Survey of North American Heat Exchanger Integrity Test Methods

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NOTE: LE RÉSUMÉ EN FRANÇAIS SUIT IMMÉDIATEMENT LE RÉSUMÉ EN ANGLAIS.

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Canada Mortgage and Housing Corporation (CMHC) has commissioned the Canadian Gas Research Institute (CGRI) to carry out this survey of natural gas furnace heat exchanger integrity test methods. The results of this survey are intended to be used by qualified and experienced housing and heating (and / or gas) industry personnel to assist and improve their ability to identify defective natural gas furnace heat exchangers. **The responsibility for the detection and diagnosis of combustion venting problems and the identification of defective natural gas furnace heat exchangers remains with the qualified industry personnel.** Neither CMHC nor CGRI can accept any reponsibility for any consequences resulting from the use of the results and / or conclusions drawn from the results presented in this report.

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SUMMARY

This survey has been carried out as part of larger project in which the intention is to develop an improved field test method for furnace heat exchanger crack / leak detection, which is repeatable, reliable, practical in field use and preferably quantitative.

The need for this work has arisen from a rising number of complaints from home owners on the subject of furnace "red-tagging" due to a cracked heat exchanger. In many cases the heat exchanger may be cracked but will not present a threat to the homeowner. One major manufacturer has stated that they expect their heat exchangers to develop some innocuous stress relieving cracks after the first few months of operation. On the other hand, a furnace heat exchanger may show no signs of cracks but may leak due to either a design or construction flaw.

Because the decision about whether a heat exchanger is cracked and presents a hazard or not is left to the descretion of the service-person performing the inspection, and because the responsibility (and liability) for making such a decision falls on them, it is not surprising that many furnaces may be being "red-tagged" unnecessarily.

This situation proves costly to the homeowner. The development of an improved field test method for determining furnace heat exchanger integrity is thus desirable at present.

As a first step in the development process this survey, carried out throughout North America, identifies the different methods currently in use to determine furnace heat exchanger integrity.

The survey was carried out by a combination of telephone contact and sending questionnaires to a total of 53 utilities in Canada and the U.S.A. These utilities were identified from an AGA survey of utilities and their services made in 1993. The questionnaires asked the utilities to state :-

- who had responsibility for field inspection of residential gas equipment?
- what methods of testing do they employ to determine cracks / leaks?
- why they use that method?
- would they prefer a quantitative to a qualitative method?

- what is the confidence level in the method they use?
- do they use specialized equipment and if so who supplies them?
- under what authority are the cracked / leaking heat exchangers to be replaced?

and finally, if they had any other comments to make.

Out of the 53 utilities contacted 41 (77 %) responded. The survey shows that almost all responding utilities are using a visible inspection of the heat exchanger and flame pattern in conjunction with a more detailed test if the service engineer is suspicious of a leak / crack. However, only about 15 % of the respondents are using a quantitative method.

Through the survey and past work conducted by GRI, CGRI, and CMHC some 15 different test methods have been identified.

Even though the confidence level in the methods currently being used is generally high, 61% of respondents would prefer a simpler quantitative alternative as compared to 22 % of respondents who would not want to change their test method.

46 % of respondents replace furnaces under the local or national governing authority, 39 % of respondents replace furnaces primarily as a company policy and 10 % of respondents allow the customer to make the decision.

Conclusions drawn from the survey indicate that no one test method stands out as being a clear candidate for development however, due to deficiencies or over-sensitivity in some methods; a process of elimination suggests that the AGA / GRI test method, the CMHC test method, and CO / CO_2 monitoring in the flue and circulating air be evaluated.

This report recommends that the above tests be evaluated against an absolute measurement of heat exchanger leakage to determine the effectiveness of each test method. A suggestion is made that the current allowable leakage from direct vent furnaces (2 % of combustion products) be used as a measure of the immediate hazard, but warns that further work would be required to establish this value as acceptable. The further work could be carried out as a theoretical study to predict potential indoor air CO / CO_2 concentrations.

RÉSUMÉ

Cette étude a été menée dans le cadre d'une recherche plus vaste devant mener à la mise au point d'une meilleure méthode d'essai en service pour la détection des fuites et des fissures des échangeurs de chaleur des générateurs d'air chaud. La méthode doit être fiable, reproductible, facile d'emploi sur le terrain et, de préférence, être de nature quantitative.

Ces travaux ont été suscités par le nombre croissant de plaintes de la part de propriétaires-occupants ayant trait aux «avis rouges» qu'ils reçoivent au sujet de leur générateur d'air chaud lorsque l'échangeur de chaleur est fissuré. Dans bien des cas, l'échangeur de chaleur peut être fissuré, mais sans poser de risque pour le propriétaire-occupant. Un important fabricant a affirmé qu'il s'attendait à ce que ses échangeurs de chaleur se fissurent, mais de façon inoffensive, en réaction à des contraintes subies au cours des premiers mois de fonctionnement. Par contre, l'échangeur de chaleur d'un générateur d'air chaud peut sembler exempt de fissures, mais fuir quand même par suite d'un défaut de conception ou de fabrication.

Étant donné que c'est au technicien chargé de l'inspection qu'il incombe de décider si un échangeur de chaleur est fissuré et présente un danger et qu'il doit en assumer la responsabilité, il n'est pas étonnant que de nombreux générateurs d'air chaud font l'objet d'avis rouges inutilement.

Cette situation s'avère coûteuse pour le propriétaire-occupant. C'est pourquoi il est souhaitable, à l'heure actuelle, de mettre au point une méthode d'essai en service améliorée permettant de déterminer l'intégrité des échangeurs de chaleur.

Première étape de ce processus de mise au point, le présent sondage, d'une ampleur nord-américaine, relève les différentes méthodes actuellement utilisées pour déterminer l'intégrité de l'échangeur de chaleur d'un générateur d'air chaud.

Le sondage a été réalisé par téléphone et au moyen de questionnaires qui ont été expédiés 53 entreprises de service public du Canada et des États-Unis. Ces entreprises ont été sélectionnées à partir d'un sondage de l'AGA, réalisé en 1993, qui portait sur les entreprises de service public et leurs services. Les questionnaires demandaient à ces entreprises de préciser :

- à qui incombait la responsabilité d'inspecter les appareils au gaz dans les résidences;
- quelles méthodes d'essai elles employaient pour déterminer la présence de fuites et de fissures;
- pourquoi elles utilisaient cette méthode en particulier;
- si elle préféreraient une méthode quantitative par rapport à une méthode qualitative;

- dans quelle mesure elles avaient confiance en la méthode utilisée;
- si elles utilisaient de l'équipement spécialisé et, le cas échéant, qui le leur fournissait;
- en vertu de quelle autorité les échangeurs de chaleur présentant des fissures ou des fuites étaient remplacés;
- si elles avaient des commentaires à formuler.

Sur les 53 entreprises de service public consultées, 41 (77 %) ont répondu. Le sondage montre que presque toutes les entreprises ayant répondu font une inspection visuelle de l'échangeur de chaleur et de la flamme et qu'elles procèdent à un examen plus poussé si le technicien d'entretien soupçonne une fuite ou une fissure. Cela dit, 15 % seulement des répondants affirment avoir recours à une méthode quantitative.

Grâce à ce sondage et aux travaux antérieurs réalisés par le GRI, le CGRI et la SCHL, quelque 15 méthodes d'essai différentes ont pu être relevées.

Même si le niveau de confiance à l'égard des méthodes utilisées est généralement élevé, 61 % des répondants préféreraient disposer d'une solution de rechange quantitative plus simple comparativement à 22 % des répondants qui ne souhaitent pas changer de méthode.

Quarante-six pour cent des répondants remplacent des générateurs d'air chaud qui sont sous la responsabilité d'une autorité locale ou nationale, 39 % des répondants remplacent les générateurs d'air chaud aux termes d'une directive de l'entreprise et 10 % des répondants permettent au consommateur de prendre la décision.

Cependant, le sondage permet de conclure qu'aucune méthode d'essai ne se démarque suffisamment des autres pour mériter un développement plus poussé à cause des défauts ou de la trop grande sensibilité que présentent certaines méthodes. On a déterminé, par élimination, que la méthode d'essai AGA/GRI, celle de la SCHL et celle qui consiste à contrôler le CO et le CO_2 dans le conduit de fumée et l'air de chauffage devraient être évaluées.

Les auteurs de ce rapport suggèrent que les méthodes susmentionnées soient évaluées par rapport à une mesure absolue des fuites d'un échangeur de chaleur afin de déterminer l'efficacité de chacune. Ils suggèrent également que le taux de fuite actuellement admissible pour les générateurs de chaleur à ventouse (2 % des produits de combustion) serve de mesure pour le danger immédiat, mais ils préviennent que d'autres études devront être menées pour établir l'admissibilité de cette valeur. Ces travaux pourraient prendre la forme d'études théoriques qui serviraient à prédire les concentrations potentielles de CO et de CO_2.

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1. INTRODUCTION & BACKGROUND

Every year, furnaces are "red-tagged" by service personnel for having cracked or leaking heat exchangers. Some of these cases are isolated incidents, while in other situations a particular furnace model may repeatedly be found to have cracks / leaks, which may indicate a design or construction flaw.

In many cases, the identified cracks would have no noticeable effect on the performance or safety of the furnace, but because the task of determining the condition and degree of hazard is left to the serviceman performing an inspection [(1)] and provincial regulations in Canada require that a defective heat exchanger be removed from service [(2)], the outcome is that many are being "red-tagged" unnecessarily.

A bulletin issued, in 1978, by the Energy Safety Branch of the Ontario Ministry of Consumer and Commercial Relations [(3)], identified this problem. It states that minor cracks can occur and may not pose a threat to life. On the other hand, it also states that minor cracks may deteriorate leading to a major defect. The bulletin further states that the degree of hazard from a cracked heat exchanger must be established beyond a reasonable doubt. The inspection protocol requires the service person make this determination and "red-tag", followed by immediate disconnection of the gas appliance if a hazard exists.

A "red-tagged" furnace represents a considerable cost to the homeowner prompting many complaints to organizations such as the Canada Mortgage & Housing Corporation (CMHC). Many complaints stem from different service personnel giving different opinions on the same furnace or from furnaces being "red-tagged" shortly after passing an inspection. Some "red-tagging" of furnaces of a particular make and of similar age located in the same area has taken place on a street-wide scale [(4)] undermining the credibility of certain furnace manufacturers. The confusion as to whether or not a furnace should be "red-tagged" or not stems from the lack of an accurate, widely employed, simple and inexpensive test method to determine a furnaces heat exchanger integrity. This situation then undermines the credibility of the gas industry as a whole.

In an effort to resolve this problem CMHC, Gas Technology Canada (GTC), and a leading North American furnace manufacturer have joined forces to develop an improved field test protocol for testing furnace heat exchanger integrity (i.e. checking for cracks and / or leaks). This method will be verified through laboratory and field testing.

As a first step in this process, a survey has been carried out (the work reported herein) to establish what test methods are being used at present, what other methods exist and which of them has the greatest potential for further development for use in the field.

Any test used for determining the integrity of a furnace heat exchanger needs to be accurate and reliable because of the potential hazards that can arise by leaving a cracked and / or leaking heat exchanger in place.

Cracked, through-the-wall perforation as a result of corrosion, or leaking heat exchangers pose a potential hazard to the health of a building's occupants. Problems arise when combustion products leak from inside the heat exchanger into the circulating house air, or circulating house air leaks into the heat exchanger preventing the proper flueing of the furnace combustion products. Most manufacturers design their heat exchangers such that the circulating house air is at a positive pressure with respect to the combustion products. This means that in the event of a small crack, air will leak into the heat exchanger rather than combustion products leaking out. It should be noted, that there are a few exceptions where the opposite to the above is true.

If sufficient air leaks into a heat exchanger it not only effects the flueing of the appliance but can also disturb the flame pattern causing high levels of Carbon Monoxide (CO) which has well known physiological effects (see Figure 1.).

The greatest hazard to health only occurs when an appliance is producing high levels of CO in its combustion products, part or all of which then gets transported into the living space and pollutes the air breathed by the building occupants.

In both cases of furnace design described above, the combustion products can be at a higher pressure with respect to the circulating house air side, when the circulating air fan is not operating, i.e. on start-up. If the appliance is generating a high level of CO and the heat exchanger is cracked, then CO that leaks into the plenum chamber on the circulating house air side of the heat exchanger will get distributed throughout the house when the fan switches on.

2. OBJECTIVES

The objectives of this project were :-

- To determine which heat exchanger test methods are currently in use.
- To determine the general confidence in the methods being used.
- To identify any other potential methods that could be used.
- To propose two or three methods worthy of evaluation in a laboratory testing program.

3. METHODOLOGY

This subject area has prompted interest in the past and three key pieces of work have been cited.

(a) GRI's "Furnace Heat Exchanger Leakage" Topical Report [5] - 1984.

(b) CMHC's "Safety of Residential Chimneys" Report [6] - 1988.

and,

(c) CGRI's "Furnace Heat Exchanger Leakage" Report [7] - 1988.

These reports have identified (together with the methods they propose) some 13 different test methods. The survey further identified another 2 test methods, bringing the total to 15.

The survey was carried out by a combination of telephone contact and sending questionnaires to a total of 53 utilities in Canada and the U.S.A. (See Appendix 1). These utilities were identified from an AGA Laboratory document titled "How to Work with Utility Companies" received at CGRI in April 1993 (public availability unknown). The primary contact names were identified from this same document in conjunction with a registration list from a GATC/Industry Workshop in November 1993.

The CGRI questionnaire (See Appendix 2) asked the utilities to state:-

Who had responsibility for field inspection of residential gas equipment ?

The methods of testing they employed to determine cracks / leaks. Why they use that method ?

Would they prefer a quantitative to a qualitative method ?

What is the confidence level in the method they use ?

Do they use specialized equipment and if so who supplies the equipment?

Under what authority are the cracked / leaking heat exchangers to be replaced ?

and finally,

If they had any other comments to make.

Figures 2, 3, 4 & 5 show the distribution of the contacts and the respondents to the survey. Out of 53 initial contacts, 41 replies were received representing a 77 % response.

4. RESULTS & DISCUSSION

A brief description of the furnace heat exchanger test methods identified from past work is presented in Appendix 3. A summary of the responses to all questions in the survey is included in Appendix 4.

A more detailed analysis of the response to each question is presented below.

Question 1 - Who in your franchise area has responsibility for field inspection of residential gas equipment ?

Since the survey was initially targeted at utilities that offer appliance servicing and service contracts for furnaces, it was not unexpected to get a 95 % indication of utility involvement in furnace inspection, as indicated in Chart 1.

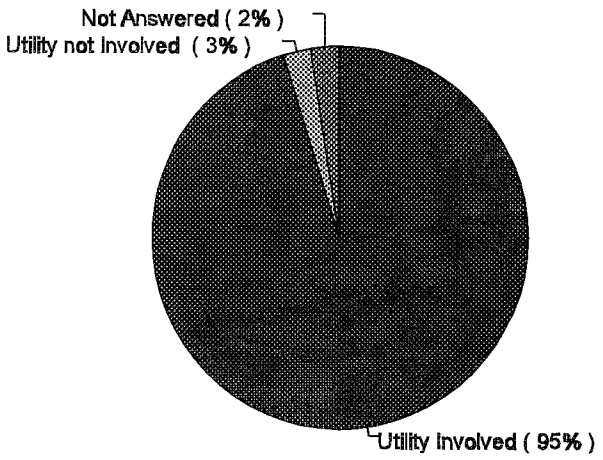
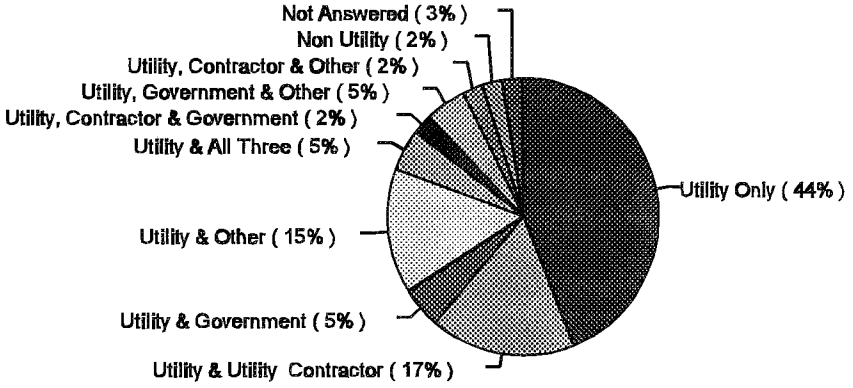


Chart 1. Inspection Responsibility.



A detailed breakdown is shown in Chart 2. Further analysis of the information shows 44 % of the responding utilities claim sole responsibility for inspecting furnaces, 2 % did not inspect furnaces and 3 % did not answer the question.

Chart 2. Detail of Inspection Responsibility

Of the utilities that share the appliance inspections, 17 % are with Government Agencies, 24 % with Contractors and 27 % with other agencies such as Home Inspectors and Heating Dealers. The greater than 100 % total being due to multiple responses.

Question 2 - What test method(s) do the inspecting authorities employ for detecting cracked and / or leaking heat exchangers?

All of the responding utilities carry out a visual inspection of both the furnace heat exchanger and the burner flame pattern. 98 % of the utilities use one or more test methods in combination with the visual tests. 49 % of the utilities use more than one test protocol (not including visual observations). Chart 3 indicates the relative popularity of the different methods. The quick and simple visual tests stand out above all other tests. The questionnaire gave a suggested list of tests and an "Other" category to cover those not listed. 24 % of respondents indicated that they carried out some "other" test, most of these were CO monitoring in the circulating air plenum chamber.

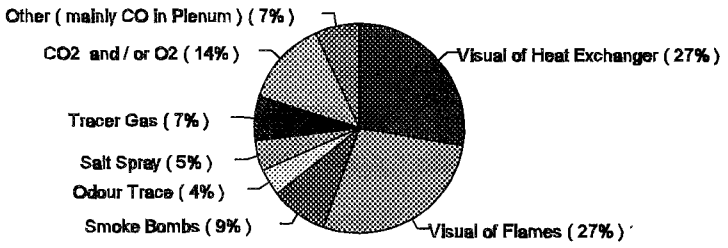


Chart 3. Popularity of Test Methods Used

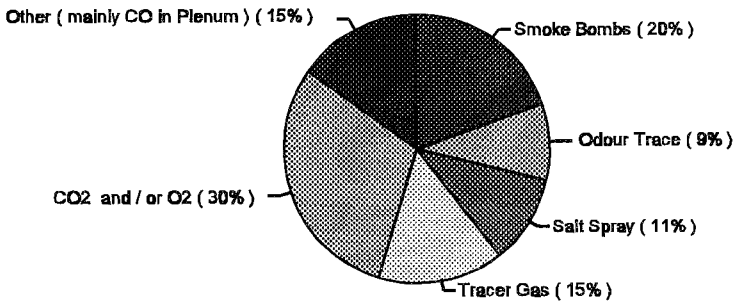


Chart 4. Popularity of Test Methods Used (other than Visual)

It was interesting to note that neither the CGRI or the CMHC method were directly referenced, although one respondent was using a modified version of the CMHC method i.e. using a flame instead of a smoke trace. The GRI / AGA developed method is commercially available as a test kit [8]; 14 % of respondents were using this test kit (Directly identified in Question 6 - Who is the Supplier of the Specialized Equipment) and possibly up to

26 % of respondents were using this method (i.e. They identified the use of the J&N Hetkit or Methane in Nitrogen tracer gas in Questions 6 and 8). Chart 4 shows that after the visual inspections CO_2 and / or O_2 monitoring in either the flue or the circulating air plenum (the question did not differentiate), is the most popular method. It was also interesting to note that odour tracing and salt spray methods are still being used by a significant number of service personnel. These tests have been previously identified as being unreliable [5,6,7].

Question 3 - What is the reason for selecting the chosen method ?

The main reason the service personnel are using the tests they do is simplicity, followed by cost and because the method is quantitative. Some other reasons given for using the tests were effectiveness and reliability in identifying defective heat exchangers. This is illustrated in Chart 5.

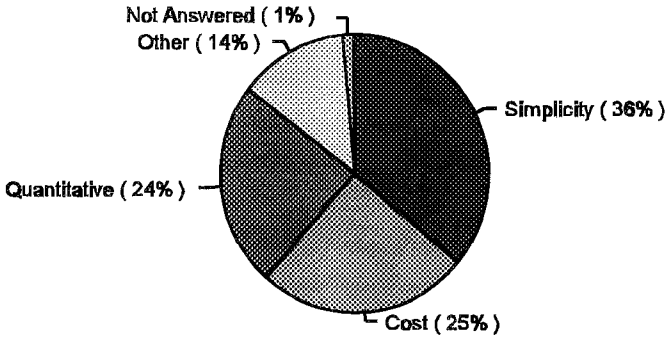


Chart 5. Reason For Using Chosen Method

Any proposed new test method would therefore need to be simple to do, low in cost, quantitative and reliable.

Question 4 - If the method used is qualitative, e.g. visual observation of flame pattern, would your company prefer a simple quantitative method which would produce a percentage leakage rate ?

Chart 6 indicates that 22 % of the respondents would not change from the tests that they are currently using, 61 % would consider it and 7 % would change on condition that the new method is less expensive (Other category).

A significant level of promotion and persuasion may be required in the introduction of any new test method.

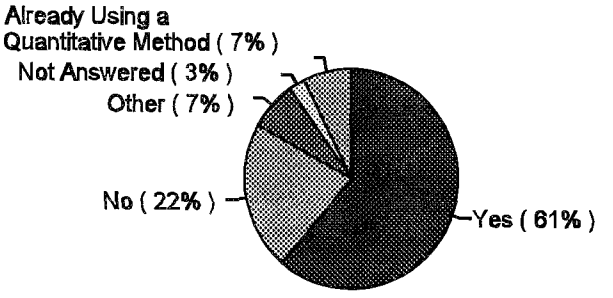


Chart 6. Preference for a Quantitative Method

Question 5 - What is the confidence level in the method currently used by your company ?

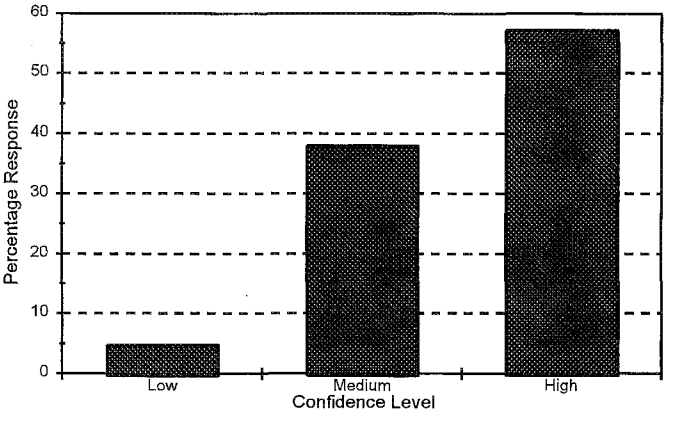


Chart 7. Utility Confidence Level

On the whole the confidence levels of the responding utilities in the methods that they are currently using is fairly high, as shown in Chart 7. This may indicate a reluctance to change to a new method unless evidence is provided that it works well enough.

Question 6 - a) Is specialized Equipment Used for your detection method ? b) If yes who is the supplier of the equipment ?

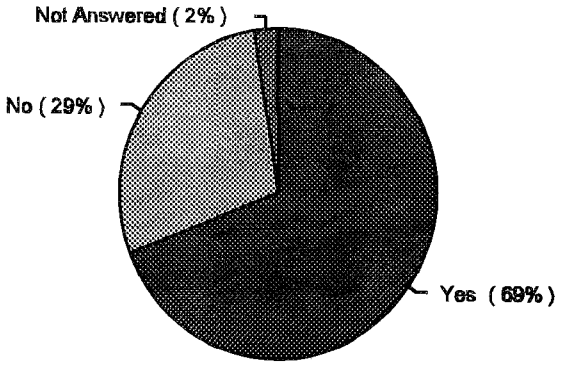


Chart 8 Use of Specialized Equipment

69 % of respondent utilities are currently using some form of specialized equipment, see Chart 8, such as the J&N Heat exchanger test kit [8] i.e. the GRI / AGA method (14 %), a CO_2, CO, or CH_4 gas analyzer (38 %) or other equipment such as salt spray kits or Draeger tubes (17 %), (See Chart 9).

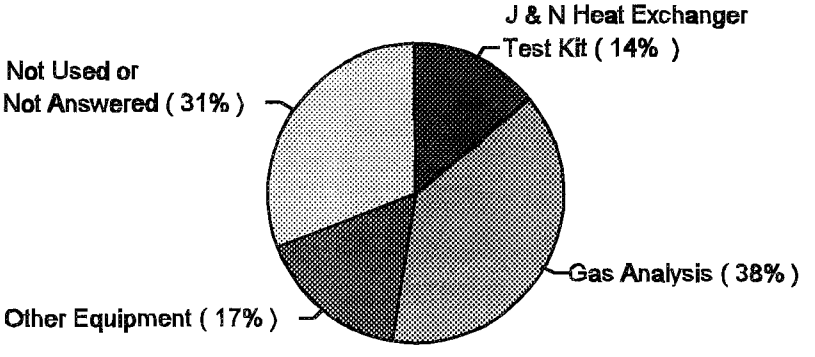


Chart 9. Specialized Equipment Breakdown

Question 7 - Under what authority / legislation are heat exchangers with cracks / leaks required to be replaced ?

46 % of respondents replace furnaces under the local or national governing authority, 39 % replace furnaces primarily as a company policy and 10 % allow the customer to make the decision. 5 % of the respondents did not answer this question. (Chart 10).

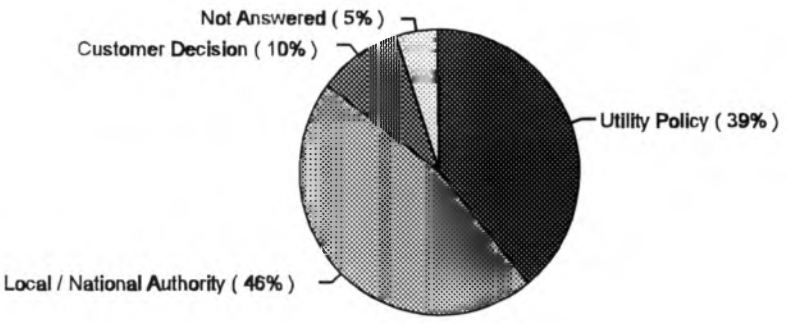


Chart 10. Replacement Authority

Question 8 - Any other comments ?

A summary of the other comments received is given in Appendix 4. The comments made were generally with respect to the test methods being used by the utilities i.e. giving a few more details. Some of the utilities went as far as sending extracts from their own service procedures handbooks. A few of the utilities expressed an interest in obtaining copies of the final report.

5. CONCLUSIONS

Some general conclusions can be made from this survey :-

- A wide variety of test methods are still in use and even though most utilities are confident in the tests that they are using, 61 % would consider changing to a quantitative method if it were simple and inexpensive.

- No one test stands out as being an obvious candidate for further development.

- Tests worthy of evaluation would be the CGRI method, the AGA / GRI tracer gas method, CO_2 and / or O_2 monitoring in the flue and circulating air plenum chamber, CO monitoring in the flue and circulating air plenum chamber and the CMHC smoke tracing method (or a modified version of it).

- The tests listed in the conclusions above should be evaluated in an experimental program where they are compared against an absolute measure of leakage. Such an absolute measure would be a volume flowrate out of the heat exchanger which could then be evaluated as a percentage of the combustion products.

- As an interim measure, the current requirement for leakage from a direct vent furnace could be used (i.e. 2 % of the combustion products [9]) as a measure of the immediate hazard. However, further work in this area should be carried out.

- A theoretical study of potential indoor CO / CO_2 concentrations should be carried out based on different initial concentration & volume flowrates, as well as different dwelling ventilation rates.

6. References.

1. Ontario Regulations 331, R.R.O. 1990, amended Gas Utilization Code, Section 3, (see Appendix 5).

2. CAN / CGA - B149.1M95, Section 3.21, (see Appendix 5).

3. Ontario Ministry of Consumer and Commercial Relations, Energy Safety Branch, Ontario Gas Bulletin No. 121 of Series 100, October 1978, (see Appendix 5).

4. Personal communication with CMHC.

5. DeWerth, D.W. & Connelly, S.M., "Environmental Control of Gas Appliances: A Three-Step Method for Detecting Unacceptable Flue Gas Leakage from Furnace Heat Exchangers", Topical Report GRI 84/0162, August 1984.

6. Scanada-Sheltair Consortium Inc., "Procedures for Determining the Safety of Residential Chimneys", Section 3 "Heat Exchanger Leak Test", Research Division CMHC, January 1988.

7. Tikiryan, H. & Andersen H., "Development of a Test Method for Locating Leaking Heat Exchangers in Domestic Furnaces", CGRI SR-286, December 1988.

8. Heat Exchanger Test Kit available from J & N Enterprises, 648W 300N, Valparaiso, IN 46383, Phone (219) 759 1142, Fax (219) 759 1835.

9. American National Standard / National Standard of Canada for Gas Fired Central Furnaces, ANSI Z21.47 - 1993, CAN/CGA - 2.3 - M93, Part IV Section 4.4.9.

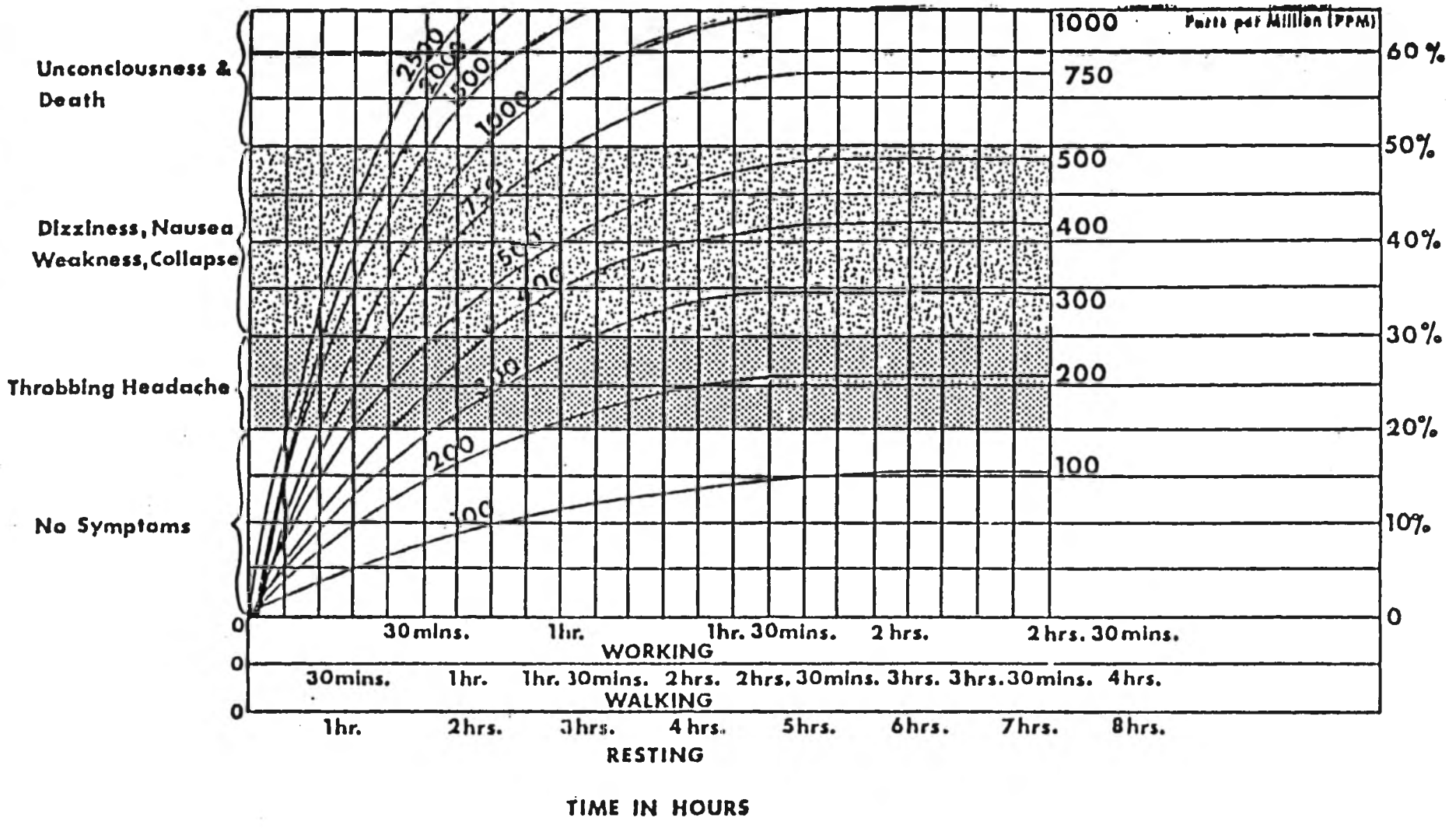


Figure 1. The Physiological Effects of CO on Humans.

(Source of graph unknown, but it compares well with other existing data)

Distribution of Survey Forms - Canada

Figure 2. Survey Distribution Within Canada.

Returned Survey Forms - Canada

Figure 3. Survey Returns from Canada.

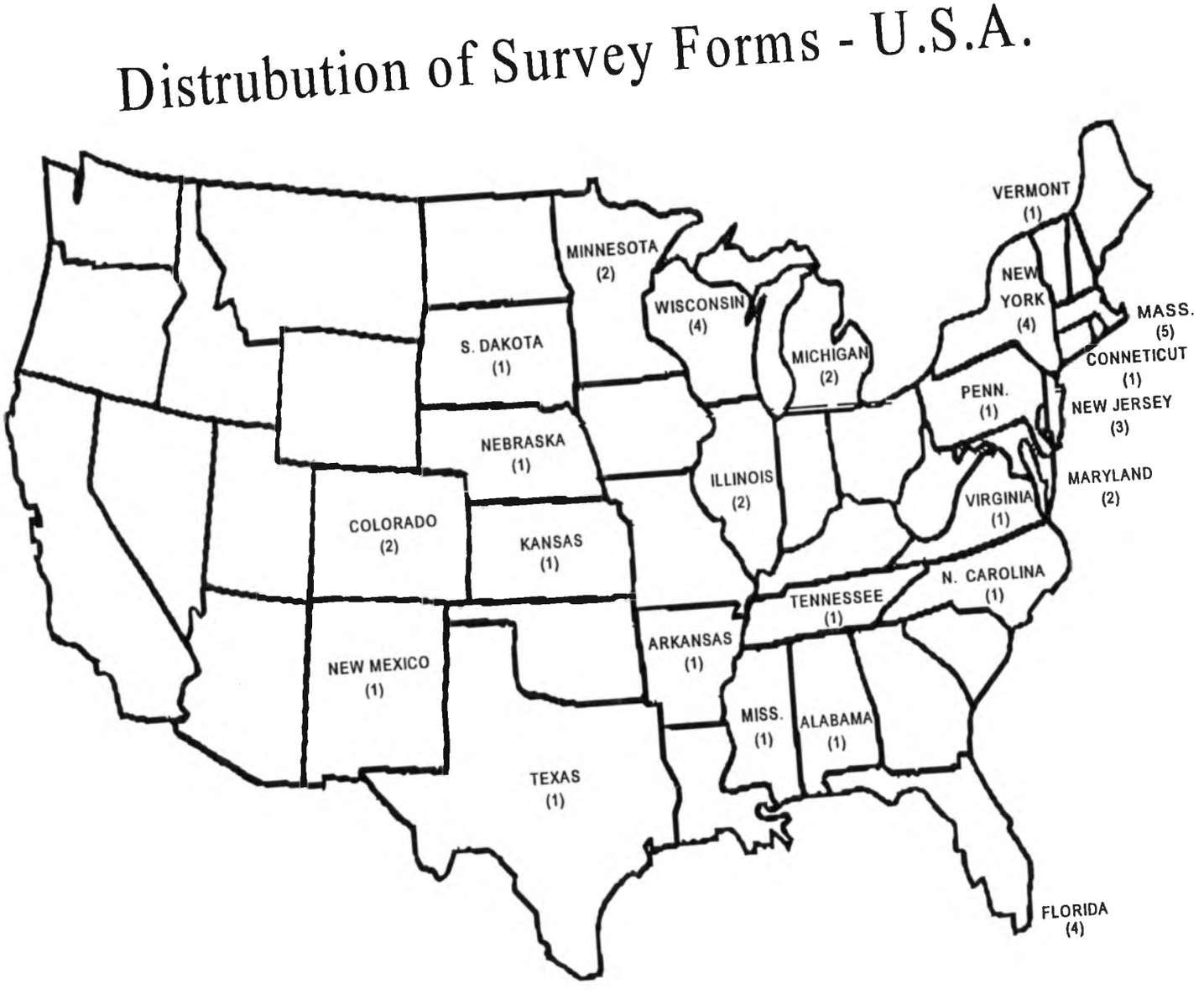


Figure 4. Survey Distribution in the U.S.A.

Returned Survey Forms - U.S.A.

Figure 5. Survey Returns from the U.S.A.