Assessment of methods to detect leaks in the casing of room sealed appliances

Prepared by
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for the Health and Safety Executive

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A series of experiments was performed to determine suitable procedures for detecting leaks from the case and seals of fan pressurised central heating boilers. The work was done using a type of boiler which has been involved in several incidents associated with the escape of carbon monoxide into a property.

Procedures involving the following equipment were found to have the potential to detect leaks:

- a visual and tactile inspection of the case and seal;
- smoke tubes to produce smoke for flow visualisation;
- smoke matches to produce smoke for flow visualisation;
- ordinary matches and wax tapers to produce a flame for flow visualisation.

A flue gas analyser detects the drop in oxygen concentration or the presence of carbon monoxide due to a leak of combustion products. A boiler burning well but leaking slightly often produces only a small change which may be missed using a flue gas analyser. This method is not recommended.

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## CONTENTS

1 **INTRODUCTION** 1  
  1.1 Reported Incidents with Potterton Netaheat boilers 1  
2 **TYPES OF BOILER** 2  
3 **EXPERIMENTAL METHODS** 3  
4 **RESULTS** 6  
5 **DISCUSSION** 12  
6 **TRIALS AND SUGGESTED MODIFICATIONS TO THE PROPOSED PROCEDURES** 15  
  6.1 Trials 15  
  6.2 Discussion 20  
7 **RECOMMENDATIONS** 21  
8 **REFERENCES** 22  
APPENDIX A **WHY SOME LEAKAGE IS ALLOWED** 23  
APPENDIX B **ORIGINAL CHECKLIST FOR USE BY A SERVICE ENGINEER (SEPARATE SHEETS)** 28  
APPENDIX C **SERVICE ENGINEERS COMMENTS** 33  
APPENDIX D **EXTRACT FROM DATA SHEET ON SMOKE TUBES** 55  
APPENDIX E **MODIFIED PROCEDURES** 56  
APPENDIX F **MODIFICATIONS TO CHECKLIST** 61
SUMMARY

Previous work \(^1\) considered the various methods available for detecting leaks in the seals of fan pressurised central heating boilers. This phase is aimed at prescribing a suitable procedure for a CORGI registered engineer to follow when assessing leakage on fan pressurised boilers.

The Potterton Netaheat has been involved in several incidents involving the escape of carbon monoxide into a property. An example of this type of boiler was used to devise and evaluate the procedures. The most promising methods from the previous phase were used (flue gas analyser, smoke tubes, and the internal pressure of the boiler), as well as smoke matches. In addition one of the methods which did not work successfully in the previous phase (smoke pellets) was again tried.

The leakage rate from the boiler was determined (when the boiler was not running) by pressurising the boiler and measuring the air inlet rate and internal pressure. This was done for each of the leak scenarios used.

For the leak detection tests the boiler was normally operated with the air intake and flue exhaust outlet unobstructed. The success of the various methods in detecting leaks due to, for example, loose case screws and thermocouple capillaries along and through the case seal, was recorded.

Three methods were found suitable for use in the trials of the procedures under simulated conditions – smoke tubes, smoke matches and a flue gas analyser. Twenty CORGI registered engineers with experience in servicing gas central heating boilers used the procedures, and their comments noted. A fourth method, using a naked flame from a match or wax taper, was suggested and used in the later trials.

All the methods had advantages and disadvantages, and the use of one method does not preclude the use of any other. However, the conclusions after the trials were:-

- A visual and tactile inspection before the case is put back on may show that the case or seal needs attention. However leaks may occur even if the condition of the seal and the case seems satisfactory. The effectiveness of various methods in detecting these leaks is summarised below.
- Smoke tubes, smoke matches, ordinary matches or a wax taper can be used to successfully show a leak, even when combustion products are not present in the ejected gas.
- Smoke tubes are the easiest to use, but contain noxious chemicals and are the most expensive method.
- Smoke matches are cheaper, but they produce smoke forcefully which may obscure a leak. The smoke matches also leave a lingering odour.
- Ordinary matches are much cheaper but still show most leaks. Ordinary matches, or a cigarette lighter or other source of a similar flame are almost certainly in the toolbag of a boiler engineer. Wax tapers may be slightly better at detecting leaks, but are less likely to be carried. These two methods, using a naked flame, have the fewest drawbacks.
- A flue gas analyser detected most leaks in the laboratory. However the concentrations of combustion products detected were often very small, and could easily be mistaken for, or obscured by, instrument drift. This method cannot be recommended for finding leaks in seals.

1 INTRODUCTION

Some instances have occurred where malfunction of a balanced flue (room sealed) appliance has resulted in significant amounts of carbon monoxide entering the room containing the appliance. Carbon monoxide is responsible for the deaths of approximately 25 - 30 people a year in the UK from piped gas incidents.

Whilst room sealed gas appliances tend to minimise the risk of combustion products entering a property by virtue of a design which uses combustion air from outside and exhausts the products of combustion to the outside also, there are ways in which combustion products can enter a domestic environment. They can either flow from the flue terminal and enter a property from outside through an opening (window, door, etc.), or flow directly in through openings or gaps in the case or seals of the appliance. The former is a consequence of where the flue terminal is positioned. A previous phase of the current work\(^1\) looked at ways to detect the leakage from an appliance. This phase is aimed at prescribing a suitable procedure for a CORGI registered engineer to follow when assessing leakage on fan pressurised boilers.

One complication in this respect has been that boilers approved by a notified body in complying with the BS\(^2\) and EN\(^3\) standards are permitted a particular level of leakage. This leakage is considered in APPENDIX A. The amount of leakage from the boiler was therefore monitored during the investigations.

1.1 REPORTED INCIDENTS WITH POTTERTON NETAHEAT BOILERS

The incidents listed in Table 1 feature in the Advantica CO Incident Database, which has been compiled from company (BG plc and previously British Gas plc) reports of serious incidents. Several incidents were due to the case not being fitted correctly, with a lower number due to distortion or buckling of the boiler back plate. One incident may have been exacerbated by blockage of the flue.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cause of incident</th>
</tr>
</thead>
<tbody>
<tr>
<td>90/91</td>
<td>Deliberate tampering</td>
</tr>
<tr>
<td>90/91</td>
<td>Case not fitted</td>
</tr>
<tr>
<td>90/91</td>
<td>Badly / incorrectly fitted case</td>
</tr>
<tr>
<td>90/91</td>
<td>Badly / incorrectly fitted case</td>
</tr>
<tr>
<td>91/92</td>
<td>Case seal not fitted correctly</td>
</tr>
<tr>
<td>93/94</td>
<td>Unauthorized modifications to flue</td>
</tr>
<tr>
<td>93/94</td>
<td>Case not seated into gasket</td>
</tr>
<tr>
<td>93/94</td>
<td>Cause not given</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Cause of incident</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/01/97</td>
<td>Casing bolts loose</td>
</tr>
<tr>
<td>09/03/97</td>
<td>Deliberate tampering</td>
</tr>
<tr>
<td>17/03/97</td>
<td>Buckled back plate/possible explosive ignition</td>
</tr>
<tr>
<td>24/10/97</td>
<td>Badly / incorrectly fitted case</td>
</tr>
<tr>
<td>15/12/97</td>
<td>Buckled back plate/possible explosive ignition</td>
</tr>
<tr>
<td>20/01/98</td>
<td>Casing bolts loose or missing</td>
</tr>
<tr>
<td>23/11/98</td>
<td>Back plate distorted/flue blocked by wasps nest</td>
</tr>
<tr>
<td>05/02/99</td>
<td>Trapped thermostat capillary tube allowed leakage</td>
</tr>
<tr>
<td>27/10/99</td>
<td>Case not fitted correctly, seal defective</td>
</tr>
</tbody>
</table>
2 TYPES OF BOILER

Some boiler leakage is allowed because in practice it is impossible to eliminate all leaks. The amount of leakage allowed depends on the type of boiler and when it was made. Details of the different types of room sealed boiler and the permitted leakage are given in APPENDIX A, and in the report on the previous phase of work.1
3 EXPERIMENTAL METHODS

Test were performed using a Potterton Netaheat boiler, a type which has featured in the incident statistics (see Section 1.1). A photograph of the boiler with the case removed is shown as Figure 1.

![Figure 1 Potterton Netaheat with the case removed](image)

The rate of leakage was determined by sealing the flue outlet and connecting a fan and rotameter to the air inlet of the boiler. A small hole in the backplate, close to the air fan on the boiler and shown on Figure 1, was used to enable the pressure inside the boiler to be measured. A schematic diagram of the set up is shown in Figure 2. The speed of the fan could be varied, enabling the leak rate at a particular internal boiler pressure to be determined. Leaks in the boiler were simulated by

- Partially loosening the case screws and pulling the case away from the backplate.
- Placing thermocouple capillary tubes in and across the seal between the case and the backplate, as shown in Figure 3.

Thus the rate of leakage for a particular scenario could be measured.

The air inlet and flue outlet were then unblocked, a short length of pipe fitted to the flue outlet so that the flue products could be safely removed, and the boiler lit. The leakage from the boiler was then checked using the following methods:-

- Flue gas analyser
- Smoke tubes
- Smoke matches
- Internal pressure of the boiler
The first two methods were used in the previous work\(^1\), and are described there. The third method uses a smoke match which is similar in size to an ordinary match, but when struck produces smoke rather than a flame. Smoke is only produced for a few seconds, but, because the match is self-contained and small, the match can be easily and rapidly moved around the boiler.

Smoke is used to show air movement, perhaps from the leak. The flue gas analyser is used to look the presence of carbon monoxide or the depression in the concentration of oxygen due to the presence of combustion products. However, it was found beneficial to modify the flue gas analyser by using just a flexible tube, rather than the normal tube and probe assembly, so that measurement could be made in a much more precise area. This is shown in Figure 4.

Additional measurements were taken of the concentrations of oxygen and carbon monoxide in the flue products and, by using the hole through the backplate, the operating pressure of the boiler and the concentrations of oxygen and carbon monoxide in the “air” inside the boiler case could also be measured.
Figure 3  Thermocouples trapped in case seal

Figure 4  Use of a probe (as supplied) and a flexible tube with a flue gas analyser
(a) thermocouple trapped along case seal
(b) thermocouple trapped across case seal
(c) trapped thermocouple in (b) after case has been fitted
4 RESULTS

The experimental conditions and the results, such as rate of leakage and the detection of the leaks, are summarised in Table 2. The variation of internal (working) boiler pressure with leak rate is shown in Figure 5. The variation of carbon monoxide and oxygen concentration inside the boiler and in the flue products is shown in Figure 6 and Figure 7. The position of trapped thermocouples (when used) and the position of leaks together with the method used to detect them are given in Figure 8, Figure 9 and Figure 10.
Figure 6  Oxygen and carbon monoxide concentrations inside the boiler casing

Figure 7  Oxygen and carbon monoxide concentrations in the flue products
<table>
<thead>
<tr>
<th>Test no.</th>
<th>Experimental conditions</th>
<th>Leakage at 1¼ mbar</th>
<th>Boiler running pressure</th>
<th>Composition of \textquotesingle air\textquotesingle inside boiler</th>
<th>Composition of flue products</th>
<th>Leak seen by</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>m³/hr</td>
<td>mbar</td>
<td>CO ppm</td>
<td>O₂ %</td>
<td>CO ppm</td>
</tr>
<tr>
<td>1</td>
<td>Case fitted normally</td>
<td>7</td>
<td>0.9</td>
<td>1</td>
<td>20.5</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Top screws loosened by 1½ turns</td>
<td>7</td>
<td>0.95</td>
<td>0</td>
<td>20.7</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>Top screws loosened by 3 turns</td>
<td>16</td>
<td>0.85</td>
<td>0</td>
<td>20.8</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>Top screws loosened by 4½ turns</td>
<td>32</td>
<td>0.6</td>
<td>1</td>
<td>20.8</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>Top screws loosened by 6 turns</td>
<td>45</td>
<td>0.5</td>
<td>1</td>
<td>20.8</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Top screws loosened by 6 turns</td>
<td>64</td>
<td>0.4</td>
<td>1</td>
<td>20.8</td>
<td>150</td>
</tr>
<tr>
<td>7</td>
<td>Bottom screws loosened by 3 turns</td>
<td>8</td>
<td>0.8</td>
<td>1</td>
<td>20.8</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Bottom screws loosened by 6 turns</td>
<td>71</td>
<td>0.6</td>
<td>120</td>
<td>20.8</td>
<td>14000</td>
</tr>
<tr>
<td>9</td>
<td>All screws loosened by 3 turns</td>
<td>12</td>
<td>0.7</td>
<td>2</td>
<td>20.2</td>
<td>32</td>
</tr>
<tr>
<td>10</td>
<td>Top screws loosened by 6 turns, bottom screws loosened by 3 turns</td>
<td>50</td>
<td>0.5</td>
<td>3</td>
<td>20.7</td>
<td>61</td>
</tr>
<tr>
<td>11</td>
<td>All screws loosened by 6 turns</td>
<td>90</td>
<td>0.5</td>
<td>250</td>
<td>20.6</td>
<td>12700</td>
</tr>
<tr>
<td>12</td>
<td>Top screws loosened by 3 turns, bottom screws loosened by 6 turns</td>
<td>50</td>
<td>0.65</td>
<td>100</td>
<td>20.8</td>
<td>9000</td>
</tr>
<tr>
<td>13</td>
<td>Thermocouple tube trapped in case seal repeat</td>
<td>9</td>
<td>1.2</td>
<td>2</td>
<td>20.6</td>
<td>150</td>
</tr>
<tr>
<td>13a</td>
<td>Thermocouple tube trapped in case seal repeat</td>
<td>9</td>
<td>1.15</td>
<td>2</td>
<td>20.6</td>
<td>130</td>
</tr>
<tr>
<td>14</td>
<td>Thermocouple tube trapped in case seal</td>
<td>9</td>
<td>1.1</td>
<td>1</td>
<td>20.6</td>
<td>65</td>
</tr>
<tr>
<td>15</td>
<td>Thermocouple tube trapped in case seal</td>
<td>7</td>
<td>1.15</td>
<td>1</td>
<td>20.5</td>
<td>66</td>
</tr>
<tr>
<td>16</td>
<td>Thermocouple tube trapped in case seal</td>
<td>9</td>
<td>0.8</td>
<td>1</td>
<td>20.7</td>
<td>21</td>
</tr>
<tr>
<td>17</td>
<td>Thermocouple tube trapped in case seal</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>20.6</td>
<td>17</td>
</tr>
<tr>
<td>18</td>
<td>2 x Thermocouple tube trapped in case</td>
<td>9</td>
<td>1.15</td>
<td>0</td>
<td>20.6</td>
<td>35</td>
</tr>
<tr>
<td>19</td>
<td>Thermocouple tube trapped through case</td>
<td>41</td>
<td>0.7</td>
<td>110</td>
<td>20.7</td>
<td>7500</td>
</tr>
</tbody>
</table>
Figure 8  Location of detected leaks on the boiler, Tests 1 - 8

Leak seen with smoke tubes
Leak seen with smoke matches
Leak seen with flue gas analyser
Figure 9 Location of detected leaks and trapped thermocouples on the boiler, Tests 9 - 15

- Leak seen with smoke tubes
- Leak seen with smoke matches
- Leak seen with flue gas analyser
- Position of thermocouple trapped in seal
Figure 10  Location of detected leaks and trapped thermocouples on the boiler, Tests 16 - 19

Leak seen with smoke tubes
Leak seen with smoke matches
Leak seen with flue gas analyser

Position of thermocouple trapped in seal
Position of thermocouple trapped through seal
5 DISCUSSION

During the tests the concentration of carbon monoxide and oxygen were measured both inside the boiler and the flue (see Figure 6 and Figure 7). None of these measurements gave a consistent response to the rate of leakage and thus potential hazard. The pressure inside the boiler was also measured (see Figure 5). A trend can be clearly seen. However the change in pressure is low (a few tenths of a millibar), a pressure test point would have to be made on the backplate, and the previous work\(^1\) showed that (partial) obstruction of the flue or air intake could also affect the internal pressure. These methods do not therefore seem suitable.

Smoke can be used to show the air movement produced by a leak. Smoke pellets produce a lot of smoke, and often obscure rather than enhance observation of such movement. Smoke tubes and / or smoke matches could be used so that the smoke is delivered more accurately. A small leak could be seen with either method as shown in Figure 11. Most of the smoke can be seen dispersing into the atmosphere, but some is taken by the flow from the leak to the left, just above the top of the boiler case. When no leak is present the smoke just disperses randomly, as shown in Figure 12.

![Figure 11](image1.png) \[a\] ![Figure 11](image2.png) \[b\]

Figure 11 Smoke tube (a) and smoke match (b) showing a small leak

![Figure 12](image3.png)

Figure 12 Smoke tube with no leak present

At the bottom of the boiler the control electronics prevented direct access to the case seal, as shown in Figure 13. However the smoke tubes were able to be positioned to clearly show the presence of a leak. The leak was also seen with smoke matches, but rather less clearly.
Figure 14 shows smoke pellets used to detect a leak. In Figure 14(a) a small leak, easily detected with smoke tubes or smoke matches, is present. There is no clear definition of the leak using smoke pellets. In Figure 14(b) the same leak as in Figure 13 can be detected by the smoke movement. However the leak is much more clearly seen in Figure 13.

Smoke matches produce a much more easily controlled source of smoke, although deposits from combustion of the match may be left on the boiler case, as shown in Figure 15. Similar marks may be left by the combustion of smoke pellets, but they are normally used at a greater distance from appliances. The smoke produced by both smoke matches and pellets may also leave a lingering odour.

Smoke tubes produce smoke when air is passed over crystalline material in the tubes. This smoke is slightly acidic, but does not stain the appliance and is only produced when required, unlike smoke pellets and matches which produce smoke until all the material is consumed. The effect of the smoke on smoke alarms has not been investigated.

The flue gas analyser was used to detect either the presence of carbon monoxide or the reduction in the concentration of oxygen due to leakage from the boiler. As can be seen from Figure 6, the air inside the boiler case was hardly contaminated by combustion products until serious leaks had developed, and so the presence of a leak was often indicated by only a small change in the reading on the flue gas analyser. However, when the leak was near the bottom of the appliance (near the burner) the concentration changes seen by the flue gas analyser were sometimes greater than the boiler “air” measurements indicated. This enhancement was useful as it was only possible to use the flue gas analyser probe some distance from the case seal because of the control electrics at the bottom of the boiler.
Additional practical measures for checking that the case has been replaced properly are given below:

- Are the screws holding the case tight?
- Is the case seated properly –
  - Is a “tide mark” showing the old position of the case visible?
  - Is an untarnished part of the case securing screws visible?

![Figure 14](image) Use of smoke pellets to show leaks

![Figure 15](image) Stains on boiler case caused by smoke matches

A checklist which might be used by service engineers is shown as APPENDIX B.
6 TRIALS AND SUGGESTED MODIFICATIONS TO THE PROPOSED PROCEDURES

6.1 TRIALS

The original intention was to trial the detection methods in the "field", at domestic premises. However, when several gas installation/service companies were approached, they were not able to identify where positive pressure room-sealed appliances could be found. It was also thought that, where they may be found, leakage test could provide a 100% negative result, i.e. no leaks found, because the seals were made correctly. This would not prove the methods were appropriate, only the detection of leaks would. Therefore it was decided to trial the methods in a controlled environment, where leaks could be simulated.

A total of 20 CORGI registered engineers, familiar with the servicing of gas boilers undertook the procedures (see APPENDIX B). In addition, comments were obtained from people without the CORGI certification but familiar with boiler servicing.

The case of the boiler was removed and the electrical control panel at the bottom of the boiler was allowed to rotate downwards to allow access to the case fastening screws. The boiler case and seal was examined, as suggested in the procedures. Although many engineers commented on the seal being compressed, very few would have replaced that particular seal on visual inspection alone. The case was put back on and the boiler started. The various methods suggested in the procedures were tried (flue gas analyser, smoke match and smoke tube). Additional methods employed by some engineers were standard matches, a lit taper (a long, thin candle) and feeling for a draught with the back of the hand.

The air inlet to the boiler was then obstructed. Because the boiler was not able to get sufficient air for complete combustion the amount of carbon monoxide produced increased considerably.

A summary of the Service Engineers comments is shown in Table 3, and copies of the actual sheets in APPENDIX C. Some verbal comments were also made. These are summarised below

- Smoke tubes seem effective at showing small leaks
- Smoke tubes are much easier to use than a smoke match
- Are smoke tubes sufficiently robust to be carried round in a tool box
- The smell of the smoke from smoke matches lingers, and is not popular with the householder
- The lack of effectiveness of the flue gas analyser in detecting leaks unless the boiler air supply was restricted was commented on by several service engineers.

The disposal of the chemicals used in the smoke tubes was thought to be a problem by British Gas Services (see Data Sheet, APPENDIX D).
The Telegan did not register the leak which was picked up by the smoke tube and matches. Was this because it was detecting air rather than flue gas emissions?

I was impressed to note that a small spillage was detected using the glass [smoke] tube. Before, using conventional methods, I would have passed the appliance. But having used the glass tube I would have changed the seal on the boiler casing.

<table>
<thead>
<tr>
<th>Service Engineer, Company, date</th>
<th>Were the procedures clear?</th>
<th>Were the procedures easy to use?</th>
<th>Was a leak detected?</th>
<th>Which method was most successful?</th>
<th>Are there better methods for finding these leaks?</th>
<th>How often do you find leaks in seals?</th>
<th>Please give other comments on the procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Len Eastell, Advantica, 20th July 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>Sometimes a naked flame on a long wax taper can be used. It is disturbed quite easily by a leak</td>
<td>n/a</td>
<td>The Telegan did not register the leak which was picked up by the smoke tube and matches. Was this because it was detecting air rather than flue gas emissions?</td>
</tr>
<tr>
<td>D. Hartlebury, Certification Services, 26th July 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube and smoke match</td>
<td>No</td>
<td>4 - 6 services</td>
<td>Start with case on</td>
</tr>
<tr>
<td>D. Shipman, Certification Services, 26th July 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>Probably not</td>
<td>Frequently</td>
<td>-</td>
</tr>
<tr>
<td>Paul Greenwood, William Freer, 26th July 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Not very often</td>
<td>I was impressed to note that a small spillage was detected using the glass [smoke] tube. Before, using conventional methods, I would have passed the appliance. But having used the glass tube I would changed the seal on the boiler casing.</td>
</tr>
<tr>
<td>Service Engineer, Company, date</td>
<td>Were the procedures clear?</td>
<td>Were the procedures easy to use?</td>
<td>Was a leak detected?</td>
<td>Which method was most successful?</td>
<td>Are there better methods for finding these leaks?</td>
<td>How often do you find leaks in seals?</td>
<td>Please give other comments on the procedures</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>---------------------</td>
<td>----------------------------------</td>
<td>-----------------------------------------------</td>
<td>---------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Steve Goldthorpe, British Gas Services, 9th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>Yes, I believe a lit match would be better</td>
<td>Not often, but most boilers negative pressure and no problem</td>
<td>-</td>
</tr>
<tr>
<td>John Moseley, British Gas Services, 9th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>? Use of standard match</td>
<td>-</td>
<td>Comments made on &quot;Procedures&quot; sheet. See Figure C7</td>
</tr>
<tr>
<td>A.J. Swann, T.M.S., 9th August 2001</td>
<td>Very clear</td>
<td>Smoke match was difficult to use successfully around seal</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>Not that I'm aware of</td>
<td>Quite often, but only by means of visual check</td>
<td>The by far most successful method is the smoke tube, the only drawback is that accurate measurement of what products of combustion are coming out cannot be taken. RWH - Are smoke tubes sufficiently robust</td>
</tr>
<tr>
<td>Steve Harrison, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>Not that I'm aware of</td>
<td>Replace seals when required, around 5%</td>
<td>Found procedures informative and helpful for future situations with this type of boiler</td>
</tr>
<tr>
<td>Richard Bates, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Replace seals when required, around 5% of the time</td>
<td>Smoke tube was most successful due to casing seals proving to be in good condition but the smoke test finding spillage from casing</td>
</tr>
<tr>
<td>Service Engineer, Company, date</td>
<td>Were the procedures clear?</td>
<td>Were the procedures easy to use?</td>
<td>Was a leak detected?</td>
<td>Which method was most successful?</td>
<td>Are there better methods for finding these leaks?</td>
<td>How often do you find leaks in seals?</td>
<td>Please give other comments on the procedures</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------</td>
<td>----------------------------------</td>
<td>---------------------</td>
<td>----------------------------------</td>
<td>---------------------------------</td>
<td>---------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>Dave Whitehead, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke match or tube</td>
<td>No</td>
<td>Rarely</td>
<td>-</td>
</tr>
<tr>
<td>Anthony Pass, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Not very often</td>
<td>-</td>
</tr>
<tr>
<td>Anthony Taylor, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>Match</td>
<td>Very few</td>
<td>-</td>
</tr>
<tr>
<td>Dave Harris, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>Match</td>
<td>Very few</td>
<td>-</td>
</tr>
<tr>
<td>Anthony Ames, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Very rarely</td>
<td>I found the tests we did were very good for safer servicing</td>
</tr>
<tr>
<td>Jim Norman, William Freer Ltd, 13th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Very rarely</td>
<td>Very good</td>
</tr>
<tr>
<td>Robert Baxter, William Freer Ltd, 14th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>10% - 20%</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3  
(continued)

<table>
<thead>
<tr>
<th>Service Engineer, Company, date</th>
<th>Were the procedures clear?</th>
<th>Were the procedures easy to use?</th>
<th>Was a leak detected?</th>
<th>Which method was most successful?</th>
<th>Are there better methods for finding these leaks?</th>
<th>How often do you find leaks in seals?</th>
<th>Please give other comments on the procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Flynn, William Freer Ltd, 14th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>15%</td>
<td>-</td>
</tr>
<tr>
<td>Dave Parnell, William Freer Ltd, 14th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Quite often</td>
<td>Although all procedures detected leaks, far clearer was the smoke tube</td>
</tr>
<tr>
<td>Stuart Whitehead, William Freer Ltd, 14th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Quite often</td>
<td>Smoke tube was a lot better than smoke matches we use. Good information for checking Boilers Seals</td>
</tr>
<tr>
<td>Trevor Reavenall, William Freer Ltd, 14th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Rarely</td>
<td>-</td>
</tr>
<tr>
<td>Brian Tester, William Freer Ltd, 14th August 2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Smoke tube</td>
<td>No</td>
<td>Not often</td>
<td>-</td>
</tr>
</tbody>
</table>
6.2 DISCUSSION

6.2.1 Flue Gas Analyser

The flue gas analyser detected most leaks. However the gas ejected from the leaks is mainly air, and combustion products (carbon monoxide and carbon dioxide) are only present in low concentrations unless combustion inside the boiler is poor. Thus the leak may be detected, but the change in reading of the analyser is very small, and could be masked by drift in the reading of instrument. However, when combustion was poor (caused by, for example, restricting the air inlet to the boiler) concentration of several hundred ppm were recorded at the site of the same leaks.

6.2.2 Smoke Matches

A smoke match ejects smoke with some force, which may mask the movement of air caused by a leak. However most leaks could be detected with this method. Because each match only lasts for few seconds, several were required to inspect the seal. The smoke from the matches goes into the room, and produces a lingering smell. This may not be popular with the occupier.

The cost per match is only a few pence.

6.2.3 Smoke tubes

Although the most sensitive and easiest method to use used smoke tubes, disposal of the tubes may present problems, and there may possible hazards when in use. New tubes have been produced, but they still present disposal problems, and they are more expensive than other methods.

An extract from the Data Sheet on the tubes is shown in APPENDIX D. The smoke produced by the new smoke tubes is either based on sulphur trioxide or the reaction between ethylenediamine and acetic acid (to produce non corrosive smoke). The manufacturers state that

“The residues left in both types of tube are highly acrid and should be disposed of as special waste. There are no hazards presented by mere use of the tubes.”

The initial cost for a smoke tube kit includes the aspirator bulb for blowing air through the tube. Thereafter tubes can be bought in packs of 10 or twelve, at a cost for each tube of about £1.50 (sulphur trioxide based) or about £7 (non corrosive smoke). However as the tubes may be resealed and used at a later time, the cost per boiler may be lower.

6.2.4 Naked flames

The simplest method used the movement of a flame from an ordinary match. This showed leaks well and produced little odour. However access to confined locations may be difficult. A wax taper may be better because the flame lasts much longer, is more steady burning, and the length of the taper allows it to be placed in otherwise inaccessible positions. Little odour is produced, although some molten wax may be dropped.

Matches are very cheap. Wax tapers are more expensive, but still cost only a few pence per boiler.
7 RECOMMENDATIONS

A visual and tactile inspection before the case is put back on may show that the case or seal needs attention. However leaks may occur even if the condition of the seal and the case seems satisfactory. The effectiveness of various methods in detecting these leaks is summarised below.

Smoke tubes, smoke matches, ordinary matches or a wax taper can be used to successfully show a leak, even when combustion products are not present in the ejected gas.

- Smoke tubes are the easiest to use, but contain noxious chemicals and are the most expensive method.
- Smoke matches are cheaper, but they produce smoke forcefully which may obscure a leak. The smoke matches also leave a lingering odour.
- Ordinary matches are much cheaper but still show most leaks. Ordinary matches, or a cigarette lighter or other source of a similar flame are almost certainly in the toolbag of a boiler engineer. Wax tapers may be slightly better at detecting leaks, but less likely to be carried. These two methods, using a naked flame, have the fewest drawbacks.

A flue gas analyser detected most leaks in the laboratory. However the concentrations of combustion products detected were often very small, and could easily be mistaken for, or obscured by, instrument drift. This method cannot be recommended for finding leaks in seals.

The procedures for checking for leaks have therefore been revised, and are shown in APPENDIX E. The modifications made to the original procedures are shown in APPENDIX F.
8 REFERENCES


2. BS 5258-1:1986 Safety of domestic gas appliances. Specification for central heating boilers and circulators

3. BS EN 483:2000 Gas-fired central heating boilers. Type C boilers of nominal heat input not exceeding 70 kW
   BS EN 625:1996 Gas-fired central heating boilers. Specific requirements for the domestic hot water operation of combination boilers of nominal heat input not exceeding 70 kW
   BS EN 677:1998 Gas-fired central heating boilers. Specific requirements for condensing boilers with a nominal heat input not exceeding 70 kW
APPENDIX A WHY SOME LEAKAGE IS ALLOWED

To understand why leakages are allowed and why the amount of leakage allowed varies in terms of the way standards have been written one has to study the previous and recent standards and evaluate the levels permitted for different types of boilers.

All domestic appliances are classified into the three main types according to their flue systems and the source of combustion air:

- **Type A** - Flueless appliances.
- **Type B** - Open-flued appliances. These can be natural draught, fan-powered with draught diverters, fan–powered without draught diverters and fan-powered with integral fan in the secondary flue, Figure A1.
- **Type C** - Room sealed appliances. These can be balanced-flued or se-duct appliances, (either natural draught or fan-powered), Figure A2.

![Figure A1 Natural draught type B appliance with draught diverter](image)
Figure A2 Type C room sealed appliances
Table A1 briefly summarises the main provisions for permitted leakages detailed in the old and new boiler standards. Old boilers such as Potterton Netaheat, which were built before 1995, had to comply with the old standards whereas newer boilers have to comply with BS/EN standards. The terminology concentric and separate pipe refers to the position of the combustion products pipes relative to the fresh air supply. Figure A3 – Separate pipes means the combustion and the fresh air supply are completely separate. Figure A4 - Concentric pipes refers to where the combustion products duct is surrounded by the fresh air supply.

A small amount of leakage is permitted from the seals, case, and flue of room-sealed appliances. The amount depends on the type of boiler and its age. Leakage is allowed simply because there is always some leakage and it is not practical or realistic to achieve zero leakage.

A small, entirely safe, amount of leakage is permitted in recognition of the methods of construction, which use folded metal seams, non-airtight gaskets and sliding fits (for the ducts) secured with tape. Wires and pipes also have to pass through the appliance enclosure and also the appliance must be capable of being dismantled from within the room, for servicing. All of these are necessary to meet the standards, for safety reasons, but complete air tightness is virtually impossible.
Room sealed appliances (type C) are inherently much safer from burnt gas hazards than the open flue appliances (type B) and for decades have proven this advantage in terms of much lower numbers of burnt gas incidents. Historically, leakage tests for natural draught appliances would have been written around what was practical in manufacturing. As techniques changed, safety expectations have increased, such tests have been ‘tightened up’.
Table A1  Summary of permitted leakage

<table>
<thead>
<tr>
<th>Type</th>
<th>Older (BS) standard</th>
<th>Current (BS/EN) standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pressure (mbar)</td>
<td>Pressure (m²/hr/kW)</td>
</tr>
<tr>
<td>Natural draught</td>
<td>1¼ mbar</td>
<td>½ mbar in combustion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>product circuit</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.6 (appliance)</td>
</tr>
<tr>
<td>Concentric flue</td>
<td>1¼ mbar</td>
<td>½ mbar in combustion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>product circuit</td>
</tr>
<tr>
<td>Separate pipes</td>
<td>1¼ mbar</td>
<td>½ mbar in combustion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>product circuit</td>
</tr>
<tr>
<td>Fan on flue outlet</td>
<td>1¼ mbar</td>
<td>½ mbar in combustion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>product circuit</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.6 (appliance)</td>
</tr>
<tr>
<td>Concentric flue</td>
<td>1¼ mbar</td>
<td>½ mbar in combustion</td>
</tr>
<tr>
<td>Separate pipes</td>
<td>1¼ mbar</td>
<td>½ mbar in combustion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>product circuit</td>
</tr>
<tr>
<td>Fan elsewhere in boiler</td>
<td>1¼ mbar</td>
<td>½ mbar in combustion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>product circuit</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.6 (appliance)</td>
</tr>
<tr>
<td>Concentric flue</td>
<td>1¼ mbar</td>
<td>working pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+½ mbar in combustion</td>
</tr>
<tr>
<td>Separate pipes</td>
<td>1¼ mbar</td>
<td>product circuit</td>
</tr>
</tbody>
</table>

Notes: Working pressure is determined by fitting the manufacturers stated maximum length of flue to the appliance, and measuring the pressure developed.

2. BS EN 483:2000 Gas-fired central heating boilers. Type C boilers of nominal heat input not exceeding 70 kW.
   BS EN 625:1996 Gas-fired central heating boilers. Specific requirements for the domestic hot water operation of combination boilers input not exceeding 70 kW.
   BS EN 677:1998 Gas-fired central heating boilers. Specific requirements for condensing boilers with a nominal heat input not
APPENDIX B ORIGINAL CHECKLIST FOR USE BY A SERVICE ENGINEER (SEPARATE SHEETS)

A checklist has been produced to check the boilers. For use in the field it has been split into two A4 sheets and an A5 sheet, as shown in Figure B1, Figure B2 and Figure B3. The A3 sheet is shown as Figure B4.

1. **Before the case is put back on**
   - Is the backplate or the case distorted or damaged. Pay particular attention to the area where the case and seal meet.
   - Is the case seal intact and in good condition?
   - Is anything trapped in it?
     - Is anything likely to be trapped when the case is put back on?
       - Wires
       - Thermocouple capillaries
       - Tubes
   - Are other gaskets and seals intact?
   - Are the case screws and lugs in good condition?
     - Screws stripped
     - Lugs bent or damaged
   - Are there any signs of discolouration which may have been caused by leaks from the boiler?

2. **When the case has been put on**
   - Is the case on properly?
   - Is a “tide mark” visible showing that the case had previously been fitted closer to the backplate?
   - Is a bright area visible on the screw thread of any of the case securing screws, showing that the screw used to be done up more tightly. Is the screw done up properly?
   - Is anything trapped and showing through the seal?

3. **Light the boiler**
   - If possible check the composition of the flue gases. Typical readings are 7 – 12% oxygen, and less than 100ppm carbon monoxide.
   - Check for leakage from the boiler, ensuring that the main burner remains lit (e.g. set the boiler and room thermostats to the highest setting).

---

Figure B1  First sheet
Use a Flue Gas Analyser

Put a flexible tube (rather than the supplied probe assembly) on the flue gas analyser. Start the analyser in clean air and note the readings. Place the open end of the tube next to the case seal of the boiler. Do the concentrations of oxygen or carbon monoxide alter? (The analyser may take at least 30 seconds to respond). Move the tube slowly round the boiler looking for any changes in the readings. To investigate the seal at the bottom of the case – place the tube between the bottom of the case and the electrical control panel. DO NOT USE A METAL PROBE.

Using Smoke tubes

Place the end of the tube as close as possible to the join between the case and the backplate. Eject smoke slowly. Does it drift randomly away, or is it taken by air flowing from the case? Repeat around the seal. To investigate the seal at the bottom of the case – place the end of the tube between the bottom of the case and the electrical control panel. Eject a lot of smoke. Does it drift randomly away, or is it taken by air flowing from the case?

Using smoke matches

Strike the match and then hold it as close as possible to the join between the case and the backplate. Does the smoke drift slowly away, or is it taken by air flowing from the case? Move the match around the seal as required. To investigate the seal at the bottom of the case – hold the match between the bottom of the case and the electrical control panel. Does the smoke drift slowly away, or is it taken by air flowing from the case? Try a match in several positions.

4. Back of boiler, flue, and around pilot inspection glass

Leaks may also occur around the seals and gaskets elsewhere on the boiler. The pilot inspection glass on the front of the case can be inspected in the same way as the case seal. The backplate of the boiler has tubes, wires and bolts passing through. In addition the flue assembly is connected to the back of the boiler. The back of the boiler is less accessible than the front, making it difficult to use a flue gas analyser or smoke matches in some locations. The back of the boiler becomes hot during use. Do not confuse natural convection with a leak.
1. Before the case is put back on

Rectify if necessary and proceed to 2

2. When the case has been put on

3. Light the boiler

Use a Flue Gas Analyser

If there is, or appears to be, a leak the boiler should be turned off and a visual inspection made. Any faults should be rectified and the procedure repeated from 2

4. Back of boiler, flue, and around pilot inspection glass

If no faults are apparent the case should be removed and the procedure repeated from 1

Will a new case seal cure the problem?

If the boiler still leaks Gas Industry Unsafe Procedures should be followed

Boiler working safely

Figure B3
1. **Before the case is put back on**
   - Is the backplate or the case distorted or damaged. Pay particular attention to the area where the case and seal meet.
   - Is the case seal intact and in good condition?
   - Is anything trapped in it?
     - Is anything likely to be trapped when the case is put back on?
     - Wires
     - Thermocouple capillaries
     - Tubes
   - Are other gaskets and seals intact?
   - Are the case screws and lugs in good condition?
   - Screws stripped
   - Lugs bent or damaged
   - Are there any signs of discolouration which may have been caused by leaks from the boiler?
   - Rectify if necessary and proceed to 2

2. **When the case has been put on**
   - Is the case on properly?
   - Is a “tide mark” visible showing that the case had previously been fitted closer to the backplate.
   - Is a bright area visible on the screw thread of any of the case securing screws, showing that the screw used to be done up more tightly. Is the screw done up properly?
   - Is anything trapped and showing through the seal?

3. **Light the boiler**
   - If possible check the composition of the flue gases. Typical readings are 7 – 12% oxygen, and less than 100ppm carbon monoxide.
   - Check for leakage from the boiler, ensuring that the main burner remains lit (e.g. set the boiler and room thermostats to the highest setting).
   - Use a Flue Gas Analyser
     - Put a flexible tube (other than the supplied probe assembly) on the flue gas analyser. Start the analyser in clean air and note the readings. Place the open end of the tube next to the case seal of the boiler. Do the concentrations of oxygen or carbon monoxide alter? The analyser may take at least 30 seconds to respond. Move the tube slowly round the boiler looking for any changes in the readings. To investigate the seal at the bottom of the case – place the tube between the bottom of the case and the electrical control panel. Do NOT USE A METAL PROBE.
   - Using Smoke tubes
     - Place the end of the tube as close as possible to the join between the case and the backplate. Eject smoke slowly. Does it drift randomly away, or is it taken by air flowing from the case? Repeat around the seal.
     - To investigate the seal at the bottom of the case – place the end of the tube between the bottom of the case and the electrical control panel. Eject a lot of smoke. Does it drift randomly away, or is it taken by air flowing from the case?
   - Using Smoke matches
     - Strike the match and then hold it as close as possible to the join between the case and the backplate. Does the smoke drift slowly away, or is it taken by air flowing from the case? Move the match around the seal, using fresh matches as required. To investigate the seal at the bottom of the case – hold the lit match between the bottom of the case and the electrical control panel. Does the smoke drift slowly away, or is it taken by air flowing from the case? Try the match in several positions.

4. **Back of boiler, flue, and around pilot inspection glass**
   - Leaks may also occur around the seals and gaskets elsewhere on the boiler. The pilot inspection glass on the front of the case can be inspected in the same way as the case seal. The backplate of the boiler has tubes, wires and bolts passing through. In addition the flue assembly is connected to the back of the boiler. The back of the boiler is less accessible than the front, making it difficult to use a flue gas analyser or smoke matches in some locations. The back of the boiler becomes hot during use. Do not confuse natural convection with a leak.
   - If there is, or appears to be, a leak the boiler should be turned off and a visual inspection made.
   - Any faults should be corrected and the procedure repeated from 2
   - If no faults are apparent the case should be removed and the procedure repeated from 1
   - Will a new case seal cure the problem?
   - If the boiler still leaks Gas Industry Unsafe Procedures should be followed
   - Boiler working safely

---

Figure B4
APPENDIX D EXTRACT FROM DATA SHEET ON SMOKE TUBES

MSA Smoke Generators

Applications
The MSA Smoke Generators produce a dense smoke that is carried along by the slightest current thus indicating the flow pattern. The Smoke Generators are suited for the following applications:

• Check of air-conditioners and ventilating equipment
• For tracing leaks in tubes, furnaces, windows
• To check airflows in mining
• For function test of exhausters
• To check current of air at home or at workplace

Description
The MSA Smoke Generators consist of a mechanical or electric smoke pump and a smoke tube or smoke cartridge depending on the required quantity of smoke.

The smoke producing chemical sulfur trioxide is on a carrier material safely enclosed in a glass tube. For use both tips of the glass tube are broken off. In case of Ventilation Smoke Tubes the smoke producing chemical is ethylenediamine and acetic acid therefore generated smoke is non corrosive.

The chemicals are on carrier materials separated in two glass ampoules which are fixed in a plastic tube. The user must crash the ampoules by bending the plastic tube.

All MSA Smoke Generators are inserted into manual pumps or the Toximeter II in use as electric smoke pump. The air flow through the tube develops dense white smoke.

There are three types of smoke generators:

Smoke tube
The smoke tube consists of a glass tube, approx. 125 mm long, diameter 7.5 mm. The produced smoke is based on sulfur trioxide.

Smoke cartridge
The smoke cartridge has a diameter of 24 mm and develops 10 times more smoke than the smoke tube. The produced smoke is based on sulfur trioxide.

Ventilation smoke tube
Two ampoules in plastic tube approx. 125 mm long, diameter approx. 12 mm. Produced smoke is based on neutralization of acetic acid and ethylenediamine. In factory sealed condition smoke tubes and smoke cartridges can be stored or years.

Manual pump
The manual pump is a mechanical smoke pump, consisting of a plastic ball and a connection hose. With the hand pump both smoke tubes and smoke cartridges can be used. The smoke tube or the smoke cartridge is connected to the connection hose; the hand pump blows air through the tube. The rubber aspirator bulb is especially or Ventilation Smoke Tubes it can be operated with one hand.

Electric Smoke pump
MSA Toximeter II is an electronically controlled, automatic Detector Tube, Sampling and Smoke Pump. The Toximeter II produces smoke with a constant flow of approx. 300 ml/min with all types of smoke generators. The time of smoke generation is up to 25 minutes with a Smoke Tube, up to 10 minutes with a Ventilation Smoke Tube and up to 100 minutes when a Smoke Generation Cartridge is used.

Toximeter II is powered by a rechargeable NiCd-battery. Toximeter II is Ex-protected/intrinsically safe. The operating time for one battery charge is approx. 8 hours.

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Fax +49 [30] 6886-1517
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Fax +44 [0] 1236 440881
E-mail info@msabritain.co.uk
Subject to change without notice
08-620.2 ITL5.14.01/S
1. Before the case is put back on
   Rectify if necessary and proceed to 2

2. When the case has been put on

3. Light the boiler
   Using a Naked Flame
   Using Smoke tubes
   Using Smoke matches

4. Back of boiler, flue, and around pilot inspection glass
   If there is, or appears to be, a leak the boiler should be turned off and a visual inspection made.
   Any faults should be corrected and the procedure repeated from 2
   If no faults are apparent the case should be removed and the procedure repeated from 1
   Will a new case seal cure the problem?

If the boiler still leaks Gas Industry Unsafe Procedures should be followed

Boiler working safely

Figure E1 Summary (A5 sheet)
1. **Before the case is put back on**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there any water leaks?</td>
<td></td>
</tr>
<tr>
<td>Are the combustion chamber linings intact?</td>
<td></td>
</tr>
<tr>
<td>Is the backplate or the case distorted or damaged. Pay particular attention to the area where the case and seal meet.</td>
<td></td>
</tr>
<tr>
<td>Is the backplate or case corroded. Is the corrosion likely to affect the integrity of the case, backplate, or seal.</td>
<td></td>
</tr>
<tr>
<td>Is the case seal intact and in good condition? (e.g. pliable, free from discolouration and trapped particles.) Will it form a seal between the case and the backplate?</td>
<td></td>
</tr>
<tr>
<td>Is anything trapped in it?</td>
<td></td>
</tr>
</tbody>
</table>

Rectify if necessary and proceed to **2**

2. **When the case has been put on**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the case on properly?</td>
<td></td>
</tr>
<tr>
<td>Is a “tide mark” visible showing that the case had previously been fitted closer to the backplate</td>
<td></td>
</tr>
<tr>
<td>Is a bright area visible on the screw thread of any of the case securing screws,</td>
<td></td>
</tr>
<tr>
<td>showing that the screw used to be done up more tightly. Is the screw done up properly?</td>
<td></td>
</tr>
<tr>
<td>Is anything trapped and showing through the seal</td>
<td></td>
</tr>
</tbody>
</table>

3. **Light the boiler**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>If possible check the composition of the flue gases. Typical readings are 7 - 12% oxygen, and less than 100ppm carbon monoxide</td>
<td></td>
</tr>
<tr>
<td>Check for leakage from the boiler (see second sheet), ensuring that the main burner remains lit (i.e. set the boiler and room thermostats to the highest setting).</td>
<td></td>
</tr>
</tbody>
</table>

4. **Back of boiler, flue, and around pilot inspection glass**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaks may also occur around the seals and gaskets elsewhere on the boiler. The pilot inspection glass on the front of the case can be inspected in the same way as the case seal. The backplate of the boiler has tubes, wires and bolts passing through. In addition the flue assembly is connected to the back of the boiler. The back of the boiler is less accessible than the front, making it difficult to use a flue gas analyser or smoke matches in some locations. The back of the boiler becomes hot during use. Do not confuse natural convection with a leak.</td>
<td></td>
</tr>
</tbody>
</table>

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**Figure E2** Details, first A4 sheet
### Using a Naked Flame

Use a match, or a wax taper, or similar. A taper can be used to get into less accessible locations.

Light the match / taper, and allow the flame to establish. Move the flame very close to the seal or suspected leak. The flame is blown quite easily by the draught from a leak. Use fresh matches as required.

**DO NOT** look for a gas leak with this method.

**DO NOT** set fire to the boiler.

### Using Smoke tubes

Place the end of the tube as close as possible to the join between the case and the backplate. Eject smoke slowly. Does it drift randomly away, or is it taken by air flowing from the case? Repeat around the seal. To investigate the seal at the bottom of the case – place the end of the tube between the bottom of the case and the electrical control panel. Eject a lot of smoke. Does it drift randomly away, or is it taken by air flowing from the case?

### Using Smoke matches

Strike the match and then hold it as close as possible to the join between the case and the backplate. Does the smoke drift slowly away, or is it taken by air flowing from the case? Move the match around the seal, using fresh matches as required. To investigate the seal at the bottom of the case – hold the lit match between the bottom of the case and the electrical control panel. Does the smoke drift slowly away, or is it taken by air flowing from the case? Try the match in several positions.
1. **Before the case is put back on**
   - Are there any water leaks?
   - Are the combustion chamber linings intact?
   - Is the backplate or the case distorted or damaged. Pay particular attention to the area where the case and seal meet.
   - Is the backplate or case corroded. Is the corrosion likely to affect the integrity of the case, backplate, or seal.
   - Is the case seal intact and in good condition? (e.g. pliable, free from discoloration and trapped particles.) Will it form a seal between the case and the backplate?
   - Is anything trapped in it?
   - Is anything likely to be trapped when the case is put back on?
   - Wires
   - Thermocouple capillaries
   - Tubes
   - Are other gaskets and seals intact?
   - Are the case fastenings and fixings in good condition?
   - Screws stripped
   - Lugs bent or damaged

   **Rectify if necessary and proceed to 2**

2. **When the case has been put on**
   - Is the case on properly?
   - Is a "tide mark" visible showing that the case had previously been fitted closer to the backplate
   - Is a bright area visible on the screw thread of any of the case securing screws, showing that the screw used to be done up more tightly. Is the screw done up properly?
   - Is anything trapped and showing through the seal

3. **Light the boiler**
   - If possible check the composition of the flue gases. Typical readings are 7 - 12% oxygen, and less than 100ppm carbon monoxide
   - Check for leakage from the boiler, ensuring that the main burner remains lit (i.e. set the boiler and room thermostats to the highest setting).

   **Use a Naked Flame**
   - Use a match, or a wax taper, or similar. A taper can be used to get into less accessible locations.
   - Light the match / taper, and allow the flame to establish. Move the flame very close to the seal or suspected leak. The flame is blown quite easily by the draught from a leak. Use fresh matches as required.
   - DO NOT look for a gas leak with this method.
   - DO NOT set fire to the boiler.

   **Using Smoke tubes**
   - Place the end of the tube as close as possible to the join between the case and the backplate. Eject smoke slowly. Does it drift randomly away, or is it taken by air flowing from the case? Repeat around the seal. To investigate the seal at the bottom of the case – place the end of the tube between the bottom of the case and the electrical control panel. Eject a lot of smoke. Does it drift randomly away, or is it taken by air flowing from the case?

   **Using Smoke matches**
   - Strike the match and then hold it as close as possible to the join between the case and the backplate. Does the smoke drift slowly away, or is it taken by air flowing from the case? Move the match around the seal, using fresh matches as required. To investigate the seal at the bottom of the case – hold the match between the bottom of the case and the electrical control panel. Does the smoke drift slowly away, or is it taken by air flowing from the case? Try the match in several positions.

4. **Back of boiler, flue, and around pilot inspection glass**
   - Leaks may also occur around the seals and gaskets elsewhere on the boiler. The pilot inspection glass on the front of the case can be inspected in the same way as the case seal. The backplate of the boiler has tubes, wires and bolts passing through. In addition the flue assembly is connected to the back of the boiler. The back of the boiler is less accessible than the front, making it difficult to use a naked flame or smoke matches in some locations. The back of the boiler becomes hot during use. Do not confuse natural convection with a leak.

   **Any faults should be corrected and the procedure repeated from 2**

   **If no faults are apparent the case should be removed and the procedure repeated from 1 Will a new case seal cure the problem?**

   **If the boiler still leaks Gas Industry Unsafe Procedures should be followed**

   **Boiler working safely**

---

Figure E4
APPENDIX F MODIFICATIONS TO CHECKLIST

1. Before the case is put back on
- Are there any water leaks?
- Are the combustion chamber linings intact?
- Is the backplate or the case distorted or damaged. Pay particular attention to the area where the case and seal meet.
- Is the backplate or case corroded. Is the corrosion likely to affect the integrity of the case, backplate, or seal?
- Is the case seal intact and in good condition? (e.g. pliable, free from discoloration and trapped particles). Will it form a seal between the case and the backplate?
- Is anything trapped in it?
- Is anything likely to be trapped when the case is put back on?

Rectify if necessary and proceed to 2

2. When the case has been put on
- Is the case on properly?
  - Is a “tide mark” visible showing that the case had previously been fitted closer to the backplate.

Check if the screw thread of any of the case securing screws, showing that the screw was used to be done up more tightly. Is the screw done up properly?

Is anything trapped and showing through the seal

3. Light the boiler
- If possible check the composition of the flue gases. Typical readings are 7-12% oxygen, and less than 100ppm carbon monoxide.

Check for leakage from the boiler, ensuring that the main burner remains lit (i.e. set the boiler and room thermostats to the highest setting).

4. Back of boiler, flue, and around pilot inspection glass
- Leaks may also occur around the seals and gaskets elsewhere on the boiler. The pilot inspection glass on the front of the case can be inspected in the same way as the case seal. The backplate of the boiler has tubes, wires and bolts passing through. In addition the flue assembly is connected to the back of the boiler. The back of the boiler is less accessible than the front, making it difficult to use a naked flame or smoke matches in some locations. The back of the boiler becomes hot during use. Do not confuse natural convection with a leak.

Any faults should be corrected and the procedure repeated from 2

If no faults are apparent the case should be removed and the procedure repeated from 1
Will a new case seal cure the problem?

If the boiler still leaks Gas Industry Unsafe Procedures should be followed

Additions are shaded thus

Boiler working safely

The section on “Use a Flue Gas Analyser” has been deleted.