



ADVANTICA

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**FURTHER EVALUATION OF
PROPOSED PROCEDURES FOR
THE MEASUREMENT OF GAS
APPLIANCE CO EMISSIONS**

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Further Evaluation of Proposed Procedures for the Measurement of Gas Appliance CO Emissions

Executive Summary

This report is the fourth in a series intended to establish the feasibility of using the measurement of carbon monoxide (CO) emissions alone, for diagnosing the performance of domestic gas appliances. Following laboratory-based evaluations, it was agreed to perform trials under practical service conditions, using measurements carried out by appropriate servicing engineers on both as-found and serviced appliances. Combustion analysis records, based on measurements using a flue gas analyser (FGA) were received from three participating organisations. For those appliance types with sufficient data, graphs of CO versus CO/CO₂ ratio were produced, to help in visualising the nature of any correlations.

From the results, it is recommended that current British Gas Service operational procedures, using a CO/CO₂ combustion performance ratio limit of 0.008, should continue for central heating boilers. There is also evidence to suggest that this might be extended to cover water heaters and cooker ovens. On the other hand, measurements indicate that new CO/CO₂ combustion performance ratio limits of 0.01 and/or 0.02 should be considered for fires/space heaters and cooker grills. The situation should then be monitored for at least one year, to validate these changes. In addition, further work should be undertaken, both to include other domestic gas appliances and to establish a database of sufficient field measurements to justify the chosen limits.

Information regarding the flame picture observed on appliance burners has been analysed to find whether it can be used as an accurate predictor of appliance condition. It is suggested that, whilst flame picture is a useful supporting tool for the experienced servicing engineer, it cannot be relied upon in isolation. This exercise has not enabled any further analysis on the suitability of individual gas sampling probe designs, due to the lack of suitable information contained in the majority of the reports. However, measurement difficulties were reported in only a few cases, and each of these was associated with inset live fuel effect fires, as had been predicted previously. There were no apparent effects due to thermal conditioning of burners, or fuel usage.



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Further Evaluation of Proposed Procedures for the Measurement of Gas Appliance CO Emissions

1 INTRODUCTION

This report is the fourth in a series (see References 1 to 3) intended to establish the feasibility of using the measurement of carbon monoxide (CO) emissions alone, for diagnosing the performance of domestic gas appliances. Proposals have been made (Reference 4) regarding possible procedures and equipment that could be used for this purpose, but there is a need to confirm their validity. Following laboratory-based evaluations, it was agreed to perform trials under practical service conditions, using measurements carried out by appropriate servicing engineers from:

- The Confederation of Registered Gas Installers (CORGI),
- The Society of British Gas Industries (SBGI), and
- British Gas Services (B-Gas).

The measured data were from appliances that were either,

- (i) As-Found (ie. possibly operating outside the manufacturer's specification) or
- (ii) Serviced (ie. operating within the manufacturer's specification).

2 MEASURED DATA AND RESULTS

Table 1 summarises the numbers of combustion analysis records, based on measurements using a flue gas analyser (FGA) as received from the three participating organisations. It should be noted that some records could not be used for comparing CO and CO/CO₂ ratio, due to the absence of one or other of these two parameters. Overall, about 82% of the data were useable, but this proportion varied for each type of appliance. The particular FGA instrument used by each organisation is not necessarily known, and it is believed that each source was likely to use different makes of instrument. However, it is assumed for the purposes of this study that all measurements were taken with instruments conforming to BS 7927 (Reference 5) that were correctly calibrated and used as specified by the manufacturer.

For those appliance types where sufficient data were generated, graphs of CO versus CO/CO₂ ratio appear in Figures 1 to 11. These have also been combined into overall groups for all central heating boilers and for all fires/space heaters, to give a comprehensive view. In addition, magnifications at lower levels of CO and CO/CO₂ ratio are included, where this is thought to be helpful in visualising the nature of any correlations. From these graphs, the following observations can be made:



- a) There are very few data points for back boiler units, so it is difficult to draw conclusions for these appliances independently. However, central heating boilers taken as a whole seem to follow a similar pattern, especially at lower levels of CO, which supports the previously deduced CO/CO₂ combustion performance ratio limit of 0.008 (Reference 6) presently used by British Gas Services for such appliances. This assumes that back boiler units are operated alone, with fire-fronts in position.
- b) Fires and space heaters do not show any reasonable correlation between measured CO and CO/CO₂ ratio. However, examination of the observed variability indicates that it might be appropriate to impose a CO/CO₂ combustion performance ratio limit of 0.02 for ILFE fires and 0.01 for other types, as a first approximation. Note that this should be confirmed on a larger sample size, and also that both new and existing appliances may be produced to a standard that allows a maximum CO/CO₂ ratio of 0.02.
- c) There are only a few data points for water heaters, but these show a similar pattern to central heating boilers, so the same CO/CO₂ combustion performance ratio limits may be considered suitable, again as a first estimate.
- d) The small number of available data points for cooker ovens might be thought to show a similar pattern to central heating boilers so, initially, the same CO/CO₂ combustion performance ratio limits may be considered suitable.
- e) There are only a few data points for cooker grills, and these do not show any reasonable correlation between measured CO and CO/CO₂ ratio. However, examination of the observed variability indicates that it might be appropriate to impose a CO/CO₂ combustion performance ratio limit of 0.01 for CE-marked appliances and 0.02 for all other cookers, as a first approximation.

3 FURTHER DISCUSSION

One of the aspects on which this exercise has not enabled any further analysis, is the suitability of individual gas sampling probe designs. This was due to the lack of suitable information contained in the majority of the reports. However, it is believed that most measurements, except those for cooker grills, were undertaken with a plain tube probe. Laboratory trials (Reference 3) indicated that this would probably be adequate under a wide range of circumstances for experienced engineers in practice. Measurement difficulties were reported in only a few cases, and each of these was associated with inset live fuel effect fires, as had been predicted in Reference 3.

Information had also been requested relating to the effects of burner thermal conditioning, but very few measurements (less than 1% of the total) were apparently taken under conditions of a cold start-up, and these did not form any particular pattern. Similarly, the relatively few appliances fuelled by LPG rather than natural gas (about 5% of the total) did not exhibit any pattern in terms of performance or measured parameters.



More information was available regarding the flame picture observed on the appliance burner, and this has been analysed to find whether flame picture can be used as an accurate predictor of appliance condition. Table 2 shows that, of the records that could be compared with measured data, 15% incorrectly predicted the result given by FGA, and over half of these cases (9% of the total) yielded an unsafe conclusion whereby an appliance fault would have been missed. It is therefore suggested that, whilst flame picture is a useful supporting tool for the experienced servicing engineer, it cannot be relied upon in isolation.

4 CONCLUSIONS

1. Combustion data for domestic central heating boilers indicate the overall variability to be expected from measurements using flue gas analyser instruments, and confirm the present CO/CO₂ combustion ratio operational limits used by British Gas Services, assuming that back boiler units are operated alone with fire-fronts in position.
2. Limited data indicate that it might be appropriate to treat water heaters and cooker ovens in a similar manner to central heating boilers.
3. Fires/space heaters and cooker grills appear to behave very differently, but it has been possible to suggest suitable combustion performance ratio limits, at least as a first approximation.
4. Insufficient data are available to deduce limits for other appliance types.
5. In general, measurements of CO and CO/CO₂ combustion ratio made on serviced appliances were lower than those made on as-found appliances.
6. Flame picture of the gas burner cannot be relied upon as a diagnostic servicing tool in isolation.
7. It has not been possible to make any significant comment regarding gas sampling probe designs, burner thermal conditioning or fuel usage.

5 RECOMMENDATIONS

1. Current British Gas Service operational procedures, using flue gas analysers and a CO/CO₂ combustion performance ratio limit of 0.008, should continue for domestic central heating boilers, and be extended to cover water heaters and cooker ovens.
2. New CO/CO₂ combustion performance ratio limits of 0.02 should be considered for ILFE fires and 0.01 for other fires/space heaters.
3. New CO/CO₂ combustion performance ratio limits of 0.01 or 0.02 should be considered for cooker grills, depending on whether the cooker is CE-marked.
4. The situation should be monitored over a typical servicing period (ie. at least one year) to validate these changes, and further work should be undertaken, both to include other domestic gas appliances and to establish a database of sufficient field measurements to justify the chosen limits.

References

1. A review of gas appliance CO emissions legislation. Advantica Technologies Ltd report R4162 by J A Cotton and M Waters, December 2000.
2. Comparison of measurements of absolute CO and CO/CO₂ ratio as combustion performance indicators. Advantica Technologies Ltd report R4188 by S J Bullman, January 2001.
3. Initial evaluation of proposed procedures for the measurement of gas appliance CO emissions (using combustion performance survey data). Advantica Technologies Ltd report R4271 by J A Cotton, March 2001.
4. Code of practice for the measurement of carbon monoxide and carbon dioxide in buildings and from gas-fired appliances, by the use of electronic portable combustion gas analysers. Draft BS 7967, February 2000.
5. Heating appliances for domestic applications – portable apparatus designed to detect and measure specific combustion flue gas products – requirements. BS 7927:1998.
6. Servicing – right first time. IGE Communication 1397 by J Newcombe, M D Price and A D Sussex, June 1989.

Table 1 – Sources of Measured Data

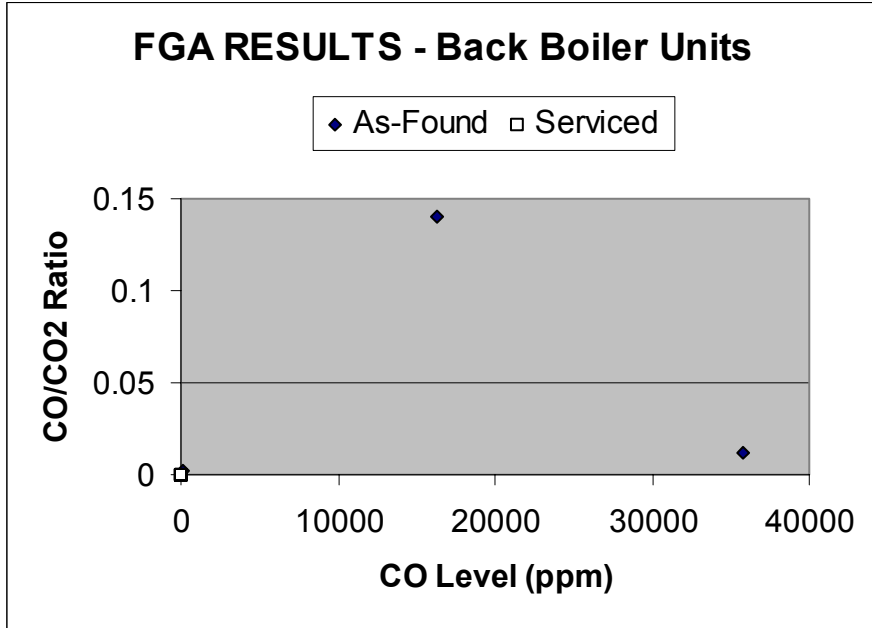
Appliance Type	Data Received From:			Total Data	Useable Data
	CORGI	SBGI	B-Gas		
Back Boiler Unit	6	0	6	12	9
CH Boiler	14	0	74	88	72
Combi Boiler	6	0	9	15	11
DFE Fire	4	14	0	18	14
ILFE Fire	2	43	0	45	42
Other Heater	18	13	17	48	39
Water Heater	1	0	8	9	9
Warm Air Heater	0	0	2	2	2
Cooker Oven	13	7	3	23	19
Cooker Hob	1	0	3	4	2
Cooker Grill	6	7	6	19	11
Range Oven	0	0	2	2	2
Refrigerator	1	0	0	1	1
Tumble Dryer	1	0	0	1	1
All Appliances	73	84	130	287	234

Table 2 – Flame Picture Analysis

Accuracy of gas appliance predicted condition based on flame picture, compared with actual CO or CO/CO₂ ratio measurements

Appliance Type	Flame	Picture	Prediction	Useable Data	Percent of Total Data
	Correct	Incorrect	Unsafe		
Back Boiler Unit	8	0	0	8	67%
CH Boiler	37	0	0	37	42%
Combi Boiler	8	2	2	10	67%
DFE Fire	1	2	2	3	17%
ILFE Fire	1	1	1	2	4%
Other Heater	21	5	2	26	54%
Water Heater	2	2	1	4	44%
Warm Air Heater	2	0	0	2	100%
Cooker Oven	12	2	0	14	61%
Cooker Hob	2	0	0	2	50%
Cooker Grill	3	4	2	7	37%
Range Oven	0	0	0	0	0%
Refrigerator	1	0	0	1	100%
Tumble Dryer	1	0	0	1	100%
All Appliances	99	18	10	117	41%

Figure 1 – Back Boiler Units (9 results)



NB. Results are for BBU operating alone, with the fire-front in position.

As above, magnified at lower levels

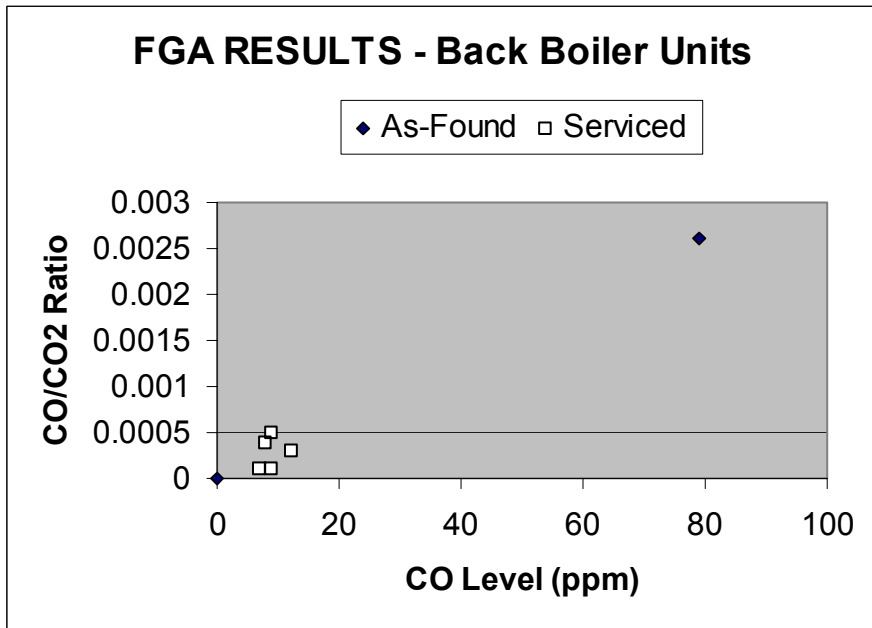
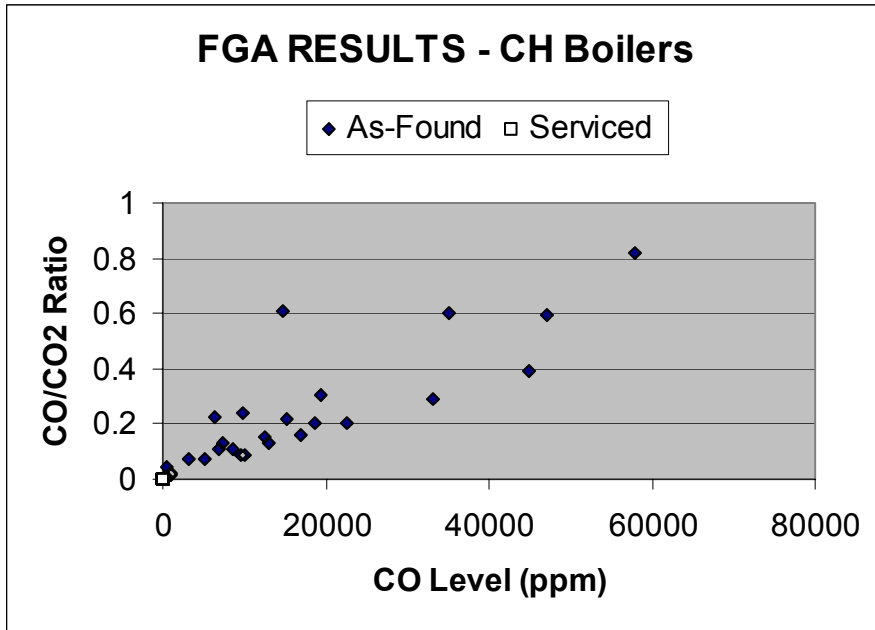


Figure 2 – CH Boilers (72 results)



As above, magnified at lower levels

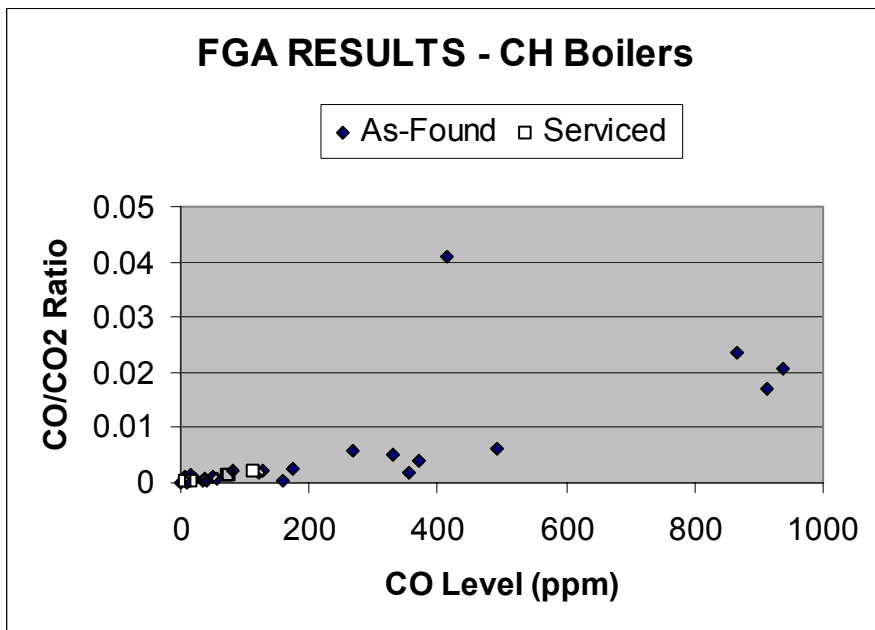
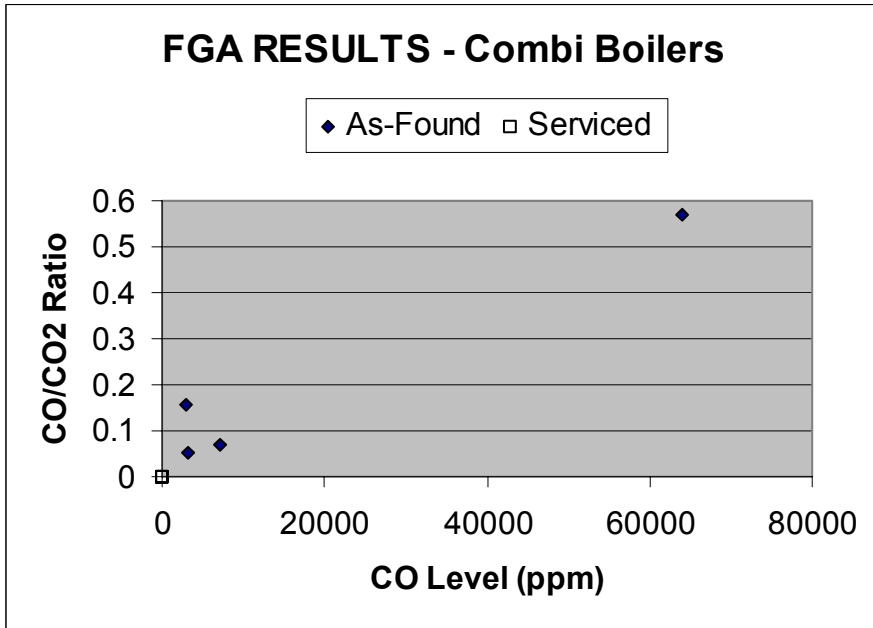


Figure 3 – Combination Boilers (11 results)



As above, magnified at lower levels

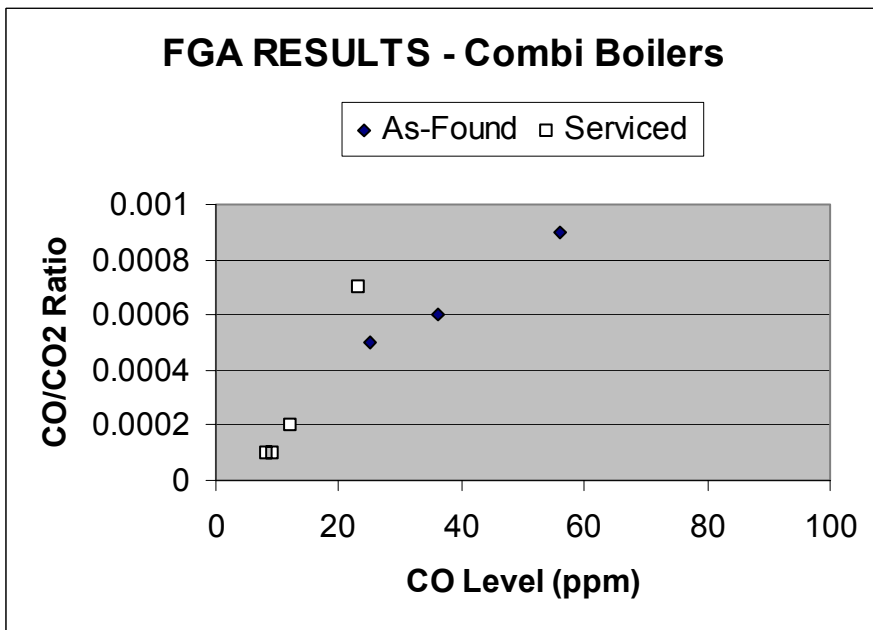
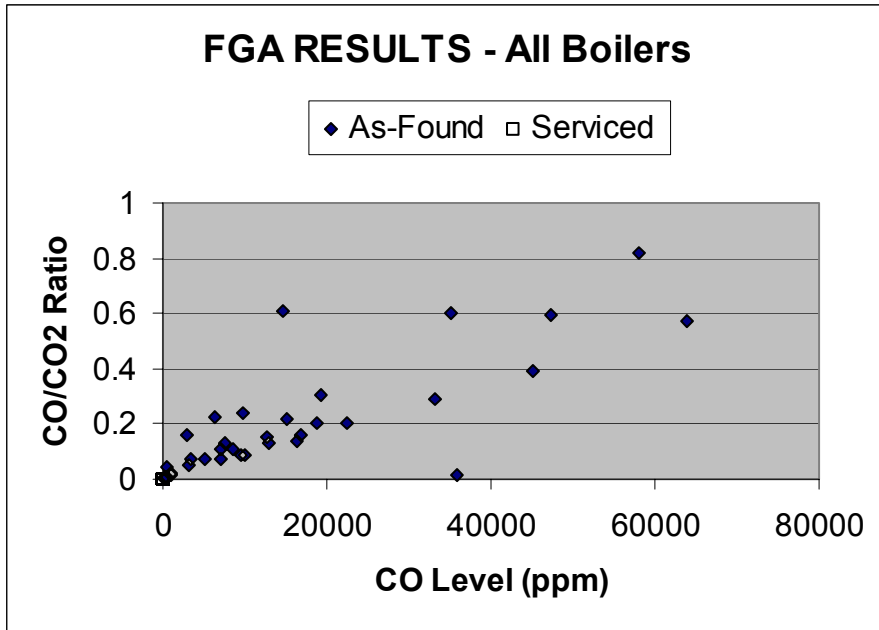


Figure 4 – All Central Heating Boilers (92 results)



As above, magnified at lower levels

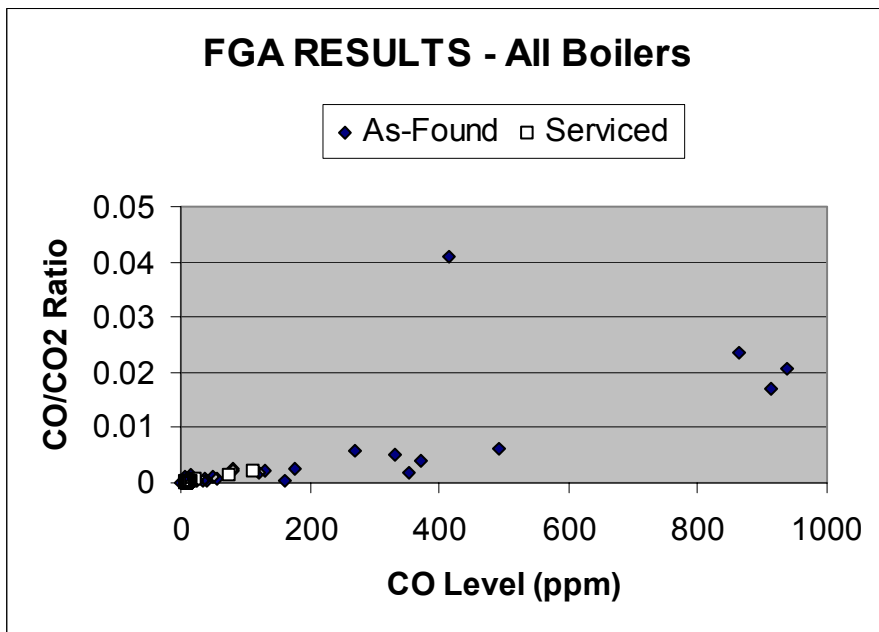


Figure 5 – Decorative Fuel Effect Fires (14 results)

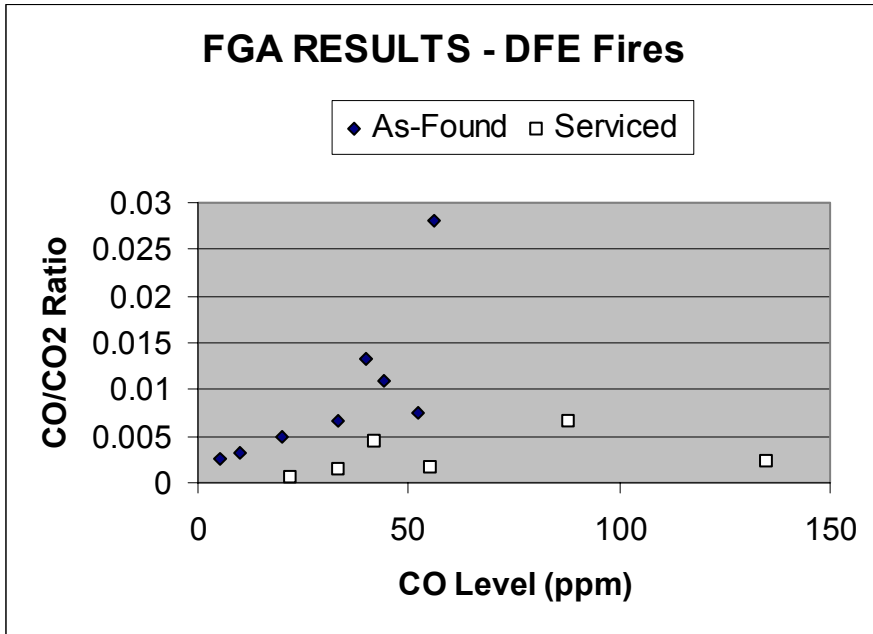


Figure 6 – Inset Live Fuel Effect Fires (42 results)

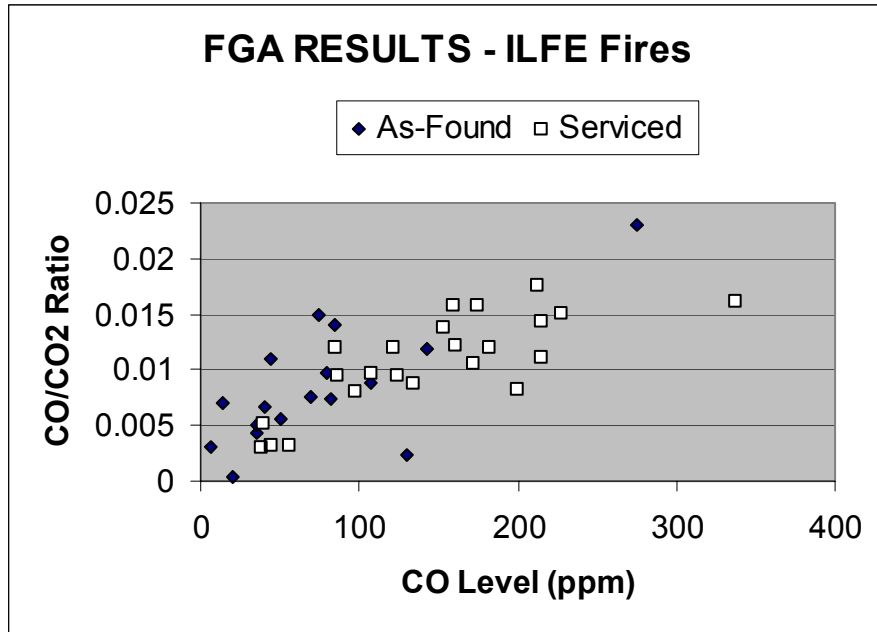
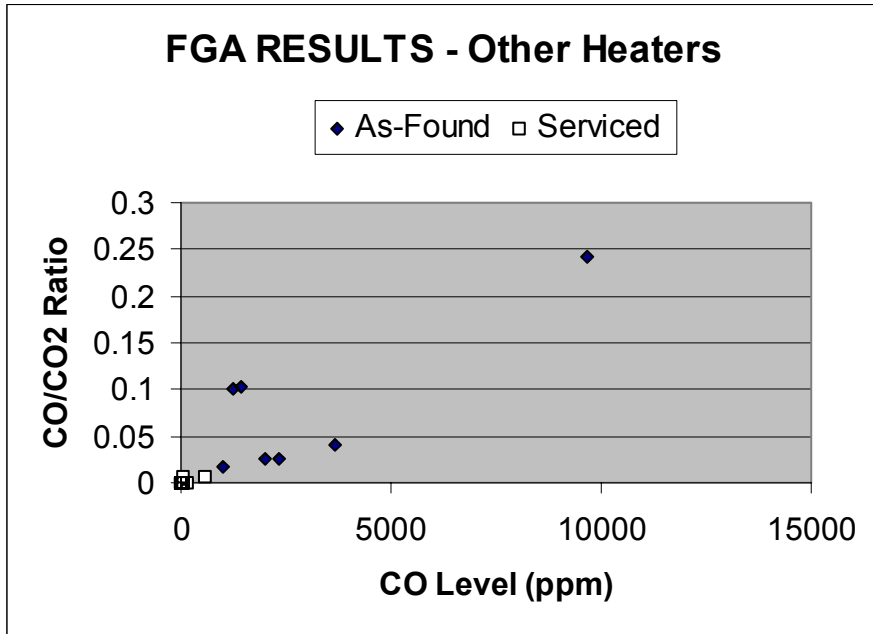


Figure 7 – Other Fires/Space Heaters (39 results)



NB. Results include convector heaters, cabinet heaters plus unspecified fire types.

As above, magnified at lower levels

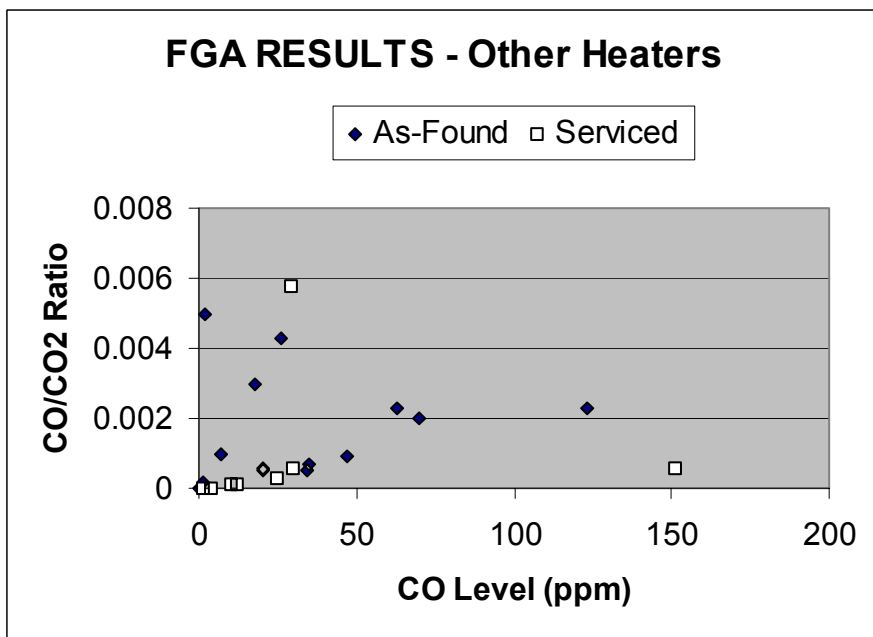
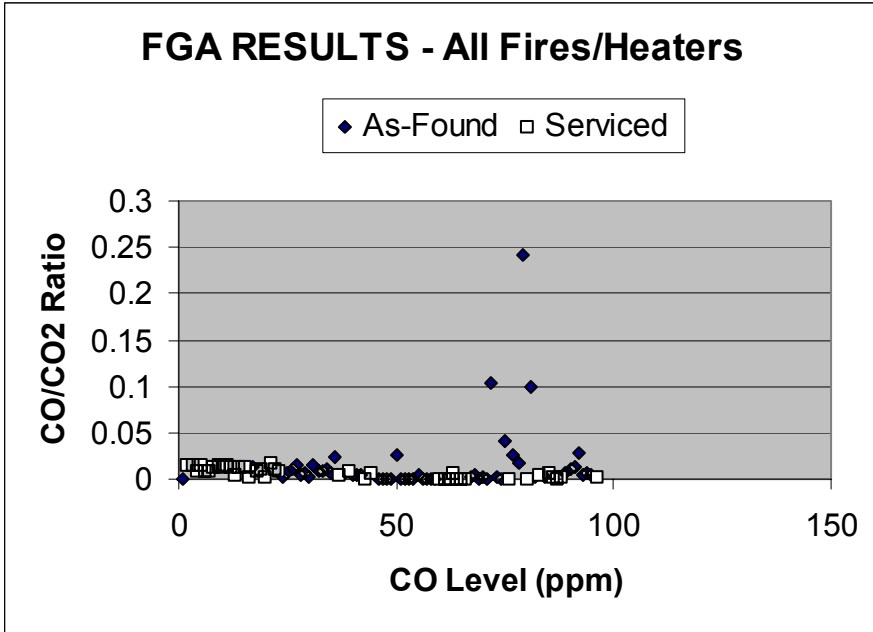


Figure 8 – All Fires and Space Heaters (95 results)



As above, magnified at lower levels

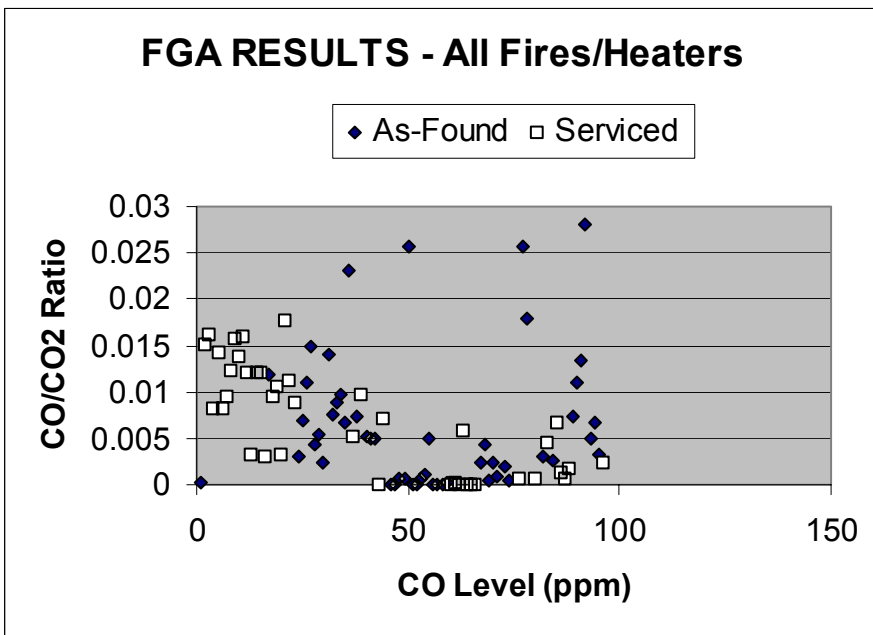
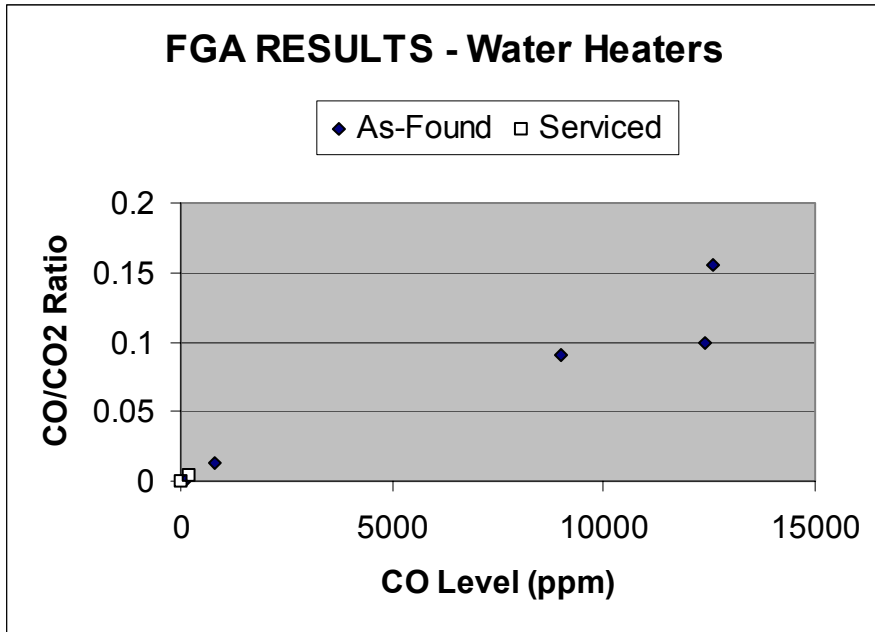


Figure 9 – Water Heaters (9 results)



As above, magnified at lower levels

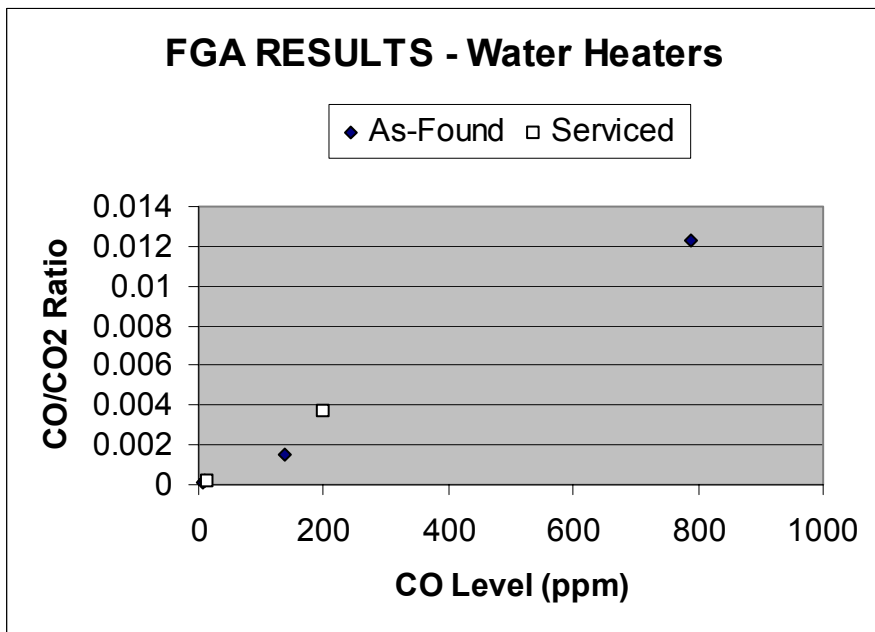
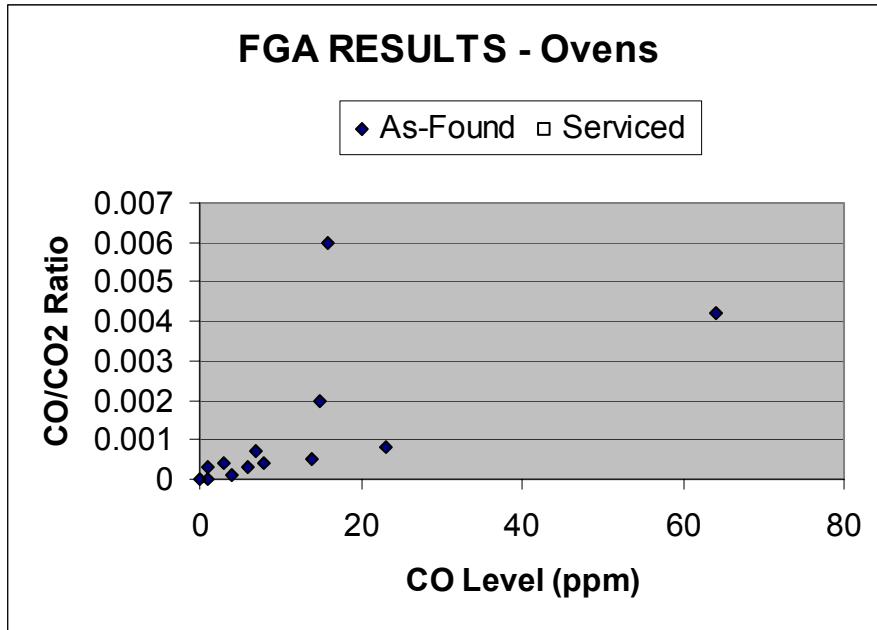
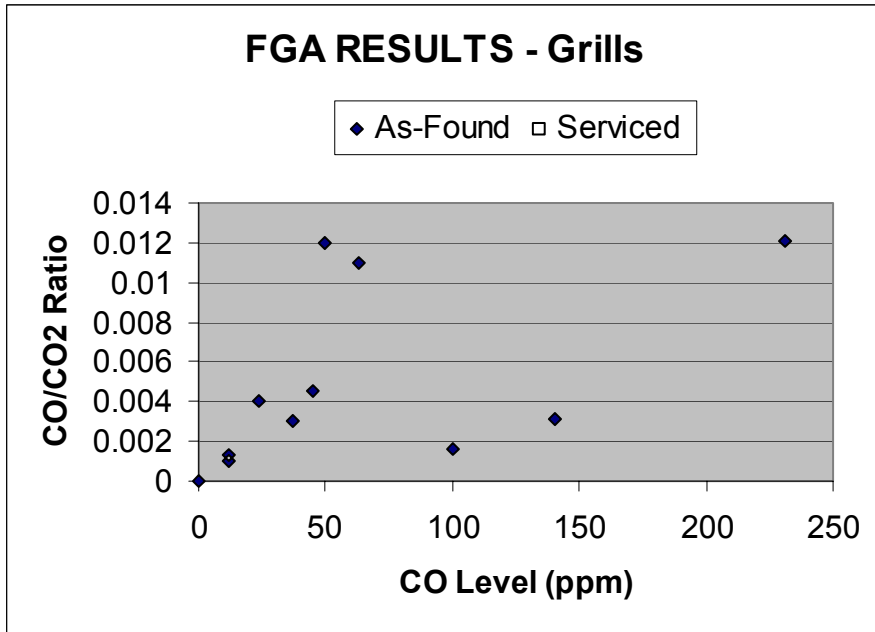


Figure 10 – Cooker Ovens (19 results)



NB. Results apparently cover as-found appliances only.

Figure 11 – Cooker Grills (11 results)



NB. Results apparently cover as-found appliances only.