Installation of a subject appliance had different requirements depending on appliance type. Appliances such as water heaters, clothes dryers and fireplaces which discharge manageable quantities of heat into the test chamber, permitted themselves to be completely enclosed inside the chamber with the use of reasonable auxiliary cooling as required. The greatest difficulty was in dealing with the large heat outputs of central heating furnaces. One approach would be to enclose the entire appliance in a chamber and supply auxiliary cooling to counter the heat output but this would require a very large cooling capacity. Benefits of this approach would be in containing any combustion product leakage occurring within the circulating air compartment of the furnace and eliminating any interference with measured exfiltration quantities due to the circulating air blower possibly removing unmeasured quantities of chamber atmosphere. An alternate approach, selected for this project, was to install the furnaces through the internal partition wall such that the furnace vestibule was isolated in the original sub-chamber used for all other appliances and the circulating air compartment was isolated in the other sub-chamber. This installation method allowed ducting of the heated air away from the chamber and minimized the heat into the sub-chamber containing the vestibule. Due to this split system approach, extra measures were invoked to monitor for CO_2 in the circulating air and to ensure that no unaccounted exfiltration was incurred. The difficulty of ensuring that the circulating air stream does not contain furnace combustion products was that at the high flow rates for circulating air, even 10 ppm CO_2 difference which was the sensitivity of the instrumentation, can amount to a quantity which may be considered relatively significant by some people. The approach used to prevent chamber atmosphere from being removed by the furnace circulating blower was to pressurize the sub-chamber enclosing the circulating air compartment. This promoted any leakage across the partition wall or furnace panels to be directed into the sub-chamber enclosing the furnace vestibule. This necessitated a higher auxiliary blower flow to achieve desired depressurization levels.

4. REQUIRED TEST MEASUREMENT DATA

Recorded data necessary to determine combustion product leakage relative to internal depressurization are summarized below.

4.1 Chamber Depressurization Level

This value was continuously monitored throughout the test period to ensure a constant depressurization condition at the desired value. In most cases, a stable depressurization level could be maintained without continuous adjustment being necessary.

4.2 Appliance Input Rate and Vent CO_2 Concentration

This data was the basis for calculating exfiltration due to the appliance itself drawing air from the chamber interior. In many cases, this quantity of flow was capable of generating the desired level of depressurization by manipulating the leakage characteristics of the chamber. A CGRI combustion analysis computer program calculated the total chamber air ingested by the appliance and exhausted via the vent, as well as, the total volume of combustion gases generated by the appliance. This approach was considered to yield the greatest accuracy on calculated leakage and was felt more accurate than any flow rate determinations made with anemometer, velocity head or tracer gas instrumentation.

4.3 Appliance Combustion Gases CO_2 Concentration

This measurement was taken ahead of any intentional design dilution opening to provide information on dilution ratios of the representative appliances. Some appliances did not have dilution openings. In these cases, and in the case of clothes dryers where significant dilution air is normal, only vent CO_2 concentrations were recorded.

4.4 Chamber Atmosphere and Background CO_2 Concentrations

The net rise of chamber CO_2 concentration was indicative of combustion product leakage into the chamber. This data value, by itself, was not immediately a quantitative indicator. However, when taken in conjunction with other data, quantitative determinations of leakage can be made.

4.5 Standing Pilot Burner Input Rate

Some sidewall-vented appliances utilize constant burning standing pilots. Since the exhaust venter does not operate during standby periods, all combustion products from the standing pilot might be assumed to enter the structure. Calculated CO_2 emissions could be determined just for the pilot itself. Appliances which utilize intermittent pilots or direct ignition were not subject to this condition.

4.6 Auxiliary Blower Tracer Gas Concentration

Appliances which could not generate the desired level of depressurization by themselves, were supplemented with additional exfiltration via an auxiliary blower exhausting from the room. Sealed ducting from the room to the auxiliary blower included an injection probe and sample port for determining flow by using tracer gas injection. Commercial grade bottled CO_2 was used as the tracer gas to optimize use of the 0 - 20% CO_2 infra-red analyzer. Flow tubes were used to measure tracer gas flow rates.

5. LEAKAGE SOURCES IDENTIFICATION AND CORRECTIVE MEASURES

Each appliance was exposed to a preliminary depressurized condition and probed to qualitatively identify leakage sources. The methodology for this measure was to simply traverse all potential leakage sites with the sampling probe and watch the analyzer for any indication of detected CO_2. Potential leakage sites included burner access openings, drafthood relief openings, blower housings, motor shaft entry hole, and blower connections to the vent system. The level of depressurization used for this qualitative test would of course ideally be the maximum depressurization level of interest. Following the primary test program, minor corrective measures were invoked to reduce the leakage from those sources identified as most obvious and readily correctable only on appliances indicating significant leakage. Repeat tests at selected depressurization were conducted to indicate the degree of improvement attained with these simple measures.

6. PROPOSED TEST AND CALCULATION PROCEDURE

The test procedure itself was quite simple. The subject appliance was merely operated continuously in the test chamber under the desired level of interior depressurization. Continuous monitoring of the chamber static pressure was made to ensure uniform depressurization level was applied. Measurements were taken at intervals and established steady state conditions in time frames which depended on rates of exfiltration and combustion product leakage occurring under the given test condition. Each test was typically conducted for a minimum of one hour with data collection being spaced at intervals ranging from five to fifteen minutes depending on the number of data items being recorded and the rate of steady state establishment. When at least three consecutive readings indicated steady state establishment had been achieved, the test was concluded.

The depressurization levels selected for the test program were 12.5, 25, 37.5 and 50 Pa (0.05, 0.10, 0.15 and 0.20 inches wc).

The total chamber exfiltration rate (TEFR) was determined by calculating the chamber air being exhausted by the appliance vent and adding, when appropriate, the calculated exhaust flow by the auxiliary blower determined by tracer gas technique. The combustion analysis computer program uses the measured gas input and the net vent CO_2 concentration to calculate the actual chamber air ingested by the appliance. The net vent CO_2 concentration is the difference between room ambient and gross vent CO_2 concentrations to account for the contaminated air supply.

The net rise in CO_2 concentration (CO_2 NET) in the chamber was determined by the difference between laboratory ambient and chamber atmosphere concentrations.

The total exfiltration flow rate (TEFR) and net rise in chamber CO_2 (CO_2 NET) were then applied to equation 1 which calculates the flow rate of CO_2 entering the chamber (CO_2 IN);

$$CO_2IN = TEFR \times CO_2\ NET \times CORRECTION\ FACTORS \qquad (1)$$

The correction factors of equation 1 account for measurement units only (ie. ppm to decimal factor, etc).

The net combustion product CO_2 concentration (COMBNET) was determined as the difference between the chamber atmosphere and the gross appliance combustion product CO_2 concentration before any intentional dilution. Conversion of the flow rate of CO_2 entering the chamber (CO_2 IN) to a corresponding flow rate of combustion gases entering the chamber (CGASIN) was achieved with equation 2;

$$CGASIN = CO_2\ IN / COMBNET \times CORRECTION\ FACTORS \qquad (2)$$

The correction factors of equation 2 account for measurement units only. This value expresses the total leakage determined as if it were all undiluted combustion products. This enabled determination of the percentage of appliance combustion gases leaking into the chamber by the ratio of CGASIN to the total flow rate of combustion gases generated by the appliance (determined by the combustion analysis computer program).

When a constant burning standing pilot was utilized, the pilot input rate was measured and applied to the 0.473 L/min (0.0167 SCFM) of CO_2 stoichiometrically generated per 293 W (1000 btu/hr). This figure was not recorded in the data summaries for two reasons as follows. Pilot input rates are manually adjustable rendering actual measured values of questionable quantitative merit unless a worst case scenario were to be applied wherein the maximum obtainable pilot input rate was to be used to determine applicable CO_2 generation. Also, a given standby/operating cycle would have to be established since pilot CO_2 generation would only be applicable during periods of standby. The second reason for omitting this data, was to protect the anonymity of the sample appliances used in this study since only some models use standing pilots.

The nominal NOx ratio determined for each appliance is recorded in the data summaries and applied to CO_2 determinations to estimate NOx emissions. Make special note that NOx emissions are recorded in SCCM NOT SCFM.

Following the four selected depressurization tests, a hybrid test was conducted to determine whether duplication of true depressurization conditions could be reliably achieved by a combination of chamber depressurization and vent blockage. Some chamber depressurization is necessary since containment of the appliance is mandatory in order to contain the leakage. Chamber depressurization of 25 Pa (0.10 in wc) was used in conjunction with a 25 Pa (0.10 in wc) positive static pressure imposed around the vent terminal by enclosing it in a box with an adjustable outlet orifice.

7. VALIDATION OF TEST METHODOLOGY

Two verification tests were conducted to judge accuracy of the overall test methodology. One test used only an appliance induced draft blower to generate the desired depressurization and the second test used both an appliance blower and the auxiliary chamber blower so that the tracer gas technique for determining auxiliary blower flow could be evaluated. In both cases, the appliance was fired to establish steady state conditions so that correction for appliance CO_2 leakage could be made. A measured flow rate of bottled CO_2 was injected into the inlet of the mixing fan inside the chamber such that a gross chamber CO_2 concentration of around 4,500 ppm was obtained. This level of pollutant was selected to minimize the impact of instrument sensitivity on final accuracy determination. Measured CO_2 injection rates were then compared to calculated rates using the calculation procedures outlined in the previous section. In the case using only the appliance blower, the calculated value was within 5% of the measured injection value. The test using auxiliary blower exfiltration indicated a 7.7% difference between measured and calculated values. Based on these determinations, the accuracy of the method is between 92% and 95% with the instrumentation used.

It is important to understand that instrument sensitivity affects the potential repeatability especially if leakage rates are low and/or exfiltration rates are high resulting in a low ppm concentration of pollutant in the chamber.

8. TEST PROGRAM DATA PRESENTATION

Tables 1 through 10 present the results obtained with the test and measurement method. Presentation is made with a minimum of two significant digits. Figures 1 through 3 graphically display the leakage characteristics of the ten appliances tested as received. The maximum leakage rate shown on the Y-axis of Figures 1 and 2 is the same for easy comparison. Comments are made below for each appliance in explanation of individual data. In evaluating CO_2 emission rates, it must be remembered that emission occurs only during an appliance cycle except in the case of a standing pilot. Also, to give some scale to emission rates, human metabolic emission of CO_2 is in the range of 0.3 to 0.4 litres per minute during periods of low activity (3).

8.1 Appliance #1

When this water heater was probed for leakage sources under depressurization, two sources were identified. Spillage was detected at one corner of the drafthood relief opening and leakage was found to occur at the joint between the exhaust blower and the drafthood assembly. The joint had silicone sealant applied yet leaked presumably due to improper application of the sealant and being exposed to positive pressure on the flue gas side.

This appliance was retested at 50 Pa (0.20 in wc) following replacement application of the silicone seal by CGRI. This minor corrective measure reduced CO_2 leakage by 18% at this test condition. The drafthood spillage continued to be the cause for combustion product leakage.

8.2 Appliance #2

This water heater was probed for leakage sources under depressurization and two sources were identified. Some spillage was detected exiting the burner access opening and leakage from the blower discharge flange was found to occur due to small gaps in the metal fabrication with no sealant used.

8.3 Appliance #3

Two sources of leakage under depressurization were identified when this water heater was probed. Leakage was found to occur at the joint between the exhaust blower and the drafthood assembly as well as at the blower discharge flange due to gaps in the metal fabrication with no sealant used.

8.4 Appliance #4

This water heater was probed for leakage sources under depressurization and two sources were identified. Leakage was found to occur at the joint between the exhaust blower and the drafthood assembly as well as at the blower discharge flange due to gaps in the metal fabrication with no sealant used.

8.5 Appliance #5

When this fireplace was probed for leakage sources under depressurization only one source was identified. The venter assembly leaked slightly from joints and seams which did not have sealant applied An adjustable damper in the venter assembly was originally set at the minimum flow setting for the data shown as a worst case scenario. A retest at 50 Pa (0.20 in wc) with this damper set for maximum venter flow indicated no combustion product leakage at all. This indicates that leakage would be a function of field installation and set-up.

8.6 Appliance #6

This fireplace was probed for leakage sources under depressurization and two sources were identified. The venter assembly leaked slightly from joints and seams which did not have sealant applied and from the motor shaft entry hole in the blower housing.

8.7 Appliance #7

This clothes dryer showed no evidence of any flue gas leakage when used with sealed exhaust vent. For information purposes only, a retest was conducted with unsealed solid metal venting including multi-piece elbows. The data from this retest is presented in Table 7. Due to the extremely high dilution of the combustion gases in this type of appliance, CO_2 leakage still did not amount to much. The criteria for leakage from this type of appliance may be better based on water vapour content from the drying of the wet clothing than on combustion product leakage. The water vapour content would be a somewhat transient commodity itself as the drying process progresses.

8.8 Appliance #8

This multi-cell forced air furnace was probed for leakage sources under depressurization and three sources were identified. Some spillage occurred at the burner access opening, leakage was found at the blower inlet connection to the flue collector box, and leakage was found at the blower discharge connection. The leakage source at the blower discharge was particularly obvious with a gap of around 1/8 inch by 5 inches evident with no sealing means applied. Following the principal test program, supplementary tests at 50 Pa (0.20 in wc) were conducted with incremental sealing of obvious leakage sources. Sealing of the 1/8 inch by 5 inch gap at the blower discharge reduced leakage by 90 %.

Further sealing of the leakage source at the blower inlet connection reduced leakage to only 6% of the original value. These simple remedial measures brought this appliance more in line with the other appliances tested.

8.9 Appliance #9

This clothes dryer was probed for leakage sources under depressurization and three sources were identified. Leakage occurred predominantly from thermal sensor mounting flanges where they protruded through positive pressure exhaust ducting on the appliance. Some minor leakage occurred from the mounting flanges of the ducting itself where it attaches to the appliance. Other minor leakage was found from openings intended for dilution air entrainment. Comments made for appliance #7 also apply regarding minimal CO_2 emission and considering water vapour as the limiting factor in determining leakage criteria.

8.10 Appliance #10

This multi-cell forced air furnace was probed for leakage sources under depressurization and only one minor source was found at the blower connection to the flue collector box.

8.11 Hybrid Test Results

The hybrid test comprised a combination of 25 Pa (0.10 in wc) chamber depressurization and 25 Pa (0.10 in wc) positive exhaust static around the exhaust terminal. This combination was investigated to address a postulated theory that it could simulate the same driving force promoting leakage as the 50 Pa (0.20 in wc) depressurization condition. Test results generally agreed within 10% except where low contaminant concentrations were involved or significant appliance flow reduction resulted as a reaction to the positive static imposed on the exhaust. The data base was insufficient to determine whether location of leakage source was the most significant factor in determining agreement between methods.

CONCLUSIONS

1. The quantities of combustion product leakage determined from representative appliances tested in this investigation were found to be minor in most cases. Those instances where significant leakage was found, minor corrective measures resulted in significant reductions of leakage, indicating new criteria for OEM quality control may be required for some manufacturers.

2. Leakage of combustion products was not a strong function of the depressurization of the indoor environment for the appliances tested in this project as evidenced by the relatively flat slopes of the curves shown in Figures 1 and 2. For these appliances, the minor leakages would occur whether or not a depressurized condition existed. Only appliances 5 and 8 showed a tendency for significantly higher leakage under depressurization. Appliance 5 data was obtained with a manual venter adjustment set for minimum capacity. When retested at 50 Pa and set for maximum venter capacity, no leakage was found indicating leakage is a stronger function of field set-up. Appliance 8 leakage was reduced by 94% at 50 Pa by minor corrective measures indicating leakage was a function of OEM quality control.

3. The test methodology used in this investigation was shown to be capable of determining CO_2 pollutant emission rates with an accuracy of 92% to 95% depending on whether auxiliary exfiltration, measured by the tracer gas technique, was required to achieve the desired chamber depressurization.

4. The minor quantities of leakage found do not support the implementation of a test protocol as a certification requirement for side-wall vented

appliances especially when staffing and equipment requirements are considered. A much more simple approach of leakage probing could be implemented under the auspices of a general clause contained in most CGA appliance Standards which relates to the construction being in accordance with reasonable concepts of safety, substantiality and durability.

5. The quantification of combustion product leakage requires containment of any leakage in a dynamic measurement system. This renders the methodology unsuitable to field use in most cases because of containment difficulties. A simple qualitative probing method such as that used in this investigation to identify leakage source locations could be used in the field with only the most obvious leakage sources being of concern.

6. Potential interferences due to transient background CO_2 levels must be minimized. The chamber atmosphere and vent gases exhausted during the test must be directed away from the test site to an exhaust system. Other fired appliances, especially in a combustion laboratory environment, can also contaminate the background. It is transient background levels that are problematic whereas a constant background can be reasonably accounted for. The use of a more unique tracer gas could eliminate the potential background interference from other appliances.

RECOMMENDATIONS

1. Standards and Code authorities should use the findings of this report, in conjunction with other information, to determine whether indicated quantities of combustion product leakage warrant such a labour and equipment intensive test to be made a certification test requirement for side-wall vented appliances.

2. A directive from the CGA Standards department should be issued to the CGA certification laboratory indicating greater attention to combustion product leakage/spillage should be applied, especially to appliance types using inducer fans which may not have specific test requirements designed to indicate such. The CGA certification laboratory could, in turn, issue a strongly worded announcement to all manufacturers indicating that greater scrutiny will be invoked to ensure that combustion product leakage/spillage is minimized.

3. Should the test protocol developed in this investigation be adopted as a certification test requirement, the tightest possible chamber and highest sensitivity instrumentation should be used to maximize accuracy of determinations. Further investigation is needed to address the issue of repeatability.

REFERENCES

1. Canadian Gas Association Central Furnace Committee, 1990. *Determining Gas Furnace Sensitivity to House Depressurization.*

2. Moffat, P. 1991. *House Depressurization Tolerance of Draft-Induced Gas-Fired Appliances.* Sheltair Scientific.

3. ASHRAE, *1989 ASHRAE Handbook.* Fundamentals.

TABLE 1

Data Summary - Appliance #1

WATER HEATER

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	300	360	400	410
Net Appliance CO_2	(%)	8.47	8.41	8.86	8.76
Net Vent CO_2	(%)	1.47	1.52	1.76	1.76
Vent Dilution Ratio		5.76	5.53	5.03	4.98
Exfiltration Flow	(SCFM)	43.05	41.42	36.19	35.95
	(L/min)	1,219	1,173	1,025	1,018
Auxiliary Exhauster Used		No	No	No	No
CO_2 Leakage	(SCFM)	0.013	0.015	0.014	0.015
	(L/min)	0.37	0.42	0.41	0.42
Nox Leakage	(SCCM)	0.054	0.065	0.069	0.071
Comb. Product Leakage	(SCFM)	0.15	0.18	0.16	0.17
	(L/min)	4.32	5.02	4.63	4.77
Total Comb. Product	(SCFM)	8.60	8.60	8.30	8.33
	(L/min)	244	244	235	236
% of Comb. Product Leaked		1.77	2.06	1.97	2.02

Nominal ppm NOx Per CO_2% = 8.47

TABLE 2

Data Summary - Appliance #2

WATER HEATER

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	210	180	220	220
Net Appliance CO_2	(%)	9.78	9.58	9.78	9.93
Net Vent CO_2	(%)	3.13	2.98	3.08	3.08
Vent Dilution Ratio		3.12	3.21	3.18	3.22
Exfiltration Flow	(SCFM)	21.07	22.19	21.31	21.06
	(L/min)	597	628	603	596
Auxiliary Exhauster Used		No	No	No	No
CO_2 Leakage	(SCFM)	0.0044	0.0040	0.0047	0.0046
	(L/min)	0.13	0.11	0.13	0.13
NOx Leakage	(SCCM)	0.032	0.028	0.033	0.032
Comb. Product Leakage	(SCFM)	0.045	0.042	0.048	0.047
	(L/min)	1.28	1.18	1.36	1.32
Total Comb. Product	(SCFM)	7.81	7.98	7.77	7.68
	(L/min)	221	226	220	217
% of Comb. Product Leaked		0.58	0.52	0.62	0.61

Nominal ppm NOx Per CO_2% = 7.94

TABLE 3

Data Summary - Appliance #3

WATER HEATER

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	60	40	35	50
Net Appliance CO_2	(%)	9.30	9.30	9.20	9.60
Net Vent CO_2	(%)	1.25	1.25	1.25	1.45
Vent Dilution Ratio		7.44	7.44	7.36	6.62
Exfiltration Flow	(SCFM)	53.11	53.86	53.31	45.03
	(L/min)	1,504	1,525	1,510	1,275
Auxiliary Exhauster Used		No	No	No	No
CO_2 Leakage	(SCFM)	0.0032	0.0022	0.0019	0.0023
	(L/min)	0.090	0.061	0.053	0.064
NOx Leakage	(SCCM)	0.0107	0.0072	0.0063	0.0085
Comb. Product Leakage	(SCFM)	0.034	0.023	0.020	0.023
	(L/min)	0.97	0.66	0.57	0.66
Total Comb. Product	(SCFM)	8.35	8.46	8.45	7.98
	(L/min)	236	240	239	226
% of Comb. Product Leaked		0.41	0.27	0.24	0.29

Nominal ppm NOx Per CO_2% = 8.83

TABLE 4

Data Summary - Appliance #4

WATER HEATER

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	0	0	15	15
Net Appliance CO_2	(%)	8.80	8.80	9.00	9.50
Net Vent CO_2	(%)	1.25	1.25	1.25	1.35
Vent Dilution Ratio		7.04	7.04	7.20	7.04
Exfiltration Flow	(SCFM)	79.79	79.68	79.36	74.58
	(L/min)	2,260	2,257	2,247	2,112
Auxiliary Exhauster Used		No	No	No	No
CO_2 Leakage	(SCFM)	0.0	0.0	0.0012	0.0011
	(L/min)	0.0	0.0	0.034	0.032
NOx Leakage	(SCCM)	0.0	0.0	0.0051	0.0049
Comb. Product Leakage	(SCFM)	0.0	0.0	0.013	0.012
	(L/min)	0.00	0.00	0.37	0.33
Total Comb. Product	(SCFM)	13.14	13.12	12.82	12.42
	(L/min)	372	372	363	352
% of Comb. Product Leaked		0.00	0.00	0.10	0.09

Nominal ppm NOx Per CO_2% = 10.86

TABLE 5

Data Summary - Appliance #5

FIREPLACE

Data at minimum venting adjustment, no leakage at maximum adjustment.

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	100	110	140	170
Net Appliance CO_2	(%)	2.99	2.99	3.04	3.03
Net Vent CO_2	(%)	2.19	2.29	2.44	2.58
Vent Dilution Ratio		1.37	1.31	1.25	1.17
Exfiltration Flow	(SCFM)	19.84	33.42	42.71	51.58
	(L/min)	562	946	1,210	1,461
Auxiliary Exhauster Used		Yes	Yes	Yes	Yes
CO_2 Leakage	(SCFM)	0.0020	0.0037	0.0060	0.0088
	(L/min)	0.056	0.10	0.17	0.25
NOx Leakage	(SCCM)	0.032	0.063	0.11	0.17
Comb. Product Leakage	(SCFM)	0.066	0.12	0.20	0.29
	(L/min)	1.88	3.48	5.57	8.20
Total Comb. Product	(SCFM)	9.91	9.91	9.74	9.77
	(L/min)	281	281	276	277
% of Comb. Product Leaked		0.67	1.24	2.02	2.96

Nominal ppm NOx Per CO_2% = 7.84

TABLE 6

Data Summary - Appliance #6

FIREPLACE

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	15	30	40	40
Net Appliance CO_2	(%)	0.75	0.75	0.80	0.85
Net Vent CO_2	(%)	0.60	0.60	0.65	0.70
Vent Dilution Ratio		1.25	1.25	1.23	1.21
Exfiltration Flow	(SCFM)	62.91	62.53	57.88	53.89
	(L/min)	1,782	1,771	1,639	1,526
Auxiliary Exhauster Used		No	No	No	No
CO_2 Leakage	(SCFM)	0.0009	0.0019	0.0023	0.0022
	(L/min)	0.027	0.053	0.066	0.061
NOx Leakage	(SCCM)	0.0019	0.0038	0.0048	0.0045
Comb. Product Leakage	(SCFM)	0.13	0.25	0.29	0.25
	(L/min)	3.56	7.08	8.20	7.18
Total Comb. Product	(SCFM)	50.78	50.47	47.47	44.82
	(L/min)	1,438	1,429	1,344	1,269
% of Comb. Product Leaked		0.25	0.50	0.61	0.57

Nominal ppm NOx Per CO_2% = 0.89

TABLE 7

Data Summary - Appliance #7

CLOTHES DRYER

This test with leaky ducts, no leakage with sealed ducts.

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	20	25	30	80
Net Appliance CO_2	(%)	N/A	N/A	N/A	N/A
Net Vent CO_2	(%)	0.41	0.43	0.44	0.46
Vent Dilution Ratio		N/A	N/A	N/A	N/A
Exfiltration Flow	(SCFM)	86.54	83.01	80.66	80.27
	(L/min)	2,451	2,351	2,284	2,273
Auxiliary Exhauster Used		No	No	No	No
CO_2 Leakage	(SCFM)	0.0017	0.0021	0.0024	0.0064
	(L/min)	0.049	0.059	0.069	0.182
NOx Leakage	(SCCM)	0.025	0.029	0.034	0.091
Comb. Product Leakage	(SCFM)	0.42	0.48	0.55	1.40
	(L/min)	12.0	13.7	15.6	39.5
Total Comb. Product	(SCFM)	86.89	83.37	81.01	80.63
	(L/min)	2,461	2,361	2,294	2,283
% of Comb. Product Leaked		0.49	0.58	0.68	1.73

Nominal ppm NOx Per CO_2% = 5.00

TABLE 8

Data Summary - Appliance #8

FURNACE

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	6,900	4,880	4,360	4,500
Net Appliance CO_2	(%)	N/A	N/A	N/A	N/A
Net Vent CO_2	(%)	7.55	7.81	8.06	8.45
Vent Dilution Ratio		N/A	N/A	N/A	N/A
Exfiltration Flow	(SCFM)	16.49	32.02	42.74	46.80
	(L/min)	467	907	1,210	1,325
Auxiliary Exhauster Used		No	Yes	Yes	Yes
CO_2 Leakage	(SCFM)	0.11	0.16	0.19	0.21
	(L/min)	3.22	4.43	5.28	5.96
NOx Leakage	(SCCM)	1.97	2.70	3.22	3.64
Comb. Product Leakage	(SCFM)	1.51	2.00	2.31	2.49
	(L/min)	42.7	56.7	65.5	70.6
Total Comb. Product	(SCFM)	17.53	17.17	16.69	16.28
	(L/min)	496	486	473	461
% of Comb. Product Leaked		8.60	11.65	13.85	15.31

Nominal ppm NOx Per CO_2% = 6.10

TABLE 9

Data Summary - Appliance #9

CLOTHES DRYER

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	30	30	30	30
Net Appliance CO_2	(%)	N/A	N/A	N/A	N/A
Net Vent CO_2	(%)	0.37	0.35	0.36	0.36
Vent Dilution Ratio		N/A	N/A	N/A	N/A
Exfiltration Flow	(SCFM)	90.13	94.78	92.16	92.66
	(L/min)	2,552	2,684	2,610	2,624
Auxiliary Exhauster Used		No	No	No	No
CO_2 Leakage	(SCFM)	0.0027	0.0028	0.0028	0.0028
	(L/min)	0.077	0.081	0.078	0.079
NOx Leakage	(SCCM)	0.070	0.074	0.071	0.072
Comb. Product Leakage	(SCFM)	0.73	0.81	0.77	0.77
	(L/min)	20.7	23.0	21.7	21.9
Total Comb. Product	(SCFM)	90.46	95.12	92.49	93.00
	(L/min)	2,562	2,694	2,619	2,634
% of Comb. Product Leaked		0.81	0.85	0.83	0.83

Nominal ppm NOx Per CO_2% = 9.13

TABLE 10

Data Summary - Appliance #10

FURNACE

Depressurization	(in wc)	0.05	0.10	0.15	0.20
	(Pa)	12.5	25	37.5	50
Net Chamber CO_2	(ppm)	80	75	80	80
Net Appliance CO_2	(%)	N/A	N/A	N/A	N/A
Net Vent CO_2	(%)	7.70	7.80	8.10	8.40
Vent Dilution Ratio		N/A	N/A	N/A	N/A
Exfiltration Flow	(SCFM)	16.05	36.35	41.39	45.73
	(L/min)	455	1,029	1,172	1,295
Auxiliary Exhauster Used		No	Yes	Yes	Yes
CO_2 Leakage	(SCFM)	0.0013	0.0027	0.0033	0.0037
	(L/min)	0.036	0.077	0.094	0.104
NOx Leakage	(SCCM)	0.033	0.071	0.086	0.095
Comb. Product Leakage	(SCFM)	0.017	0.035	0.041	0.044
	(L/min)	0.47	0.99	1.16	1.23
Total Comb. Product	(SCFM)	17.21	17.01	16.52	16.69
	(L/min)	487	482	468	473
% of Comb. Product Leaked		0.10	0.21	0.25	0.26

Nominal ppm NOx Per CO_2% = 9.17

FIGURE 1

APPLIANCE #1 THROUGH #5

CO_2 LEAKAGE VS CHAMBER DEPRESSURIZATION

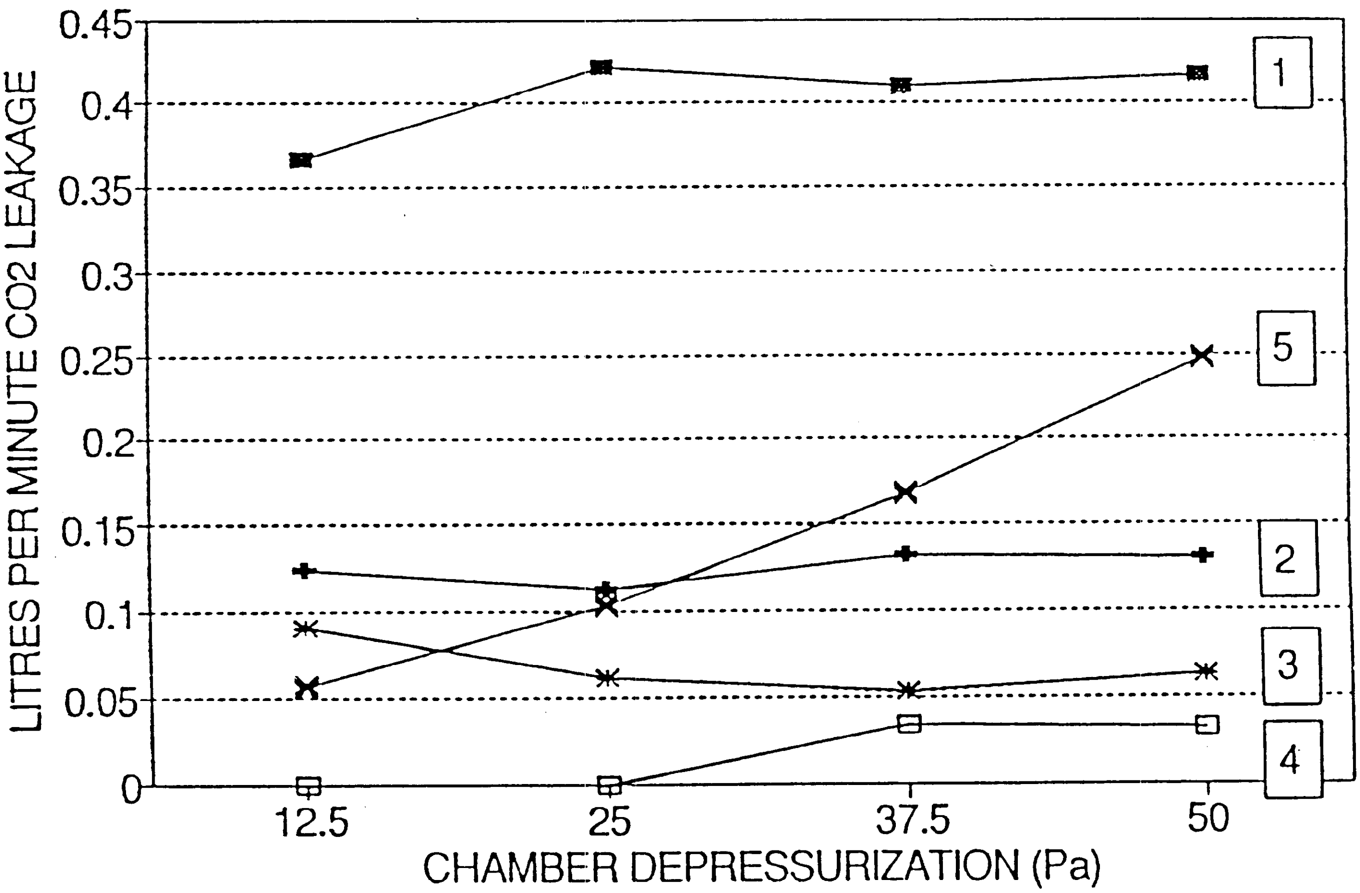


FIGURE 2

APPLIANCES #6, #7, #9 AND #10

CO_2 LEAKAGE VS CHAMBER DEPRESSURIZATION

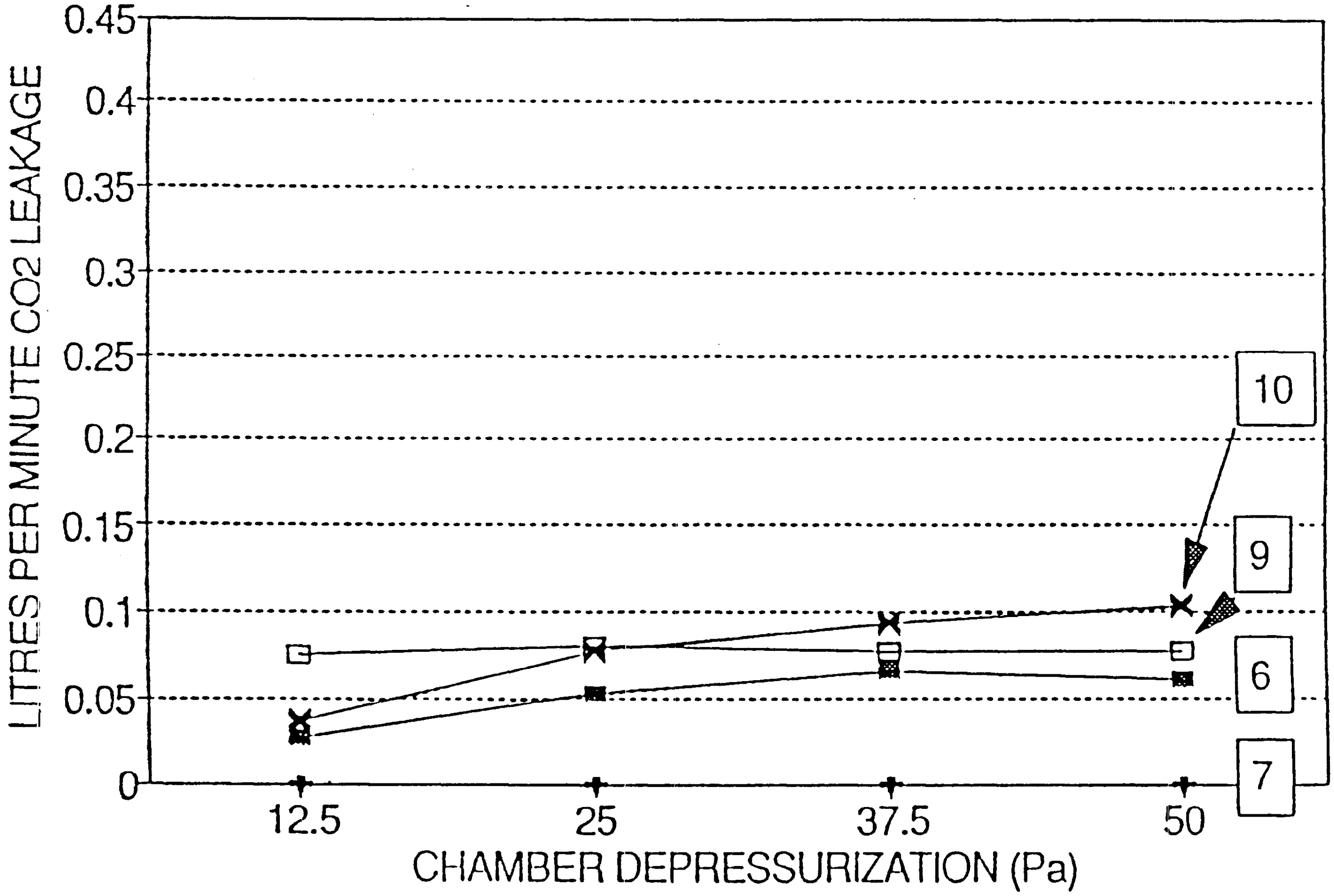
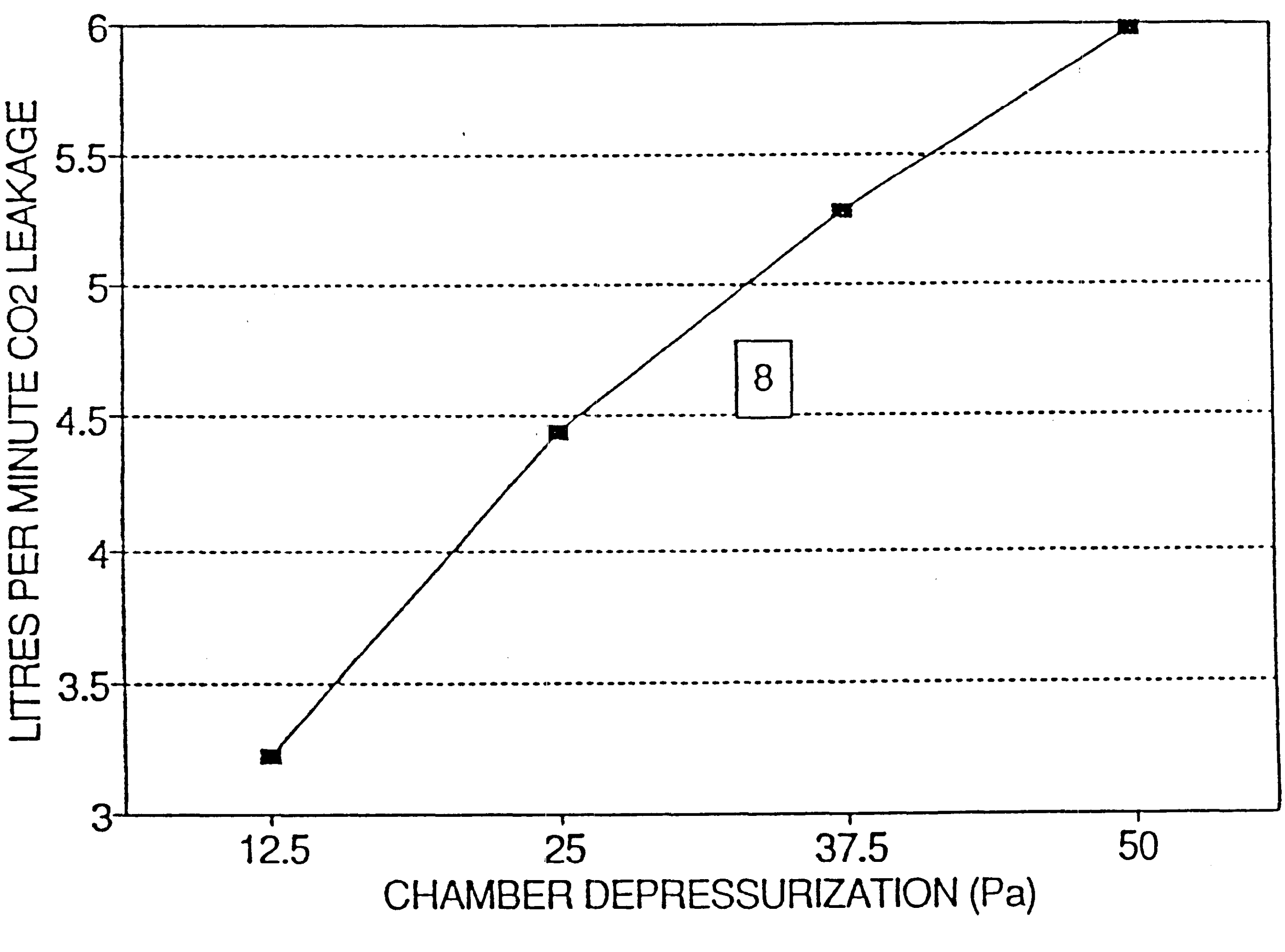


FIGURE 3

APPLIANCE #8

CO_2 LEAKAGE VS CHAMBER DEPRESSURIZATION



ITEM 18.
Z21/CGA Joint Water Heater
Subcommittee Meeting,
September 23-24, 1993

STATUS OF GRI-FUNDED RESEARCH PROJECTS INVOLVING GAS-FIRED WATER HEATERS

Action Requested

The subcommittee is requested to review for information the status of the following Gas Research Institute (GRI)-funded research project involving gas-fired water heaters:

Operation of Gas-Fired Appliances at High Altitudes

History

In 1985 the Z21 Chairman's Advisory Committee (CAC), the Z21 Committee, the Z83 Committee, the Gas Research Institute (GRI) and the American Gas Association Laboratories (AGAL) cooperated in establishing a program whereby the members of the Z21 and Z83 Committees and their subcommittees can recommend safety related test methods investigation projects for study by GRI. Such projects are processed through a panel comprised of the CAC and the Chairman of the Z83 Committee for recommendation to GRI. The Gas Appliance Technology Center (GATC) coordinates submitting the recommended projects to GRI with a request for funding.

Background

The purpose of this item is to provide the joint subcommittee with a list of the various projects and their status related to gas-fired water heaters.

The following is an excerpt from agenda Item 20 of the April 8, 1993 meeting of the Z21 Committee, and the April 7, 1993 meeting of the Z21 CAC:

CSA testing in their high alt. chamber.

APPROVED PROJECTS TO BE INITIATED

I. Develop a test method investigation project on the effects of "high altitude" on the operation of gas appliances.

Status

A joint ad hoc working group met on August 27, 1991 to review a GRI report on "high altitude." The working group reviewed (1) the circumstances that had prompted the original request that the effects of high altitude on current appliance designs be investigated, and (2) the resultant GRI sponsored white paper.

During consideration of the GRI white paper, the ad hoc working group had noted that only a very limited sample of appliances had been tested and some of the test results raised questions which had remained unanswered due to limited availability to a altitude simulation chamber. Consequently, the working group agreed that additional research was needed to (1) address a wider variety of the appliances/appliance designs, (2) develop information on the correlation of tests conducted in an altitude simulation chamber to actual appliance operation at high altitudes, and (3) investigate various methods in which adjustments are made to address the effects of high altitude. In conclusion, the working group drafted a work statement for additional research on the effects of altitude on appliance operation for recommendation to GRI for funding.

At its October 1991 meeting, the project panel considered the above noted draft work statement. The project panel was informed that CGA has a separate standard for gas-fired appliances for use at high altitudes (CAN/CGA-2.17-M91). It was reported that a report completed by CGA during the 1960's was the basis for CGA 2.17. It was agreed that this CGA report should be forwarded to the GATC for additional information. In conclusion, the project panel recommended that GRI fund a test method investigation project to address the effects of "high altitude" on the operation of gas appliances.

At its April 8, 1992 meeting, the project panel was informed that the GATC would be refining the original work statement to focus on selected appliances that would be representative of the myriad of appliances identified in the original work statement. It was reported that this project would be coordinated with the Canadian Gas Research Institute (CGRI). It was also noted that Mountain Fuel Supply, Salt Lake City, Utah, is very interested in the high altitude work and may co-fund the research project.

The chairman of the joint ad hoc working group met with GRI and AGAL staff in August 1992 to discuss the draft work plan. A revised work plan was prepared and distributed to the joint ad hoc working group and central furnace technical working group for review and comment. A preliminary allocation of funding in the 1992 GATC budget was made to initiate work when the work plan was approved. Several members of the joint ad hoc high altitude working group and other selected individuals have been designated as the technical advisory group (TAG) for this activity. A meeting of the TAG is scheduled for March 16, 1993. A verbal report is anticipated at that meeting.

Additional Background

It is anticipated that a verbal status report will be presented at this meeting by one of the high altitude project TAG representatives.

ITEM 19.
Z21/CGA Joint Water Heater
Subcommittee Meeting,
September 23-24, 1993

REPORT ON STANDARDS STRATEGIC PLANNING ACTIVITY

Action Requested

This item is to inform the subcommittee that a standards strategic planning activity is underway.

Background

In recent times issues have been raised regarding the need to increase participation on the subcommittees and joint subcommittees. In 1991 a "white paper" was presented to the American Gas Association Technology Committee addressing this issue and also the importance of standards activities involving new technologies. The subject was addressed by the A.G.A. Laboratories Managing Committee (LMC) and the Standards Advisory Committee (SAC) of Canada. As a result, both the LMC and SAC requested that a strategic plan be developed.

The A.G.A. Administrative Secretary, Allen J. Callahan, undertook the formation of an industry-based Standards Strategic Planning Committee, including gas utility, manufacturer, propane supplier, U.S. and Canadian secretariat and Canadian regulatory representation.

At the committee's first meeting on February 3-4, 1993, broad discussions addressed that there is a critical need for a system of developing standards for the gas industry, that they must be of the highest quality, there are no better standards developing organizations to meet the needs of the gas industry, and we do have to improve the program.

It was agreed that key factors to a successful program include: quality standards, timeliness in processing (and addressing new technologies for the market), broad acceptance (by industry, code officials, etc.), and cost effectiveness.

Focusing on particular issues, it was agreed that the program needs to remain a function of the gas industry. Other notable issues concerned the need for marketing the standards and the value of the program, increased gas utility and other non-manufacturer participation (and evolving ideas on how this may be addressed), and funding.

With regard to participation, having regulators and building officials on the subcommittees was also seen as a distinct advantage for the program. It was thought that having regulators and building officials actively participating would help promote acceptance and implementation of the standards. Other opportunities for participation, it was thought, might come from the contractor/installer community, however, this may require funding support to attend meetings.

With regard to program funding, it was understood that the current level of funding by A.G.A. and CGA would continue. However, it was agreed that demands on the program have increased with, e.g., harmonization and new technologies. Some ideas for other funding sources were brought out, such as from the manufacturing community.

Additional meetings were held on February 22-23 and April 6, 1993. A strategic (business) plan, "vision" and "mission" statements were finalized as shown in the Attachments to this item. It addition several action steps are being recommended:

- Documenting the benefit of the standards for the industry, appropriate government agencies and code authorities;
- a "value chain analysis" of gas suppliers, manufacturers and government agencies/code authorities to be completed by April 1994;
- a "participation information program" (training/engineering resources) - outlined to be completed by July 1993; and
- an "outreach program" to be completed by July 1994.

Other major actions/goals that took place at the above meetings addressed:

- alternate methods regarding processing of proposals (canvass and committee ballots), concentrated meeting sites, supplemental participation (code officials/building inspectors) and alternate funding;
- continuation of U.S. and Canadian standards harmonization;
- a secretariat "functional business plan" by year end 1993; and
- a NGV family of standards by year end 1996;

Attachment I

BUSINESS PLAN

VISION	(You first must have a "Vision")
MISSION	(The "Mission" must support the Vision)
CRITICAL ISSUES	(Identify the major issues to the business plan)
GOALS	("Goals" are responsive to the critical issues, must be measurable, address the critical issues, and have attainable time frames for completion)
ACTIONS	(Specific "Actions" to be taken to reach the goals)

Attachment II

VISION AND MISSION STATEMENTS

The "vision" and "mission" statements for the standards program were modified and adopted by the committee as follow:

VISION

To have the standards developers served by the AGA/CGA secretariats recognized by the gas industry, the standards community and the authorities having jurisdiction, as the foremost developer, coordinator and provider of safety, performance and installation standards for the safe utilization of gas equipment.

MISSION

To develop, maintain and promote the use of consensus standards which continue to enhance the safe utilization of gas equipment, benefit the consumer, all sectors of the gas industry and appropriate government agencies. These standards will be developed in a timely and cost effective manner that is responsive to market needs and changes in technology.

A "mission" statement for the secretariats was adopted by the committee as follows:

MISSION

Administer the standards programs of the gas industry in a timely and effective manner.

ITEM 20.
Z21/CGA Joint Water Heater
Subcommittee Meeting,
September 23-24, 1993

SI EQUIVALENT UNITS FOR "PRESSURE"

Action Requested

Consider recommendation from the Z21/CGA joint automatic gas controls subcommittee, to add a scope provision to Z21 vented heater standards (Z21.11.1, Z21.44, Z21.48 and Z21.49) to address SI equivalent units for "pressure."

Background

At its January 28-29, 1992 meeting, the Z83/CGA joint food service equipment subcommittee considered a comment received during the industry review period of the proposed harmonized draft standard for deep fat fryers. The comment addressed the present method of specifying the SI (International System of Units) equivalent units for pressure following the English units for pressure (e.g., 2 ½ psig [17.2 kPa]). The comment noted that in the SI system of units an acceptable "equivalent" abbreviation for "psig" or "psia" does not exist. Therefore, it was suggested that the joint subcommittee consider adopting the convention in ASTM E-380 (Metric Practice Guide), which states:

> "3.5.5 *Attachment*--Attachment of letters to a unit symbol as a means of giving information about the nature of the quantity under consideration is incorrect. Thus MWe for "megawatts electrical (power)," Vac for "volts ac," and kJt for "kilojoules thermal (energy)" are not acceptable. For this reason, no attempt should be made to construct SI equivalents of the abbreviations "psia" and "psig" so often used to distinguish between absolute and gage pressure. If the context leaves any doubt as to which is meant, the word *pressure* must be qualified appropriately. For example:
>
> '...at a gage pressure of 13 kPa'
>
> or
>
> '...at an absolute pressure of 13 kPa'"

In response to the above, the joint food service equipment subcommittee agreed to revise its proposed harmonized draft standards to reflect the ASTM E-380 standard, wherever psia or psig appeared in the draft standards. The wording to that effect is as follows:

"...at a gage pressure of ***U.S. units*** psi (***SI equivalent units*** kPa)"

or

"...at an absolute pressure of ***U.S.units*** psi (***SI equivalent units*** kPa)"

At its February 11-13, 1992 meeting, the Z21/CGA joint central furnace subcommittee considered a similar comment on provision 8.9.1 of the proposed harmonized central furnace standard. In response, the joint central furnace subcommittee agreed that the gage pressure specified in 8.9.1 was correct as written. No recommendation to revise the standard was taken by the joint subcommittee.

At its April 22, 1992 meeting, the Z21/CGA joint automatic gas controls subcommittee also considered a comment regarding the SI units for pressure.

During discussion, it was commented that since gage pressure is generally understood throughout the industry, an uncomfortable situation would not be created if the standard was revised to be consistent with the convention in ASTM E-380. It was also commented that absolute pressure is mentioned in very few places throughout the gas appliance and accessory standards.

Following consideration, the joint automatic gas controls subcommittee agreed to adopt for distribution for review and comment the following scope provision for inclusion into the gas appliance pressure regulator (Z21.18), automatic valve (Z21.21), and combination control (Z21.78) standards:

"All references to psi throughout this standard are to be considered gage pressures unless otherwise specified."

In addition, the joint automatic gas controls subcommittee recommended that the Z21 and Z83 Committees direct their subcommittees to incorporate the above proposed scope provision in all the applicable standards under the subcommittees' supervision. The joint subcommittee also recommended the following rationale statement as substantiation for the added scope provision:

"**RATIONALE:** To eliminate any confusion to conversion of SI equivalents and to be consistent with the ASTM E-380 standard."

Additional Information

At its October 22, 1992 meeting, the Z83 Committee directed its technical subcommittees to place a scope provision in the standards under their supervision as recommended above by the Z21/CGA joint automatic gas controls subcommittee. The Committee agreed that the new scope provision could be placed in the standards at the time of printing a new edition. In response to a similar recommendation from the Z21 Chairman's Advisory Committee, a similar action was taken by the Z21 Committee at its April 8, 1993.

ITEM 21.
Z21/CGA Joint Water Heater
Subcommittee Meeting,
September 23-24, 1993

NPGA
National PROPANE GAS Association
TY V. LOTZ
Vice President, Technical Services

1600 Eisenhower Lane • Suite 100 • Lisle, IL 60532 • (708) 515-0600

July 30, 1993

Mr. Allen J. Callahan
Administrative Secretary, Z21 and Z83
8501 E. Pleasant Valley Road
Cleveland, OH 44131

Dear Mr. Callahan:

The National Propane Gas Association proposes that all Z21 and Z83 appliance standards for "permanently installed appliances" (see definition below) require the appliance to incorporate both an inlet and outlet pressure tap as is currently required in the Z21.13 Standard (Hot Water Boilers), Section 1.12.17.

Definition of "Permanent Installation" - an installation of an appliance for use indefinitely at a particular location; an installation not normally expected to change in status, condition, or place.

Redline denotes proposed additions
~~Strike-out~~ denotes proposed deletions

Proposal:

Two ~~1/8 inch or 1/4 inch~~ N.P.T. plugged or capped tappings, accessible for test gauge connection, shall be furnished. The connections shall be a minimum of 1/8 inch N.P.T. One shall be upstream of the gas appliance pressure regulator for measuring the minimum permissible gas supply pressure for the purpose of input adjustment. The other shall be downstream from the last main line gas control valve for measuring the manifold gas pressure. The plugs for the tappings shall not be of the slotted head type.

(b) CLEARED:
✓ No Mfrs Identified
____ Excepted
____ Mfrs Notified
Comments Processed

Rationale:

1. To facilitate the setting of the appliance input rate as required by the manufacturer's appliance installation instructions.

2. To facilitate pressure, flow and leak testing to properly conform with necessary testing procedures in the interest of appliance user safety.

Please advise each appliance subcommittee for "permanently installed appliances" of this proposal. If you have any questions, please contact me.

Sincerely yours,

Ty V. Lotz

TVL/jd

File: Z21.13

A. O. SMITH
WATER PRODUCTS COMPANY
PRODUCT ENGINEERING
POST OFFICE BOX 600 McBEE, SOUTH CAROLINA 29101
(803) 335-8281

September 10, 1993

Mr. Daryl L. Hosler
Chairman, Z21/CGA Subcommittee
on Standards for Gas Water Heaters
American Gas Association
8501 East Pleasant Valley Rd.
Cleveland, OH 44131

SUBJECT: Proposed Revision to Storage Heater Temperature Limits Requirement

Dear Mr. Hosler:

There is a need for some water heaters to provide hot water limited to a temperature noticeably less than 160F. Under the present requirements such a model would have to be provided with a miscalibrated thermostat for testing. This should not be necessary. Enclosed is a proposed revision to section 2.13 which would eliminate the need for a miscalibrated thermostat test. It also combines 2.13.1 and 2.13.2 for easier readability and eliminates a non-pertinent paragraph.

Please place this item on the agenda for discussion at the next Subcommittee meeting.

Yours truly,

Wilbur L. Haag
Applications Engineer

cc: A. J. Callahan

Enclosure

2.13 STORAGE HEATER TEMPERATURE LIMITS

When a separate nonadjustable thermostat in the upper part of the water heater is provided by the manufacturer to limit the water temperature in the top part of the tank, in addition to the thermostat used to control the operation of the appliance, both thermostats shall be considered as a single thermostat for test purposes under this section.

~~2.13.1~~ When water heaters ~~are intended to~~ deliver water at a temperature ~~not in excess of 160 F (71 °C), the outlet water temperature shall not rise more than 30 F (16.5 °C) above the initial water temperature, and in no case shall the outlet water temperature exceed 190 F (88 °C) when tested as specified in the following Method of Test.~~

(a) not in excess of 160F, the outlet water temperature shall not rise more than 30F above its maximum initial temperature, or

(b) in excess of 160F, the outlet water temperature shall not rise more than 20F above its maximum initial temperature and in no case shall the outlet water temperature exceed 200F.

Method of Test

~~The appliance supplied for test shall be equipped with a thermostat calibrated between 155 and 160 F (68 and 71 °C) at the thermostat level.~~ The temperature adjustment means on thermostats ~~provided~~ with adjustable features for consumer use shall be set against the high stop. ~~and the thermostat shall not be recalibrated during any part of this test. Other types of~~ Non adjustable thermostats shall be tested as received.

The system shall be filled with water at 65 ± 5 F (18.5 ± 3 °C). A quick-acting valve shall be installed on the outlet connection of the storage vessel. The minimum cross-sectional area through this valve shall be equal to or greater than that of a ¼-inch (6.4 mm) nipple. A flow restricting device shall be connected to the outlet of this valve. The flow restricting device shall be adjusted or constructed so as to maintain a flow rate of 3 gallons per minute (11.36 L/min.) during test draw periods. A mercury thermometer graduated to 1 F (0.5 °C) or a suitable thermocouple shall be placed in the outlet flow stream as close to the outlet connection of the storage vessel as practical. A suitable thermocouple shall also be located in the storage vessel at the thermostat level. A water pressure regulator shall be located between the inlet connection to the storage vessel and the water supply line and adjusted so that, at a steady flow rate of 3 gallons per minute (11.36 L/min.), the pressure at the inlet connection will be 40 pounds per square inch (275.8 kPa). During the test, inlet water temperature shall be maintained at 65 ± 5 F (18.5 ± 3 °C).

The appliance shall be operated at normal inlet test pressure with the test gas for which the highest rating is requested until the thermostat reduces the gas supply to the burner(s) to a minimum. The water temperature at the thermostat level shall be ~~within the limits of 155-160 F (68-71 °C)~~ recorded. Water shall then be immediately drawn at the specified draw rate until the thermostat functions, and the maximum outlet temperature shall be recorded as the maximum initial temperature. This operation shall be repeated until a constant outlet water temperature is attained. When this condition has been reached, the maximum outlet water temperature shall be recorded. ~~The outlet water temperature shall not increase more than 30 F (16.5 °C) above its maximum initial temperature, nor exceed 190 F (88 °C).~~

[redacted]

Arthur D Little

GAMA Flammable Vapor Ignition Study

Discussion of Test Plan with Consumer Product Safety Commission

February 17, 1993

Arthur

Referei

Agenda

The purpose of this presentation is to discuss the Flammabl Ingnition Study Test Plan with representatives of the Consun Safety Commission.

- Introduction
- Summary of Data Collection and Analysis Task
- Analytical Modeling
- Experimental Testing

Arthur D Little

The purpose of this study is to investigate and characterize t posed by the ignition of flammable vapors. To accomplish tl divided the effort into three tasks.

Task	Objec
1. Data Collection and Analysis	Determine the characteristics incidents
2. Analytical and Experimental Testing	Analytically anc experimentally scenarios defin in Task 1
3. Analysis of Consumer and Installer Activities	Determine insta procedures anc effectiveness of labels and instr

The interaction and data-flow between these tasks has been improve communications on this project.