three interleaved helical springs **61** interwoven with three more springs **61** but with their sense of rotation reversed. The pitch of each of the six helices is substantially equal to six times the axial spacing between the centre of adjacent (hollow) slugs **5**. (Or to a sub-multiple of this spacing). Thus two oppositely wound springs **61** intersect at each of three equispaced points around the circumference of each slug **5** where they locate the slugs (axially and radially) by contact with pins **62** attached thereto.

The ends of the framework **60** are attached to the hot and cold ends of the member. In operation, if the framework **60** is compressed axially the slugs **5** all move into contact with each other.

In a (non-illustrated) modification, the coils of the framework **60** may be of strip form. The strips would take up less room between the slugs **5** and tube **6** than the circular-section coils of FIG. **4**. Use of strips allows the pairs of pins **62** to be replaced by single pins, locating the strips by holes formed therein.

Alternatively, the framework **60** could be replaced by a cylinder made up of an expanded sheet of metal.

In the embodiments of FIGS. **2** and **3**, the ball and socket joints **7, 12** at the "hot" ends, although useful, are not essential. If used, further advantages result from providing the "cold" ends of the support members with ball and socket joints. However, this would require some re-design of the said "cold" ends.

I claim:

1. A member for conducting heat from a heat source, said member being of elongated form and comprising a stack of heat-conductive slugs disposed in interspaced relationship along the longitudinal axis of the member, slug support means for locating the slugs in axial alignment, means for attaching an end one of the slugs to the heat source and means operable on overheating of said end one of the slugs whereby the slugs are able to move into heat-conducting contact with each other so as to conduct the excess heat away from said heat source.

2. A member as claimed in claim **1** having fusible attachment means for attaching the slugs to the slug support means.

3. A member as claimed in claim **1** provided with means for biasing the slugs towards contact with each other.

4. A member as claimed in claim **3** wherein said slugs are hollow and the means for biasing the slugs towards contact with each other comprise a tie-member attached to said end one of the slugs and extending through the stack of slugs and means for applying tension to said tie-member.

5. A member as claimed in claim **1** provided with means for biasing the slugs towards contact with each other and further provided with counter-acting means for biasing the slugs apart.

6. A member as claimed in claim **5** wherein the slugs and hollow and an elongated compression member extends through the stack of slugs to act against said one end of the slugs, the member being further provided with means for applying a compression force to said compression member.

7. A member as claimed in claim **6** wherein a body of fusible material is disposed between the end of the compression member adjacent said end one of the slugs and said end one itself.

8. A member as claimed in claim **1** wherein the slug support means comprise a tubular member.

9. A member as claimed in claim **1** wherein the slug support means comprise a resilient frame located by the bore of a tubular member.

* * * * *