THERMOSTAT ISSUES AND SELECTION,
for Silver Shadows (SY), Silver Spurs (SZ) and their Derivatives

Don Elliott and Phil Birkeland, (WA) and Brian Vogel, (VA)
With contributions from Bill Coburn, RROC-A, Canberra, Australia

April 2012

A. Background

Everybody knows how our cars are cooled don't they? Oh really? Are you sure? Certainly when the gauge on the dash heads for the **"red sector"** it is enough to get your attention, because an overheated engine is frequently a destroyed engine. But how much attention is paid when the gauge barely gets off the peg? Perhaps the heater doesn't work with its regular punch, but that's about all. Ah, but if the car does not reach its optimum operating temperature, the fuel economy will be crummy (or crummier), the engine is likely to experience accelerated wear, and the power can be reduced. So it behooves us all to pay attention to the temperature gauge and to begin to poke around a bit when it seems abnormal.

Fig. 1

The interest in this subject was prompted by the low reading shown on the temperature gauge of my 1988 Silver Spur (NAJ-24409). Other than the ominous red band at the top of the scale, my temperature gauge has no tick marks, white bands, numbers, or any other markings that would facilitate a repeatable monitoring of the temperature. But it just seemed to be consistently low. Therefore, I used an infra-red (IR) temperature sensor[1] to check the temperature on top of the thermostat housing shown in Fig. 1. See TSD4700 Chapter L (for the Silver Spur) for more information.

If the testing showed the engine to be at a normal operating temperature, this project would have been diverted to addressing temperature gauge or sensor malfunctions, but the measurement showed that the engine was operating at ~186°F when fully hot. For this car, the manual states that the thermostat will begin to open at ~190°F and will be fully open in maximum cooling mode when the temperature reaches ~210°F. This is fairly typical for a so-called "modern" car. Temperatures significantly below (or above) this number when the car is fully warmed up could mean that the thermostat is acting up. Therefore, my engine was running ~10°F too low and an investigation into its thermostat condition was launched.

B. Cooling System Design History

It has been widely reported that the cooling system on RR/B cars is unique and amateur tinkering with such a finely tuned system is to be avoided. However, the engine in the Silver Shadow through the Silver Spur cars is a large V8 equipped with a typical internal bypass arrangement to facilitate engine warm up. From a purely engineering viewpoint, there is nothing significantly different from the cooling system requirements of other V8s. Similarly, the radiator and water pump are also relatively straight-forward predictable designs. But when it comes to the thermostat that controls this system, here indeed is something unique to our beloved Crewe motorcars. The history of how we came to have this particular thermostat is a tangled path that reads much like an Agatha Christie mystery, but unfortunately not all of the facts are explained at the end.

The saga began with the introduction of the first RR/B V-8, fitted to the Silver Cloud II/S2. In the early 1960's RR changed to a pressurized system that required a wax pellet thermostat. Continued use of the older alcohol-filled bellows design is not possible if the system is pressurized. A decade earlier, virtually the entire automotive industry rapidly converted to the wax pellet type of thermostat as it was quite comfortable operating in a pressurized system. The principle of the wax pellet design involves a special sealed wax capsule that, when heated, expands and causes the thermostat valve to open. Being conservative, RR designed their own thermostat, but the initial design was troublesome. David Chaundy's insightful paper[2] gives an excellent description of the problems experienced with the early thermostats fitted to the SC II. The pressurized wax containment system leaked and, without the expanding wax, the thermostat could not open at all. Such failures caused disastrous overheating. Crewe's solution to this emergency was to drill eight 8mm diameter holes in the flange skirting of the thermostat and fill the holes with a low melting point lead solder (~124°C). The intent was when the thermostat failed to open; the solder would melt and provide an emergency flow of coolant to prevent destroying the engine. Thus, the lead plugs were a work-around solution attempting to address a basic design flaw. For over 50 years the Crewe UE36600 thermostat has featured

[1] An infra-red temperature sensor is available at auto parts stores and is usually quite inexpensive (<$25 USD). It measures the temperature without touching the surface.
[2] Silver Cloud II Cooling system. Available on the KDA132 web site at http://www.kda132.com

these lead plugs, in spite of the fact that modern quality control systems eliminated the basic problem with the wax containment envelope many years ago. The lead plugs could be considered an artifact of history.

Meanwhile, the rest of the world went about their business making thermostats without the use of lead plugs. Their thermostats had a different design for the wax containment capsule and they did not stick shut. Today, no other car manufacturer offers thermostats that feature fusible lead plugs. Manufacturers using the far more common non-lead plug design include: Aston Martin, Audi, BMW, Ferrari, Lotus, Maserati, Mercedes, and all of the American produced cars. RR/B motorcars stand quite alone in this regard. Having eight additional potential failure spots made it essential that the UE thermostat be changed every two years to be certain the lead plugs stay in place. As will be seen In Section E of this paper, failures have been experienced with lead plugs from causes other than melting.

But it is not just the lead plugs that require the UE36600 (UE) thermostats to be changed on such a frequent basis. There was one other troublesome characteristic of this design. The UE is made of 100% stainless steel. Thus, the stainless steel shaft slides on a stainless steel body. From a metallurgical standpoint, sliding stainless steel on stainless steel risks eventual galling. Galling is process where microscopic transfer of metal from one surface to another occurs until the surfaces become roughened and they eventually stick together. The UE design is particularly prone to galling and failures have been reported (also in Section E). Most failures occur on the cooling stroke when the valve is being closed only by the force of the internal spring. Whereas the common failure mode in the early days was to stick shut, the most common failure mode today of the UE is to not close properly, causing the car to fail to reach the proper operating temperature.

It is interesting to compare the Crewe advocated two year thermostat replacement schedule with BMW and Mercedes that have no periodic thermostat replacement schedule at all. BMW believes that their thermostat (a Behr-Thomson) should last at least 60,000 miles. Mercedes will replace a thermostat only on an engine rebuild. Apparently not all thermostats are created equal.

In 2002 Crewe revisited this old design and in TSD 6000 superseded the UE with the PG58252PA thermostat. This is a significantly better design. Not only did the design eliminate the lead plugs, it also changed the metallurgy to a brass plated body. The new thermostat now slides a stainless steel shaft on a brass plated body thus eliminating any issues from galling. But curiously, Crewe specified that this new thermostat was to be used only in 1987 and newer cars. The Silver Shadows and the early Spirit/Spur series were left behind to deal with the older the lead plug variety. In 2005 Gordon Norris from the RROC-A wrote to Crewe questioning why the pre-20000 serial number cars (1987 and earlier) must use the older thermostat. A three week delay ensued, but the eventual reply was most interesting. On April 5, 2005 Mr. Norris posted this reply from Crewe on the RROC-A Forum.

> *"The reason for the delay (in replying) is that our Engineering department have been looking into whether there is a need to use the lead pellet type of thermostat prior to 1987 as this is old technology. It is looking like a new thermostat will replace it similar to the new one which has been introduced in 2002 for all cars from 1987 MY (Model year). However this has not been officially released yet. We will advise more in due course."*

Unfortunately there was no further reply and this issue remains unresolved some seven years later.

It is also interesting that in this same year, the likely OEM Supplier to Crewe, *"Waxstat"*, owned by Western-Thomson Controls Ltd, was dissolved and production was shifted to Western Thomson (India) Limited, Chennai at their Gummidipoondi plant in India. The closure of the UK supplier may have had a bearing on the remaining unresolved question about the UE thermostat use in Shadows and early Spirits/Spurs. Aftermarket parts firms such as "Flying Spares" supply both the UE and the PG thermostats that are made in the Gummidipoondi plant of Western Thomson (India) Ltd.

Adding to the puzzlement is the fact that the current Crewe Genuine Parts catalog (www.**crewegenuineparts**.com*)* shows no listing for any thermostat for the Silver Shadow or Silver Spirits/Spurs at all. Yet a direct inquiry resulted in Bentley Motors Ltd stating that both thermostats remain available. These two facts seem curious and contradictory. Where is Miss Marple when you need her?

C. How it Works

The conceptual sketch in Fig. 2 shows what is under the thermostat housing. The sketch is divided into two halves. The left half shows the thermostat when cold. The right half shows it when fully hot. Since Shadows and Spurs are V-8s, coolant enters the compartment below the thermostat housing lid from both sides. The thermostat operates by closing the discharge

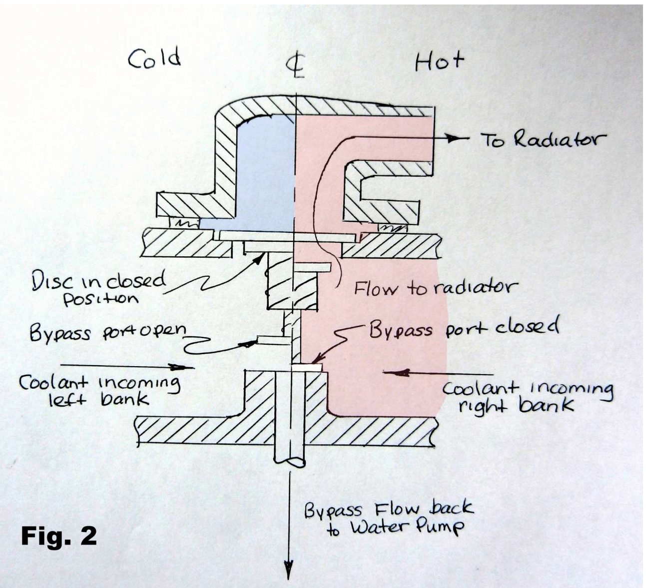

Fig. 2

valve to the radiator when the coolant is cold thus forcing the coolant to bypass the radiator and return to the water pump via the bottom bypass port. When the coolant heats up to the set point temperature, the wax pellet inside the thermostat spool expands forcing the thermostat spool to move downward thus opening the outlet valve. The motion of the spool also begins to restrict the flow through the bypass port. As the coolant temperature continues to rise, the outlet valve continues to open and the bypass to close until a balance between engine heat and radiator cooling is reached. Under heavy load and high ambient air temperatures the thermostat will be wide open and the bypass valve will be completely closed with all the coolant routed to the radiator. TSD 4700 indicates this will occur at temperatures of 210–215°F. The sketch shows the fully open position of the spool to the right of the centerline. Thus, the thermostat for the SY and SZ Series cars has two functions, opening the flow to the radiator, and closing off the bypass. It is essential that the thermostat be able to perform both functions.

D. Testing the Thermostat

If the temperature on top of the housing is too low, it may mean that the thermostat is opening too early or is defective. Conversely, if the temperature is too hot perhaps the thermostat cannot shut the bypass port. Consequently, if something odd is suspected with the performance, it might be useful to remove the thermostat for testing. Removal is very easy. Pulling off the upper radiator hose will cause about a quart of coolant to spill. Removal of the four screws and their washers allow the upper housing and the thermostat to be removed. If the housing is stuck, a thin-bladed putty knife may be used to destroy the gasket, but care is needed not to gouge the flange surfaces as they are aluminum. A new gasket is easily made or purchased. Section L3 of TSD 4700 describes the procedure to refill the system on a SZ car[3].

The testing apparatus is simply a pot of water on the stove with a thermometer and spoon to agitate the water. Resting the thermostat on a piece of scrap plastic avoids direct heat transfer to the metal surface. Alternatively, suspending the thermostat in a kitchen sieve also works well. Testing showed that my original Silver Spur's thermostat began to open at 182°F, in spite of its rating of 190°F. This confirmed the observed low engine operating temperature. The common commercial tolerance for non-precise instruments is ±5% and our evaluations found wide variance from the stated opening temperatures on several thermostats. Therefore, it is significant that one should verify the actual opening temperature and not merely rely on the stamped or marked temperature on the box. However, once the initial opening point was established for a particular thermostat, the opening and closing points were repeatable for subsequent cycles. The test continued by raising the temperature to boiling to enable the distance between the lower part of the mounting flange and the bottom of the bypass shutoff plate to be measured while hot. This distance determines if the thermostat is capable of shutting off the bypass. For the Silver Spur and Silver Wraith II, the required dimension was 45mm.

E. Failure Analysis of the UE36600 Thermostat

The original thermostat for the SY and SZ cars (UE36600) has eight holes that were intentionally plugged off with a low melting point solder as discussed in Section B. These lead plugs have been found to be missing in some early Spurs thus causing the thermostat to become ineffective. Fig. 3 shows two UE36600 thermostats. The thermostat shown on the left is from Brian Vogel's 1978 Silver Shadow II, SRH33576 and the one on the right is from a 1979 Silver Wraith II, LRK37110. The thermostat on the left shows an undamaged, but quite soiled thermostat. The solder plugs are still in place and the performance was in the middle of the normal temperature range. The thermostat on the right is missing its solder plugs which MIGHT indicate that it has been overheated; however, it is remarkably clean with no distortion or discoloration that might indicate such an event. Certainly there is no residual melted product remaining around the holes, and it is quite significant that this thermostat still opens and closes normally. Clearly it was not "stuck shut". These facts add to the doubt of it being subjected to an overheating event.

A similar thermostat was removed from my 1988 Silver Spur. While its lead plugs were still in place, all lead surfaces were found to have been subjected to some sort of corrosive attack. Portions of the plugs were pockmarked, were "furry" in appearance, and flaked away easily if touched. It was obvious that they were failing. My experience in the chemical process industry is that lead alloys are commonly affected by cold flow, cracking, poor adherence, and odd corrosion issues. Therefore, the actual mechanism of failure of Brian's lead plugs may well be something other than simple overheating.

A 4th Crewe UE36600 lead plug thermostat was examined from a Bentley Azure. This thermostat was found to be unable to close completely. We verified that it was not "stuck", but always returned to a partially open position. It was suffering from

[3] If the radiator plastic bleed or drain screw described in Section L3 is found to be broken on the SZ series cars, see Section F for a suitable replacement.

galling as previously discussed. The result was that this car never warmed up at all. Its lead plugs were also experiencing similar corrosion damage and failure is predicted. Three other failures to reach the proper operating temperature were reported. Therefore, a total of seven cars in our short little study experienced low operating temperatures resulting from using the UE thermostat. Significantly, no failures were reported by those who had switched to the PG58252PA thermostat.

F. Non-Crewe Replacements

The authors were initially led to believe that only Crewe could supply an adequate thermostat for these cars, yet wax pellet thermostats have been used in many millions of internal combustion engines from huge to small, foreign and domestic, gas or diesel for the last 75 years. So, not particularly surprisingly, a little leg work yielded positive results in finding a suitable locally available non-Crewe alternative for the SY and SZ cars. Of the tested thermostats, the Stant 13558 (or the equivalent NAPA 136) proved to be nearly an exact match for the required dimensions for the 6.7 liter engine in the Shadow through the Spur line of cars. Appendix A offers a detailed comparison of the Stant with the Crewe UE thermostat, and in Appendix B for a variety of other tested thermostats. The Stant 13558 is made by Behr-Thomson of Baden-Württemberg, Germany, a supplier of OEM thermostats to BMW (for which BMW claims a >60,000 mile life). That the names of the likely OEM supplier to Crewe (Western-Thomson), the present supplier of after market parts (Western-Thomson India) and the selected non-Crewe alternative (Behr-Thomson) all contain the word "Thomson" is probably not a coincidence. Thermostats are a world commodity and there is much overlap between manufacturers in the industry (See Appendix B).

The Stant 13558 has an overall flange diameter of 67mm and the UE and PG dimension is 69mm. This difference is insignificant as both the Stant and the two Crewe designs rest comfortably in the counterbore of the engine. Once the upper housing and gasket are replaced, the thermostat is immobilized in place. Another difference is the lack of ability for air to escape from under the Stant thermostat when the system is refilled. To rectify this omission, Brian salvaged the jiggle pin from his scrap UE thermostat and adapted it to his new Stant #13558 as shown in Fig. 4. He recommends drilling a 3/16" hole and removing the burrs underneath. Doing so takes about five minutes. Inserting the jiggle pin and spreading the U-shaped arms of the pin holds it in place. Rounding the bottom of the plastic bulb to a near spherical shape (see Fig. 4 insert) minimizes the risk of it becoming trapped in the mechanism thereby jamming the thermostat open. Drilling a smaller hole (~3/32" or so) in the skirt will also provide an air vent without using the pin. Having a jiggle pin is likely a better solution since it will keep the hole clear of debris and the float will minimize the leakage past the thermostat.

Stant (non-Crewe thermostats) have been operating normally at the proper operating temperatures since September 2011 in Brian Vogel's Silver Shadow II (SRH33576) and since January in his Silver Wraith II (LRK37110) and my 1988 Silver Spur (NAJ-24409). With their 8% greater open area design (Appendix A), summertime operation is expected to be improved.

F. Conclusions and Recommendations

- Multiple failures by galling and from lead plug issues in the Crewe UE36000 thermostats have been reported. The failure of the low temperature solder plugs may be due to some other reason than overheating. Corrosion, cracking, or failure to adhere is suspected. The most common failure mode today is not closing properly. This differs from the early days when the thermostats commonly stuck shut. Crewe recommends replacing its thermostats each two years.
- There have been no failures reported for the newer PG58252PA thermostat authorized for the 1987 and newer RR/B cars. The PG design addresses both the potential for lead plug problems and galling. It is clearly superior to the UE36600. Whether Silver Shadows and early Spirit/Spur cars can use the newer PG58252PA thermostat remains an open issue, but it is clear that in 2005 Crewe intended to discontinue the use of the UE36600 model using lead plugs.
- Bentley dealers are able to supply the UE and PG models in spite of having no listing for them in their catalog. Current price in Washington State is $139 USD for the UE36600 and $195 USD for PG58252PA. Aftermarket vendors also sell UE and the PG model made by Western-Thomson (India) Ltd at just over $100 USD each.
- A functional equivalent to the Crewe UE36600 thermostat is the Stant #13558 (made by Behr-Thomson in Germany). The cost of the Stant #13558 is about $20 USD. BMW claims that the Behr-Thomson thermostats (including the Stant) have a life in excess of 60,000 miles.
- It is recommended that an air vent be provided if the Stant thermostats are used. Transplanting the jiggle pin assembly from another thermostat is the preferred technique. A small hole drilled in the skirt would also work.
- If the bleed or drain screw used in the cooling system on the SZ series cars is found broken, a replacement is available at the BMW Dealer's Parts counter. It is BMW part 17-11-1-468-467, Plug 17999. The cost was ~$3.60 USD.

APPENDIX A.
COMPARISON OF THE CREWE AND STANT THERMOSTATS

PARAMETER	SUB CATEGORY	STANT 13558 or NAPA 136	USED CREWE UE36600	COMMENTS
FLOW CAPACITY	Valve diameter, mm Shaft Stroke mm, Open area, sq mm	39 9 1102	36 9 1017	Comparison of open area when the thermostat is fully open The Stant/NAPA has an 8.3% larger open area
MATERIALS OF CONSTRUCTION	Valve trim Body	Stainless steel Brass	Stainless steel Stainless steel	Stainless steel sliding on stainless steel is prone to galling. It is expected that the Crewe thermostat would be prone to sticking particularly when closing. One Crewe UE unit is in hand that cannot close and is always 20% open.
DIMENSIONS	Max OD, mm Min OD, mm Thermostat flange OD, mm	70 65 67	70 65 69	Thermostat housing dimension Thermostat housing dimension The difference is non critical since both fit onto the counter bore in the Housing.
	Req'd minimum Bypass Plate OD, mm Thermostat plate, mm	26 35	26 38	Thermostat housing dimension Both can close the bypass port
	Stroke required to close the bypass port, mm Thermostat stroke, mm	45 45	45 45	Both can reach the bypass port to close it
TEMPERATURE RATING	Engine Design goal, ^{o}F Thermostat rating:, ^{o}F Actual opening temp, ^{o}F	190 183 192	190 190 182	From TSD 4737 The actual opening temperature may vary from the stamped rating, but once the opening temp is established, subsequent opening and closing temperatures will be repeatable. It is precise but not very accurate. Typical industrial tolerance is ±5%.
FUSIBLE LEAD PLUGS	The lead plugs are intended to melt to provide emergency flow when the engine reaches ~255 ^{o}F. The lead plugs were added after the thermostat was initially designed for the SCII to mediate a design flaw consisting of a loss of containment for the wax pellet.	No lead plugs are featured and none are needed since stainless steel slides freely on the brass body and the containment capsules for the melted wax have been made reliable.	8 holes of 8mm each are drilled into the thermostat body. The holes are filled with a low melting point solder. The materials of construction of the Crewe unit also make it prone to sticking	Adding holes weakens the body and may allow it to flex thus loosening the lead plugs. Plugs have been found to be missing without evidence of melting in one thermostat. The plugs in two other Crewe thermostats were found to be pitted and flaking away from some sort of corrosion process. ~90% of the examined Crewe thermostats (8 cars) have failed to meet the intended performance standard. Crewe superseded the UE with the PG58252PA for 1987 and later SZ cars in 2002. Edition 12-1 of the FL (p 10344) recommends replacement of the Crewe UE36600 lead plug thermostat each two years. This is likely prudent due to the potential for failure of the lead plugs and for galling of the shaft. No other car manufacturer was found to offer lead plugs in their thermostats.
COST		~$20 USD at NAPA stores or on the internet	UE36600 = $139 USD PG58252PA = $194 USD from Bentley of Bellevue, WA April 16, 2012	BMW claims a >60,000 mile life for the Behr-Thomson thermostat. Mercedes Benz changes thermostats only on an engine rebuild. Neither BMW nor Mercedes Benz has a scheduled maintenance replacement interval for their thermostat.

APPENDIX B.
COMPARISON OF THE CREWE AND ALTERNATIVE THERMOSTATS

Brand and Part #	Flange diameter	Bypass disc diameter.	Depth when hot and cold	Rating, °F	Work OK?
DIMENSIONAL DESIGN REQUIREMENTS for the Silver Shadow II, Silver Wraith II, and Silver Spur	**>65mm minimum to seat on the lip, <70mm to fit in the counterbore**	**>26mm minimum to cover the top of bypass port to close it off.**	**~45 mm to close bypass when hot, & typically ~36mm when cold**	**185-192°F per TSD4700**	**NA**
Used Crewe thermostat UE 36600	**69mm**	**38mm**	**45mm hot and 35mm cold**	**Rated 190°F Opened 182° F**	**YES, but too cold**
New Flying Spares UE 36600P (Gummidipoondi)	**69.1 mm**	**39.3mm**	**49mm hot and 38.7mm cold**	**Rated 190°F Opened 192° F**	**YES, but dimensions differ.**
Stant #13558[4]	**67mm. The 2mm smaller flange size is unimportant.**	**35mm**	**45mm when hot, 36mm when cold**	**Rated 183°F Opened 192°F**	**YES, but no air vent**
NAPA 136, identical to the Stant 13558	**67mm**	**35mm**	**45mm hot and 36mm cold**	**Rated 183°F Opened 191°F.**	**YES, but no air vent**
NAPA 280/ Stant #13649	67mm	43mm	34mm hot, and 23mm cold	Rated 195 Opened 192°F	NO, Can't shut the bypass
Murray Plus 4168	64mm. Too small.	43mm	Probably Ok.	Rated 180°F	NO
Stant 14168	64mm. Too small.	43mm	Probably OK	Rated 180°F	NO
Wahler, Germany	64mm. Too small.	25mm Too small	Too long	Rated 180°F	NO
Murray Plus #3689: Strangely, the thermostat in the box was not even close to the catalog dimensions. It was likely in the wrong box					

About the Authors and Contributors:

- Donald Elliott is a Chemical Engineer with over 50 years of experience in investigating the causes of industrial accidents involving hazardous materials including Root Cause Investigations, Hazard and Operability studies, Process Design, and Emergency Response. This is the 23rd technical article written by Mr. Elliott covering RR/B motorcars. Many have appeared in the Regional-Lady, the EPW Society, the Modern Car Society, and regional publications.
- Philip Birkeland is a licensed Mechanical, Structural, and Civil Engineer (ret); and holds a BS degree in Mechanical Engineering, a Masters Degrees in Applied Mechanics, and an MBA. He has a lifetime of experience in the design, manufacturing, and development of aviation bearings, high temperature materials, structures, vibrations, gears, drives, hydraulics, structural analysis, and hydraulics. He has published papers on RR/B motorcars in the Flying Lady, the Goshawk Society (of which he is Editor), and the RROC's Pacific NW Region's “Hoseclamp."
- Brian Vogel holds a B.S. in Computer Science and an M.S. in Communication Sciences and Disorders (Speech-Language Pathology) and has over 25 years experience in information technology. Mr. Vogel maintains an extensive cross-over parts and literature database for RR/B motorcars as a service to their owners.
- Bill Coburn is the moderator of the RROC-A Tee One Topics and is a well renowned RR/B enthusiast.

Disclaimer: The authors believe the information presented herein is accurate. However owners are cautioned to understand that this paper does not constitute a recommendation to install any non-Crewe parts. Alternatives to Crewe supplied parts are presented for information only. Installation and use is at the owner's discretion and risk.

---

[4] The Stant 13558 is made by Behr-Thomson in Germany. Behr-Thomson's parent corporation is Behr-Thermot-tronik GmbH which owns Behr-Thermot-tronik, Italia S.p.A which is the Technical Partner of Western-Thomson (India). All are related.