**EVALUATION AND DEMONSTRATION OF
DECENTRALIZED SPACE AND WATER HEATING
VERSUS CENTRALIZED SERVICES FOR NEW
AND REHABILITATED MULTIFAMILY BUILDINGS**

Final Report

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ABSTRACT AND KEY WORDS

ABSTRACT

The general objective of this research was aimed at developing sufficient technical and economic know-how to convince the building and design communities of the appropriateness and energy advantages of decentralized space and water heating for multifamily buildings. Two main goals were established to guide this research. First, the research sought to determine the cost-benefit advantages of decentralized space and water heating versus centralized systems for multifamily applications based on innovative gas piping and appliance technologies. The second goal was to ensure that this information is made available to the design community.

To achieve the two main goals of this research project, eight specific tasks were performed :

- Conduct a review of extant literature and research on comparisons between centralized versus decentralized space and water heating in multifamily dwellings.
- Analyze energy requirements and potential for savings as a result of technical innovations applicable to decentralized gas-fired space and water heating systems for three prototypical multifamily dwellings.
- Characterize the multifamily building stock in the State of New York. Determine which types of multifamily buildings are most likely to benefit from innovations in decentralized space and water heating systems.
- Investigate the regulatory barriers in the State of New York to the use of innovative technology for new gas piping and decentralized gas-fired space and water heating systems in multifamily dwellings.
- Develop strategies for overcoming the identified institutional barriers or for promoting the adoption of new gas piping systems and appliance technologies.
- Conduct a survey to identify emerging technologies for gas piping, gas metering, gas utilization equipment, and appliance vents for rehabilitated and newly constructed multifamily buildings.
- Conduct a survey to identify innovative construction technologies for chaseways, appliance venting, fire protection, insulation, and other affected areas of rehabilitated and newly constructed multifamily buildings.
- Document the results of the research in a comprehensive final report. This is the vehicle for information transfer to the design community.

Several surveys, literature reviews, assessments, and analyses were conducted to achieve the project goals.

The results of the research clearly indicate that there exists a sizable new and retrofit multifamily market for decentralized space and water heating systems in the State of New York. Furthermore, substantial energy savings are achievable in multifamily buildings solely as a result of the decentralized heating configurations. Also, shifting the responsibility for heating costs to tenants alone results in energy savings. Potential energy savings can range from 6 to 77 percent.

However, institutional constraints could affect the implementation of new gas piping systems and appliance technologies. More specifically, there exists potential code barriers to the acceptance of corrugated stainless steel tubing (CSST) gas piping systems and dual integrated appliances (DIAs) in multifamily buildings. The constraints focus on the use of elevated gas pressures, the use of circulating potable water for heating or cooling, and the actual approval or installation of the tubing material (CSST). A great deal of work will be required to inform and educate the affected parties before acceptance and use of the technologies is achieved.

The technology survey, which identified emerging gas technologies that are considered innovative relative to conventional approaches that are in use today, concluded: 1) there are commercially available small residential meters that could be used for multifamily new and rehabilitated construction projects in the State of New York; 2) a combination of rigid steel pipe (vertical riser) and/or semirigid tubing (CSST or copper tubing) operated at elevated pressure (up to 5 psi) offer the most advanced technologies that will result in the lowest total installed costs for multifamily new and rehabilitated buildings; and 3) combination space and water heating systems require a Category I vent because the water heater portion of the system produces combustion products. However, no other special materials or installation practices are required for the vent systems of combination space and water heating systems.

KEY WORDS

Interior gas distribution	Energy use by buildings
Decentralized space and water heating systems	Multi-attribute analysis
Dual integrated appliances	Energy savings
Corrugated stainless steel tubing	Multifamily buildings

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Mr. Adrian Tuluca - Steven Winter Associates. Mr. Tuluca conducted the economic/energy assessment. This study analyzed the energy requirements and potential savings as a result of technical innovations applicable to decentralized gas-fired space and water heating systems for multifamily dwellings. The study also characterized the multifamily building stock in the State of New York.

Ms. Kate McQueen - National Conference of States on Building Codes and Standards. Ms. McQueen provided an assessment of the codes and standards that address institutional concerns associated with available technologies for decentralized gas applications in multifamily buildings in the State of New York.

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SUMMARY

This research project has determined the cost-benefit advantages of decentralized space and water heating versus centralized systems for multifamily applications based on innovative gas piping and appliance technologies. A complete review was performed to assess the energy requirements and potential for savings as a result of technical innovations applicable to decentralized gas-fired space and water heating systems for multifamily dwellings in the State of New York. The review included the characterization of the multifamily building stock in the State of New York to determine which types of multifamily buildings are most likely to benefit from innovations in decentralized space and water heating systems.

For the retrofit multifamily market, the analysis concluded that buildings with 10 to 49 apartments and buildings with 50 or more apartments represent the largest segment of the multifamily market in the State of New York (over 70 percent). Another segment with a high potential is defined by low-rise (one to three floors) buildings with three to nine apartments, that have gas-fired hydronic heating. Buildings with over 10 units are appropriate for decentralized heating/domestic hot water systems, provided they are less than 4 stories high and either have gas heating or the economies of fuel switching are attractive. Seventy-five to eighty percent of these buildings use fuel oil. Regarding new multifamily buildings, the largest market segment, when defined solely by the number of units in New York State, currently appears to be that with 50 or more apartments.

Finally, the assessment indicated that substantial energy savings are achievable in multifamily buildings solely as a result of the conversion to a decentralized configuration. The savings range from 11 to 15 percent for the pre-1940 building types, and from 7 to 17 percent for the post-1980 building types. However, the heating energy cost increases for dual-integrated appliance (DIA) systems. In the Consolidated Edison and Brooklyn Union Gas service territories, the increase ranges from 42 to 53 percent for pre-1940 building types, and 59 to 83 percent for post-1980 building types. The cost increases are a result of the high gas rate for the first few therms, and to the service charges assessed on each apartment. This rate structure constitutes a significant institutional impediment.

The literature review of decentralized versus centralized heating systems revealed (through several studies) that shifting the responsibility for heating costs to tenants results in energy savings. Furthermore, based on those studies, energy savings ranged from 6 to 77 percent.

Institutional constraints that may affect the implementation of new gas piping systems and appliance technologies were investigated and identified, and strategies to overcome them were developed. The potential code barriers to the acceptance of corrugated stainless steel tubing (CSST) gas piping systems and DIAs in multifamily buildings focused on the use of elevated gas pressures, the use of circulating potable water for heating or cooling, and the actual approval or installation of the tubing material (CSST).

From the informal survey of professionals with an interest in these applications, the National Conference of States on Building Codes and Standards (NCSBCS) found that several issues of concern presented in Section 3 are fairly pervasive throughout the State of New York. These included but were not limited to: concerns about gas pressures over 0.5 psig inside a residential structure, the use of potable water for space heating, and the lack of a long-term safety record for CSST, despite its listings. In conclusion, a great deal of work will be required to inform and educate the affected parties before acceptance and use of these technologies is achieved. Strategies for overcoming the restriction on using potable water for space heating and elevated gas pressures in multifamily buildings were developed.

A technology survey was conducted by Foster-Miller to identify emerging gas technologies that are considered innovative relative to conventional approaches that are in use in New York State today. Areas of investigation included metering, gas piping, space and water heating systems, and appliance venting. A second survey was conducted by Steven Winter Associates (SWA) to identify installation methods for gas piping located in chaseways, fire protected areas, and other affected areas of rehabilitated and newly constructed multifamily buildings. The results of the SWA survey were documented by the development of 15 construction drawings showing details of flexible tubing and rigid piping installation techniques needed for the implementation of this recently developed technology.

Three of the most significant conclusions drawn from the survey are:

- There are commercially available small residential meters that could be used effectively for multifamily new and rehabilitated construction projects in the State of New York. These downsized meters, which are 40 percent smaller than existing meters of the same flow capacity, can save valuable space in submetering closets. Several compact gas meters are under development, but are not commercially available and are still a few years from commercial availability.
- A combination of rigid steel pipe (vertical riser) and/or semirigid tubing (CSST or copper tubing) operated at elevated pressure (up to 5 psi) offers the most advanced technology that will result in the lowest total installed costs for multifamily new and rehabilitated buildings.
- Combination space and water heating systems require a Category I vent because the water heater portion of the system produces combustion products. However, no special materials or installation practices are required for the vent systems of combination space and water heating systems.

Section 1

INTRODUCTION

The primary objective of this research was aimed at developing sufficient technical and economic know-how to convince the building and design communities of the appropriateness and energy advantages of decentralized space and water heating for multifamily buildings. Several recent political and technical events have made this project especially timely. Renewed concerns for energy independence and efficiency are lending new impetus to utilizing natural gas as the residential fuel of choice. New methods and requirements for appliance venting and gas piping are affecting the costs of installing gas service. New combustion-gas space and water heating, heating/air conditioning, and space heating only equipment all require new evaluations in light of current economic conditions.

More cost-effective use of natural gas specifically, but also energy for space and water heating, in general, will have economic benefits to the citizens of the State of New York. In particular, occupants of multifamily buildings, who do not have any say in the space/water heating fuel, are left to pay the bill for the decisions of others. The number of citizens living in multifamily buildings in New York represents a significant proportion of the total state population. It is essential that this large population be given some future options regarding the use of more cost-effective energy alternatives.

GOALS AND OBJECTIVES

There were two main goals established and achieved through this research. First, the research sought to determine the cost-benefit advantages of decentralized space and water heating versus centralized systems for multifamily applications based on innovative gas piping and appliance technologies. The second goal was to ensure that this information is made available to the design community.

In order to achieve these goals, nine specific tasks were developed , eight of which were performed:

- Task 1: Conduct a review of extant literature and research on comparisons between centralized versus decentralized space and water heating in multifamily dwellings.

- Task 2: Analyze energy requirements and potential for savings as a result of technical innovations applicable to decentralized gas-fired space and water heating systems for three prototypical multifamily dwellings.
- Task 3: Characterize the multifamily building stock in the State of New York. Determine which types of multifamily buildings are most likely to benefit from innovations in decentralized space and water heating systems.
- Task 4.: Investigate the regulatory barriers in the State of New York to the use of innovative technology, for new gas piping and decentralized gas-fired space and water heating systems, in multifamily dwellings.
- Task 5: Develop strategies for overcoming the identified institutional barriers or for promoting the adoption of new gas piping systems and appliance technologies.
- Task 6: Conduct a survey to identify emerging technologies for gas piping, gas metering, gas utilization equipment and appliance vents for rehabilitated and newly constructed multifamily buildings.
- Task 7: Conduct a survey to identify innovative construction methods and technologies for chaseways, appliance venting, fire protection, insulation, and other affected areas of rehabilitated and newly constructed multifamily buildings.
- Task 8: Provide demonstrable verification of the predicted results based on the engineering/market studies.
- Task 9: Document the results of the research in a comprehensive final report. This is the vehicle for information transfer to the design community.

All but Task 8 were successfully completed in this research project. A demonstration was originally proposed by Foster-Miller in conjunction with a piping study sponsored by Brooklyn Union Gas (BUG). Unfortunately, BUG had to cancel the piping study, which forced the Energy Authority and Foster-Miller to delete the demonstration task from this research project.

The economic/energy assessment is reported in Section 2. The economic assessment evaluates the opportunities for decentralized space and water heating systems in the New York State multifamily housing stock. The energy assessment focuses on the energy savings associated with natural gas and water heating equipment in two multifamily building types. Section 3 investigates and identifies institutional barriers and develops an action plan for the adoption of new gas piping systems and appliance technologies. Section 4 presents and discusses technical innovations. Emerging

technologies are identified that are considered innovative to conventional approaches that are currently in use in New York State today. Section 5 contains conclusions and recommendations based on the reported research.

Section 2

ECONOMIC AND ENERGY ASSESSMENT

ANALYSIS OF OPPORTUNITIES FOR DECENTRALIZED SPACE HEATING/ DOMESTIC HOT WATER HEATING IN NEW YORK STATE

This section represents one component of the research effort to evaluate the opportunities for decentralized space and water heating systems in the New York State multifamily housing stock. Steven Winter Associates, Inc. (SWA) performed a multiple attribute analysis (MAA) to detect the characteristics of multifamily housing that could most benefit from decentralized heating/domestic hot water (DHW).

The MAA can help reach decisions on the merit of different options when attributes (features) of these options are *not* easily quantifiable and directly comparable. This project, in particular, addresses the *potential* for installing decentralized heating/DHW in different types of multifamily housing. As shown below, the potential is determined by an interplay of several attributes (features) of each housing type: how many apartments there are per building, how many stories there are per building, how old the building is, what type of fuel it uses, what type of heating system it has, etc.

Some of these attributes are easily quantifiable (e.g., the total of New York State apartments that are located in buildings composed of 3-4 apartments, 5-9 apartments, 10-49 apartments and over 50 apartments). Other attributes are more difficult to quantify because data are scarce (e.g., total of New York State apartments that are located in buildings with 1-3 stories *and* with over 50 apartments). Each attribute has a different weight (importance) in deciding whether the decentralized heating/DHW system is feasible. The number of stories in a building, for instance, is very important; the number of apartments in a building is not. *Very important* and *not important* have different meanings in different contexts. The MAA offers a unifying framework for the evaluation of all attributes, with both quantitative and qualitative aspects.

The first step in the MAA was to collect data on the housing stock and on its evolution. The following sources yielded usable information on number of units, number of floors, age, fuel, heating system, and type of ownership:

- Bureau of the Census, U.S. Department of Commerce
- U.S. Department of Housing and Urban Development
- New York State Division of Housing and Community Renewal
- New York City Department of Housing Preservation and Development
- New York City Housing Authority
- F.W. Dodge, National Information Services.

The housing stock (past, current and future) was then examined from several perspectives.

- Ownership
- Number of units per structure
- Housing stock as of 1970
- Housing growth 1960 - 1990
- Newer housing stock (1970 - 1990)
- Number of units grouped according to the number of floors per building
- Heating fuel used in units
- Heating system used in units.

Specifically, each analysis created a table where the housing stock was classified according to the total number of units extant in buildings (refer to Tables 2-1 to 2-10):

- 3-4 apartments
- 5-9 apartments
- 10-49 apartments
- 50 or more apartments.

This breakdown roughly corresponds to the following:

- Attached housing (3-4 apartments)
- 1-3 story detached walkups (5-9 apartments)

**Table 2-1. Units Per Structure,
Weighting Factor = 1-2**

Units in Structure	Potential Opportunity Rating
3-4	5
5-9	5
10-49	5
50 >	3

**Table 2-2. Housing Stock (1970),
Weighting Factor = 5**

Units in Structure	1970 Stock	Potential Opportunity Rating
3-4	340,190	3
5-9	300,099	3
10-49	907,128	5
50 >	821,976	5

- 1-3 story buildings without elevator (10-49 apartments)
- Buildings that could have more than 3 stories (50 or more apartments).

The separation between these categories is not sharp. Some 40 apartment buildings could have more than 3 stories and, therefore, an elevator, especially in an urban environment. On the other hand, buildings with more than 50 apartments could have 2-3 stories, especially in a suburban area.

Table 2-11 segments the housing stock according to ownership. The percentage of owner-occupied units has been increasing steadily since 1950, but still accounted for only 10 percent of the multifamily building stock in 1980. Data for 1990 is not available yet; it is expected by 1993.

The great majority of published housing statistics either refers only to renter-occupied units or does not differentiate between the two categories. *For this reason, the remainder of the MAA is conducted on renter-occupied units.*

MAA Tables with Statistics on Multifamily Homes

Tables 2-2, 2-3, 2-4, 2-6, 2-8, and 2-9 present analyses by number of apartments in a building. (For the other tables see Heuristic Information section below.) These tables also contain two additional values: a *weighting factor (WF)* for each table, and a *potential opportunity rating (ORT)* for each building configuration (3-4 apartments, 5-9 apartments, etc.) A WF of 5 signifies that the table contains data of high importance

Table 2-3. Existing Heating Fuel Replacement Potential (1980)

Units in Structure	Heating Fuel Used in Units	Potential Opportunity Rating
	Oil (WF - 2-3)	
3-4	161,677	2
5-9	158,086	2
10-49	535,082	4
50 >	701,346	5
	Gas (WF = 5)	
3-4	173,396	2
5-9	115,216	2
10-49	196,299	2
50 >	205,476	2
	Electricity (WF = 2)	
3-4	21,136	1
5-9	25,051	1
10-49	44,679	1
50 >	72,246	1
	LPG (WF = 4)	
3-4	6,986	1
5-9	5,229	1
10-49	9,977	1
50 >	7,866	1
	Other (WF = n/a)	
3-4	2,144	n/a
5-9	3,102	n/a
10-49	13,319	n/a
50 >	19,232	n/a
	All Systems (WF = n/a)	
3-4	365,339	n/a
5-9	306,684	n/a
10-49	799,356	n/a
50 >	1,006,166	n/a

Table 2-4. Existing Heating System Replacement Potential (1980)

Units in Structure	Heating System Used in Units	Potential Opportunity in Units
	Steam or Hot Water System with Piping (WF = 5)	
3-4	241,064	2
5-9	221,864	2
10-49	671,632	5
50 >	801,076	5
	Central Warm Air Ducted System (WF = 3-4)	
3-4	66,162	1
5-9	43,240	1
10-49	61,670	1
50 >	120,703	1
	Built-In Electric Units (WF = 2)	
3-4	16,044	1
5-9	19,346	1
10-49	33,985	1
50 >	50,615	1
	Floor, Wall or Pipeless Furnace (WF = n/a)	
3-4	4,777	n/a
5-9	3,128	n/a
10-49	6,610	n/a
50 >	7,714	n/a
	Other Means (WF = 1)	
3-4	37,292	1
5-9	19,106	1
10-49	26,228	1
50 >	23,068	1

Table 2-5. Floors Per Structure in New York State, Weighting Factor = 5

No. of Floors	Potential Opportunity Rating
1-3	5
4 and above	2-3

Table 2-6. Number of Units Grouped According to Number of Floors, Weighting Factor = 5

No. of Floors	Percentage of Construction 1986 - 1990 (%)	Potential Opportunity Rating
1-3 floors	74-84	5
4 and above	17-26	2

Table 2-7. Gas Availability, Existing Housing Stock, Weighting Factor = 5

Gas Availability	Potential Opportunity Rating
Gas used already on premises	5
Gas not used on premises, but available on street	3-4
Gas not available in neighborhood	1

Table 2-8. Housing Growth 1960 to 1990, Weighting Factor = 1-2

	10 Year Percent Growth in Multifamily Housing Stock by Comparison to Previous Decade				Potential Opportunity Rating
Units in Structure	1950-60	1960-70	1970-80	1980-90	
3-4	-11.5	6.0	7.5	35	5
5-9	-7.8	-3.2	2.35	20	5
10-49	4.3	3.0	-11.7	13.5	4
50 >	58.3	30.5	22.5	11.26	1

Table 2-9. New Housing Stock (1970-90), Weighting Factor = 2-3

Units in Structure	Multifamily Housing Stock In		Apartments Less than 20 Years Old	Potential Opportunity Rating
	1970	1990		
3-4	340,190	493,938	153,748	4
5-9	300,099	368,792	68,693	2
10-49	907,128	908,883	1,755	1
50 >	821,976	1,120,102	298,126	5

Table 2-10. Gas Availability, New Construction, Weighting Factor = 5

Gas Availability	Potential Opportunity Rating
Gas used already on premises	n/a
Gas not used on premises, but available on street	3-4
Gas not available in neighborhood	1

Table 2-11. Total Stock of Multifamily Units in the State of New York (Renter and Owner Occupied, 1950 to 1990)

Year	Renter-Occupied Units	Owner-Occupied	Percent of Total	Total Number of Units (3 or more in a structure)
		Number of Units		
1950	1,940,712	123,332	6.0	2,064,044
1960	2,141,358	159,299	6.9	2,300,657
1970	2,369,393	219,118	8.5	2,588,511
1980	2,480,189	285,545	10.3	2,765,734
1990	2,891,715	n/a	n/a	n/a

in deciding whether the distributed gas heating/DHW has an opportunity for application in New York State. A WF of 1 indicates that the table is of little consequence to the market potential of this heating/DHW system.

Within each table, the building configurations (3-4 apartments, 5-9 apartments, etc.) were assigned ratings on a scale of 1 to 5. A rating of 5 means that, based solely on the information provided by that specific table, the building configuration has the highest potential to receive distributed gas DHW/heating in the State of New York.

In some instances, the WF and the ORT are defined by ranges, rather than by unique values, to reflect the uncertainty in the experience-based rating process. The multiple-attribute analysis, described later, explores all combinations of values in these pages.

For reasons behind the selection of values for WF and ORT, please refer to “Criteria for Assigning WFs and Opportunity Ratios” of Appendix A.

Tables Containing Only Heuristic Information

Several MAA Tables 2-1, 2-5, 2-7, and 2-10) contain only information derived from experience (heuristic). For example, Table 2-5 assigns an ORT of 5 for buildings with 1-3 floors, and an ORT range of 2-3 for buildings with 4 or more floors. This is because buildings with elevators require a higher investment to accommodate distributed heating/DHW (chases, rigid gas conduits, possible flue venting), present substantial building code barriers, and are perceived by most designers as inappropriate for systems that bring gas to each apartment. These heuristic tables are important because they bring into the MAA analysis factors that are not captured by housing statistics, but are nonetheless essential in the decision process that determines whether or not distributed heating/DHW is specified.

Multiple Attribute Analysis

The information first presented in Tables 2-1 to 2-10 is re-organized in Appendix B in a multi-tiered system as Tables 11A through 18A, and 11B through 14B. The “A” Tables (11A, 12A, etc.) address the older housing stock (built before 1970), which is a prime candidate for heating system replacement. The “B” Tables (11B, 12B, etc.) are concerned with relatively new and future construction.

MAA on Existing Housing Stock. Within the A tables, three parallel analyses are undertaken: The first analysis (rows 1-4) examines the opportunity for distributed heating/DHW systems in each of four building configurations: 3-4 units, 5-9 units, 10-49 units, and 50 and more units. The second analysis (rows 5 and 6) examines the opportunity for distributed heating/DHW systems according to the number of floors in a building. The third analysis (row 7) investigates the effect of gas availability.

The three analyses are combined, qualitatively, in the next subsection of this report. Numerical relationships between the three analyses could not be established because of lack of statistical data.

The MAA mechanism is simple. Each row corresponds to one table, or to a portion of one of the Tables 2-1 to 2-10. Each row is associated with the WF previously assigned in Tables 2-1 to 2-10. The columns are organized according to the classification criteria used to differentiate the housing stock (number of units per building, number of floors per building, etc.) The intersection of a row and a column contains the ORT previously assigned in Tables 2-1 to 2-10. The WF is multiplied by the ORT and the result of the multiplication is squared and entered under the heading "attribute score."

For example, within the first analysis, Table 11A has WF=5 for row 2, HOUSING STOCK (1970). This, as explained for Table 2-2, signifies that the number of old multifamily units is an important indicator since these units are very likely to undergo heating system renovation. The ORT for buildings with 3-4 units is 3. This rating was assigned in Table 2-2 according to the relative number of units in buildings with 3-4 apartments. Since the largest number of such units existed in buildings with over 50 apartments, that category received a rating of 5. Proportionately, the 3-4 apartment category received a rating of 3.

The attribute score is $(5 \times 3)^2 = 225$. The highest score points to the highest likelihood for applications. The squaring is used to magnify differences between entries and, therefore, to penalize the entries with a low rating. Since the 3-4 unit configuration has a mediocre rating (ORT=3) in an important indicator (WF=5), this configuration compares poorly with others that have received a higher ORT. It can be seen that the

category with 10-49 units and the category with over 50 units have scores about three times higher than the category with 3-4 units (625 versus 225).

Each table has subtotals and totals of the scores, which are then normalized on a scale of 1 to 10. A normalized score of 10 indicates highest opportunity. For example, the first analysis (rows 1-4) of Table 11A yields the following normalized scores for the segmentation by number of apartments shown in Table 2-12.

These scores indicate that, *in absence of information about number of stories and gas availability*, the greatest market potential for distributed heating/DHW systems exists in buildings with 10 or more apartments.

Another set of normalized scores, shown in Table 2-13, refers to fuel type and existing heating system type. The scores show that, in general, those pre-1970 buildings with oil or gas fuel and hydronic systems have by far the greatest potential for distributed heating/DHW retrofit. An examination of the MAA table also yields information beyond the normalized scores.

The subtotals for rows 3a+4a and 3b+4a show that, for pre-1970 buildings with 3-49 units, the gas-fired, hydronic systems present a higher application potential than oil-fired hydronic systems. For buildings with 50 and more apartments, the calculated potential is the same (725) because, while existing gas supply gives an advantage to gas systems, more buildings use oil-fired boilers.

The second analysis of Table 11A for pre-1970 buildings shows a clear preference for low-rise buildings. (The total normalized score is 10.00 for 1-3 floors and 1.60 for 4-and-above floors.) The third analysis of Table 11A for pre-1970 buildings shows a

Table 2-12. Normalized Scores for the Segmentation by Number of Apartments

Number of Apartments/Buildings				
	3 to 4	5 to 9	10 to 49	50 and more
Total normalized scores	3.35	3.35	9.87	10.00

Table 2-13. Normalized Scores for Full Type and Heating System Type

Attribute	Total Normalized Score
Existing Heating Fuel Replacement Potential	
a. Oil	4.90
b. Gas	10.00
c. Electricity	0.40
d. LPG	1.60
Existing Heating System Replacement Potential	
a. Hydronic piping	10.00
b. Warm air ducts	0.25
c. Electric units	0.11
d. Other	0.03

high preference for gas available in the building (normalized score of 10), a modest potential for the situation where gas is available on street but not in the building (normalized score of 3.6), and practically no chance for the situation where gas is not available on-street. Similar analyses are carried in Tables 12A through 24A, with variations in WFs and ORTs.

MAA on Newer and Future Housing. Tables 11B through 14B contain the MAA on new multifamily housing. The first analysis examines the housing growth patterns and the post-1970 housing stock. While the high growth rate is clearly established in 3-4 and 5-9 apartment building categories (row 8), the existing post-1970 stock (row 9) still has a preponderance of buildings with 50 units and above. The buildings with over 50 apartments grew at a slow rate between 1970 and 1990, but this rate is measured with respect to a large existing base. As a result, buildings in the 50 or more apartment category accounted for more apartments than all other building categories combined. Overall, the near-term potential appears to be in two categories: buildings with 3-4 apartments (high growth rate, modest stock less than 20 years old), and buildings with 50 or more apartments (low growth rate, but very high stock less than 20 years old). The same analysis on number of floors applies as for retrofit: walk-up buildings (1-3 floors) retain a substantial advantage. Finally, gas availability to the project is essential.

Conclusions

An examination of all MAA tables shows the results to have little sensitivity to the reasonable changes in WFs and ORTs. The following conclusions comment on the numerical results and draw inferences across the three analyses of each table.

It should be noted that energy and fuel cost savings are discussed separately in the Energy Simulations section since the amount of data available did not permit generalizations.

Retrofit of Pre-1970 Multifamily Buildings. The following conclusions apply to pre-1970 multifamily buildings:

1. The buildings with 10-49 apartments and the buildings with 50 or more apartments have by far the highest number of units in the State of New York (over 70 percent). For this reason, they receive the highest normalized scores (9.6 to 10 versus 3.24 to 3.74 for the 3-4 and 5-9 apartment buildings).

This large potential can be realized only in buildings with 1-3 stories. The statistical data available for the State of New York do not correlate between number of stories and number of apartments in a building.

Vendor information on decentralized heating/DHW systems installed in the Northeast shows that low-rise buildings with a large number of units exist and offer good opportunities. It is not possible to ascertain whether, state-wide or even region-wide, such buildings are found in large numbers. The only information that relates the number of apartments per building to the number of stories per building was found for New York City. In New York City, relatively few units are located in low-rise, 50 or more apartment buildings (see No. 3 below). However, New York City is not representative of suburban conditions.

2. The next tier is formed by buildings with 3-9 apartments. They constitute close to 30 percent of the pre-1970 multifamily housing stock and are overwhelmingly built with 1-3 stories. *This market, although smaller, is clearly identified by the extant data as being appropriate for decentralized heating/DHW system conversions.*
3. While the issue of number of floors versus number of apartments could not be resolved at the New York State level, inferences could be drawn on pre-1970 multifamily stock in New York City based on *The Estimation of Building Stocks and Their Characteristics in Urban Areas: An Investigation of Empirical Regularities by Project*, by Barclay G. James, Donald M. Manson, John E. Mulford and Mark A. Chain of Cornell University (1976).

Calculations based on the Cornell study show that the New York City multifamily stock can be classified as shown in Table 2-14.

**Table 2-14. Classification of Pre-1970
Multifamily Buildings in New York City by
Number of Units and Building Height**

Number of Units per Building	Percent of Total No. Units	
	1-3 stories (%)	4 and above (%)
3-4	18	1
5-9	2	9
10-49	1	18
50 >	2	49
Total units	23	77

These percentages cannot be applied to the entire State of New York, given the unique characteristics of New York City. Also, the data are 13 years old, and the process of demolition/reconstruction has proceeded at a relatively brisk pace during the 1980s.

However, for New York City alone, it can be reasonably stated that buildings with 3-4 apartments offer the clear, dominant opportunity for dual-integrated appliance (DIA) applications (18 percent) of total pre-1970 apartment stock with 1-3 stories. The 1-3 story apartment stock of all the other building types combined is smaller by a factor of 3 to 4.

4. Gas availability is essential for the feasibility of a heating/DHW system retrofit. Gas availability on-premises is preferred to gas availability on-street. Two caveats apply:
 - If the building would convert to gas anyway (e.g., to avoid repairing the oil tank), then there is no particular disadvantage, from the perspective of decentralized systems, if gas is available on-street but not on-premises.
 - The first cost of bringing gas from street to building is more important for small buildings (e.g., 3-4 apartments). However, some utilities fully pay for the gas line to the building, so this criterion may not always be relevant.
5. A building subject to gut rehabilitation or major HVAC work is more likely than others to be a candidate for decentralized heating/DHW systems.
6. In any renovation except gut rehabilitation, buildings with hydronic heating systems are by far the most attractive for conversion.
7. Those buildings already using gas for heating are much more likely to be converted to the decentralized system. (In all analyses, gas heating scores

either 9 or 10; oil scores in 50 percent of the analyses 5, and in the other 50 percent scores 10, depending on WFs.)

However, buildings using oil can also be good candidates since they form about 65 percent of the pre-1970 housing stock. Their preponderance is 75 to 80 percent among buildings with 10-49 apartments and 50 or more apartments, so conversions in this particular market segment are heavily dependent on the economics of fuel switch. The gas/oil breakdown is relatively equal in the 3-4 and 5-9 apartment buildings.

8. Although not analyzed numerically in the MAA, codes and customary practice need to be discussed. Both present obstacles to the implementation of decentralized heating/DHW systems. Both impact greatly all mid- and high-rise buildings. Both impact the last buildings with 1-3 floors. Actually, all experience to date on heating/DHW installations has been in low-rise buildings.
9. Energy use and energy cost need also be discussed, even though the MAA could not address it. The section titled Central Versus Decentralized Heating in Multifamily Buildings, A Literature Review, shows that substantial heating/DHW savings (6 -77 percent) can be achieved via energy use metering on an apartment-by-apartment basis, and/or via decentralized equipment. DOE-2.1D energy simulations by SWA indicate savings of 7 to 17 percent due solely to decentralized equipment, in absence of any occupant behavior changes (such as thermostat setback).

The range is wide enough to recommend site monitoring for obtaining more information and further computer analyses. The extant energy data, within its limitations, indicates that older housing stock has the highest potential for energy use savings.

These energy use savings may not translate in energy cost savings, unless utility rates are changed. The computer simulations for Manhattan and Brooklyn show that, because of a high cost of gas for the first few therms, the decentralized heating/DHW systems save energy but result in an increase in fuel cost.

Summary. The segment with a clear, high potential is defined by low-rise (1-3 floors) buildings with 3-9 apartments that have gas-fired hydronic heating. The potential is clear since all conditions are met by large numbers of multifamily units.

- The great majority of buildings with 3-9 apartments have 1-3 stories (90 percent assumed).
- About 69 percent of buildings with 3-9 apartments use hydronic heating.

The buildings with 3-9 apartments contain over 640,000 units, or about 27 percent of the New York State multifamily stock built before 1970. At a minimum, 170,000 units satisfy the above conditions.

Buildings with over 10 units can be even more appropriate for decentralized heating/DHW systems, provided they are less than 4 stories high and that

either (a) they have gas heating or (b) the economics of fuel switching are attractive, since 75 to 80 percent of these buildings use oil fuel. In most instances (83 percent), the buildings with 10 or more units use hydronic heating.

A numerical estimate of the multifamily housing segment satisfying the above conditions cannot be made since a correlation between number of floors and number of units does not exist.

New Multifamily Buildings. The following apply to new multifamily buildings:

1. The largest market for new multifamily buildings, when defined solely by the number of units in New York State, appears to be for buildings with 50 or more apartments. Over the past 30 years, this market has been flattening out. The 3-9 apartment buildings experienced a fivefold growth rate, and the 10-49 apartment buildings close to a fourfold growth rate by comparison to the 50 or more apartment category. Therefore, in the more distant future, the smaller buildings may present higher opportunity if the trend persists.
2. As with existing buildings, the 1-3 story segment is a clear favorite. The per unit first cost advantage when compared to taller buildings should be somewhat smaller since it is much less expensive to design a gas network from the beginning rather than to retrofit it, and since taller buildings are more heavily affected by the cost of retrofit.
3. Gas availability is a determining factor.
4. The same building code and customary practice considerations apply as in retrofit situations (see No. 8 above).
5. The same considerations for energy use and cost apply as in retrofit situations (see No. 9 above).

ENERGY SIMULATION

SWA undertook DOE-2.1D simulations to estimate the decrease in heating/DHW energy use when a decentralized system replaces a central system in multifamily buildings.

Building Prototypes

Two multifamily building types were selected from a previous Gas Research Institute (GRI) study conducted by Lawrence Berkeley Laboratory (LBL): *Multifamily Heating and Cooling Requirements: Assumption, Methods, and Summary Results*, prepared by R.L. Ritschard and Y.J. Huang. In that study, the buildings are identified as Building 3 and Building 4, and were developed based on the 1980-1982 residential energy consumption survey of Energy Information Administration. For the purpose of this

work, the buildings are designated as pre-1940 and post-1980. Tables 2-15 and 2-16 summarize the major characteristics of each multifamily prototype.

The DOE 2.1 input for New York State buildings, created by LBL for GRI, was used as the starting point for the development of each multifamily building model in this study. Therefore, the description of the building prototypes is substantially similar to the one in the GRI 1989 study by Ritschard and Huang. Portions of the LBL description (pages 2-6) of the prototypes are repeated or paraphrased in this paper because numerous references to the document would have resulted in a text that is difficult to follow. Also, the prototypes modeled in this study differ to some extent from those described in the LBL report:

Table 2-15. Characteristics of Pre-1940 Prototype

Parameter	Specification
Year built	Pre-1940
No. of units/floor	10
No. of floors	4 and 10
Unit floor area (ft ²)*	675
Envelope	
No. of windows/unit	4
Glazing type	Single
Average window size (ft ²)	15.52
No. of sliding glass doors/unit	None
Average sliding door size (ft ²)	N/A
Glazing area (%)	9.2
Exterior wall facade	Brick
Wall insulation	None
Ceiling insulation	None
Operations	
Heat set point (F)	70
Heating night setback 11 p.m. - 7 a.m (F)	64
Cooling set point (F)	78
Other characteristics	
Number of occupants	1.25
Cooking fuel type	Gas
Domestic hot water fuel type	Gas
Sensible internal loads (Btu/day)	30,846
Latent internal loads (Btu/day)	7,088
*Average floor area per dwelling unit is conditioned floor space only.	

Table 2-16. Characteristics of Post-1980 Prototype

Parameter	Specification
Year built	1980s
No. of units/floor	10
No. of floors	4 and 10
Unit floor area (ft ²)*	920
Envelope	
No. of windows/unit	4
Glazing type	Double
Average window size (ft ²)	12.2
No. of sliding glass doors/unit	None
Average sliding door size (ft ²)	20.0
Glazing area including sliding door (%)	14.0
Exterior wall facade	Brick
Wall insulation	R-13
Ceiling insulation	R-30
Operations	
Heating set point for apartments (F)	70
Heating night setback for apartments 11 p.m. - 7 a.m. (F)	64
Heating set point for corridors (F)	64
Cooling set point for apartments (F)	78
Cooling set point for corridors (F)	82
Other characteristics	
Number of occupants	2.07
Cooking fuel type	Gas
Domestic hot water fuel type	Gas
Sensible internal loads (Btu/day)	41,034
Latent internal loads (Btu/day)	9,276
*Average floor area per dwelling unit is conditioned floor space only.	

- Glazing area in the post-1980 prototype is 14 percent rather than 5 percent (typo in LBL study).
- No shading by adjacent buildings was simulated.
- The HVAC system was changed to hot water baseboard and direct expansion (DX) through-the-wall air conditioners.
- A decentralized system was also modeled.

Each building type has 40 or 100 units. Each building floor has 10 family units.

Each building type is modeled either with central boiler or with decentralized heating/

DHW units (also called dual integrated appliances or DIA). Fin-tube baseboards deliver heat into each zone (apartment or common area) of the buildings.

When a central boiler is used, it provides DHW and hot water for space heat in each unit of the building and in each common space. When DIA units are used, they are installed in each family unit and also in the common spaces. Each DIA unit provides DHW and hot water for space heating.

Building Geometry

Many adjoining apartment units have the same thermal characteristics (e.g., center units that are neither located on the first floor nor on the last floor). In such cases, one unit was modeled and assigned a multiplier to compute the combined effect of all units of this type.

Units differing in their heat flow characteristics were modeled separately. These include ground floor units, top floor units, and end-units on all floors. Common spaces such as stairwells, hallways and basements were modeled as separate zones. Common spaces were assumed to be air-conditioned.

Infiltration

Air infiltration is simulated with the Sherman-Grimsrud model. This model receives as input the leakage area of the building.

For the pre-1940 building the average fractional leakage area of 0.00050 (total leakage area/floor area) was assumed. For the post-1980 building, tighter construction with an average fractional area of 0.00035 was assumed.

Solar Gain

The solar gain of a building depends on the orientation of the windows and walls, and on shading by nearby buildings and trees. In this study, a building that represents a statistical average was modeled. An average building orientation was created by apportioning the amount of walls, windows and doors equally in the four cardinal directions. The glass shading of 0.80 was used during the winter and 0.60 during the summer. No shading from other buildings was assumed.

Operating Assumptions

During the heating season, the apartment units were assumed to maintain 70°F during the day, with setback to 64°F between 11 p.m. and 7 a.m. During the cooling season, the temperature was maintained at 78°F for all hours.

Window venting was permitted in winter when indoor temperatures rose above 78°F. During the cooling season, windows were assumed to be open until the indoor temperature reached 72°F, if the following criteria were met: 1) the outdoor temperature was lower than indoor temperatures; 2) the outdoor temperature was not higher than 78°F; 3) the enthalpy of outdoor air was less than that of indoor air; and 4) the cooling load that hour could be met totally through window venting. The windows were assumed to retain until 7 a.m. the same status they had at 11 p.m. (i.e., open or closed) unless indoor temperatures dropped to below the heating setpoint.

Lobbies, stairwells, hallways, and basements were modeled as separately heated and cooled zones. Basements were simulated as unconditioned zones. The other common spaces had heating and cooling set points of 64°F and 82°F, respectively.

Internal Loads

The internal load assumptions are listed in Table 2-17. The hourly distribution of internal loads was based on the profile developed by the California Energy Commission (CEC) for single-family residences. This profile includes heat gain from hot water standby losses. For central systems, the water heater standby losses were assigned to the basement. Because of their smaller surface-to-volume ratio, central boilers are assumed to have standby losses per unit that decrease proportionally to $NA_{pt}^{1/3}$, where NA_{pt} is the number of apartments in the building.

Domestic Hot Water Loads Methodology

Energy use for heating water is a function of variables including water storage temperature, inlet and outlet temperatures, air temperatures, and the rate of usage of hot water. To calculate the annual hot water load per apartment, the following methodology was used:

**Table 2-17. Estimated Average Annual Internal Loads
Per Multifamily Apartment Unit**

End Use	Sensible Heat Load Per Unit (Btu/day)	Latent Heat Load Per Unit (Btu/day)
Occupants	2700 x NOCC*	2140 x NOCC*
DHW standby	5480	
DHW use	5639 x NOCC	539 x NOCC
Television	1244	
Refrigerator	10520	
Electric range (if exist)	7480	3740
Lighting	8.42 x SF**	
Miscellaneous	1870**	
Totals per unit	21114 + 3239 x NOCC + 8.42 x SF = 5480 (for units w/indirect DHW only)	3740 + 2679 x NOCC
DHW standby in basement (for apts. w/central DHW only)	8220/N Apt 1/3**	
Dryer in basement	560	
*NOCC = number of occupants. **NApt = number of apartment units in building.		

$$\text{Load} = \text{NOCC} \times W \times C_p \times (T_T - T_M)$$

Where NOCC = Number of occupants per unit

W = Average daily hot water consumption (based on 18.5 gal/day/person)

C_p = Energy required per gallon heated (8.33 Btu/gal/°F)

T_T = Tank set temperature (120°F)

T_M = City water main temperature (50°F)

The DHW load includes the heat necessary to raise the temperature from the main to the tank temperature of 120°F. The effects of burner efficiency and standby losses are not considered in the calculation of water heating loads, but standby losses are included in the interloads assumptions (Table 2-17).

HVAC System

Each apartment was cooled by wall air conditioning units. The common areas were cooled by a central forced air packaged system.

The heating in all the apartment units was provided by hot water baseboards. Hot water was produced by either a gas-fired central boiler or by DIA units. The basement of the building was unconditioned.

RESULTS OF SIMULATIONS

Tables 2-18 and 2-19 show a summary of the detailed results of the DOE-2.1D simulations listed in Tables 2-20 and 2-21.

Note that, because of the gas rate structure, *the DIA units save energy in every case yet incur a higher energy cost*. This discrepancy is major. Energy savings range from 7 to 17 percent. Cost increases range from 42 to 83 percent. The gas rate structures of Consolidated Edison and BUG are given in Appendix S.

Table 2-18. Energy and Cost of Multifamily Units for Heating and DHW

Building Type	Central	DIA	Central	DIA	Central	DIA
	Energy use (therms)	Energy use (therms)	ConEd cost (\$)	ConEd cost (\$)	BUG cost (\$)	BUG cost (\$)
Pre-1940, 40 unit	11,702	10,399	7,731	11,308	8,299	11,789
Pre-1940, 100 unit	26,545	22,603	16,723	25,660	18,487	26,693
Post-1980, 40 unit	6,715	6,272	4,510	8,242	4,873	8,434
Post-1980, 100 unit	15,488	15,488	12,244	20,482	13,160	20,938

Table 2-19. Change in Energy Use and Energy Cost Between Central and DIA Systems

Building Type	Central	DIA	Central	DIA	Central	DIA
	Energy use (therms)	Energy use (therms)	ConEd cost (\$)	ConEd cost (\$)	BUG cost (\$)	BUG cost (\$)
Pre-1940, 40 unit	11,702	10,399	7,731	11,308	8,299	11,789
Pre-1940, 100 unit	26,545	22,603	16,723	25,660	18,487	26,693
Post-1980, 40 unit	6,715	6,272	4,510	8,242	4,873	8,434
Post-1980, 100 unit	15,488	15,488	12,244	20,482	13,160	20,938

Conclusions

The energy savings achievable solely as a result of the decentralized configurations are substantial. Savings range from 11 to 15 percent for the pre-1940 prototypes, and from 7 to 17 percent for the post-1980 prototypes.

Higher percent savings are achieved for 10-story and greater buildings. The variation in savings from 4-story to 10-story can be explained as follows: In a 10-story building, the center apartments, in aggregate, account for a higher percentage of the fuel use. These apartments have low heating loads. As a result, solar gains can often reduce the heating loads considerably. Decentralized units can more efficiently follow such load fluctuations than central systems.

The heating energy cost increases for DIA systems. In the Consolidated Edison and BUG service territories, the increase ranges from 42 to 53 percent for pre-1940 prototypes, and from 59 to 83 percent for post-1980 prototypes.

The cost increases are due to the high gas rate charge for the first few therms, and to the service charges assessed on each apartment. This rate structure constitutes a significant institutional impediment.

Table 2-20. Pre-1940 Building Natural Gas Consumption for Space Heating and DHW (therm)

Unit Type	40 Family Unit				100 Family Unit			
	Central System	Individual System	Multiplier	Total	Central System	Individual System	Multiplier	Total
40 family unit	11,702				26,545			
100 family unit								
End unit ground		253	4	1,012		253	4	1,012
End unit middle		231	8	1,848		231	32	7,392
End unit top		423	4	1,692		423	4	1,692
Mid unit ground		208	6	1,248		208	6	1,248
Mid unit middle		185	12	2,220		185	48	8,880
Mid unit top		389	6	2,334		389	6	2,334
Hallway		45	1	45		45	1	45
Total building	11,702			10,399	26,545			22,603
Savings %	$\frac{11,702 - 10,399}{11,702} \times 100$ 11.13				$\frac{26,545 - 22,603}{26,545} \times 100$ 14.85			

Note: Changes due to user behavior will yield savings above those noted in this report. Specifically, the users could: a) lower the space heating thermostat settings; b) extend the period of thermostat setback; and c) reduce hot water use. The literature review has shown that aggregate DIA/behavior savings can reach in the 30 to 70 percent range.

Table 2-2.1. Post-1980 Building Natural Gas Consumption for Space Heating and DHW (therm)

Unit Type	40 Family Unit				100 Family Unit			
	Central System	Individual System	Multiplier	Total	Central System	Individual System	Multiplier	Total
40 family unit	6,715							
100 family unit					18,758			
End unit ground		186	4	744		186	4	744
End unit middle		162	8	1,296		162	32	5,184
End unit top		149	4	596		149	4	596
Mid unit ground		172	6	1,032		172	6	1,032
Mid unit middle		148	12	1,776		148	48	7,104
Mid unit top		138	6	828		138	6	828
Total building	6,715			6,272	18,758			15,488
Savings %	$\frac{6,715 - 6,272}{6,715} \times 100$ <p align="center">6.6</p>				$\frac{18,758 - 15,488}{18,758} \times 100$ <p align="center">17.43</p>			

Recommendations

DOE-2.1 can only simulate hourly energy use steps, while the boilers might cycle on/off more often. It is recommended that monitoring be undertaken to verify the range of savings found in this work. It is also recommended that gas utilities be encouraged to set separate pricing structures for DIA installations.

CENTRAL VERSUS DECENTRALIZED HEATING IN MULTIFAMILY BUILDINGS, A LITERATURE REVIEW

The literature review was undertaken by SWA to investigate differences between centralized versus decentralized space and water heating in multifamily dwellings.

Executive Summary

General studies undertaken during the 1970s and 1980s on multifamily tenant-occupied buildings showed that energy was saved by shifting responsibility for heating costs from landlords to tenants. Three main strategies are used to this end: 1) allocation of common heating bill to tenants; 2) submetering of the apartments and; 3) replacement of central boilers with individual systems, one per apartment.

Five to twenty percent savings in heating energy consumption was documented when master-metered properties were converted to individual metering. However, little testing and analysis was performed on the advantages of using individual systems for space conditioning and DHW instead of a central system for the entire building.

A preliminary study by Bohac, et al. (1990) has shown 13 to 19 percent savings by installing new individual heating/DHW systems in place of older central systems. A study by Palermi and Hewitt (1991) has shown savings of 69 to 77 percent by replacing a central gas system with individual space-heating gas units, and also by weatherizing the apartments.

The authors could not find any comparisons of decentralized (individual) systems and centralized systems with the same annual fuel utilization efficiency (AFUE). The data available do not support a determination of savings due solely to more efficient operation of distributed equipment (as differentiated from savings due to modified tenant behavior as a result of direct billing).

Methods to Save Heating/DHW Energy through Tenant Control and Decentralized Equipment

The following subsections review savings obtained in heating the space and/or the DHW of multifamily buildings by making the tenants directly responsible for heating/DHW costs and by installing decentralized equipment. Although this Energy Authority project specifically investigates the seasonal efficiency of decentralized

heating/DHW systems, other methods that solely affect the behavior of tenants are also relevant since decentralized heating/DHW systems can be controlled by tenants and, therefore are likely to result in modification of tenant behavior.

Three methods are reviewed based on results from literature:

- Billing allocation
- Individual metering
- Decentralized systems.

Decentralized systems in turn, are separated in two groups:

- Decentralized heating systems
- Decentralized heating/DHW systems.

This review also discusses the relevance of the savings achievable with the first two techniques on decentralized heating/DHW systems and makes recommendations for the remainder of the Energy Authority's study.

Residential Utility Billing Allocation. As an energy conservation tool, the effectiveness of energy cost allocation to tenants of multifamily housing was shown to vary substantially. The most common method involves allocation of master-metered energy costs using proportional division based on the relative floor areas of the individual units. A 1980 study performed by the University of Colorado, and an update published in 1983, found that billing by formula allocation, while easily administered, yielded savings of only 6 percent on average for space heating and DHW heating (McClelland 1980). This effect may diminish over time and even become negative in the long term, the study predicted. Tenants who realize that their energy bills are not noticeably affected by their individual conservation efforts may reduce those efforts or abandon them altogether (Scott 1991).

Metering. The energy savings obtained by converting a master-metered property to individual meters, submeters, or individual consumption monitors vary over a wide range. Reductions in the use of gas for space and water heating were shown to average 14 percent, ranging from a low of 5 percent to a high of 20 percent, in the McClelland (1983) study.

A study of 20 multifamily properties, each with 90 units or more, located in the Denver area and in Colorado Springs, CO, reports significant energy savings due to allocation of central boiler fuel cost based on monitored use of heating systems (Scott 1991). Reductions in gas consumption were achieved in all units and range from about 2 percent to almost 66 percent for the post-conversion predicted use, as compared with the pre-conversion predicted use. Leaving out results for two properties that registered unusually high savings, the average reduction in predicted gas use was over 18 percent (Scott 1991).

Another study on an apartment complex in Milwaukee, WI (Maher 1991), showed savings of 20 percent in heating season gas consumption and 13 percent in summer season gas consumption. The savings resulted from converting a 204-unit apartment complex from a billing system that included gas costs in the base rent, to a billing system that separated rent from gas costs, and that billed gas directly to the residents. The conversion involved the installation of a Btu metering and allocation system.

Individual Heating Units. A few studies have compared central systems and individual systems for space conditioning and DHW in new multifamily buildings. Palermini and Hewitt (1991) conducted a study of 37 multifamily buildings in Portland, OR. These buildings: a) had been converted from central-boiler heating systems to individual tenant-metered heating systems; or b) had installed secondary metering systems on the central-boiler system to allocate the heating costs to each tenant. Thirty-one buildings had undergone conversion of the heating system from a central boiler to individual heating systems in each apartment. Of these buildings, 22 were converted from an oil- or gas-fired central boiler to electric resistance heating systems. Eight of the remaining buildings were converted from a gas-fired boiler system to individual gas space-heating units in each apartment. The buildings that were converted to individual systems contain a total of 661 apartments.

Of the 37 buildings studied, only 7 were included in the final analysis. The others had insufficient data, significant data gaps, or poor data fit to the analysis methodology. The savings are shown in Table 2-22. The two shaded rows are of most interest for the Energy Authority's project since they compare central gas systems to individual gas systems.

Table 2-22. Energy Savings in the Palermini and Hewitt (1991) Study

Apartment Building	Type of Modification	Pre-NAC*	Post-NAC*	Energy Savings (%)
1	Central oil to individual electric conversion	95,878 kWh	68,787 kWh	28
2	Central oil to individual electric conversion	60,371 kWh	43,644 kWh	28
3	Central gas to individual gas conversion	7,511 therms	2,361 therms	69
4	Central gas to individual gas conversion	8,355 therms	1,906 therms	77
5	Central gas with allocation systems added	10,253 therms	9,789 therms	6
6	Central gas with allocation systems added	9,659 therms	8,387 therms	13
7	Central gas with allocation systems added	18,170 therms	12,868 therms	29
*NAC - Normalized Annual Consumption - The Princeton Scorekeeping Method (PRISM, Fels, 1986) was used to track the record of energy conservation retrofits.				

The energy savings for the buildings that were converted to individual apartment heating were substantial. However, these savings were likely to result from several interactive effects, including the replacement of the old heating system with a more efficient system; the increased control the tenant could now exercise over the heating system, which resulted in a lower average interior temperature; and the savings attributable to weatherization. The study showed 28 percent energy savings due to the conversion of central oil boilers to individual electric baseboard systems. Most important for the Energy Authority project, Palermini and Hewitt found 69 to 77 percent energy savings in those apartments that underwent the conversion of the central gas-heating system to individual gas-heating systems.

Byrene and Fay (1989) compared central and individual systems for space conditioning and DHW in new multifamily buildings. The two types of systems were simulated with DOE 2.1C in prototypical apartment buildings in Chicago and Atlanta.

The buildings were equipped with: a) central chiller and gas-fired boiler, with four-pipe fan coils in each apartment; or b) packaged terminal air conditioners.

The building energy consumption for Chicago was reported to be 899 million Btu per year (MBtu/year) for packed terminal air conditioners (PTAC), 857 MBtu/year for PTAC system with night temperature setback, and 1,300 MBtu/year for four-pipe fan coil system. This translates into heating and cooling savings for the PTAC systems of over 30 percent.

For Atlanta, the building energy consumption was reported to be 442 MBtu/year for PTAC, 421 MBtu/year for PTAC with night temperature setback, and 560 MBtu/year for the four-pipe fan coil system. This translates into heating and cooling savings for PTAC systems of over 20 percent.

The study also showed that if the building had less than 5 apartments and was located in Chicago, the PTAC system had lower life-cycle cost than the four-pipe fan coil system. Similarly in Atlanta, a building with less than 30 apartments had lower life-cycle cost for the PTAC system than for the central system.

Combination Space/Water-Heating Systems. Gas-fired domestic water heaters are increasingly used as combination space-heating/DHW systems for apartments and single-family homes. A study by Talbert et al. (1992) showed that conventional gas-fired water heaters are capable of meeting both DHW and space heating loads even during peak winter design conditions when the components of the combination systems are properly sized. It is important that some oversizing be designed into combination systems, in terms of the ratio of water heater output to the fan/coil heating capacity. This ratio should be at least 1.2, as discussed in Pietsch and Talbert (1989).

An interim report by Bohac et al. (1990) compared Type II dual integrated appliances (DIA) with central heating systems. The dual integrated appliance is defined as a unit that provides both DHW and space heat to a building. The Type II DIA unit is a water heater that has the primary function of supplying DHW, but includes a separate heating coil and pump for producing space heat. The study examined five multifamily apartments that were located in a 2-story, 8 apartment building erected in the early 1980s. The apartments had either 2 or 3 bedrooms.

The savings of the Type II DIA systems were determined by comparing their measured gas use to the gas use of the existing central system. This analysis, which employed the PRISM method, is more accurate for an entire year of data. However, the systems were monitored only from February 1990 to November 1991 and require further heating season monitoring to obtain a full year of data. The normalized annual consumption of four units for the February/November period ranged from 592 to 870 hundred of cubic feet per year (ccf/year) and represented savings from 13 to 19 percent. There was a 17 percent increase in the energy use of one unit, which was most likely due to the change in occupants that occurred shortly after the system was installed.

It is important to note that the individual heating/DHW systems, with AFUE of 76 percent or higher, were compared to furnaces with AFUE of 60.2 percent. Further analysis will compare the combined energy use of the DIA systems to central units with the same AFUE.

Conclusions

Several studies show that shifting the responsibility for heating costs to tenants results in energy savings. Table 2-23 summarizes results from these studies.

Table 2-23 lists savings ranging from 6 to 77 percent. Only three studies have compared central heating systems with decentralized heating (Palermini and Hewitt, Bohac et al., and Byrene and Fay).

None of these studies breaks down the savings obtained through change in tenant behavior due to direct billing versus savings obtained through more efficient operation by decentralized equipment. Furthermore, the savings reported by metering studies are of the same order of magnitude with the savings reported by studies where the central heating system was replaced with decentralized heating equipment. Therefore, it is not possible to assess the contribution of decentralized equipment only. (Note: The Palermini and Hewitt study did report very high savings for decentralized equipment, but these savings also included the effect of weatherization.)

Finally, all studies were performed on different types of multifamily units and in different climates. This compounds the problem of comparing the results and

Table 2-23. Summary of Energy Savings Achieved by Shifting Responsibility of Heating Costs to Tenants of Multifamily Buildings

Study	Building Type	Year	Type	Savings (%)
Palermini D. and Hewitt D.	Multifamily building	1991	1) Central oil to individual electric conv.	28
			2) Central gas to individual gas conv.	69-77
			3) Central gas with allocation system added	6-29
Scott W.L.	Multifamily buildings 90 units or more each. Low-rise 4 stories or less and high-rise 10 stories or more	1991	Metering	19
Bohac, et al.	Multifamily building single and 2-story	1990	Decentralized heating DHW	13-19
Byrene and Fay	Multifamily building 3-story	1989	Computer modeling (DOE 2.1C)	20
McClelland, L.	Multifamily buildings	1983	Metering	14

reinforces the fact that extant data do not support any conclusions on the energy-saving effect of decentralized heating equipment in and by itself, without contribution from tenant behavior.

Recommendations

In view of the scant information on the energy use and seasonal efficiency of distributed heating/DHW units, the originally planned monitoring in the Energy Authority project would have provided important data. Specifically, the tests performed in the other studies have addressed the total energy savings obtained; a) through cost allocation; b) through individual metering; or c) through replacement of a central system with individual units. However, these tests did not differentiate between reductions as a result of the psychological effect of direct billing and reductions as a result of more efficient operation of distributed equipment under part-load conditions. Unless such equipment-related reductions are documented and found

to be significant, there would be little incentive to provide decentralized heating rather than individual metering. The original Energy Authority project, which included a demonstration, attempted, among other goals, to provide information on the energy use of individual heating/DHW units.

Section 3

INSTITUTIONAL CONSTRAINTS

INTRODUCTION

The National Conference of States on Building Codes and Standards (NCSBCS) conducted the institutional constraints investigation. The development, application, and installation of new technologies in new and existing buildings is affected by codes, standards and regulations. For the State of New York, multifamily building energy research and development is critical to advance the level of energy efficiency in these structures. Advances in energy research and development can reduce utility costs and energy consumption for the state as well as for owners and renters of these buildings.

Energy-saving strategies include development of more energy-efficient appliances and energy delivery and billing systems. In the latter strategy, those who pay directly for their utility bills have a financial incentive to reduce consumption. In the former strategy, decentralized appliances and systems that make users directly responsible for their energy use are now more efficient than in the past; larger and more centralized systems had historically been more energy efficient than smaller, individual units. In either case, building construction regulations will impact the acceptance and application of any technology.

Beginning with work by the U. S. Department of Housing and Urban Development in the mid-1960s, there have been considerable efforts devoted to the issues of individual and master metering of energy use and the efficiency and economics of individual and central systems. These issues were actively studied and debated by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and utility companies until the mid-1980s. With new emphasis on energy conservation and more efficient and less centralized appliances, the opportunity for reductions in gas consumption can be revisited.

This opportunity is made even more viable with new technologies in gas piping and metering. However, building health and life safety must take precedence over energy savings. This means that state and local building codes and ordinances and gas utility regulations that regulate construction or gas installations in New York State must be satisfied before any technology can be readily approved for use. The

development of technologies that do not satisfy the requirements or intent of these documents may never be marketable.

PURPOSE

This section investigates the regulatory barriers in New York State to using innovative technology for decentralized gas-fired space and water heating. The administrative criteria in the state and local construction codes and utility regulations and directives that will impact use of this innovative technology are also identified.

After the barriers presented by code limitations were identified, analysis of these regulatory criteria was carried out to provide insight into the application of the criteria. The potential impact of code requirements was delineated. Informal discussions with fire and code officials, utility representatives, and other interested parties, formed the basis for development of strategies for overcoming these barriers or for promoting the use of the technologies.

PROJECT OVERVIEW

In the development and application of decentralized gas systems in multifamily buildings, building construction regulations can either be a hindrance or a help. This investigation focuses on a review of New York State and local codes and utility regulations to identify issues that may arise with the application of these gas systems. The resulting identification of issues and assessment of the impacts of codes, standards and regulations lead to a series of recommendations and strategies to overcome the barriers or limitations.

The tasks necessary to determine the feasibility of decentralized gas applications in multifamily buildings from a regulatory perspective include the following:

- Task 1: Reviewing the available technologies.
- Task 2: Identifying issues upon which the codes and standards and utility directives will have an impact.
- Task 3: Reviewing the state and local codes and utility regulations for each of the technologies identified in Task 1 for prohibitions or limitations.
- Task 4: Recommending strategies for the successful use of the decentralized gas technology.

As part of Task 4, it is critical to communicate with those individuals with some interest in the implementation and enforcement of codes and regulations. Therefore, an integral part of the task has been to informally canvas various code officials, gas utility representatives, insurance company officials, and people in the trades. This contact has elicited opinions on the acceptance of the new technologies, the code enforcement implications, and the potential support or resistance that might be expected from various interested parties.

Task 1 - Review of Available Technologies

NCSBCS received product literature on innovative gas piping and appliance technologies for decentralized applications in multifamily buildings from Foster-Miller and Steven Winter Associates. A review of this literature defined the two areas of technology critical to this project: dual integrated appliances (DIAs) and corrugated stainless steel tubing (CSST).

DIAs (also known as combo units in the industry) are space and domestic water heating systems that typically utilize domestic hot water heaters (DHW) as the single heat source. Hot water generated by the DHW is circulated through a heating coil in an air handler. A fan circulates air over the heating coil and moves the heated air into an air duct system that distributes it into the space for comfort heating. A circulating pump and the fan motor are activated by a room thermostat upon a call for heating. After the hot water passes through the heating coil, it is re-introduced to the DHW tank to be reheated and available for domestic hot water use. A mixing valve is used to maintain a pre-set domestic hot water temperature. Valves are installed that allow the heating coil to be isolated and flushed, so that water stagnation will not occur.

CSST, American Gas Association (AGA) design-certified for use in fuel gas piping systems, utilizes semirigid corrugated tubing made of 304 stainless steel. The corrugated tubing is covered with a polyethylene (PE) or polyvinyl chloride (PVC) coating, approximately 0.025 in. (0.63 mm) thick. The purpose of the coating is twofold: to protect it against household chemicals and abrasion, and to reduce friction while snaking it through stud walls and floor joists. Special mechanical fittings are provided to interconnect the tubing with other components within the overall gas piping system. It is currently supplied in coils of 100 to 250 ft in length and is manufactured in four different sizes: 3/8, 1/2, 3/4, and 1 in. internal diameters (ID). Larger sizes, up to 1-1/2 in. ID, may be available in the future.

Task 2 - Identification of Code Issues

After reviewing the product literature, NCSBCS listed all the possible building and mechanical issues that applied to the innovative technologies (DIAs and CSST) as contained in building construction regulations. It must be noted that not all the issues identified as having a potential impact in the use of these technologies will necessarily be covered in the building codes.

The issues identified are :

A. Pre-equipment issues (gas distribution system)

1. Structural requirements
2. Configuration of gas supply system
3. Inspection/enforcement responsibility
4. Gas meters
5. Gas valves
6. Gas regulators
7. Piping/tubing
 - a. Joint and support requirements
 - b. Installation requirements
 - c. Sizing/design/pressure limits

B. Equipment issues

1. Performance efficiencies
2. Controls
3. Component venting requirements
4. Equipment sizing
5. Enclosures/locations
6. Installation/service

C. Post-equipment issues

1. Combustion air

2. Venting/chimneys/flues
3. Other issues

Task 3 - Review of Building Construction Regulations

Subsequent to the delineation of the applicable issues that might impact the acceptance of DIAs and CSST, NCSBCS conducted a review of the codes and regulations in New York that apply to multifamily buildings. The documents reviewed include the following:

- The New York State Uniform Fire Prevention and Building Code, mandatory in all jurisdictions except New York City.
- The New York State Energy Conservation Construction Code, mandatory throughout the state.
- The New York State Multiple Dwelling Law, mandatory in cities with a population of 350,000 or more.
- The New York State Multiple Residence Law, mandatory in municipalities with less than 350,000 population.
- The Building Code of the City of New York.
- Any local amendments to the State Uniform Fire Prevention and Building Code for Albany, Buffalo, Rochester and Syracuse (local jurisdictions are permitted to amend the state building code, with state approval, to provide more stringent requirements).
- Any relevant regulations of the 12 major gas utility companies.

The summaries of code criteria by issue found in all the reviewed documents are found in the following matrices. Note that not all the issues identified are covered in the codes. In addition, a review of the State Multiple Residence Laws found no references to the issues identified; therefore, these documents are not included in the matrices. The major city amendments were reviewed and also found to not apply to the issues identified. The gas utility companies all use the National Fuel Gas Code (NFGC), 1988 edition; a review of the relevant issues in the NFGC is included in the matrices. The New York State Uniform Fire Prevention and Building Code references the 1984 edition of NFGC, and the New York City Building Code references the 1974 edition. The major difference between these editions is that only the 1988 edition recognizes CSST. The number that appears in parenthesis after the text indicates the relevant section in the code.

	New York State Uniform Fire Prevention and Building Code
A. Pre-equipment issues	
1. Structural requirements	<p>Hazardous piping not allowed in exits, stairways, or hoistways. (850.11)</p> <p>Gas pipe must not be installed in cinderfill or other corrosive material unless protected. (1001.1(c))</p> <p>Fuel gas piping and equipment must not be located in ducts, chutes, chimneys, flues, hoistways, stairways, or exits. (1001.1(e))</p> <p>Buildings having service >1 psig must have exterior wall openings below grade within 10 ft of gas pipe made airtight. (1001.5b)</p>
2. Configuration of gas supply system	
3. Inspection/enforcement responsibility	Fuel gas and piping system requirements per NFPA 54-84. ((B-1001.1), 850, 610, and RS38-12 in 1250.3)
4. Gas meters	Must be located in dry, well-ventilated, readily accessible area, free from steam or chemical fumes, protected from extreme heat. Must be located as near as practicable to point of entry of gas service. Meter's location protected from damage, not in spaces designed for storage of flammable products, and away from bottom of stairway. (1163.2(d), 1001.3(a))
5. Gas valves	<p>Gas service piping lines must have accessible means for shutting of gas supply to building. Additional means must comply with State Public Service Commission regulations. (1001.2(a), 1163.2(a))</p> <p>An easily accessible shut-off valve or cock must be provided in close proximity and upstream of each gas outlet or appliance connection. (1001.2(b), 1163.2(c))</p>
6. Gas regulators	Locate to be protected from damage and away from bottom of stairway. (B-1001.3)

	New York State Uniform Fire Prevention and Building Code
7. Piping/tubing	
a. Joint and support requirements	
b. Installation requirements	<p>Cleanouts must be provided where contaminants may collect. (1001.1(d))</p> <p>Fuel supply connections to equipment must be made with pipe or tubing of solid metal or means of generally accepted methods. (B-1000.2e)</p>
c. Sizing/design/pressure limits	<p>Gas systems must be designed and installed to supply sufficient gas to meet maximum demands of installed gas appliances. (1001.1(f))</p> <p>Fuel gas piping system must be of approved material resistant to the corrosive effects of gases conveyed by them. (1001.1(b))</p> <p>Service connections supplying gas at a pressure >1 psig must have device to reduce pressure to ≤0.5 psig prior to entering meter, except where system designed for higher pressures. (1001.5(a))</p>
B. Equipment issues	
1. Performance efficiencies	
2. Controls	<p>Hot water supply systems must be provided with safety devices arranged to relieve hazardous pressure and excessive temperatures. (902.6(a))</p> <p>An approved combustion pressure/temperature relief valve may be used on equipment with storage capacity ≤120 gal, and hourly input ≤100K Btu/hr. (902.6(d))</p> <p>Safety controls will prevent overheating and operation of pilots and burners during conditions of overheat or excessive pressure. (1000.2(j)(1)(2)(i)(ii)(iv))</p>
3. Component venting requirements	
4. Equipment sizing	

	New York State Uniform Fire Prevention and Building Code
5. Enclosures/locations	<p>Do not install so equipment is potential hazard to occupants. (B-1000.2d4)</p> <p>When in, on, or adjacent to combustible materials, limit surface temperature to such materials to 175°F. (B-1000.2f)</p>
6. Installation/service	
C. Post-equipment issues	
1. Combustion air	<p>Provide direct fired heat-producing equipment and its enclosure with air for combustion and ventilation. When $\geq 250,000$ Btu/hr rated capacity, provide via fixed openings to the exterior. (B-1005.6)</p>
2. Venting/chimneys/flues	<p>Connect to suitable chimney, flue, or gas vent unless of the direct vent type with combustion air inlet directly to the exterior. (B-1000.2h)</p> <p>Connectors to chimneys or gas vents in >1 story not allowed. Equipment in different tenancies cannot be connected to the same flue.</p> <p>Terminate gas vents ≥ 2 ft above point within 10 ft and ≥ 15 ft horizontal to windows or other exterior opening higher than and ≤ 30 ft above the opening. For masonry and metal chimneys, provide ≥ 20 ft vertical clearance, ≥ 3 ft above highest roof point where flue passes and ≥ 2 ft above point within 10 ft (B-1005.6)</p> <p>Locate integral venting system outlet per applicable appliance standard. (B-1005.6)</p>
3. Other issues	

	New York State Energy Conservation Construction Code
A. Pre-equipment issues	
1. Structural requirements	All joints and openings in building envelope must be caulked, gasketed, weather-stripped, or otherwise sealed. (7813.4(b))
2. Configuration of gas supply system	
3. Inspection/enforcement responsibility	Governmental entity that is responsible for administration and enforcement of Building Construction Code or the Fire Prevention and Building Construction Code within municipality. (7810.9(a))
4. Gas meters	
5. Gas valves	Separate valve must be provided to permit burning off the energy supplied to the main burner or burners of gas-fired equipment. (7813.34(d)(2))
6. Gas regulators	
7. Piping/tubing	
a. Joint and support requirements	
b. Installation requirements	
c. Sizing/design/pressure limits	
B. Equipment issues	
1. Performance efficiencies	Gas-fired water heaters (U.S. DOE covered) must meet the following performance (efficiency) requirements. Energy factor, overall heating efficiency $\geq 0.62 - 0.0019v$ (v = storage volume in gallons).
2. Controls	Each separate dwelling unit must have open thermostat capable of automatically adjusting the space temperature set point. (7813.13(a) and (b)) Thermostat must have a 5°F dead band between full heating and full cooling. (7813.13(b))

	New York State Energy Conservation Construction Code
2. Controls (continued)	Service water heating systems must be equipped with automatic temperature controls capable of adjusting from the lowest to the highest temperature settings for the intended use. (7813.34)
3. Component venting requirements	
4. Equipment sizing	In accordance with generally accepted engineering practice. (7813.12(b))
5. Enclosures/locations	
6. Installation/service	
C. Post-equipment issues	
1. Combustion air	
2. Venting/chimneys/flues	
3. Other issues	

A. Pre-equipment issues

1. Structural requirements	Tubing ≤ 4 in. may pass through fire resistance rated construction if area around penetration is $\leq 1/2$ in. and packed with noncombustible materials. ([1600.8] 27-903, 27-343, Article 5)
2. Configuration of gas supply system	Gas pipe shafts cannot be located in stairways, must be sealed to prevent gas leakage, conform to high hazard requirements, be vented to open air at top. (RS16 P115.8)
3. Inspection/enforcement responsibility	New gas distribution systems must be approved/inspected by Department of Buildings according to code. ([1606.4] 27-922(d), [1606.1] 27-919)
4. Gas meters	Locate as near as practical to point of service entrance. Locate in cellar or basement unless permitted by commissioner. Location must be clean and dry, free of refuse and steam, protected from extreme heat and cold, readily accessible for reading and inspection, and properly ventilated. Do not locate multiple dwelling meters in boiler rooms or public hall above lowest story. (P115.6(b))
5. Gas valves	Per ANSI Z21.15-1979 and Addenda Z21.15a-1981, Z21.15b-1984 (manually operated gas valves). Provide on supply side of meter and any service regulator. (P115.2(a))

Install emergency shutoff in gas pipe outside building. (P115.5(a)) |
| 6. Gas regulators | Regulator must reduce supply pressures >0.5 psig to ≤ 0.5 psig except where higher pressures are permitted. [RS16, P115.4]

When located inside building, regulators must vent directly to outside air. Pipe is sized according to utility requirements. Gas vents must be identified by suitable markings on outlet. (P115.4(b)) |

	New York City Building Code
7. Piping/tubing	
a. Joint and support requirements	<p>Provide per NFPA 54-74 when system operates at $\leq 1/2$ psig. Do not use screwed joints on pipe >4 in. dia. (P115.7(a))</p> <p>Butt weld all welded pipe >3 psig inside buildings and subject to controlled inspection. (P115.7(k))</p>
b. Installation requirements	<p>Provide service piping per serving utility (P115.8(a)). Provide gas distribution per NFPA 54-74. (P115.8(g) and (k))</p>
c. Sizing/design/pressure limits	<p>Limit to $1/2$ psig within buildings except ≤ 3 psig for commercial, industrial and other large areas. (P115.3)</p> <p>May use >10 psig when piping in 3-hr walls and partitions and 2-hr floor and ceilings. (P115.8(n))</p> <p>May use >15 psig when in 3-hr rating, fire protection provided, gas detection system alarm, gas pipe shafts are not for stairways, compressors are located in separate rooms, and other safeguards provided. (P115.8(n))</p> <p>Size per NFPA 54-74 and provide $\geq 3/4$ in. outlet to gas ranges. (P115.9)</p> <p>Provide per NFPA 54-74 when system operates at $\leq 1/2$ psig except:</p> <ul style="list-style-type: none"> - Plastic pipe and tubing cannot be used - Provide materials per serving utility - Limit primary stress to 20 percent of piping yield strength (P115.7(a)) <p>When system >1.2 psig, provide per ANSI B31.2-1968. (P115.7(a))</p> <p>Gas pipe must be sized in accordance with ANSI Z223.1-1974, RS16 P115.9. Size per NFPA 54-74 and provide $\geq 3/4$ in. outlet to gas ranges. (P115.9)</p>

	New York City Building Code
B. Equipment issues	
1. Performance efficiencies	
2. Controls	
3. Component venting requirements	
4. Equipment sizing	
5. Enclosures/locations	<p>Floor-mounted combustion or heating equipment to be mounted on noncombustible construction, or combustible construction if protected as required in RS-14-17. Equipment tested to standards listed in RS-14 to be installed at clearances determined by such test. ([C26-1406.1] 27-804, [C26-1407.1] 27-805, RS-14-17)</p> <p>Air handling equipment to be located in separate compartment having a fire resistance rating not less than 1 hr (not applicable to fans $\leq 1,000$ cfm). (RS-13, 2-5.3)</p> <p>Clearances for water heaters top, sides, back 6 in., front 18 in. [Reference Standard RS 14-15]</p> <p>All fans on roof or floor, other than on grade, must be mounted on vibration isolators. ([C26-1208.3 27-770(b))</p> <p>Insulation on surfaces of heat-producing equipment must be of noncombustible materials. (1000.2(j)(2))</p> <p>Hot water heating systems must be provided with expansion tanks or other means to allow for the expansion of water in the system. (1000.2(k))</p> <p>Low-capacity heater rooms not required to be enclosed. When enclosed, enclosure must have 3/4-hr fire resistance rating, and interior finish must provide at least 10 minutes of fire protection to combustible members. Where serving one dwelling unit, openings in one interior wall are allowed without opening protective. (739.4(f)(3))</p>

<p>5. Enclosures/locations (continued)</p>	<p>Heat-producing equipment must be mounted on noncombustible floor construction, or protected combustible floor protection, must be installed with sufficient clearance from adjacent combustible materials to prevent ignition. If ceiling above reaches temperature in excess of 175°F, must be protected for 3 ft on all sides of equipment by noncombustible material providing at least 10 min of fire protection, except if ceiling is of noncombustible construction and has a fire resistance rating with at least 3/4 hr. (717.3(3)(1))</p> <p>Fuel-burning heat-producing equipment on levels having habitable space, walls, floor and ceiling ≤3 ft from the equipment must have 3/4 hr fire resistance rating, and interior finish providing at least 10 min of fire protection to combustible members. Protection not required when test made to generally accepted standards show that heat-producing equipment will not create a fire hazard or heat adjacent materials >175°F. When doors are provided for enclosures, they must be self-closing or finished on interior with noncombustible material. (717.3(e)(2))</p> <p>Fuel-burning water heaters may not be located in sleeping, bath or toilet rooms. (1000.2(d)(2))</p> <p>Fuel-burning equipment may not be hazard to occupants in event of accidental contact. (1000.2(d))</p>
<p>6. Installation/service</p> <p>C. Post-equipment issues</p> <p>1. Combustion air</p>	<p>Air intakes and exhausts cannot be located to interfere with other openings, interfere unreasonably with occupants and general public, or create a fire or health hazard. (27-776(d))</p> <p>When mechanical ventilation supplies combustion air, interlock with burner. (27-807(d))</p>

	New York City Building Code
1. Combustion air (continued)	<p>Heat-producing equipment within enclosure must be provided with adequate air for complete combustion at rated gross output and ventilation to prevent heat accumulation. Ventilating systems must have adequate openings for intake and exhaust. Intake air must come from an uncontaminated source. (1000.2(g)(1), 1004.2(b)(3))</p> <p>Rooms having fuel-burning equipment with combined gross capacities $\leq 250K$ Btu/hr. must have openings to the exterior, or fixed openings to be spaced open to the exterior. (1000.2(g)(2))</p> <p>Gas-fired space heating equipment must connect to suitable chimney flue or gas vent, except equipment having integral vent systems (intake and exhaust connected to exterior are not required to be connected to chimneys, flues, or gas vents). (1000.2(h)(2) and (4))</p>
1. Combustion air (continued)	<p>When gas vent is permitted, a permanent sign containing type of equipment that may be connected to gas vent must be located where gas vent passes through wall or ceiling. (1000.2(h)(6))</p> <p>Equipment requiring mechanical draft must be interlocked to shut off fuel supply when vent system is in operation. (1000.2(g)(5))</p>
2. Venting/chimneys/flues	<p>Extend chimneys for low temperature appliances ≥ 3 ft above highest construction and $\geq$ height of highest construction within 2 x free area (sq. in.). (27-859)</p> <p>May use Type B-W vents with multistory installations. (27-884(b))</p> <p>Unless Type B or B-W vents used, cannot use a common vent to serve equipment on >1 floor. (27-884(d))</p> <p>Extend gas vents as for chimneys above except 2 ft rather than 3 ft. (27-888)</p>

	New York City Building Code
2. Venting/chimneys/flues (continued)	<p>Masonry and factory-built chimneys, gas vents, and supports must be structurally safe, secure, smoketight, noncombustible, and resistant to flue gas deterioration. (1005.1(a))</p> <p>Masonry chimneys, except approved prefabricated chimneys, must have noncombustible foundations. (1005.1(c))</p> <p>Flue lines must be resistant to flue gas deterioration. (1005.1(d))</p> <p>Metal chimneys must be sufficiently separated from building construction to prevent potential hazard. (1005.1(e))</p> <p>Openings for connectors must have means of easy connection without restriction of flue. (1005.1(f))</p> <p>No chimney or gas vent must have connections in more than 1 story of a building. (1005.2(a))</p> <p>Fuel-burning equipment located in different tenancies must not be connected to same flue. (1005.2(b))</p> <p>Chimneys, gas vents, or other draft-producing devices installed on fuel-burning equipment must provide sufficient draft to develop the rated output of the connected equipment. (1005.3(a))</p> <p>Gas-fired equipment operating in natural draft and connected to a chimney or gas vent must have draft hood (except prohibited on incinerators). (1005.3(b))</p>
3. Other issues	<p>No supply water piping must be directly connected to drainage system. (902.2(d)(1))</p> <p>Water used for process heating or cooling, etc., cannot be re-introduced to potable water supply. (902.2(d)(2))</p> <p>Flush valves directly connected to potable water supply must be equipped with vacuum breaker. (902.2(d)(3))</p> <p>No cross connection of potable water supplies that may contaminate, pollute, or render water unpotable. ([1601.3] 27-908)</p>

	National Fuel Gas Code - 1988
A. Pre-equipment issues	
1. Structural requirements	<p>Installation of gas piping may not cause structural stresses within building components to exceed allowable limits. (3.3.1(a))</p> <p>Structural members may not pass through gas utilization equipment operating $\geq 500^{\circ}\text{F}$. Structural members passing through equipment operating $\leq 500^{\circ}\text{F}$ must be of noncombustible material. (5.1.8)</p>
2. Configuration of gas supply system	Gas systems supplying separate users on the same premises may not be interconnected after the meters or regulators when meters are not provided. (2.3.1)
3. Inspection/enforcement responsibility	
4. Gas meters	<p>Must be located in areas protected from temperature extremes, accessible for reading, replacement, service. Must be 3 ft from source of ignition. (2.7.2)</p> <p>Meter must be adequately supported. (2.7.3)</p> <p>Piping of multiple meter installations must be permanently marked designating areas served. (2.7.5)</p>
5. Gas valves	<p>Accessible gas shutoff valve must be placed upstream of each pressure regulator. When two regulators installed in series in a single line, second valve not required at the second regulator. (3.10.1)</p> <p>Main gas shutoff valves controlling several gas piping systems must be readily accessible for operation and protected from physical damage. Must be identified to system. (3.10.2(a))</p> <p>In multiple tenant buildings supplied by master meter, or one service regulator with no meter, or when meters or service regulators not readily accessible from the equipment locations, individual shutoff valve for each apartment or tenant line must be provided at convenient point of general accessibility. (3.10.2(b))</p>

5. Gas valves (continued)

All gas utilization equipment connected to piping system must have approved manual shutoff valve installed within 6 ft of equipment served. When connector used, the valve must be installed upstream of connector. Union or flanged connection must be installed downstream of valve to permit removal of control. (5.5.4)

6. Gas regulators

When gas supply pressure is greater than that required by equipment or varies beyond design pressure limits, gas line pressure regulator or gas equipment regulator, as applicable, must be installed.

Adequately sized independent gas regulator venting to outside of building must be provided when location of regulator may cause a hazard due to ruptured diaphragm. Multiple regulators require separate vents, except if authority having jurisdiction (AHJ) approves manifolding vent lines per accepted engineering practices to minimize back pressure in diaphragm failure. (2.8.4(1))

Regulators complying with ANSI Z21.18 may be used without a vent to outside if regulator and vent limiting means are installed in ventilated location. (2.8.4)

Regulators may not be vented to equipment flues or exhaust systems. (2.8.4(A)(4))

Over-pressure protection devices not required on systems operating ≤ 60 psig.

7. Piping/tubing

Materials and components must conform to nationally recognized standards or specifications or be approved by AHJ. Materials not covered by standards must be tested to ensure suitability and safety for proposed service, recommended by manufacturers for service intended. (2.6.1)

Corrugated stainless steel conduit must be tested and listed as to compliance with construction, installation, and performance requirements for use in interior gas piping systems. ((AGA-1-87) 2.6.3(d))

	National Fuel Gas Code - 1988
a. Joint and support requirements	<p>Piping must be installed in substantial and workmanlike manner with adequate hanger supports or brackets. Must be installed to prevent undue stress and loads on connected equipment. (3.3.6)</p> <p>When installing concealed gas piping, unions, tubing fittings, running threads, right and left couplings, bushings and swing joints made by a combination of fittings must not be used.</p> <p>Reconnection of tubing in a concealed space is prohibited. (3.4.6)</p>
b. Installation requirements	<p>Pipe slopes of not less than 1/4 in. per 15 ft required, unless using dry gas. (3.3.2, 3.3.3)</p> <p>Gas piping may be installed in accessible above-ceiling spaces, whether or not such places are used as a plenum. Valves may not be installed in such spaces. (3.3.4)</p> <p>Gas piping may not be run through a circulating air duct, clothes chute, chimney or gas vent, ventilating duct, dumbwaiter, or elevator shaft. Does not apply to combustion or ventilation air ducts. (3.3.4)</p> <p>Concealed gas piping must not be located in solid partitions. (3.4.3)</p> <p>Tubing may not run horizontally in hollow walls or partitions unless protected for full concealed length against physical damage. Tubing may run vertically inside hollow walls or partitions along its entire length if a steel striker barrier of not less than 0.0508-in. thick or equal is installed between the tubing and the finished wall and extends at least 4 in. beyond concealed penetrations of plates and firestops, and tubing is not rigidly secured. (The preceding provisions do not apply to tubing that pierces walls, floors, or partitions.) (3.4.4)</p>

	National Fuel Gas Code - 1988
b. Installation requirements (continued)	<p>If pressure reduction is necessary in branch connections, reduction must take place either inside chase or immediately adjacent to outside wall of chase. Regulators equipped with vent limiting means may be vented into chase. Regulators not equipped with vent limiting means must vent directly to outside or a point within 1 ft of top of chase. (3.5.1)</p> <p>Chase construction must comply with local building codes for fire resistance and protection of horizontal and vertical openings.</p> <p>Chase may only be vented to the outside and only to the top. Minimum free area (in.²) equals 1/2 of maximum pressure in piping (psig) times the largest nominal diameter of piping (in.), or the cross-section area of the chase, whichever is smaller. When more than one system is present, largest is used. (Note only vertical chases are recognized, welded joints are preferred for horizontal line.) (3.5.3)</p> <p>Bends in metallic piping must be made only with bending equipment and procedures especially intended for that purpose. All bends must be smooth and free from buckling, cracks, or other evidence of mechanical damage. Pipe may not be bent through an arch of more than 90 deg. Inside radius of a bend must be ≥ 6 times the pipe outer diameter (OD) (3.6.1)</p> <p>Each above-ground portion of gas pipe system upstream from equipment shut-off valve must be electrically continuous and bonded to any grounding electrode as defined in National Electrical Code.</p> <p>Gas pipe may not be used as a grounding electrode. (3.14(a) and (b))</p>
c. Sizing/design/pressure limits	<p>Gas system must be sized to adequately supply gas to the gas utilizing equipment. Procedure for sizing NFGG NFPA-54, ANSI Z223.1 Appendix C.</p> <p>System sized to provide adequate pressure at equipment. (2.4.4)</p>

	National Fuel Gas Code - 1988
c. Sizing/design/pressure limits (continued)	<p>Maximum pressure in system inside building ≤ 5 psig, unless approved by AHJ and system is welded or piping is located in ventilated chase, or enclosed to protect against gas accumulation, or piping is located inside buildings not in habitable areas. (2.5.1)</p> <p>Gas/air mixtures maximum pressure 10 psig. (2.5.2)</p> <p>Gas appliance pressure regulators requiring access to atmosphere for operation must have vent piping to outdoors or, if regulator is an integral part of the equipment, to the combustion chamber at the pilot, unless equipped with a vent limiting means to limit escape of gas from vent due to diaphragm failure. (5.1.19(a))</p> <p>Vent limiting means must be employed on listed gas appliance regulators only. (5.1.19(b))</p> <p>Regulators must not be vented to equipment flue or exhaust system. (5.1.19(d))</p> <p>Any combination of gas utilization equipment, attachments, or devices used together in any manner must comply with the standards that apply to the individual equipment. (5.1.21)</p>
B. Equipment issues	
2. Controls	Water heater installations must be provided with over-pressure and over-temperature protection by an approved device constructed, listed, and installed in accordance with its listing and manufacturer's instructions.
3. Component venting requirements	Equipment must be installed to allow for adequate circulation of air for combustion, ventilation, and dilution of flue gases from within the building. When normal infiltration does not provide the necessary air, outside air must be introduced. (This does not apply to direct vent equipment.) (5.3.1(a) through (d))

Task 4 - Development of Strategies

With the information obtained from the first three tasks, NCSBCS analyzed the regulatory criteria to provide insights into the application of the criteria and the potential impacts of code requirements. Such insights were a necessary component of the development of strategies for accepted use of the technology.

Insights by Issues

A. Pre-equipment

1. Tubing run in hollow walls during retrofit requires protection from physical damage.
2. Higher operating pressures (>0.5 psig) require testing at minimum 90 psig for 1 hr.
3. Meter placement in New York City in other than basement areas must be approved by the building commissioner and service utility.
4. Multiple regulators require separate venting unless the authority having jurisdiction approves manifolding of vent lines.
5. In New York City, no piping of gas at >0.5 psig may be run in a building unless commercial or industrial.
6. In New York City, gas systems ≥ 0.5 psig in commercial and industrial use may be installed with commissioner approval. No mention of approval available for elevated pressures in residential buildings.
7. In New York State code, gas systems >0.5 psig require regulators to reduce pressure to ≥ 0.5 psig unless the system is designed for higher pressures.
8. New York City requires gas systems to be sized per NFPA 54-74. New York State requires systems to be sized to meet maximum demand.
9. Both New York City and New York State reference NFPA 54-84 and -74, respectively, for gas piping/tubing. CSST is not mentioned as an acceptable metallic tubing in either NFPA 54 edition.
10. Pressure reductions for branch connections must take place either inside the chase or immediately adjacent to the outside wall of the chase. Pressure regulator (with vent limiting means) venting may be into the chase. Regulators without vent limiting means must vent to the outside.

B. Equipment

1. DIA equipment efficiencies conform to State Energy Code and U.S. DOE requirements.

C. Post equipment

- 1. State Energy Code requires caulking and sealing of all construction joints, which may constitute "unusually tight construction." Combustion air requirements for DIAs may be affected.**
- 2. New York City prohibits water used for process heating, cooling, etc. from being re-introduced to potable water supply.**

As an integral part of the strategy-development effort (Task 4), NCSBCS initiated informal telephone contact with a number of individuals having a professional interest in code adoption and enforcement, the acceptance of new technologies, and the fire and life safety implications of gas installations. This survey was undertaken with existing contacts of NCSBCS in New York State to elicit opinions and ideas about possible code changes or innovative technologies. The rationale for this informal assessment of perceptions among code officials and other interested parties was to enable NCSBCS to provide realistic strategies for technology acceptance - to stay within the realm of what is possible.

The entities that were contacted for this survey work include the following:

- Officials from the New York City Fire Marshal's Office, the New York City Department of Buildings, and the New York City Fire Prevention Bureau**
- The town engineer and the fire marshal in Eastchester, NY**
- Officials from Suffolk County fire and building departments**
- Representatives from Brooklyn Union Gas Company, Central Hudson Gas and Electric Corporation, Corning Natural Gas Corporation, and the New York Public Service Commission**
- Representatives from Metropolitan Life Insurance Company and State Farm Insurance**
- A spokesman for Local 2 of the Plumbers Union (operating in Manhattan and the Bronx)**
- An official in the New York State Energy Office**
- An official in the New York State Housing and Building Codes Bureau.**

Survey Results

The fire marshals all indicated a concern over gas pressures over 0.5 psig inside a residential structure. Their concerns increased when they found pressures were to be in a relatively new type of gas distribution tubing. The fire prevention community relates CSST performance to that of typical flexible gas connectors, and all relayed negative experiences with them. They voiced strong opposition to the prospect of code changes that would allow CSST and higher gas pressures. No opposition was voiced concerning DIAs.

Code officials generally accepted the concept of DIAs. No contact felt that water heaters in DIAs should meet ASME boiler requirements. Most code officials indicated that once restrictive language was removed from the code, that they had no problem with accepting DIAs.

Opinions on CSST differed appreciably. New York City code officials felt that CSST was not a proven safe product, despite listings, etc. An "if it isn't broke, don't fix it" attitude prevailed. The use of typical steel piping methods for gas distribution systems was preferred, and any mention of code changes to allow CSST was frowned upon. The use of ≥ 0.5 psig gas pressures was not favored.

State code officials were not as negative regarding CSST applications and generally indicated that if a product was listed for its intended use by a nationally recognized listing agency, they had no major opposition to its implementation. State code officials noted that adoption of NFPA 54-1988 by reference would provide necessary language to allow CSST. State code officials voiced no negative opinions on DIAs.

Gas utility representatives all have positive comments regarding DIAs. Energy savings were their primary considerations. Opinions and comments on CSST applications all appeared to center on elevated gas pressures in the systems. The concerns over CSST applications ranged from possibilities of punctures during construction to meter and regulator applications. Most utility representatives indicated that new metering technology would be favorably reviewed if it assisted DIA and CSST application. The utilities also would look at innovative meter and regulator placement and be willing to adjust utility metering on regulator requirements for certain applications on an individual basis. Certain unique system configurations would be reviewed for

approval if requested. Some utility representatives have been very active in attempting to gain city- and state-wide acceptance of DIAs and CSST.

Insurance company representatives contacted did not appear to have any specific knowledge or concerns about CSST or DIAs. The only concern of the two companies contacted was that the building meet all applicable codes and regulations. If a building meets code, the insurance company saw no need for additional surcharges due to DIAs or CSST at this time.

The New York State Energy Office had no comments regarding CSST. The use of DIAs received favorable comments. Efficiency ratings for DIAs may be included in the energy code at a later date.

The Office of Uniform Fire Prevention and Building Code had no comment on DIAs. Discussion on CSST and elevated gas pressures was apprehensive. Code changes necessary to allow CSST and higher residential gas pressures were not anticipated. A generally negative view of CSST exists, and appears to be supported by bad experience with flexible gas connector malfunction and associated problems.

The plumbing trade union had no comment or experience with DIAs. The union official voiced strong negative opinions on CSST. Construction problems were cited. The union also recognizes that CSST systems are not as labor intensive as standard gas systems and therefore affect union plumbers financially. The union official also noted that special additional training must be supplied for the correct installation of CSST. It was felt that this training may not be readily available, and CSST systems may be installed with sub-standard workmanship.

Strategies

The use of potable water for space heating restriction appears to be the greatest regulatory drawback for DIAs. The informal survey revealed that some officials feel that the possibility of the occurrence of Legionnaires' disease is unusually high with DIAs. This may or may not be a legitimate concern. The opposition, however, must be researched and extensive testing to prove or disprove these assertions should be referenced. If the concern is disproved, then code amendments should be undertaken to allow the use of DIAs. If the concern is proven valid, use of only those DIAs that do

not use the potable water for space heating should be promoted. There does not appear to be any other major code restrictions to the use of DIAs. Typical construction practices that would apply to any gas heating and hot water generator would equally apply to DIA applications.

The use of CSST in multifamily dwellings appears to have several regulatory barriers. First, the use of elevated gas pressures (above 0.5 psig) in residential applications does not appear to be generally acceptable in the fire prevention, code official, or utility communities. Extensive research, testing, and experience information must be transmitted to the three groups in order to change current opinions and positions on elevated gas pressure applications. Second, the use of CSST remains a very controversial subject. Local fire officials and state code officials must be exposed to more positive information about CSST.

Dialogue must begin with the plumbing trade unions to begin to resolve the philosophical problems with CSST installations. As a technology of the future, CSST must be shown to installers as a positive opportunity—one that promotes more rehabilitation of existing structures, thereby saving or providing jobs.

If hybrid systems (combination CSST and steel pipe) are designed that will not require more than 0.5 psig operating pressures, the acceptance of CSST would be facilitated.

The adoption by New York City and the State of New York of NFPA 54-1988 will provide the necessary code language to allow CSST implementation. The less-than-positive views of those contacted who would have some direct influence on code changes does not appear to facilitate general acceptance of CSST for gas distribution systems in multifamily residences. The availability and proliferation of educational materials about the use and safety of CSST must occur before general acceptance will occur.

SUMMARY

The purpose of this investigation was to identify and delineate the institutional constraints to the use of innovative technologies in decentralized gas space and water heating applications in multifamily buildings. The potential code barriers to the acceptance of DIAs and CSST in this residential setting relate primarily to the use of

elevated gas pressures, the use of circulating potable water for heating or cooling, and the actual approval or installation of the tubing material.

From the informal survey of professionals with an interest in these applications, NCSBCS found that areas of concern mentioned in the previous paragraph are fairly pervasive throughout the state. A great deal of work will be required to inform and educate the affected parties before acceptance and use of the technologies is achieved.

Section 4

TECHNICAL INNOVATIONS

INTRODUCTION

The technical innovations survey was not performed to conceive advanced technologies for the distribution of natural gas within multifamily buildings, but rather to identify emerging technologies that are considered innovative relative to conventional approaches that are in use in New York State today. Furthermore, the information compiled in this section was used as input for the Economic/Energy Assessment (Section 2) and the Institutional Constraints (Section 3) of this research project.

The objectives of the survey were to:

- Identify emerging technologies for gas piping, gas metering, gas utilization equipment and appliance vents for use in rehabilitated and newly constructed multifamily buildings
- Identify installation methods for gas piping located in chaseways, fire protected areas, and other affected areas of rehabilitated and newly constructed multifamily buildings.

The technical innovations surveyed were categorized as:

- Technologies that affect energy distribution/utilization equipment
- Technologies that affect the building structure.

The first category includes all of the gas piping hardware and equipment necessary to efficiently transport and consume natural gas from the utility meter to the decentralized space and water heating equipment. The second category addresses available building construction practices necessary to facilitate the implementation of the technologies identified in the first category.

CATEGORY ONE - TECHNOLOGIES THAT AFFECT ENERGY DISTRIBUTION/ UTILIZATION EQUIPMENT

The following technologies were considered in the survey:

- Metering: Gas Research Institute (GRI) and others have developed advanced, compact, and intelligent meters, some of which will be commercialized in the near future. These and other metering technologies uncovered in the survey were reviewed for applicability to the New York State building market.
- Gas piping technologies: Foster-Miller has been involved in developing/evaluating advanced gas piping systems for GRI, gas utilities and gas piping manufacturers since 1983. Foster-Miller's experience puts it in a position to assess the gas piping technology needs of the building market in New York State, and to offer several alternatives. Although the project was focused on corrugated stainless steel tubing systems, macro-composite tubing systems (KITEC and MEPLA PIPE) were also considered, as well as modified copper tubing.
- Space and water heating systems: A review of combined space and water heating systems was conducted to identify commercially available units. These included the Apollo-Hydro Heat, First Co. - Aqua Thermaire, and Mor-Flo Industries, Inc. - Polaris.
- Appliance venting: New developments in appliance venting, such as the new method of characterization that has led to new vent sizing tables, were reviewed for applicability to the combined space and water heating systems.

Common appliance and multi-story venting were also investigated by performing a literature search and discussions with key industry organizations, such as the Gas Appliance Manufacturers Association (GAMA), AGA and GRI.

This survey was conducted by extracting technical information from a number of industry sources that included:

- Foster-Miller's research files
- American Gas Association
- American Gas Association Laboratories
- Gas Appliance Manufacturing Association
- Gas utilities
- Manufacturers of gas decentralized space and heating systems
- Manufacturers of gas piping products and associated hardware.

CATEGORY TWO - TECHNOLOGIES THAT AFFECT THE BUILDING STRUCTURE

Installation methods for gas piping located in chaseways, fire protected areas, and other affected areas of rehabilitated and newly constructed multifamily buildings were surveyed. The information was collected from builders/developers who tend to use innovative technologies. The search focused on demonstration projects which are most likely to incorporate technical advances. Organizations that were contacted included:

- Trade associations
 - Institute of Heating and Air Conditioning Industries
 - Mechanical Contractors Associations
 - National Association of Plumbing, Heating, and Cooling Contractors
 - Mechanical Contractors Association
 - General Building Contractors Association
- Industry organizations
 - Gas Research Institute
 - American Gas Association
 - Gas Appliance Manufacturing Association
- Federal and state energy offices
 - U.S. DOE
 - New York State Energy Office
 - New York State Energy Research and Development Authority
 - Washington State Energy Office
 - California Energy Commission
 - Minnesota Energy Office
 - Colorado Energy Office
 - Massachusetts Energy Office
 - Pennsylvania Energy Office

- Utilities
 - Brooklyn Union Gas
 - Yankee Gas
 - Bonneville Power Authority
- Major construction companies
 - Tishman
 - Turner.

METERING

Two technology areas related to metering are needed to promote the development of new gas distribution technology for multifamily buildings. They are:

- Automatic meter reading (AMR) systems
- Compact gas meters.

Although metering technology as applied to residential and commercial applications by the gas industry is essentially unchanged since the turn of the century, the collection, transfer, and processing of the flow data have undergone dramatic changes. The diaphragm type gas meter is still the overwhelming choice by gas utilities for residential, commercial and, to a large extent, industrial applications. It is a time-proven device that is accurate over large flow ranges and reliable over its long service life of 20 years. Coupled with the fact that it is also a low-cost item, it is hard to find a suitable replacement. However, by current standards it has two distinct drawbacks: its relatively large size and how it measures (i.e., flow based on "volume" instead of "mass" or "energy").

There are several gas meter technologies currently under investigation and/or development by GRI and others. These include:

- Small diaphragm meter (developed by Battelle/National Meter)
- Digital electronic flowmeter (developed by Select Corporation)
- Microcomputer-controlled N-type diaphragm gas meter (developed in Japan and referred to as the intelligent gas meter)

- Domestic compact turbine meter (currently under development in Japan)
- Fluidic flowmeter (developed by Japan)
- Fluidic flowmeter (developed by Illinois Institute of Technology/Alnor Instrument Co.)
- Ultrasonic meter (currently under development by British Gas).

None of these non-diaphragm types have been commercialized to the point where they can be given serious consideration as replacements for the diaphragm meter. But like many other technological innovations, once they are introduced into the market, a switchover is likely to take place. However, it will probably be several years before any of these new gas metering technologies find a place in the market that serves the residential industry. The following subsections are an appreciation of what is needed more than what is currently available. By identifying the current needs and trends, technology developers may be enticed to follow with the necessary (and acceptable) hardware and software. The realities of the marketplace will determine if new meters are introduced to the gas industry.

Automatic Meter Reading Systems

By far the biggest change in metering has been in the development of AMR technology. The use of remote terminal units (RTUs) on the gas transmission and distribution pipelines for control, monitoring, and enhanced safety has opened up the field for new applications. AMR promises to help solve several problems for the gas utilities regarding residential/commercial meter reading:

- Inaccessible meters
- Estimated billings
- Injuries to utility field personnel
- Customer property damage
- Customer complaints and security concerns.

There are several different types of AMR systems available on the market today. They substantially vary in operating procedure, technology, and cost. Most AMR systems consist of three components:

- An electronic field unit
- A communications link
- A host computer and software system.

Some of them use the public telephone network (PTN) as the communications link, while others use RF (radio frequency) to transmit stored data. Also, systems that use PTN are either inbound or outbound. Inbound systems are programmed to send data from the user to the host computer as often as desired. For the outbound system, the host computer systematically calls each customer for data. Each has advantages and disadvantages. For example, the outbound system requires a utility to keep a database of all of its customers' current phone numbers. Table 4-1 provides a current listing of available AMR systems.

A simple diaphragm meter can be easily adapted with an RTU for signal transmission regarding real-time or cumulative gas flow data. Figure 4-1 gives an example of one such product. This was first done for large industrial customers to monitor gas volume flow and provide current usage rates for both the utility and customer. Now several companies have developed AMR systems that can read thousands of meters almost instantly.

How does this apply to multifamily buildings? First, if the building is submetered with each tenant having a meter, the data could be routed via signal cable to a central computer in the building for transmission directly to the local utility via a gateway and telephone wires. An alternative for utilities that still use meter readers would be to collect the information and route it to a central location in the building where all services (electric, gas, water, etc.) could be accessed by the appropriate service personnel. There are even automated collection systems on the market (one example is ACCESSplus) that not only read the gas, electric, and water meters, but phone the utility as well.

Most of the electronic devices for these meters will include an integrator that converts flow rate on a volume basis to accumulated volume as a function of time. They will, however, correct actual flow rates to flows and volumes at standard conditions. Also, the readout unit can be located any place the owner/developer desires. Billing will be accomplished by interrogating the meter via remote computer control.

Table 4-1. Sources on AMR

Here is a partial listing of the manufacturers of automated meter reading (AMR) equipment and the type of systems they specialize in. AMR also has its own trade association, the Automatic Meter Reading Association, P.O. Box 500, Westwood, NJ 07675. For information, call Stan Kulp at (201) 666-0902.
<i>Alpha Omega Technology, Inc.</i> , 1279 Route 46, Parsippany, NJ 07054, (201) 334-4321. Remote-based.
<i>American Meter</i> , 13500 Philmont Ave., Philadelphia, PA 19116, (215) 673-2100. Radio- and remote-based.
<i>Badger Meter Inc.</i> , 4545 W. Brown Deer Road, P.O. Box 23099, Milwaukee, WI 53223, (414) 355-0400. Telephone-, radio- and remote-based.
<i>Computer Metering Corp.</i> , 450 7th Ave., New York, NY 10123, (212) 279-7215. Telephone- and remote-based.
<i>Datamatic Inc.</i> , 2121 North Glenville Dr., Richardson, TX 75082, (214) 234-5000. Radio- and remote-based.
<i>Digitec Telecom Inc.</i> , 11 Indell La., Brampton, Ont., Canada L6T 3Y3, (416) 791-0333. Telephone-based.
<i>EnScan Inc.</i> , 11095 Viking Drive, Suite 220, Eden Prairie, MN 55344, (800) 433-7323. Radio-based.
<i>Equimeter Inc.</i> , 805 Liberty Road, P.O. Box 528, DuBois, PA 15801, (814) 375-8363. Telephone- and remote-based.
<i>Hexagram Inc.</i> , 23905 Mercantile, Cleveland, OH 44122, (216) 464-1057. Remote-based.
<i>Husky Computers Inc.</i> , 13921 ICOT Blvd., Clearwater, FL 34620, (813) 530-4141. Telephone- and remote-based.
<i>IMAC Systems</i> , P.O. Box 1605, Tullytown, PA 19007.
<i>International Teldata Corp.</i> , 5910 Bowcroft St., Los Angeles, CA 90016, (213) 842-8044. Telephone-based.
<i>Iris Systems Inc.</i> , 123 Bannatyne Ave., Winnipeg, Man., Canada R3B OR3, (204) 947-9064. Radio-based.
<i>Iron Inc.</i> , East 15616 Euclid Avenue, P.O. Box 15288, Spokane, WA 99216, (800) 635-5461. Telephone-, radio- and remote-based.
<i>Metering Services Inc.</i> , 50 Chestnut Ridge Rd., Montvale, NJ 07645, (201) 930-9200. Telephone-based.
<i>Metretek Inc.</i> , P.O. Box 280, Melbourne, FL 32902-0280, (800) 327-8559. Telephone-based.
<i>Metscan Inc.</i> , 1450 Rochester St., Lima, NY 14485, (716) 624-9384. Telephone-based.
<i>RioTronics</i> , 6841 S. Yosemite, Englewood, CO 80112, (303) 73-2600. Telephone-based.
<i>Radix Corp.</i> , 4855 Wiley Post Way, Salt Lake City, UT 84116, (800) 367-9256. Remote-based.
<i>Schlumberger/Neptune Information Systems</i> , 3155 Northwoods Parkway, Norcross, GA 30071, (404) 446-1991. Telephone-based.
<i>Sparton Technology Inc.</i> , c/o RSS Marketing Department, 4901 Rockaway Blvd., Rio Rancho, NM 87124, (505) 892-5300. Telephone-based.
<i>Syscon Corp.</i> , 3990 Sherman St., San Diego, CA 92110, (619) 296-0085. Remote-based.
<i>Versa-Link Inc.</i> , 7379 Washington Ave. S., Edina, MN 55435, (612) 944-4001. Telephone-based.

Reference source: American Gas, March 1991.

**Introducing the Metretek CMU
Commercial Metering Unit**

**Now! Daily reading of
Commercial Transportation and
Variable Rate Accounts with
Metretek's New Battery Powered
Remote...at an affordable price!**

The Commercial Metering Unit (CMU) is a low cost and accurate meter reading device that offers needed telemetry for commercial and light industrial applications. The CMU is a microprocessor based, battery powered module that accepts and stores consumption pulse data from rotary and positive-displacement meters. It can report consumption and alarm information to the utility's central computer via the customer's existing telephone line. With its patented communications protocol, the CMU operates in a transparent mode always giving the customer priority over telephone access. Feasibility checking capability enables the CMU to immediately notify the utility when a predetermined level of consumption has been reached, providing significant benefits in monitoring transportation and variable rate accounts. The CMU's flexible, system oriented design makes it appropriate for most volume applications.

Some Important Benefits of installing Metretek's Automatic Commercial Meter Reading System are:

- ☐ Provides gas consumption information for commercial volume accounts
- ☐ Accelerated cash flow from same day billing capability
- ☐ Immediately notifies the utility when predefined consumption levels are reached
- ☐ Provides consumption profiling on a daily basis
- ☐ Mounts on existing meter sets
- ☐ Battery powered operation for 5 years on a daily reporting schedule
- ☐ Optional listed- nonincendive module for use in Class 1 Group D Division 2 hazardous locations

Figure 4-1. Metretek Automatic Meter Reading System

Compact Gas Meters

One of the primary design objectives for all of the advanced gas meters currently under development is size reduction. Because of the high per-square-foot cost to construct multifamily buildings, developers have indicated a need to minimize the amount of space on each floor required for service areas. Compact gas meters will substantially reduce the total area required for gas meter rooms while enhancing the overall installation appearance. They will also facilitate ease of installation and maintenance.

Smaller and smarter gas meter sets will soon be seen that:

- Provide better customer service and greater installation flexibility, particularly for multifamily installations
- Meet the demand for a more aesthetic appearance
- Lower overall customer and utility costs
- Compensate for pressure and temperature.

These benefits are applicable both to new construction and to renovations of single family, multifamily and commercial buildings.

Present meter sets — consisting of the riser that brings gas from the service line, service valve, pressure regulator, meter, and pipe fittings — are rather bulky and can be unsightly assemblies in some applications. For single-family homes, a smaller meter set would reduce the problem of space limitations, making more options available for its location, including wall mounting and free standing, without violating aesthetic sensibilities. In multifamily buildings, separate gas metering for individual apartments is becoming more common. With present meter sizes, a 10 meter two-tier manifold installation can take up to 25 ft² of wall space. Compact meters would substantially reduce this space requirement.

GRI Program

A July 1989 workshop sponsored by GRI and attended by gas industry personnel concluded that a compact meter R&D program could have two major objectives:

- A meter available in the near-term that would be suitable for multifamily buildings as well as single family attached dwellings requiring service line upgrades
- An advanced meter for the longer term that would provide additional features, such as remote shutoff and compensation for gas composition, and be suitable for a broader range of applications.

A March 1990 workshop conducted for GRI by Arthur D. Little, Inc. set target specifications for the near-term compact meter and possible specifications for an advanced meter (see Table 4-2). Generally, a major difference in a design that contributes to the compactness of the meter set will be to introduce the gas at the

Table 4-2. Target Specifications for Near-Term Meters

	Near-Term Meter
Size	200 cu. in. 3 in. D x 6.5 in. H x 10 in. W
Weight	10 lb or less
Minimum registrable flow	0.5 cf/hr
Totalizing accuracy	
Pilot flow to 20 cf/hr	±20%
20 to 200 cf/hr	±1%
Accuracy	±2% over 20 years
Piping orientation	Bottom inlet, top outlet; side outlet as possible alternative
Maximum pressure drop	1 in. wc
Pressure rating	5 psig
Pressure compensation	Desirable
Temperature compensation	Optional
Service life	20 to 40 years
Calibration interval	20 years
Readout	Totalizing
Remote reading capability	Yes
Battery life	7-year minimum

bottom of the set and take it out of the set at the top. Because of their method of operation, available meters have both inlet and outlet at the top. A more compact design and other changes will result in a near-term meter size of about 200 in.³ or less compared with 750 in.³ for available meters.

In 1991, GRI began initial work on three compact meter concepts: a convoluted-diaphragm positive-displacement meter (Battelle Memorial Institute and National Meter Co.), an electronic positive-displacement meter (Select Corp.), and a fluidic-oscillator meter (Illinois Institute of Technology and Alnor Instrument Co.). In mid-1992, GRI chose the first concept for further development and possible commercialization by 1994. Other meter designs from foreign organizations are also being evaluated.

GRI Projects Now Underway on Near-Term Compact Meters

The following GRI projects are now underway:

Fluidic-oscillator gas meter

Contractor: Illinois Institute of Technology

Participating manufacturer: Alnor Instrument Co.

Description: Meter operates by measuring the fluctuating pressures created by an oscillating pair of vortices. It will be small enough to fit between house wall studs, has no moving gear mechanisms to wear with time, and is a digital device easily adaptable to digital electronic circuitry and to automatic meter reading. By counting the number of oscillation cycles, it can be used as a totalizing flowmeter, giving total gas usage. Nonlinearities are adjusted in the meter's software. Size: less than 50 in.³; weight: less than 3 lb; accuracy: 1 percent above 15 cf/hr. Life of D-size lithium battery estimated to be at least 5 years.

Electronic positive-displacement meter

Contractor: Select Corporation

Description: New positive-displacement concept employs undulating, wave-shaped polyester membrane housed in rigid polymer chamber. Membrane traps discrete volumes of gas and moves them through length of chamber in pulses; each pulse causes a signal in a piezoelectric element. Microprocessor converts signal into volumetric flow and records cumulative volume in memory. Meter adaptable to remote reading. Accuracy within ± 0.5 percent down to 2 cf/hr. Potential power sources: lithium battery, telephone hook-up, photocell, household current. Size: 36 in.³, suitable for stud mounting; weight: less than 1.5 lb.

Convolved-Diaphragm Positive Displacement Meter

Contractor: Battelle Memorial Institute

Participating manufacturer: National Meter

Description: Four-chamber, convolved-diaphragm device uses highly reliable sliding valve principles of current gas meters. Similar accuracy and reliability are anticipated. Temperature compensated. Compatible with available remote and automatic meter reading devices and calibration equipment. Size: 200 in.³, weight: 6 to 7 lb. Totalizing accuracy $\leq \pm 10$ percent from pilot to 20 cf/hr; ± 0.5 percent from 20 to 250 cf/hr.

Although there may not be a truly compact gas meter commercially available at this time, there are two commercially available, small, lightweight residential meters that represent a major improvement over existing models. The dimensions for these two products are shown in Figure 4-2. The Westinghouse G2 meter weighs approximately 7 lb and is 40 percent smaller than conventional models of the same capacity. The Schlumberger SL-250 is slightly larger than the Westinghouse G2 meter, and weighs 7.5 lb. Appendix A contains manufacturer's literature on each meter.

GAS PIPING TECHNOLOGIES

Piping and Tubing Systems

Currently, steel pipe (both threaded and welded) is the most commonly used material for gas piping systems in multifamily buildings. This is a time-proven system that is considered by the gas industry to be both safe and reliable. To a much lesser extent, copper tubing is used either as a replacement for steel pipe or to supplement it. In the last few years, some plumbing contractors have taken a closer look at the benefits

Figure 4-2. Commercially Available Small Residential Gas Meters

of installing copper tubing gas piping systems in residential and commercial buildings. Primarily, the benefits are economics and ease of installation.

Within the last 7 years, a new product classified as semirigid tubing consisting of CSST has been developed, code approved (in many areas of the United States) and commercialized by two manufacturers. Additionally, two advanced gas piping technologies, one that is in the development stage (modified copper tubing) and one that is in the evaluation stage (macro composite tubing) are available for consideration. This subsection will discuss these conventional, new, and advanced gas piping systems for application to rehabilitated and newly constructed multifamily buildings.

Steel Pipe Systems. In large multifamily buildings, the gas piping system usually consists of two distinct portions: vertical and horizontal piping. The portion of the gas piping system in a large building that distributes gas to each floor is referred to as the “vertical riser.” All gas codes require that the vertical riser be constructed from Schedule 40 steel pipe. If the building is to have decentralized gas metering, a few gas utilities have assumed responsibility for the design, installation, and maintenance of the vertical riser. Figure 4-3 shows an engineering sketch of a typical vertical riser for an 8-story building.

The NFGC, NFPA 54, 1988 allows threaded fittings to be used on steel pipe sizes up to and including 4 in. Larger pipe sizes must be connected via welded joints. Most vertical risers are sized for pipe larger than 4 in. because the systems are typically designed for low-pressure service (7 in. of water). Some of the other model codes and/or utility practices are more restrictive and require welded joints for pipe sizes larger than 2-1/2 in.

Steel Pipe. The NFGC allows steel, wrought-iron, nodular (ductile) iron, copper, brass, and aluminum alloy pipe. However, the most commonly used material for above-ground interior gas piping in the United States is Schedule 40 steel pipe (black and hot-dipped, zinc-coated steel pipe). On a material cost basis, this is the most economical code-approved pipe. Installation costs for steel pipe are typically higher than for certain alternatives such as copper tubing or the corrugated stainless steel tubing. Physical specifications of Schedule 40 steel pipe are listed in Table 4-3.

Figure 4-3. Vertical Riser

Table 4-3. API Standard Line Pipe, Threaded

(All weights and dimensions are nominal. National Tube Division, United States Steel Corp.)

Size, in.	Weight per ft, lb		Thickness, in.	Diameter, in.		Threads per in.	Couplings			Test pressure,* psi		
	Threads and coupling	Plain end		O.D.	I.D.		Length, in.	O.D., in.	Weight, lb	Lap-welded or Grade A seamless	Grade B seamless	Grade C seamless
$\frac{1}{8}$	0.25	0.24	0.068	0.405	0.269	27	$1\frac{1}{2}$	0.563	0.04	700	700	700
$\frac{1}{4}$	0.43	0.42	0.088	0.540	0.364	18	$1\frac{3}{8}$	0.719	0.09	700	700	700
$\frac{3}{8}$	0.57	0.57	0.091	0.675	0.493	18	$1\frac{3}{8}$	0.875	0.13	700	700	700
$\frac{1}{2}$	0.86	0.85	0.109	0.840	0.622	14	$2\frac{1}{8}$	1.063	0.24	700	700	700
$\frac{5}{8}$	1.14	1.13	0.113	1.050	0.824	14	$2\frac{1}{8}$	1.313	0.34	700	700	700
1	1.70	1.68	0.133	1.315	1.049	$11\frac{1}{2}$	$2\frac{3}{8}$	1.576	0.54	700	700	700
$1\frac{1}{4}$	2.30	2.27	0.140	1.660	1.380	$11\frac{1}{2}$	$2\frac{3}{4}$	2.054	1.03	1,000	1,100	1,300
$1\frac{1}{2}$	2.75	2.72	0.145	1.900	1.610	$11\frac{1}{2}$	$2\frac{3}{4}$	2.200	1.17	1,000	1,100	1,300
2	3.75	3.65	0.154	2.375	2.067	$11\frac{1}{2}$	$3\frac{1}{4}$	2.875	2.13	1,000	1,100	1,300
$2\frac{1}{2}$	5.90	5.79	0.203	2.875	2.469	8	$4\frac{1}{8}$	3.375	3.27	1,000	1,100	1,300
3	7.70	7.58	0.216	3.500	3.068	8	$4\frac{1}{4}$	4.000	4.09	1,000	1,100	1,300
$3\frac{1}{2}$	9.25	9.11	0.226	4.000	3.548	8	$4\frac{3}{8}$	4.625	5.92	1,200	1,300	1,600
4	11.00	10.79	0.237	4.500	4.026	8	$4\frac{1}{2}$	5.200	7.59	1,200	1,300	1,600
5	15.00	14.62	0.258	5.563	5.047	8	$4\frac{5}{8}$	6.296	9.98	1,200	1,300	1,600
6	19.45	18.97	0.280	6.625	6.065	8	$4\frac{7}{8}$	7.390	12.92	1,200	1,300	1,600
8	25.55	24.70	0.277	8.625	8.071	8	$5\frac{1}{4}$	9.625	23.18	1,200	1,300	1,600
8	29.35	28.55	0.322	8.625	7.981	8	$5\frac{1}{4}$	9.625	23.18	1,200	1,300	1,600
10	32.75	31.20	0.279	10.750	10.192	8	$5\frac{3}{4}$	11.750	31.55	1,000	1,200	1,400
10	35.75	34.24	0.307	10.750	10.136	8	$5\frac{3}{4}$	11.750	31.55	1,000	1,200	1,400
10	41.85	40.48	0.365	10.750	10.020	8	$5\frac{3}{4}$	11.750	31.55	1,000	1,200	1,400
12	45.45	43.77	0.330	12.750	12.090	8	$6\frac{1}{8}$	14.000	49.27	1,000	1,200	1,400
12	51.15	49.56	0.375	12.750	12.000	8	$6\frac{1}{8}$	14.000	49.27	1,000	1,200	1,400
14 O.D.	57.00	54.57	0.375	14.000	13.250	8	$6\frac{3}{8}$	15.000	45.83	950	1,100	1,400
15 O.D.	61.15	58.57	0.375	15.000	14.250	8	$6\frac{3}{8}$	16.000	51.26	900	1,000	1,400
16 O.D.	65.30	62.58	0.375	16.000	15.250	8	$6\frac{3}{4}$	17.000	55.83	850	1,000	1,300
17 O.D.	73.20	69.70	0.393	17.000	16.214	8	7	18.000	61.67	850	950	1,200
18 O.D.	81.20	76.84	0.409	18.000	17.182	8	$7\frac{1}{8}$	19.000	66.53	800	950	1,200
20 O.D.	90.00	85.58	0.409	20.000	19.182	8	$7\frac{5}{8}$	21.000	79.37	750	850	1,100

The permissible variation in weight for any length of pipe is 10 percent above and $3\frac{1}{2}$ percent below; but the carload weight shall not be more than $1\frac{3}{4}$ percent under the calculated weight.

Furnished with threads and couplings and in random lengths, unless otherwise ordered.

The weight per foot of pipe with threads and couplings is based on a length of 20 ft, including the coupling.

* Test pressure butt-welded pipe $\frac{1}{8}$ to 1 in. = 700 psi; $1\frac{1}{4}$ to 3 in. = 800 psi.

Steel pipe coated with epoxy, polyethylene, or PVC is used for underground and above-ground plumbing where corrosion protection is required. Coating thickness varies with the material used for corrosion protection. Coated pipe must meet ANSI/ASTM A53 or A120 specifications for steel pipe. There is no reference in the NFGC for coated steel pipe. However, according to the NFGC Section 3.1.3: "Where appropriate (such as in contact with soil), piping shall be protected against corrosion in an approved manner."

Semirigid Tubing Systems. The use of semirigid tubing for natural and LP gas distribution within residential and commercial buildings has been going on for many years. Up to recent years, the tubing used was exclusively copper. In 1988, corrugated stainless steel tubing was introduced to the United States plumbing industry. Currently research has been started to develop/evaluate gas tubing products for use in the future (before the end of this century) to supplement the tubing products already available.

Corrugated Stainless Steel Tubing. CSST is an acceptable code-listed material for natural gas piping systems in the NFGC, Standard Gas Code, Basic/National Mechanical Code and One- and Two-Family Dwelling Code. Currently, CSST is considered by many to be the optimum commercially available material for natural gas piping systems. Similar to copper tubing systems, CSST systems are usually designed to operate on elevated pressure (2 to 5 psi).

The design of corrugated stainless steel tubing used for gas piping is not too dissimilar to flexible appliance connectors used by the gas industry for over 30 years. The CSST is manufactured from 304 stainless and is constructed with annular corrugations. The number of convolutions per centimeter and the amplitude of each convolution are both much smaller than found on the appliance connector. Therefore, the CSST is much less flexible and resilient than an appliance connector. However, CSST is only intended to be flexed once or twice during installation. Unlike the appliance connector, CSST is used neither as a vibration damper nor is it expected to be moved once installed. Table 4-4 shows typical dimensions for one brand of CSST used in the United States for interior distribution. Appendix E contains a brief description of the CSST systems currently offered by two manufacturers.

Table 4-4. Typical CSST Specifications

Equivalent Hydraulic diameter	EHD	14	19	26	31	
Nominal diameter	mm	10	15	20	25	32
Inside diameter (id)	mm	11.5	15.0	20.0	25.0	32.0
Outside diameter (od)	mm	14.2	18.4	24.9	30.8	38.8
Pitch/10 corrugations (p)	mm	34	38	50	60	70
Tube wall thickness (t)	mm	0.20	0.20	0.25	0.25	0.25
Coating thickness	mm	0.6	0.6	0.6	0.6	0.6
O.D. of coating (oad)	mm	15.4	19.6	26.1	32.0	40.0
Length (L)	m	76.2	76.2	54.9	54.9

CSST is sold only as a system. The manufacturer must not only supply the tubing, but also the associated mechanical fittings, multiport manifolds, special mechanical protection shields and detailed installation instructions. In the United States, CSST systems must be design-certified by an independent testing organization and each component must be marked with specific information. The system is certified in accordance with the requirements of an ANSI Standard: ANSI/AGA LC-1 entitled American National Standard for Interior Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing. CSST is lightweight on a per "coil" basis and is extremely easy to install. It has excellent corrosion resistance characteristics and is protected by an outer covering of plastic. It can be easily bundled for multiple tubing runs and can be manufactured in almost any lengths required. CSST uses simple mechanical fittings for joining, requiring only hand tools for assembly. On a total system cost basis, CSST is not as cost-effective as copper tubing, but still less than steel pipe for many multifamily and commercial applications. CSST is currently available in four sizes; 3/8, 1/2, 3/4 and 1 in. (ID).

The use of corrugated tubing has several installation advantages over rigid steel pipe. In most installations there will be no intermediate joints between the manifold and appliance because the tubing is capable of being installed in one continuous run. This minimizes the number of potential leak sites and eliminates concealed joints. Because the tubing is bendable by hand, it can be installed more quickly and in areas that would be inaccessible to rigid pipe. This feature is especially critical in the retrofitting/remodeling of existing structures. The tubing installation requires only hand tools and, therefore, needs no heavy, electrically powered cutting/threading equipment and/or truck to carry and store piping and fitting inventories.

Because the tubing comes in coils and is lightweight, a tubing reel can be used to expedite the running of the service and appliance lines. This technique makes it possible, in some cases, for one plumber to install the entire system. The installation is insensitive to the construction materials and structural elements. The tubing can be installed through holes drilled in the wooden floor joists, through open spaces in trusses, strapped to the sides of a floor joist, or beneath the joists. It can be as easily run through wooden wall studs as steel studs. Since most gas piping is field run, the added flexibility of the corrugated tubing allows the installer to seek the path of least resistance around existing obstacles, either in new construction or in remodeled structures. This eliminates the repetitive measuring, cutting, threading and joint assembly common with steel pipe systems.

Mechanical fittings are used to connect the tubing within the system. Compared to steel pipe, these connections are easier to assemble and can be completed in less time and for lower cost. The fittings are lightweight and small enough to be easily carried around in the plumber's belt pouch.

Extensive field assessments of current tubing/piping hardware and installation practices have been completed. The field tests included time and material studies in several different single-family, multifamily, and commercial buildings, including both new construction, retrofitting and rehabilitation. In all tests buildings, both low-pressure steel pipe and hybrid pressure copper and corrugated tubing systems were designed and installed. The data were analyzed for both installation labor (job hours) and total cost (labor plus materials). The results, summarized in Table 4-5, have been calculated using a labor rate and material prices that have been found to reflect average costs in the United States.

**Table 4-5. Results from Piping Field Tests Installation
Labor and Cost Comparison***

Building Type	Percent Average Labor Savings Over Steel Pipe*	Percent average Total Installed Cost Savings Over Steel Pipe*
Single-family (all types): detached/attached wood frame/new construction	30 to 50	15 to 40
Multifamily low-rise: wood frame/new construction	10 to 70	10 to 40
Multifamily high-rise: concrete and steel frame/new construction	40 to 65	30 to 40
Multifamily rehabilitation	70 to 80	50 to 60
Light commercial buildings: (all types)	40 to 80	30 to 60
*CSST versus Schedule 40 steel pipe.		

Results from the research clearly indicate that semirigid tubing systems operated at elevated pressure are both safe and reliable, and can be installed for less cost than conventional low-pressure steel piping systems. The tubing systems are easier to install for new construction and especially for rehabilitation projects. Many variations exist for the choice of system hardware, design approach, arrangement and installation practices.

Conventional Copper Tubing. Interior natural gas piping systems using copper tubing currently must comply with standard Type K or L, of the Standard Specification for Seamless Copper Water Tube, ANSI/ASTM B88. In February 1991, the ASTM B-5 Committee on Copper and Copper Alloys drafted a proposed ASTM Standard Specification for Seamless Copper Tube for Natural Gas and Propane Fuel Distribution Systems. If the proposed standard is adopted, it would replace the existing ANSI/ASTM B88 Standard for natural gas and propane fuel piping applications. Under the new standard, the tubing for natural gas and propane fuel applications would be designated Type G. No other type of copper tubing would be allowed for these applications. The most commonly used tubing sizes that provide the

necessary handling/flexibility characteristics are 1/4, 3/8, and 1/2 in. nominal. Specifications of approved copper tubing for natural gas service are listed in Table 4-6.

The tubing is available in either hard-drawn 20-ft long straight sections, or soft-drawn (annealed) 25- to 50-ft coils. The soft-drawn copper tubing is typically preferred over hard-drawn copper tubing for interior gas piping systems because it can be bent by hand and is available in long coil lengths.

Copper tubing is usually jointed with silver-brazed or SAE 45-deg flare fittings when used in a natural gas piping system. A special tool is required to flare the tubing at each end. The same tool can flare several different tubing sizes. Figure 4-4 shows a typical flare fitting with tube attached. If the local code authority does not permit mechanical flare fittings, silver-brazed joints attached with a material having a melting point in excess of 1,000°F may be substituted. Common copper water pipe fittings are used in the gas piping system to connect tubing lengths.

Modified Copper-Based Systems. Semirigid copper-tubing -based interior piping systems have been shown to be a safe, reliable and economical alternative to rigid steel pipe. In some areas of the United States, there has been concern expressed about the potential for internal corrosion of copper in this application. The GRI

**Table 4-6. Copper Tubing Dimensional Specifications
(American Brass Company)**

Nominal Size, in.	OD in. Types K, L	ID in.		Wall thickness, in.	
		Type K	Type L	Type K	Type L
3/8	0.500	0.402	0.430	0.049	0.035
1/2	0.625	0.527	0.545	0.049	0.040
3/8	0.750	0.652	0.666	0.049	0.042
3/4	0.875	0.745	0.785	0.065	0.045
1	1.125	0.995	1.025	0.065	0.050
1-1/4	1.375	1.245	1.265	0.065	0.055
1-1/2	1.625	1.481	1.505	0.072	0.060
2	2.125	1.959	1.985	0.083	0.070
2-1/2	2.625	2.435	2.465	0.095	0.080
3	3.125	2.907	2.945	0.109	0.090
3-1/2	3.625	3.385	3.425	0.120	0.100
4	4.125	3.857	3.905	0.134	0.110
5	5.125	4.805	4.875	0.160	0.125
6	6.125	5.741	5.845	0.192	0.140
8	8.125	7.583	7.721	0.271	0.200
10	10.125	9.449	9.625	0.338	0.250
12	12.125	11.315	11.565	0.405	0.280

**Figure 4-4. SAE 45-Degree Flare Fitting with Tube Attached
(Imperial Eastman)**

sponsored two related studies to address this concern. The first, performed by Southwest Research Institute (SwRI) was a study of the effects of natural gas constituents on copper corrosion.

The second, performed by Foster-Miller was the development of modified copper-based piping system concept for interior distribution of natural gas. The new system was to be highly resistant to internal corrosion and to have straightforward installation procedures. Also, the new system's total installed cost was to be equal to or less than alternate piping material systems.

Three general categories of tubing concepts were investigated: internally lined copper tubing, improved copper alloys, and corrugated copper alloy tubing. A series of laboratory experiments were performed on tubing and new joint fitting specimens to determine the feasibility of potential manufacturing processes, physical performance, and corrosion resistance, depending on the system concept and component type.

Three tubing concepts resulted from the preliminary development activities: a hypothetical polyethylene-lined welded tubing (Figure 4-5), a copper alloy tube having annular corrugations, and a cost-reduced version of existing state-of-the-art, tin-lined copper tubing. Feasibility calculations on the polyethylene-lined welded tubing concept indicated that a thin copper sheath can be welded around the thermoplastic liner without significant damage to the liner if done rapidly with low total energy input (electron beam welding).

Copper alloys studied for possible use in corrugated tubing were alloy No. C61500 and C68800. The corrosion resistance of the various copper alloys was screened using the linear polarization resistance method. Following the screening tests, SwRI performed longer term corrosion tests in a severely contaminated environment on copper alloy No. C61500 and C68800, the tin-lined copper, and copper alloy No. C12200 (as a benchmark). Copper alloy No. C61500 and C68800 and the tin-lined specimens all had significantly lower corrosion rates than copper alloy No. C12200.

Composite Tubing. Recently, a number of multilayered composite tubing products have become commercially available, some of which are suitable for natural gas applications. These new tubing products are a combination of adhesively bonded, multilayer, plastic and metallic tubings. Although not quite as flexible as CSST, they do offer a new alternative to copper tubing and steel pipe. Some of them are priced close to copper tubing. They potentially offer the most resistance to long-term corrosion effects, while at the same time can be more easily installed than steel pipe. Similar to CSST, their inherent flexible characteristic allows tubing movement to compensate for building movement under almost any conditions (e.g., earthquake, high winds, building settling).

Composite tubings are lightweight on a per-coil basis, and are connected via easy-to-install mechanical fittings. They can be bundled and field run several hundred feet in

Figure 4-5. Thermoplastic-Lined Welded Tubing Concept

chaseways with other services. Most manufacturers produce composite tubing products for several different applications. These currently include natural gas, hot water for underfloor heating, cold water for underfloor cooling, hot and cold water supply, compressed air/vacuum systems, solar heating, and electrical conduit (shielding) for electronics/telecommunications trunking. For produce demarcation, the composite tubings are manufactured in different colors. Conceivably, many services could be installed at the same time by fewer installers with tubing products from the same manufacturer. This scenario could lead to increased cost savings for both materials and labor for several different services combined.

Using a thin-wall aluminum tube as a center core, one version of the composite tubing product is designed as a sandwich arrangement. The aluminum tube is surrounded, both internally and externally, by a polymer (PE) jacket. Two commercially available products (MEPLA pipe and KITEC tubing) are undergoing laboratory evaluation. The driving issue for this approach is the cost of the metallic tubing alternatives. The cost of corrugated stainless steel is much higher than the cost of the composite tubing, thus making this approach more cost-effective on a first-cost basis.

Table 4-7 summarizes pertinent information for the two commercially available products. For each product, the thin-wall, seam-welded, aluminum tubing is laminated between two layers of polyethylene tubing. Two tubing sizes, 3/8 and 1/2 in., have been evaluated by Foster-Miller for each product. Also, each tubing product has specially designed fittings and installation tools for making connections to existing piping components. Each manufacturer has developed a piping system based on their tubing product, which includes all of the necessary hardware for a complete installation.

MEPLA Tubing. Of the two products evaluated, the MEPLA tubing is more robust. The overall wall thickness (in each size) is greater in the MEPLA products. This means the MEPLA tubing is stiffer (in all sizes) and more difficult to handle and install. The product specifications and configurations are described in Appendix E. The tubing comes with a complement of accessories, fittings, and assembly tools, and is supplied in three sizes (16, 20, 25 mm OD).

The MEPLA tubing passed all of the mechanical tests and the thermal resistance tests for the tubing only. However, the MEPLA tubing joint failed at a temperature below

Table 4-7. Summary of Composite Tubing Products

Product Name	Manufacturer	Outer Tubing Material	Inner Tubing Material	Metal Tubing Material	Min. Oper. Press (psi)	Coil Length (ft)
MEPLA Pipe	Fluid Air Energy	PE	PE	Al Al alloy	88	160 320 642
KITEC Tubing	Kitechnology Ltd.	XLPE HDPE	XLPE HDPE	AL AL	150	500 600
PE - Polyethylene AL - Aluminum XLPE - Cross-linked polyethylene HDPE - High-density polyethylene						

1000°F. Furthermore, the MEPLA tubing was noticeably more difficult to install than the corrugated stainless steel tubing.

KITEC Tubing. KITEC tubing is more flexible and comes in four sizes (14, 16, 20, 25 mm ID). The product specifications and configurations are also described in Appendix E. KITEC tubing also comes with a variety of accessories, fittings and installation tools.

Foster-Miller performance test results indicate that, except for the thermal resistance of the tubing/fitting joint and impact resistance, the KITEC tubing is essentially equal to the corrugated tubing. The requirements of the impact resistance tests can be met with a minor alteration to the present testing method. The installation of the KITEC tubing was rated equivalent to the corrugated tubing.

The fittings for both MEPLA and KITEC products must be redesigned for higher temperature resistance. This issue is being addressed by both manufacturers with assurances that the requirement can be met.

The economic analysis has shown the KITEC and MEPLA tubing systems to be significantly more cost-effective than all other systems studied, including steel pipe and corrugated stainless steel tubing. For two types of commercial buildings (multifamily low-rise and low-rise retail plaza) studied, the total installed cost of the

KITEC system was 38 and 55 percent lower than the cost of the steel pipe system, respectively.

Distribution Networks

If gas piping systems are installed in multifamily buildings, they are often designed for low-pressure service applications. This requires much larger pipe sizes than would be required if higher pressures were used to distribute natural gas within the building. As an example, if gas operating pressure was increased from 1/4 psi (approximately 7 in. of water pressure) to 2 psi, an increase of eightfold, the gas-carrying capacity of the pipe would be increased 2.8 times. As a result of operating with increased pressure, there are large potential savings to be realized with reduced pipe sizes (both material and installation costs). Couple this with the potential savings using semirigid tubing and the total cost savings could be substantial compared to installing low-pressure all rigid steel pipe systems.

A hypothetical advanced gas distribution network could be described as follows. Gas is supplied via a main at a pressure up to 60 psi and reduced to a lower pressure of 5 psi by a central regulator at the building entrance (see Figure 4-6). Portions of the hypothetical advanced gas distribution system would include corrugated stainless steel tubing. ANSI/AGA LC-1, 1991 Interior Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing limits the operating pressure of the system to 5 psig. Total gas supplied to the building would be monitored by a conventional gas meter or advanced compact flowmeter. This portion of the piping system is the gas entrance header. From that point the gas would be distributed via a vertical riser(s) to various upper level floors (including the roof) and/or a horizontal header to common or retail use areas on the first floor level within the building. The size of these pipes would be in the range of 2 to 4 in. The vertical piping would require chaseways and engineered floor penetrations and support devices. The horizontal piping would also require engineered supports and wall penetrations.

On each floor, gas would be distributed via a subnetwork including a regulator to reduce the pressure from 5 to 2 psi, compact gas meters, and semirigid distribution piping to each unit. This portion of the piping system is the gas service header. The compact gas meters, required valves and hardware to connect the components could be installed in modular cubicles. Finally, the gas would be distributed within each

64-GRI-9204-3

Figure 4-6. Gas Distribution Network - Typical Residential-Commercial Building

tenant unit via the modular distribution manifold. This is essentially a second subnetwork that includes a regulator to reduce the pressure from 2 to 1/4 psi and a multiport manifold for delivering the gas to the appliances or termination at a gas outlet. This approach should go a long way to streamline the design and installation of the piping system by making it highly compact and efficient from a fluid dynamic standpoint. To further enhance this approach, technology exists to integrate the

advanced gas distribution network into the main control system of a fully automated building.

Foster-Miller, under contract to GRI, and a number of gas companies have done some experimenting with different designs for gas piping systems for multifamily buildings. Foster-Miller conducted a study in a 15-unit, 6-story condominium where the gas meters for each unit were located in a common meter room located in the underground garage of the building (see Figure 4-7). Significant total cost savings were shown by installing either a 2-psi all-CSST or copper tubing system compared to a low-pressure steel pipe system. The CSST was installed in two separate vertical bundles that were routed through chaseways specifically designated for building services.

Conversely, the experience of one gas company has shown that placing the meters at ground level for a decentralized system where each tenant has their own gas meter and distributing the gas via a copper tubing system only works for buildings with 3-4 stories, especially if there are more than two gas appliances per unit. Buildings with more than 4 stories may not benefit from meter groupings on the ground floor.

A second approach is to submeter on a floor-by-floor basis, as shown in Figure 4-8, or on every other floor, as shown in Figure 4-9. In this gas distribution network design the vertical riser and meter room piping up to the individual unit gas meters would be steel pipe. The riser would most likely have all welded joints, whereas the meter room manifold piping would probably have a combination of welded joints for the larger pipe sizes and screw thread joints for the smaller pipe sizes. CSST (or copper tubing) would be used to distribute the gas load downstream of the individual unit meters. Multiple pressures (5, 2 and 1/4 psi) would be used to distribute the gas throughout the entire gas distribution network, thereby minimizing the size of the piping for each section of the network.

A third approach, which is currently practiced in some areas of the United States, is called "electronic submetering." It is a time-based system rather than a capacity or volume based system and requires only one master meter at the entrance of the building (see Figure 4-10). The electronic submetering system records the amount of time an appliance gas valve is open in any particular unit. The time data over some predetermined period is accumulated for all appliances in a single unit. By

Figure 4-7. Gas Distribution Network with Submeter Room Located in Parking Garage

64-GRI-9204-11

Figure 4-8. Gas Distribution Network with Submeter Room on Each Floor

84-GRI-9204-12

Figure 4-9. Gas Distribution Network with Submeter Room on Every Other Floor

proportioning the total amount of gas supplied to the building by the accumulated time data for each unit, the amount of gas supplied to each unit can be determined.

Piping System Accessories

The gas distribution network of the future for multifamily buildings will require not only advanced piping, metering, and efficient network designs, but also innovative accessory hardware to complement the total system design. In this subsection four areas will be discussed regarding accessory hardware:

- Modular meter enclosures
- Modular manifold enclosures
- Striker plates, chaseways and baseboard channels
- Intermediate line regulators and venting.

Modular Meter Enclosures. There has not been much development in the United States in this accessory area. However, British Gas has ongoing research programs that have produced some products worth evaluating. The British Gas Mark II built-in meter box shown in Figure 4-11 is a good example of a well-thought-out product that is designed to architecturally integrate both electric and gas service in one area while maintaining physical separation. The gas meter box has a reduced surface area of 25 percent compared to its predecessor, which uses the same meter. As shown in the figure, the entrance and exit piping is located near the front of the box for ease of installation .

Figure 4-11. British Gas Mark II Built-In Meter Box

Figure 4-12. British Gas Concealed Meter Box

British Gas has also developed a concealed meter box for burial outside the building (see Figure 4-12). A meter box similar to this design may have applications in multifamily buildings where adequate floor depth is available for a recessed installation. The meter can be read through a viewing port that is designed into the cover. The cover provides a watertight seal but is removable for maintenance. The box and cover are composed of a tough glass-reinforced plastic.

British Gas has developed another version of the concealed meter box called the semi-concealed meter box (see Figure 4-13). This box extends 3 in. above the floor or ground and is intended to be installed adjacent to the property wall. Here again, with some minor design modifications, this box may be quite suitable for installing in multifamily buildings. The top is hinged, which allows the meter to be read and any maintenance to be performed.

Figure 4-13. British Gas Semi-Concealed Meter Box

Modular Manifold Enclosures. Foster-Miller has identified a need to facilitate the assembly and field installation of the distribution manifold required for hybrid pressure CSST systems. In response to this recommendation, R.W. Lyall has developed a new addition to the CSST system product line — a standardized, preassembled manifold box (see Figure 4-14). The primary benefit will be reduced labor costs for the overall installation of the piping system.

The box is a prefabricated steel enclosure designed to be installed either between two standard wooden or metal wall studs or on a wall surface. The box includes a service shutoff valve, drip leg, a Maxitrol regulator (either a Model 325-3 or 325-5), a piping union (to facilitate regulator replacement), and a multiport, all welded construction

Figure 4-14. R.W. Lyall Flush-Mounted Manifold Box

steel manifold. The entire assembly can be removed to allow the easy installation of the box between the studs. The front door panel is also removable, which permits easier access during tubing installation. The door can be specified for either right or left hand opening. The enclosure is also provided with knock-outs for 10 tubing runs. The box could also be easily modified for ceiling installation. This may better accommodate installation in multifamily buildings.

The manifold can be customized both in terms of the number and size of the ports. If more ports are needed, the closed end of the manifold riser is designed so that a crossover piping assembly can be retrofitted to add a manifold-only box between the adjacent wall studs. As an option, appliance shutoff valves can be installed at each manifold port to facilitate the servicing of the piping system and provide the consumer with some enhanced safety features. Each port can be numbered and recorded on a log sheet (located on the door) so that each gas appliance can be easily identified and isolated for service without disrupting the rest of the gas piping network. Safety information and important telephone numbers can also be provided on a notice located inside the box.

The entire manifold box, including tubing fittings, can be preassembled by apprentice-level personnel. Once assembled, each manifold system can be pre-inspected and pre-tested for leakage. Once the box is installed between the studs (or in the ceiling), the entire field operation is reduced to installing the service and appliance tubing and completing joint connections.

Early production units of the manifold box are being field evaluated and may be ready for market introduction in 1993. These manifold enclosures are expected to be a valuable addition to the CSST system, and with few design changes lend themselves to installation in all building types.

AGA -Certified Striker Plates. One of the key technical concerns addressed during the GRI research to develop the CSST system involved the need for and types of mechanical protection required for CSST. Under contract to GRI, Foster-Miller developed a series of metallic striker plates, shown in Figures 4-15 and 4-16, that effectively deal with the installation variations found in both wood and metal frame construction. The Foster-Miller approach to mechanical protection was incorporated into the NFGC, and a special performance test for striker plates has been included in

Figure 4-15. Foster-Miller Striker Plate Designs

Figure 4-16. Striker Plate Installed to Protect CSST

ANSI/AGA LC-1, 1991. With GRI approval, the striker plate designs were offered to all CSST manufacturers at no cost to encourage their voluntary adoption.

Chaseways and Baseboard Channels. Chaseways are an integral part of the design of some multifamily buildings for running services between floors and along horizontal sections on each floor. These pathways are designed into some multifamily building for electric and water supply/drainage/fire suppression, but not necessarily for gas. It is important to minimize the size of gas piping to more easily accommodate already tight space requirements allowed for services requiring chaseways.

Baseboard channels usually located within rooms and offices are becoming more popular for running services such as electric power, communications, and data transmission. There is no reason why semirigid gas tubing cannot utilize the same pathways albeit separate compartments as these other services. This was demonstrated several years ago in the GRI single-family applications research house (see Figure 4-17). British Gas has also developed a system that uses baseboard channels, copper tubing, and special outlets to distribute gas within rooms/offices. Their system, called Micropoint, is shown in Figure 4-18.

Figure 4-17. Gas Tubing Installed in Baseboard Channel

Figure 4-18. British Gas Tubing and Micropoint Gas Outlet Installation Using Baseboard Channel

Intermediate Line Regulators and Venting. There are no specific code prohibitions to installing line pressure regulators within buildings in addition to the service pressure regulator that reduces high street pressure (up to 60 psi) to lesser pressure (1/2, 2, 5, or 10 psi) for interior gas distribution. The issue for multifamily buildings is what are the operating requirements and acceptable locations for the intermediate line regulator? There are three important operating functions that can be required for this type of regulator which are:

- Overpressure protection
- Dead-end lock-up
- Full relief.

The NFGC, NFPA 54, 1988, states that overpressure protection of the interior piping system is not a requirement if the gas source is 60 psig or less and the service regulator is capable of dead-end lock-up. Dead-end lock-up is defined as limiting the downstream pressure under conditions of no-flow to 150 percent of the discharge pressure under normal flow conditions. In other words, if the normal operating pressure of the interior piping system is 7 in. of water, under no-flow conditions the

downstream pressure could not rise to more than 10.5 in. of water. Most service regulators meet or exceed these specifications. However, some utilities still require an intermediate line regulator to have both dead-end lock-up and overpressure protection capabilities.

Regarding dead-end lock-up, the problem appears to be the time period. The regulator may pass the requirements of ANSI Z21.18, Gas Appliance Pressure regulators but not meet the more stringent requirements of a local gas utility. This has happened with one manufacturer's regulator. The utilities would apparently like to see no rise in pressure more than 150 percent or some other value of the set pressure for a period of time longer than that stated in ANSI Z21.18.

The overpressure protection issue is merely a matter of the gas utility wanting additional safety above that which is required by NFPA 54-1988 and, in some cases, their own local code. Overpressure protection devices, whether built into the line regulator or a separate component, add additional, unnecessary materials and labor cost to the installation of the gas distribution system. This will inhibit the development and hinder the commercialization of advanced gas distribution technology.

In addition to dead-end lock-up and overpressure protection, some utilities also require that intermediate line regulators have full-relief capability as well. First of all, NFPA 54-1988 does not require that line pressure regulators have a vent line. A vent limiting device is acceptable. However, many utilities/code officials have not accepted vent limiting devices.

For a line regulator to have full-relief capability means that a much larger vent pipe, up to 3/4 in., may be required to satisfy the requirement. Also, NFPA 54-1988 allows, if approved by the authority having jurisdiction, vent lines to be manifolded in accordance with accepted engineering practices. It is questionable how many authorities having jurisdiction would allow manifolded vent lines. From a cost standpoint, it is crucial for the intermediate line regulator vent lines to be manifolded in multifamily buildings.

The location of the regulator within the building structure is also a controversial issue for many gas utilities. Questions arise such as can the regulator be installed above a

suspended ceiling or even in a manifold box? The issue here is the degree of concealment that is acceptable that still allows the connections to be readily accessible for servicing as required by NFPA 54-1988. These issues need to be resolved before successful implementation of advanced gas distribution networks can be achieved.

Gas Outlets. Semirigid tubing systems provide the tenant with enhanced use operations that are not traditionally provided when using steel piping. Among these options is the decentralization of gas distribution within the multifamily building. Gas can be made available, with significantly less cost and difficulty, at many sites throughout the multifamily building, and not just in a utility area for the furnace and water heater. This network gives the tenant additional use options that currently are not being provided or that are being serviced by electricity.

GRI-sponsored research has led to the development of a prototype gas outlet as shown in Figure 4-19. Designed and manufactured by M.B. Sturgis, Inc., the device is engineered to meet the requirements for AGA Laboratory bench standard for gas

Figure 4-19. M.B. Sturgis Advanced Convenience Gas Outlet

convenience outlets (AGA No. 7-90). Although the M.B. Sturgis outlet is still undergoing engineering evaluation and modifications, its features and operation can be described.

Outlet Features and Operation. The outlet is designed to be operated by inserting the connecting plug and then rotating the plug 90 deg clockwise. The internal on/off valve is activated as the plug is rotated. Gas flow is initiated only after the plug has rotated a minimum of 30 deg. In the connected position, with the gas flowing, the plug cannot be removed from the outlet. Bayonet tabs on the plug engage with corresponding grooves in the outlet body to prevent the removal of the plug by simply pulling on it. The primary on/off valve is a manually operated cone (tapered plug) valve that is activated by the combined effect of the insertion and rotation of the plug. A redundant secondary valve within the outlet is actuated by a cam system, which is activated by the movement of the back surface of the cone valve. This cam unseats a poppet valve, which permits the gas to flow into and through the cone valve and plug. To disconnect the plug from the outlet, the plug must be rotated 90 deg counter-clockwise, which closes both the primary and secondary valves. The counter-clockwise rotation also releases the locking tabs on the plug and allows the plug to be removed from the outlet with a small tug.

The outlet is designed to be assembled in two packages. The rough-in assembly is mounted on the wall stud before the wallboard is installed and is considered part of the rough-in gas piping installation. The rough-in assembly is pressure tested as part of the gas piping system. The finish assembly consists of the cover plate and wall trim, which are installed after the interior walls have been completed. The outlet is designed to be installed like an electric outlet and has built-in compensation for variation in the wall thickness. The outlet can be installed in any orientation, with the gas piping entering from the top, bottom or either side. The outlet can be used outdoors, but it must be installed in a weather-resistant enclosure.

The introduction of gas outlets into multifamily buildings is intended to encourage the use of portable countertop appliances. These types of appliances are expected to be lightweight and may require a more flexible connector than is currently sold for stoves and dryers. This ultra-flexibility is needed to prevent accidental tipping of the appliance caused by a non-compliant stiff connector. These will be critical applications because of the daily interaction with the consumer in an indoor

environment. Entirely new technology that is more tolerant of abuse, extremely flexible (like wire), and fail-safe may be required and will be an important objective of ongoing GRI research. However, not all movable appliances need a highly flexible appliance connector. Freestanding range/oven units and clothes dryers could continue to get by with existing appliance connector technology but modified with the special gas outlet plug. Similarly, outdoor use with such appliances as the barbecue grill can be met with existing products. Until the appliance connector issue is resolved, both in terms of the compatibility and design needs, there could be a negative impact on both the market introduction and its growth.

Code Restriction. A complete evaluation of building standards and fuel gas codes used around the United States was conducted by the NCSBCS. In their report entitled, *Code Assessment of Acceptability of Quick Connect/Disconnect Gas Outlets*, NCSBCS summarized the results of some informal industry surveys and technical investigations into the issues addressing the use of gas outlets inside buildings. The report highlighted two key areas: product standards and installation requirements. Most model codes in the United States list acceptable gas appliances or accessories by referencing the appropriate national standard. Since the type of gas outlet being developed by GRI may require a new national standard, an interim standard is needed to get the outlet listed in the various model codes. To that end, an AGA bench standard has been developed entitled *AGA Requirements for Gas Convenience Outlets*, No. 7-90, dated 3/20/91. The standard does not currently address the geometric compatibility issue raised earlier.

Codes and building standards deal mostly with installation issues involving equipment, piping, ducts, vents and system accessories. Regarding gas outlets, most codes either allow quick connect/disconnect devices or they are silent on the issue. When using quick connect devices, the codes require an accessible, upstream manual shut-off valve to be located close to the outlet. The M.B. Sturgis type of outlet internally incorporates the shut-off valve and is intended to be installed in concealed locations. Therefore, there is a need to modify code language to permit this type of device and installation method. The approach taken was to define a new category of quick connect devices called gas convenience outlets. The definition recommended is as follows:

"Convenience Outlet, Gas. A permanently mounted hand operated device providing a means for connecting and disconnecting an appliance to the gas supply piping. The device includes an integral, manually operated gas valve with a non-displacement valve member so that disconnection can be accomplished only when the manually operated gas valve is in the closed position."

If this definition is adopted by the individual model codes, it will permit the M.B. Sturgis-type outlet to be installed without an additional upstream shut-off valve. This language has been submitted to and approved by the NFGC Z223 for adoption in the 1992 reprinting.

The other code restriction, which will affect the installation of the convenience gas outlet, is the prohibition on the use of concealed tubing joints. This prohibition appears to be universal in those codes that permit the use of tubing for natural gas distribution within the house. To address this issue, two different approaches have been proposed. In the near term, when installing the gas outlet in concealed locations, the outlet must be installed inside an air-tight enclosure that includes the tubing fitting. Figure 4-20 depicts a prototype enclosure that permits the outlet to be

Figure 4-20. Special Gas Outlet Enclosure for Concealed Joints

installed inside the plaster wall, while permitting access to the fitting. Should the joint leak, the escaping gas will vent into the room from inside the enclosure.

An alternative near-term approach is to mount the gas outlet on a steel pipe riser when the outlet is to be placed in a concealed location. The steel pipe should extend from the gas outlet to an area where an accessible transition from pipe to tubing can be accommodated. Since the prohibition on concealed joints does not apply to steel pipe, no special enclosure would be needed for the outlet.

In the long term, it will be more cost-effective to install the outlet as shown in Figure 4-21. Using a simple, inexpensive plastic box, the outlet is easily nailed to the side of the wall stud like an electric switch or duplex outlet box. This does conceal the tubing joint behind the wallboard. However, Foster-Miller is currently developing some additional testing criteria that will permit the tubing joints to be qualified for use in concealed locations. Code language was submitted to the Z223 committee (NFGC) to permit the use of tubing joints when such joints are pre-qualified for such use by a recognized testing organization. This change has been accepted for inclusion in the 1992 reprinting of the code.

Figure 4-21. Standard Gas Outlet Wall Mounting Method

SPACE AND WATER HEATING SYSTEMS

This is a critical period for the gas space and water heating appliance market. Public Law No. 100-12, which was passed in 1987, established that all new gas furnaces manufactured after January 1, 1992, must have as a minimum an AFUE of 78 percent. The law is part of the National Appliance Energy Conservation Act of 1987 (NAECA) and affects 14 classes of residential appliances, of which seven classes include gas appliances. The act requires that the Department of Energy set, review and raise minimum efficiency standards over the next 15 or 20 years. Any changes in minimum efficiency standards must be "technologically feasible" and "economically justified." The law applies to appliance installations in all states with few exceptions.

All gas water heaters manufactured after January 1, 1990, must have a minimum energy factor of 0.62 as shown in Table 4-8. The energy factor is a measure of the overall efficiency rating of the water heater. This has not presented major market problems for gas versus electric water heaters.

However, one class of gas furnaces has been devastated by the new standard. Conventional atmospherically vented furnaces cannot meet the new standard. The problem is the NAECA defines the AFUE for these appliances based on the assumption that the furnaces are installed indoors and all combustion air is supplied from the outside via ducts or grills. Any efficiency increases as a result of vent dampers are not included in the AFUE calculation. In 1991, these units accounted for approximately 65 percent of the market. The two remaining types of furnaces on the market are fan-assisted combustion systems with AFUEs of 78 to 83 percent and full-condensing units with AFUEs of 90 to 95 percent. Both of these alternatives are significantly more expensive to purchase and install than the conventionally atmospherical vented furnaces. Only one manufacturer, Lennox, has been able to market a furnace with a 78 percent AFUE that can be conventionally vented.

This change in the appliance efficiency standards has been especially difficult for southern utilities since high-efficiency gas-fired heating systems cannot economically compete with electric heat pumps. The changes in the appliance efficiency standard have resulted in lower increased costs for the electric heat pump than for the equivalent gas-fired system. The answer to this problem for the southern utilities has been the hydro-heat system, which is commonly referred to as the combo or dual

**Table 4-8. Minimum Efficiency Levels and
Effective Dates for Gas Appliances
Covered by NAECA**

**MINIMUM EFFICIENCY LEVELS
AND EFFECTIVE DATES FOR GAS APPLIANCES
COVERED BY NAECA**

PRODUCT	NAECA MINIMUM	EFFECTIVE DATE
FURNACES		
All input sizes	78% AFUE	Manufactured after 1/1/92
Mobile home use only	75% AFUE	Manufactured after 9/1/90
BOILERS		
Boilers, hot water	80% AFUE	Manufactured after 1/1/92
Boilers, steam	75% AFUE	Manufactured after 1/1/92
WATER HEATERS	Energy factor = 0.62 (RSV * 0.0019)	Manufactured after 1/1/90
Storage		
Instantaneous	Energy factor = 0.62	Manufactured after 10/12/91
SWIMMING POOL HEATERS	78% Thermal Efficiency	Manufactured after 1/1/90
RANGES AND OVENS	No constant burning pilot on models w/ electric cord	Manufactured after 1/1/90
DRYERS	No constant burning pilot	Manufactured after 1/1/88
*RSV = Rated Storage Volume		

integrated system (DIS). These systems were developed in the 1970s. As depicted in Figure 4-22, combo systems basically consist of a gas water heater and air handler.

A dual integrated system is a simple system that utilizes a domestic hot water heater and an air handler to provide both space heating and potable hot water for residential applications. Optionally, air conditioning can be incorporated into the system. The integrated system utilizes a small circulation pump to draw hot water from the water heater and circulates it through a water-to-air heat exchanger in the air handler. There the water loses 10 to 20°F before returning to the water heater to be reheated. A thermostat controls the operation of the circulating pump and the blower/motor in the air handler. Warm air is circulated into the home through a duct system. Cooling can be provided through the use of a split system, with an evaporator coil in the air handler and a remote condensing unit (optional items).

How do Gas Combo-Heaters work?

The water heater operates like any conventional water heater. When space heat is needed, the sequence of operation is as follows:

1. The wall thermostat energizes a small pump which circulates hot water from the water heater through a coil in the air handler.
2. The fan in the handler comes on and blows air over the coil where it absorbs the heat.
3. This warm air is then circulated through the ducts and into the home.

REFERENCE SOURCE: AMERICAN GAS ASSOCIATION

Figure 4-22. Combination Space and Water Heating System

A typical integrated system includes:

- **Water heater:** A high-efficiency water heater is used to satisfy both hot water heating and space heating requirements.
- **Air handler:** The air handler may be one of several configurations, including a vertical unit for closet installation, a horizontal unit for ceiling installation, a wall unit for "between-the-studs" installation, or a duct coil for retrofit applications.
- **Pump system:** A small pump circulates hot water from the water heater to the hot water coil in the air handler. The pump may be integrally mounted in the air handler (Apollo and Rheem) or may be mounted in the piping (Mor-Flo and First Co.).
- **Controls:** The control system is relatively simple and includes typical controls such as a cooling/heating thermostat, pump and fan relays, and a 115/24V transformer.
- **Water piping:** Water piping between the water heater and the air handler is field supplied. Water lines are typically 3/4 in. nominal copper or approved plastic pipe. The lines should be insulated. In addition, check valves and service valves may be required though application varies by manufacturer.
- **Condensing units:** Split system condensing units are matched to the evaporator coil in the air handler. The outdoor condensing units may be manufactured by someone other than Apollo, Rheem, First, or Mor-Flo companies.

Dual integrated systems are efficient, competitively priced, space saving, easy to install and maintain, and extend the life of the water heater by increasing water circulation, which reduces sediment buildup and corrosion. Within the United States (including Alaska), approximately 375,000 units have been installed in starter homes and multifamily buildings. If the water heater is properly sized, it works perfectly well in northern multifamily buildings. However, three states including New York restrict or do not allow installation of combo units. The problem appears to be in the classification of the unit. Some state code officials have classified the water heater used in the combo unit as a boiler, thus requiring the water heater to comply with all applicable boiler codes and standards. Since boilers are pressurized, they are designed to more rigorous standards than water heaters. All currently sold water heaters do not meet the boiler standards.

Since combination space and water heating appliances are an integrated system composed of components from several different manufacturers, a means to determine overall system efficiency was needed. To address this need, GRI sponsored research

to develop an ASHRAE Standard, ANSI/ASHRAE 124P entitled Method of Testing for Rating Combination Space Heating/Water Heating Appliances. The research was conducted by Battelle and American Gas Association Laboratories. The standard covers electric, gas-fired and oil-fired combination space and water heating appliances up to 300,000 Btu/hr rated input. A draft of the proposed standard is currently out for public review and included in Appendix F. ASHRAE published the standard in 1992.

Combination space and water heating systems offered by four manufacturers will be described that are referenced in an AGA brochure shown in Figure 4-23. They are:

- Polaris, Nautilus, and Integra: manufactured by Mor-Flo
- EnergyMate: manufactured by Rheem
- Aqua Therm System: manufactured by First Co.
- Hydro Heat System: manufactured by Apollo.

The key to choosing a combo system is to remember that if the water heater is too small the consumer may run out of hot water. Conversely, if the water heater is too large, the consumer will waste energy. AGA has published a Buyer's Guide on Efficient Gas Water Heating that can be used to properly size the combo system. Figure 4-24 provides a procedure for proper sizing.

Mor-Flo Industries, Inc.

Mor-Flo, incorporated in 1915, is an established manufacturer of a complete line of storage water heaters. They have been involved with integrated systems applications since 1985 when they made a commitment to market products to supply all the energy needed to heat homes, as well as hot water. Figure 4-25 summarizes their currently available mid- and high-efficiency systems. Appendix F contains manufacturers literature.

The Polaris system utilizes a specially designed water heater, which has a stainless steel tank, submerged combustion chamber, and power burner. It is a high efficiency (94 percent), condensing water heater that can be direct vented through an outside wall. Figures 4-26 and 4-27 show the Polaris system.

Mor-Flo American Comfort Systems
18450 South Miles Road
Cleveland, OH 44128-4296
(216) 663-7300

When living space is at a premium, choose the Integra by Mor-Flo. It's the only stacked Gas Combo-Heater and uses about the same floor space as a standard water heater.

Rheem Water Heater Division
5780 Peachtree Dunwoody Road, NE
Atlanta, GA 30342
See the Yellow Pages under Water Heaters.

The Rheem EnergyMate is a side-by-side system that integrates Rheem's EnergyMate Water Heater line with its EnergyMate air handler for optimum performance and energy efficiency.

First Co.
8273 Moberly Lane
Dallas, TX 75227
(214) 388-5751

For added flexibility, select the Aqua Therm System – a First Co. air handler that converts *any* properly sized water heater into a high efficiency Gas Combo-Heater.

Apollo HydroHeat and Cooling
500 By-Pass Road
Ashland City, TN 37015
800-365-5793

Apollo's HydroHeat System is available in vertical, horizontal, wall-mounted or ceiling-mounted configurations. With one-third as many parts as a heat pump, it is virtually maintenance free.

Gas. America's best energy value.

© 1999 American Gas Association

Figure 4-23. Combination Spacer and Water Heating Systems

PROPER SIZING

A properly sized gas water heater will deliver all the hot water you want when you need it!

The best size for a water heater is determined by its first hour rating. Starting with a full tank of hot water, the first hour rating is the maximum amount of hot water that can be supplied in a one-hour period.

The Federal Trade Commission suggests the following steps be used as a guide to correctly size a gas water heater.

- Determine the hour during which you use the most hot water.
- Find each water use from Table No. 1 that will be needed during that hour.
- From this table, list each water use that occurs during the hour of the day when your family uses the most hot water.
- Total the estimated gallons needed. This tells you the peak water heating capacity you will need.
- Select a unit with a first-hour rating that is nearly equal to your estimated use. Since the first-hour rating includes the recovery rate, a smaller unit with a good recovery rate can outperform a larger unit with a lower recovery rate.

TABLE NO. 1	
MAJOR USES OF HOT WATER	ESTIMATED GALLONS OF HOT WATER PER USE
Clothes Washer (warm/cold rinse)	10-12
Clothes Washer (hot wash/cold rinse)	30
Shower	10-15 or 3 gallons per min.
Bath	15-20
Bathing an infant	2
Automatic dishwasher	12-15
Hand dishwashing	4
Shaving	2
Hair shampoo	4
Food preparation	5
Hand and face washing	2
Housecleaning	5-12

REFERENCE SOURCE: AGA BUYER'S GUIDE: EFFICIENT GAS WATER HEATING

Figure 4-24. Proper Sizing Procedure for a Combo System

Mor-Flo does not manufacture the air handlers that are used in the Polaris system. They are manufactured for Mor-Flo by First Co. under a nameplate agreement.

The Polaris water heater is limited to a single 36-gal, 100,000 Btu/hr input model that is ample for most jobs but may be cost prohibitive for some applications, particularly multifamily applications with their minimal heating requirements.

Mor-Flo has AGA certification on its Polaris water heater. The air handling units and pump modules have Underwriters Laboratory certification under First Co. applications.

Mor-Flo/American

National No.: (216) 663-7300, Gary Bosma

Polaris

100,000 Btu/hr, 94 percent AFUE, 34 gal, power burner, sealed standby loss = 1.2 percent, energy factor about 0.90, int. ignition, system cost (trade): \$1,800, installed cost - \$2,400, includes hot and cold coils and blower, does not include thermostat, piping, and vent pipe, cost for heater alone - \$1,400.

Nautilus

38,000/40,000 Btu/hr, 85 percent AFUE, 40/50 gal atmospheric, stack standby loss = 3.7/3.2 percent (40/50 gal), energy factor = 0.60/0.62, heater cost: 40 - \$260, 50 - \$320
(10 year guarantee)

Integra

40,000 Btu/hr, 83 percent AFUE, 40 gal, induced draft, sealed modified Nautilus, int. ignition, system cost: \$950, installed cost - \$1,400/1,500, includes hot (28,000 Btu/hr) and cold coils
(1.5 - 2 tons) and blower.

Note - all costs are *trade* prices as of March, 1992

Figure 4-25. Summary of Mor-Flo Appliances for Dual Use

Since the Integra system is a modified Nautilus system, only the Integra system will be discussed. For the Integra system, a power burner replaces the atmospheric burner found on the Nautilus. It is a mid-efficiency (83 percent), near-condensing water heater, quick connected to an air heater that results in an extremely compact unit. Figure 4-28 details the Integra system. As with the Polaris water heater, the Integra water heater incorporates sealed direct venting, which eliminates the need for inside air for combustion. The floor space required for the appliance is only 20-1/4 in. wide by 24-1/2 in. deep. Overall equipment space is reduced by 50 percent compared to a separate water heater and air handling unit.

The Integra system includes a 40-gal glass-lined water heater with a submerged combustion chamber. The 40,000-Btu/hr input makes the Integra system ideal for multifamily new construction and rehabilitation, as well as electric conversions. Mor-

Thermal Efficiency: +94 percent.

Stainless steel tank assures long life. No anode rod or glass lining necessary.

Foam insulation with R-16 factor minimizes heat loss; meets California Title 24 requirements.

Stainless steel coiled flue transfers heat from flue gases to the water resulting in +94% efficiency.

Bullet-shaped submerged stainless steel combustion chamber eliminates conventional water heater heat loss, lime build-up and noise.

Burner generates intense heat that is forced through the combustion chamber and coiled flue by a powered combustion air blower.

Negative pressure gas valve maintains uniform gas/air mixture for even, efficient combustion for a variety of inlet pipe applications.

Plastic vent pipes, which can be installed through the wall, serve as combustion air inlet and flue gas outlet.

Other features/benefits:

- Solid state electronic thermostat assures precise temperature control; dial is located on front of heater for easy setting.
- LED indicator for Power, Igniter, Burner displays heater operation, simplifies troubleshooting.
- All water and vent connections are at the bottom of the water heater eliminating pipe and flue heat loss.
- Low jacket surface temperatures allow water heater to be installed with zero clearance to combustible materials.
- Silicon carbide hot surface igniter heats to 2600°F to light burner flame. Solid state electronic control eliminates pilot flame and automatically shuts off gas should flame go out.
- Built-in condensate trap.

Figure 4-26. Mor-Flo's Polaris Water Heater

Mor-Flo/American Comfort Systems™ utilizing a Polaris water heater as a single energy source, will heat homes, the hot water used in those homes — and in any climate.

These reliable and energy-efficient systems, designed primarily for use with forced air heating, combine the Polaris with Mor-Flo/American Air Heaters™.

Compact ceiling, wall and closet Air Heaters come in space heating capacities of 14,000 Btu/hr. and higher. In addition, Air Heaters are supplied with a DX cooling coil for air conditioning during warmer months.

Figure 4-27. Mor-Flo's Polaris System

Flo has AGA certification on their Integra water heater. The air handling units and pump modules have Underwriters Laboratory certification under First Co. application.

Rheem Manufacturing Company

Rheem is also an established manufacturer of a complete line of storage water heaters and air handling units. Table 4-9 summarizes their current available water heaters used in their EnergyMate systems. Appendix F contains manufacturers literature on both Rheem water heaters and air handling units. The EnergyMate system utilizes a specially designed water heater that is glass-lined with an exclusive porcelain formula. Both conventional efficiency (76 percent) and mid-efficiency (80 percent) water heaters are supplied by the Rheem Water Heater Division for the EnergyMate system. The direct vent models have sealed combustion. Figure 4-29 shows the EnergyMate system.

MOR-FLO®/AMERICAN INTEGRA® The Gas Combo Heater In A Closet

Figure 4-28. Mor-Flo's Integra System

Table 4-9. Summary of Rheem Appliances for Dual Use

Rheem National No.: (404) 256-5510, Roy Strong EnergyMate (all atmospheric burners with side taps)					
Input	Storage	SS Eff	EF	Vent	Cost
38,000	40	76	0.56	direct	400
40,000	50	76	0.54	direct	460
40,000	40	80	0.62	vertical	310
40,000	50	80	0.60	vertical	360
57,500	40	80	0.??	vertical	32
75,500	62	80	0.??	vertical	585
40,000	40	76	0.55	vertical	280
60,000	50	76	0.52	vertical	380
<p>The direct vent models are sealed combustion. The additional components to construct a complete system are being handled by their heating division. They are developing power vent models that will be both sealed combustion and using room air.</p> <p>Note: All costs or trade prices as of March 1992.</p>					

The air handling unit is supplied by the Rheem Air Conditioning Division and includes a heavy duty circulating pump. The 800 cfm unit can accommodate a cooling coil of 1-1/2- to 2-ton capacity, and the 1,200 cfm unit can accommodate a cooling coil of 2-1/2-to 3-ton capacity.

The EnergyMate system offers a range of water heater capacities from 40 to 62 gal, with inputs ranging from 38,000 to 75,500 Btu/hr, respectively. The EnergyMate systems are suitable for single and multifamily dwellings. The EnergyMate water heaters have AGA certification. The air handling units and pump modules have Underwriters Laboratory and Air-conditioning and Refrigeration Institute certification.

Apollo Hydro Heat

Apollo is probably the best known of the four major manufacturers. They have been in the business since 1979 and claim to have 100,000 units installed in 45 to 50 states. Several years ago, Apollo was acquired by State Industries, which strengthen their position and provided them with a water heater line designed specifically for the

Figure 4-29. Rheem's EnergyMate System

application. Table 4-10 summarizes the currently available water heaters used in their Apollo Hydro Heat system. Appendix F contains manufacturers literature.

They have engineered and packaged the air handler so as to include the pump and controls making for simple installation and single source responsibility. They have secured Underwriters Laboratory and various other approvals on the air handler package, including the circulator pump and controls. The water heater carries AGA certification. Figure 4-30 depicts Apollo's Hydro Heat System.

Table 4-10. Summary of State Appliances for Dual Use

State National No.: 1-800-365-0024, Sonny Ferrel Apollo Hydro Heat					
Input	Storage	SS Eff	EF	Vent	Cost
40,000	40	76	0.??	direct	
48,000	50	76	0.??	direct	
40,000	40	85	0.61	vertical	
40,000	50	85	0.58	vertical	
55,000	75	80	0.49	vertical	
40,000	40	76	0.57	vertical	
52,500	40	76	0.54	vertical	
52,500	50	76	0.52	vertical	
65,000	50	76	0.52	vertical	
75,100	75	76	0.48	vertical	
System cost (40,000, 85 percent) = \$750 for complete system; \$50 more for sealed combustion, does not include mixing valve. They carry a line of air handlers (Hydro Heat) for vertical or horizontal installations with capacities from 16,700 to 41,500 Btu/hr. The unit includes a water pump, two-speed direct drive blower, heating coil (a cooling coil can also be added), and relays. All state heaters are approved for DIA (dual integrated appliance) use, efficiencies of 75 to 81 percent. Note: All costs are trade prices as of March 1992.					

APOLLO HYDRO HEAT: ***The Inside Story***

Since the earliest days of the Apollo Hydro Heat revolution, beginning in 1979, exceptionally low operating costs have been experienced by users of this combination water heating — space heating system.

This paper will answer many of the most often asked questions about the system.

How does it work?

Apollo uses a gas water heater to furnish heat to the space of a residence, as well as its domestic hot water. A simple recirculating loop of hot water is tapped off near the top of the heater and is circulated through a finned tube heat exchanger in an air handler or duct coil that furnishes warmed air to the space. The cooled water (140° cooled to about 120°) is then returned to the water heater, near the bottom of the tank. Each Apollo air handler includes a circulating pump and controls, factory piped and wired. See Figure 1.

The Apollo water heater includes side tapplings to provide the recirculating loop connections. When a conventional heater is used, special fittings including check valves are used at the hot and cold water connections.

The control of the Apollo system is very simple. A conventional heating or heating/cooling thermostat is used. On a call for heat, the hot water circulator is energized through a relay, as is the blower motor. Hot water immediately begins circulating through the heat exchanger, and heats the air. Typical leaving air temperatures are 100—105°. When the thermostat is satisfied, the pump and blower both stop.

FIG. 1

Figure 4-30. Apollo's Hydro Heat System

Apollo offers considerable flexibility in sizes and Btu/hr input of their water heaters. In addition, they offer a direct vent model that can be installed with "zero clearance" so it can be placed in small places along outside walls.

First Co. - Aqua Thermaire

First Co. is relatively new in terms of integrated systems. However, they are a well established manufacturer with over 20 years experience manufacturing air handling units. Up until 1986 they manufactured air handling units for Apollo under a name brand agreement, and they are manufacturing units for Mor-Flo under a similar agreement today.

First Co. is a substantial manufacturer and they offer considerable flexibility in air handler configurations and options. For integrated systems application, they have designed a flow control module with a pump and valve assembly that is piped and wired for simple field installation. The air handlers and flow control modules are Underwriters Laboratory certified as a system. Appendix F contains manufacturers literature.

First Co. does not manufacture or offer hot water heaters though many of the distributors handle various water heater product lines. Their position on water heaters is to tell the contractors to buy them from their best source and First Co. will provide assistance in putting the package together. Figure 4-31 shows First Co.'s Aqua Therm system.

COMPARISON OF DUAL INTEGRATED SYSTEMS

The four manufacturers of dual integrated systems offer product lines with many similarities and differences. To further investigate these systems, two comparison matrices are provided in Tables 4-11 and 4-12. Table 4-11 compares each system based on its water heater, while Table 4-12 compares each system based on its air handler. Compared to the other four systems, the Mor-Flo Polaris system, has the highest natural gas input of 100,000 Btu/hr and the highest recovery efficiency of 94 percent. The two Mor-Flo systems (Polaris and Integra) also have power blowers for their combustion and vent systems.

AquaTherm

INSTALLATION AND APPLICATION MANUAL
FOR
HOT WATER AIR HANDLERS
AND
ADD-ON COILS

Catalog No. IAM591 (Replaces IAM990)

FIRST CO. - 8273 MOBERLY LANE - DALLAS, TEXAS USA 75227-2388 - (214) 388-5751

Figure 4-31. First Co.'s Aqua Therm System

Table 4-11. Water Heater Matrix for Dual Integrated Systems

	Mor-Flo/ Polaris	Mor-Flo/ Integra	Rheem/ EnergyMate	Apollo/ Hydro Heat	First Co./ Aqua Thermaire
Sizes (gal)	34	40	40, 50, 62	40, 50, 75	Do not manufacture line of water heater units. Approve installation with various water heaters
Input Btu/hr	100,000	40,000	38,000- 75,500	40,000- 75,000	
Recovery Efficiency	94%	83%	76-85%	75-85%	
Tank	Stainless	Re- nitrogenized steel		Steel, glass- lined	
Tank Insulation	Foam R=16	Polyurethan e R=8.33	Foam R=9.4- 11.5 R=6.3 (direct vent)	Polyurethan e R=8.33	
Burner	Stainless Steel	Steel	Glass-lined steel	Aluminized steel	
Ignition	Electric, hot surface	Electric, hot surface	Standing pilot	Standing pilot	
Vent System	Power blower	Power blower	Atmospheric ; vertical or direct vent	Atmospheric ; vertical or direct vent	
Cathodic Protection	Not required	Powered anode	Anode	Anode	
Controls	Thermostat (electronic), T&P relief	Thermostat (electronic), T&P relief	Thermostat, T&P relief	Thermostat, energy cutoff ECO, T&P relief	
Accessories	LED indicators	LED indicators	Check valves, ball type service valves and di-electric unions	Check valves, ball type service valves and di-electric unions	
Warranty	10-year tank 1-year parts	5-year tank 1-year parts	5-year, tank or parts	5-year, tank or parts	
Code Approvals	AGA certified	AGA certified	AGA certified	AGA certified	

Table 4-12. Air Handler Matrix for Dual Integrated Systems

	Mor-Flo/Polaris + Integra	Rheem/ EnergyMate	Apollo/ Hydro Heat	First Co./Aqua Thermaire
Configurations Vertical Horizontal Wall-Mounted Retrofit Coils	Do not manufacture line of air handler units. Offer First Co. units under nameplate arrangement	X X X	X X X	X X X X
Cabinet		Steel, painted	Zinc-coated steel, painted	
Cabinet Insulation		Fiberglass	Fiberglass	
Heating Coil		Cu tubes/Al fins	2 & 3 rows - cu. tubes/Al fins	2 & 3 rows - Cu tubes/Al fins
Fan/Motor		2-speed, direct drive	2-speed, direct drive	Blower/motor assembly
Circulator Pump		Heavy duty	Stainless steel or plastic impellar, bronze housing	Not included in AHU; flow control module available for field installation
Controls		Fan relay/ transformer	Pump and blower relay	Fan relay/ transformer
Valves		None, field supplied	Service/isolatio n valves	None, field supplied
Evaporator Coil		Opt 1-1/2, 2, 2- 1/2, 3 tons	Opt. 1, 1-1/2, 2 tons	Opt. 1, 1-1/2, 2, 2-1/2, 3 tons
Filter		Cleanable, permanent	1 in. throwaway	Factory installed; wall and closet models
Code Approvals		Underwriters Lab ARI certification	Underwriters Lab and/or Applied Research Labs of Florida, SBCCI, BOCA, IAMPO	Underwriters Lab (air handler and Flow Control Module), City of Los Angeles Testing Lab

Both Rheem and Apollo offer a range of natural gas inputs from approximately 40,000 to 75,000 Btu/hr and recovery efficiencies of 75 to 85 percent. Warranties on the water heater tanks range from 5 years for four of the systems to 10 years for the Polaris water heater tank. All water heaters are AGA design certified.

Air handlers are typically designed for three configurations: vertical, horizontal, and wall-mounted. Another important feature of air handlers is to provide for retrofitting of heating and/or cooling coils. The Rheem and Apollo air handler lines do not include a wall mounted unit. Otherwise, all other configurations are provided by the three manufacturers (Mor-Flo does not offer a line of air handlers). All of the air handler manufacturers offer an optional evaporator coil from 1- to 3-ton capacity for cooling applications. The Apollo unit also includes service and isolation valves. All of the other units require valves to be field installed. As a minimum, all of the air handlers are certified by Underwriters Laboratory.

A comparison of application types is presented in Table 4-13. The Polaris system has the highest space heating capacity, up to 80,000 Btu/hr. It can also accommodate a hot water and a warm air distribution system. Finally, it offers unlimited water heating capacity. However, for most multifamily applications where the heating and cooling loads are much smaller than single-family homes, the other systems are probably more suitable.

Cost is always a major factor that the builder or home owner must consider when choosing a water and/or space heating system. As presented in Table 4-14, the estimated installed cost for the five dual integrated systems range from a low of \$905 for the First Co.'s Aqua Therm system to \$2,400 for Mor-Flo's Polaris system. However, excluding the Polaris system, the range of installed costs is \$905 to \$1,425, a differential of \$520. Before a decision is reached on which system to choose, a life-cycle cost to operate and maintain each system should be factored into the total cost analysis.

BENEFITS OF DUAL INTEGRATED SYSTEMS

Dual integrated systems offer several benefits to builders, home owners, and gas utilities over conventional separate water and space heating systems:

Table 4-13. Types of Applications for Dual Integrated Systems

	Mor-Flo		Rheem	Apollo	First Co.
	Polaris	Integra			
Space Heating Capacity (Heat Loss)	To 80 MBtu/hr	25-29 MBtu/hr	38-75 MBtu/hr	30-75 MBtu/hr	30-75 MBtu/hr
Water Heating Capacity	Unlimited	Typical demand of large family	Typical demand of large family	Typical demand of large family	Typical demand of large family
Cooling Capacity	To 3 tons	To 2 tons	To 3 tons	To 2 tons	To 3 tons
Vent Type					
Direct: air in; flue products out	X	X	X	X	
Thru-the-wall flue product exhaust				X	X
Conventional			X	X	X
Space Heat Distribution Options	Warm air Hot water	Warm air	Warm air	Warm air	Warm air
<p>Note: Any one of the systems can be specified for a particular application; however, direct vent systems are more easily applied to multifamily settings. Installation space requirements for these systems usually depend upon the way in which the fan-coil unit is installed (ceiling-, wall- or floor-mounted); however, floor mounting requires an area of about 36 ft².</p>					

- Additional heating alternatives to conventional gas furnace/hot water heater combination
- Conversion opportunities on heat pump, electric heat, or oil fired systems
- Opportunity to secure summer hot water load in addition to heating only
- Lower first cost of heating/hot water/cooling system compared to electric heat pump/electric water heater combination

Table 4-14. Installed Costs for Dual Integrated Systems

	Mor-Flo		Rheem	Apollo	First Co.
	Polaris	Integra			
Equipment	\$1,800	\$950	\$490 (AHU) \$310 (WH)	\$750	\$378 (AHU) \$225 (WH)
Labor at 50%	\$600	\$475	\$400	\$375	\$302
Total	\$2,400	\$1,425	\$1,200	\$1,125	\$905
<p>Notes:</p> <p>Typical installed cost for floor-mounted systems in 30 to 40 MBtu/hr heating capacity range except for the Mor-Flo/Polaris which is 100,000 MBtu/hr as of March 1992.</p> <p>Approximate cost based on 2-1/2-ton air handler, 40-gal water heater. Does not include A/C.</p> <p>Installation costs vary for each installation. Costs shown are expected to be accurate within plus or minus 10 percent.</p>					

- Improved overall efficiency of the water heater; lower standby, flue ,and other miscellaneous losses
- An efficient heating system that can be purchased for less than gas furnace/ water heater combination of comparable efficiency.

APPLIANCE VENTING

Venting systems have not changed significantly since the 1950s. What has changed, which has had a dramatic affect on venting methods, is appliance design. The products of combustion for the new classes of appliances, mid-efficiency with AFUE = 78 to 83 percent and high-efficiency with AFUE greater than 90 percent have required that a new set of standards be developed for safe venting. To complicate matters further, many of these new appliances have fan-assisted combustion systems. The following is an overview of recent changes affecting vent sizing requirements, materials selection, and combined vent systems. Appendix G contains additional detailed information concerning the establishment of appliance categories, development of new vent sizing tables, common venting, and multistory vents.

Conventional venting systems include a draft hood or diverter and an atmospheric burner. The buoyant force of the hot gas is enough to drive it from the combustion chamber, up the vent pipe and out to the atmosphere. The draft hood, among other things, allows additional indoor air to mix with the combustion products. This is called dilution. Diluted air lowers the dew point of the mixture by reducing the humidity, which also helps reduce condensation. There is a price to pay for adding indoor heated air to the combustion products. The overall efficiency of the appliance is lowered because some of the indoor air heated by the appliance goes out the vent.

During the energy crisis of the 1970s, consumers demanded more efficient appliances. To reduce off-cycle appliance losses, fan-assisted combustion systems were developed. Fan-assisted systems reduce dilution air in the vent. Unfortunately, this causes the humidity and gas dew point to rise. Also, there is less flow in the vent. With a higher dew point temperature and less gas to warm the sidewalls of the vent, the potential for condensation increases. This is true for mid-efficiency and high-efficiency appliances, which are also referred to as near-condensing and full-condensing units, respectively.

Therefore, the development of a variety of more efficient appliances increased the need for different venting requirements. Four venting categories have been established by an ANSI standards committee are shown in Figure 4-32. Basically, the categories account for differences between:

- Positive and negative pressure vent systems
- Actual and dew point temperatures of the flue gas

Each appliance category with acceptable vent material can be characterized as follows:

- Category I: Non-condensing
 - Negative pressure
 - AFUE: 65 to 83 percent
 - Typical materials
 - Type B vent
 - Single-wall metal
 - Lined masonry chimney

Figure 4-32. ANSI Categorization Criteria per ANSI Z223.1-1988

- Category II: Condensing
 - Negative pressure
- Category III: Non-condensing
 - Positive pressure
 - AFUE: 78 to 83 percent
 - Typical materials
 - Airtight high temperature plastic
 - Airtight single-wall metal
- Category IV: Condensing
 - Positive pressure
 - AFUE: 90 percent and higher
 - Typical materials
 - Airtight high temperature plastic
 - Airtight PVC
 - Airtight CPVC.

The NFGC provides guidelines for vent sizing of Category I appliances. However, these tables are in the process of being revised based on a worst-case design assumption,

which is a steady-state appliance efficiency of 83 percent (AFUE). This category includes conventional draft-hood and most mid-efficiency, fan-assisted appliances. The new tables have been incorporated in the 1992 edition of the NFGC. Presently, appliances in Categories II, III, and IV are only vented according to the manufacturers installation instructions. Category II and IV appliances require vents with corrosion resistance and a method of condensate disposal. There are not very many, if any, Category II appliances.

The new tables can be used to size combined vent systems. These are very common systems that usually include a separate water heater and boiler/furnace. Each individual vent connector has to be sized separately for each appliance. The common vent portion of the system is sized using a separate table. On a combination space and water heating system there is only one vent pipe to size and install, which is an economic advantage over the separate appliance system.

Multistory vents are necessary for multifamily buildings where appliances on each floor are connected via a common vertical pipe system. For rehabilitated multifamily buildings, the question is whether fan-assisted appliances can be retrofitted to replace draft-hood equipped appliances originally installed with larger vent systems. For example, the original vent system may have been sized for a 60,000 Btu/hr furnace. The replacement unit is apt to be a 40,000 to 45,000 Btu/hr mid-efficiency furnace. The smaller unit has less products of combustion. Thus, the vent system will experience a lower flow rate than with the original larger furnace.

The American Gas Association Laboratories is conducting a full-scale experiment to assess this issue. Some preliminary conclusions from that study are:

- The large amount of dilution air entrained by this vent system provides a good buffer against excessive condensation
- The worst-case failure modes applied equally to the draft hood-equipped appliances and were not caused by the retrofit operation.

Overall preliminary conclusions from that study have indicated that retrofitting fan-assisted appliances into a multistory vent does not add to the risk for vent system failure.

Combination space and water heating systems require a Category I vent because only the water heater portion of the system produces combustion products. The water heaters have efficiencies ranging from 76 to 83 percent, operate in the non-condensing range and vent under negative pressure. Therefore, no special materials or installation practices are required for the vent systems of combination space and water heating systems.

CONSTRUCTION PRACTICES

This section illustrates schematic details for routing flexible gas tubing in new and renovated installations. These details were developed by SWA using their in-house expertise in design and construction of multifamily projects. Research material from Foster-Miller and trade literature from the manufacturers of flexible gas tubing products were used as reference material.

These details suggest recommended practices for generic applications of various types of construction assemblies. The following pages illustrate schematic concepts for routing flexible gas tubing through the exterior walls, interior partitions, floors, and roofs. While these details take into account the safety of tubing material during construction, buildings codes related to the use, and installation of flexible tubing are not addressed. These details suggest the most appropriate way to run flexible tubing without going into the specific design of how and where valves, connections, clips, and other accessories will be required.

INSTALLATION ASSUMPTIONS AND LIMITATIONS

Several concerns and limitations described by the manufacturers of flexible gas tubing served as guidelines in the development of these concepts. Some of these are listed below:

- The flexible tubing shall be installed within the building structure and downstream of the gas metering unit.
- All connections between incoming rigid steel pipe and flexible tubing shall be made within the building structure.
- The vertical riser is assumed to be rigid steel pipe for all multifamily structures. This riser is run vertically through a chase inside the structure.
- All flexible tubing joints shall be installed in accessible locations.

- The tubing shall never be directly embedded inside concrete walls, floors, or roofs or buried underground. When it is necessary to run through concrete, it shall be routed through rigid conduits.
- The piping material can receive significant damage as a result of impact, crushing or other abuse, and should be handled and installed according to the manufacturer's instructions. Sharp bends, stretching, kinking, or twisting of material should be avoided.
- Manufacturers' recommendations for maximum pressure requirement, bending, drilling, and notching of holes through structural members for tubing and support system shall be observed.
- The location of protection devices, branching, regulators, manifolds, and appliance connections shall be as required by the design and layout of gas lines.
- The flexible gas lines shall not be allowed to hang freely inside the structure. They should be appropriately attached to the building components.
- If the flexible tubing line creates a conflict of safety (electrical conduits) or limitations of space (close to ducts in ceilings), the piping layout shall be re-routed.
- Damaged tubing sections shall be replaced with new tubing.

Limitations

The building codes for this technology are still not developed. Hence, these illustrations are developed without considering building codes restrictions. Within the scope of this project, it was impossible to anticipate and document every possible variation in construction assemblies and installation restrictions. However, an attempt has been made to recommend standard practice for all generic types of construction assemblies and installation.

LIST OF DRAWINGS

Figure 4-33. Gas Pipe Penetration through Exterior Wall of Wood Studs and Siding

Figure 4-34. Flexible Tubing Run through Wood Frame Construction

Figure 4-35. Flexible Tubing Run through Wood Trusses at Attic Floor

Figure 4-36. Flexible Tubing Run through Wood Truss Floors

Figure 4-37. Gas Pipe Penetration through Exterior Wall of Brick Veneer on Metal Studs

Figure 4-38. Flexible Tubing Run through Stud Partition Wall

Figure 4-39. Flexible Tubing Run through Steel Stud Partition

Figure 4-40. Gas Pipe Penetration through Brick and Block Cavity Wall

Figure 4-41. Multiple Gas Lines Penetrating through Fire Wall

Figure 4-42. Gas Riser and Tubing Runs through Concrete Slab

Figure 4-43. Gas Line Penetration through Poured Concrete Slab at Roof

Figure 4-44. Gas Pipe Penetration through Hollow Core Concrete Slab at Roof

Figure 4-45. Gas Pipe Penetration Detail through Hollow Core Concrete Roof Slab

Figure 4-46. Flexible Tubing Run through Concrete Roof Slab and Steel Joist Framing

Figure 4-47. Gas Pipe Penetration through Roof with Hung Ceiling

SUMMARY

A technology survey was conducted by Foster-Miller to identify emerging gas technologies that are considered innovative relative to conventional approaches in use today. Areas of investigation included metering, gas piping, space and water heating systems, and appliance venting. A second survey was conducted by SWA to identify installation methods for gas piping located in chaseways, fire protected areas, and other affected areas of rehabilitated and newly constructed multifamily buildings. The results of the SWA survey were documented by the development of 15 construction drawings showing details of flexible tubing and rigid piping installation techniques needed to implement this recently developed technology.

Figure 4-33. Gas Pipe Penetration through Exterior Wall of Wood Studs and Siding

Figure 4-34. Flexible Tubing Run through Wood Frame Construction

Figure 4-35. Flexible Tubing Run through Wood Trusses at Attic Floor

Figure 4-36. Flexible Tubing Run through Wood Truss Floors

Figure 4-37. Gas Pipe Penetration through Exterior Wall of Brick Veneer on Metal Studs

CONCLUSIONS

A number of specific conclusions have been drawn from conducting the two surveys:

- There are commercially available, small residential meters that could be used effectively for multifamily new and rehabilitated construction projects in the State of New York. These downsized meters, which are 40 percent smaller than existing meters of the same flow capacity, can save valuable space in submetering closets. Several compact gas meters are under development, but are not commercially available and still a few years away.
- Automatic meter reading (AMR) systems can be adapted to conventional, small and compact meters. AMR systems promise to solve several utility problems, which include: inaccessible meters, estimated billings, injuries to utility field

Figure 4-38. Flexible Tubing Run through Stud Partition Wall

personnel, customer property damage, customer complaints, and security concerns. Although these systems are very popular on the gas utilities distribution systems, they have been slow to find their way to the multifamily market.

- A combination of rigid steel pipe (vertical riser) and/or semirigid tubing (CSST or copper tubing) operated at elevated pressure (up to 5 psi) offer the most advanced technologies that will result in the lowest total installed costs for multifamily new and rehabilitated buildings.
- Although not code-approved for use in New York State, composite tubing comprised of polymer and metallic layers potentially offers lower total installation costs compared to CSST and steel pipe systems. Unlike copper tubing, which is also a low installation cost alternative to CSST and steel pipe, composite tubing has excellent resistance to long-term corrosion effects.

Figure 4-39. Flexible Tubing Run through Steel Stud Partition

Figure 4-40. Gas Pipe Penetration through Brick and Block Cavity Wall

Figure 4-41. Multiple Gas Lines Penetrating through Fire Wall

Figure 4-42. Gas Riser and Tubing Runs through Concrete Slab

Figure 4-43. Gas Line Penetration through Poured Concrete Slab at Roof

Figure 4-44. Gas Pipe Penetration through Hollow Core Concrete Slab at Roof

- The key to the development of an advanced gas piping system lies in the evolution of the distribution network from strictly a low-pressure system to a multipressure network that includes step down pressures of 5, 2, and $1/4$ psi. This approach, which maintains minimum pipe and tubing sizes, has been shown to result in lower total installed costs in multifamily buildings.
- Innovative, commercially available accessory hardware already exists to enhance the gas distribution network. These include modular meter and manifold enclosures, protection devices, baseboard channels, intermediate line regulators, and combined vents for regulators.
- Within 1 to 2 years, gas convenience outlets will be commercially available to promote the decentralization of gas distribution by making gas available, with significantly less cost and difficulty, at many locations throughout the multifamily building.

Figure 4-45. Gas Pipe Penetration Detail through Hollow Core Concrete Roof Slab

- Changes in appliance efficiency standards have prompted manufacturers to develop combination space and water heating systems. These combination or dual integrated systems are efficient, competitively priced, space saving, easy to install and maintain, and ideally suited for the multifamily market.
- The advent of two new classes of appliances, mid-efficiency, and high-efficiency, has required that a new set of standards be developed for safe venting. Four venting categories (I, II, III, and IV) have been established by an ANSI standards committee that account for differences between: positive and negative pressure vent systems, and actual and dew point temperatures of the flue gas.
- Combination space and water heating systems require a Category I vent because the water heater portion of the system produces combustion products. However, no special materials or installation practices are required for the vent systems of combination space and water heating systems.

Figure 4-46. Flexible Tubing Run through Concrete Roof Slab and Steel Joist Framing

- Current installation practices to install gas piping (steel pipe and flexible tubing) are adequate as shown in the construction details prepared by SWA. They should be revised in the future to include the impact of New York State gas piping and building codes, and new installation techniques and/or hardware innovations as they become available.

Figure 4-47. Gas Pipe Penetration through Roof with Hung Ceiling

Section 5

SUMMARY AND CONCLUSIONS

This research project has determined the cost-benefit advantages of decentralized space and water heating versus centralized systems for multifamily applications based on innovative gas piping and appliance technologies. A complete review was performed to assess the energy requirements and potential for savings as a result of technical innovations applicable to decentralized gas-fired space and water heating systems for multifamily dwellings in the State of New York. The review included the characterization of the multifamily building stock in the State of New York to determine which types of multifamily buildings are most likely to benefit from innovations in decentralized space and water heating systems.

Conclusions based on the analysis of opportunities for decentralized space and domestic hot water heating are:

RETROFIT OF PRE-1970 MULTIFAMILY BUILDINGS

- Buildings with 10-49 apartments and buildings with 50 or more apartments represent the largest share of the multifamily market in the State of New York (over 70 percent).
- The next tier is formed by buildings with 3 -9 apartments.
- While the issue of the number of floors versus the number of apartments could not be resolved at the New York State level, an estimate based on a Cornell study suggests the breakdown shown in Table 5-1.
- Gas availability cannot be applied to the entire State of New York, given the unique characteristics of New York City.
- Gas availability is essential for the feasibility of a heating/domestic hot water system retrofit.
- A building that undergoes total rehabilitation or major HVAC work is more likely than others to be a candidate for decentralized heating/domestic hot water systems.
- In any renovation, except total rehabilitation, buildings with hydronic heating systems are by far the most attractive for conversion.
- Buildings already using gas for heating are much more likely to be converted to a decentralized system.

**Table 5-1. Estimate of Number of Floors
versus Number of Units**

Number of Units	Percentage of Total Number of Units	
	1-3 Stories	4 and Above
3-4	18	1
5-9	2	9
10-49	1	18
50>	2	49
Total Units	23	77

- Codes and customary practice need to be reviewed.
- Energy use and cost need to be evaluated.

In summary, for retrofit multifamily buildings, the segment with a clear, high potential to benefit from conversion can be defined by low-rise (1-3 floors) buildings with 3-9 apartments that have gas-fired hydronic heating. Buildings with over 10 units can be even more appropriate for decentralized heating/domestic hot water systems, provided the buildings are less than 4 stories high, and either have gas heating or are attractive because of the economies of fuel switching. Seventy-five to 80 percent of these buildings use fuel oil.

NEW MULTIFAMILY BUILDINGS

- The largest market for new multifamily buildings, when defined solely by the number of units in New York State, currently appears to be buildings with 50 or more apartments.
- As with existing buildings, the 1-3 story segment is a clear favorite.
- Gas availability is a determining factor.
- The same building code and customary practice considerations apply as for retrofit situations.
- The same considerations for energy use and cost apply as for the retrofit situation.

ENERGY ASSESSMENT

- The energy savings achievable solely as a result of the decentralized configurations are substantial. They range from 11 to 15 percent for the pre-1940 buildings types, and from 7 to 17 percent for the post-1980 building types.
- Higher percent savings are achievable for the 10-story and more buildings.
- The heating energy cost increases for DIA systems. In the Consolidated Edison and Brooklyn Union Gas service territories, the increase ranges from 42 to 53 percent for pre-1940 buildings types, and 59 to 83 percent for post-1980 building types. The cost increases are a result of the high gas rate for the first few therms, and the service charges assessed on each apartment. This rate structure constitutes a significant institutional impediment.

INSTITUTIONAL CONSTRAINTS

Institutional constraints that may affect the implementation of new gas piping systems and appliance technologies were investigated, identified, and strategies to overcome them were developed. The potential code barriers to the acceptance of CSST gas piping systems and DIAs in multifamily buildings focused on the use of elevated gas pressures, the use of circulating potable water for heating or cooling, and the actual approval or installation of the tubing material.

From the informal survey of professionals with an interest in these applications, NCSBCS found that areas of concern mentioned in Section 3 are fairly pervasive throughout the State of New York. These include:

- Fire marshals indicated a concern about gas pressures over 0.5 psig inside a residential structure.
- Code officials generally accepted the concept of DIAs. However, the use of potable water for space heating restriction appears to be the greatest regulatory drawback for DIAs.
- New York City code officials felt that CSST was not a proven safe product, despite listings, etc.
- The plumbing trade union official voiced strong negative opinions on CSST.
- The concerns over CSST applications by gas utility representatives ranged from possibilities of punctures during construction to meter and regulator applications.
- The Office of Uniform Fire Prevention and Building Code had no comment on DIAs, but discussion on CSST and elevated gas pressures was apprehensive.

Code changes necessary to allow CSST and higher residential gas pressures were not anticipated.

In conclusion, a great deal of effort will be required to inform and educate the affected parties before acceptance and use of the technologies are achieved. To help accomplish this, strategies for overcoming the restriction to use potable water for space heating and elevated gas pressures in multifamily buildings were developed and presented in Section 3.

TECHNICAL INNOVATIONS

A technology survey was conducted by Foster-Miller to identify emerging gas technologies that are considered innovative relative to conventional approaches that are in use today. Areas of investigation included metering, gas piping, space and water heating systems, and appliance venting. A second survey was conducted by SWA to identify installation methods for gas piping located in chaseways, fire protected areas, and other affected areas of rehabilitated and newly constructed multifamily buildings. The results of the SWA survey were documented by the development of 15 construction drawings showing details of flexible tubing and rigid piping installation techniques needed for the implementation of this recently developed technology.

A number of specific conclusions have been drawn from conducting the two surveys:

- There are commercially available, small residential meters that could be used for multifamily new and rehabilitated construction projects in the State of New York. These downsized meters, which are 40 percent smaller than existing meters of the same flow capacity, can save valuable space in submetering closets. Several compact gas meters are under development, but are not commercially available and still a few years away.
- AMR systems can be adapted to conventional, small, and compact meters. AMR systems promise to solve several utility problems, which include: inaccessible meters, estimated billings, injuries to utility field personnel, customer property damage, customer complaints, and security concerns. Although these systems are very popular on the gas utilities distribution systems, they have been slow to find their way to the multifamily market.
- A combination of rigid steel pipe (vertical riser) and/or semirigid tubing (CSST or copper tubing) operated at elevated pressure (up to 5 psi) offer the most advanced technologies that will result in the lowest total installed costs for multifamily new and rehabilitated buildings.

- Although not code-approved for use in New York State, composite tubing comprised of polymer and metallic layers potentially offers lower total installation costs compared to CSST and steel pipe systems. Unlike copper tubing, which is also a low installation cost alternative to CSST and steel pipe, composite tubing has excellent resistance to long-term corrosion effects.
- The key to the development of an advanced gas piping system lies in the evolution of the distribution network from strictly a low-pressure system to a multipressure network that includes step down pressures of 5, 2, and 1/4 psi. This approach, which maintains minimum pipe and tubing sizes, has been shown to result in lower total installed costs in multifamily buildings.
- Innovative commercially available accessory hardware already exists to enhance the gas distribution network. These include modular meter and manifold enclosures, protection devices, baseboard channels, intermediate line regulators, and combined vents for regulators.
- Within 1 to 2 years, gas convenience outlets will be commercially available to promote the decentralization of gas distribution by making gas available, with significantly less cost and difficulty, at many locations throughout the multifamily building.
- Changes in appliance efficiency standards has prompted manufacturers to develop combination space and water heating systems. These combination or dual integrated systems are efficient, competitively priced, space saving, easy to install and maintain, and ideally suited for the multifamily market.
- The advent of two new classes of appliances, mid-efficiency, and high-efficiency, have required that a new set of standards be developed for safe venting. Four venting categories (I, II, III, and IV) have been established by an ANSI standards committee, which account for differences between: positive and negative pressure vent systems, and actual and dew point temperatures of the flue gas.
- Combination space and water heating systems require a Category I vent because the water heater portion of the system produces combustion products. However, no special materials or installation practices are required for the vent systems of combination space and water heating systems.
- Current installation practices to install gas piping (steel pipe and flexible tubing) are adequate as shown in the construction details prepared by SWA. These practices should be revised in the future to include the impact of New York State gas piping and building codes, and new installation techniques and/or hardware innovations as they become available.

Appendix A
CRITERIA FOR ASSIGNING WEIGHTING FACTORS
AND OPPORTUNITY RATINGS

Table 1: Units Per Structure

Weighting Factor:	Number of units in a structure is not very important since low-rise multifamily buildings, which can more easily receive distributed heating, are built in a whole range of configurations from 3-4 apartments to over 50 apartments.
Opportunity Rating:	The additional first cost of decentralized heating versus central heating increases in large developments because many small boilers must be provided to replace a single central boiler.

Table 2: Housing Stock (1970)

Weighting Factor:	The units built prior to 1970 have a high market potential because they are likely to need a change in heating equipment, opening the possibility to specify decentralized heating/DHW.
Opportunity Rating:	Proportional to the number of units built

Table 3: Replacement Potential for Existing Heating Fuel (1980)

Weighting Factor:	Oil: Connection to gas required Gas: Everything is in place Electricity: Distribution problem LPG: Pressure may not be adequate
Opportunity Rating:	Number of units

Table 4: Replacement Potential for Existing Heating System (1980)

Weighting Factor:	Steam or hot water with piping: No additional or small additional distribution cost (piping, radiators) involved. The weighting factor is high. Central warm air ducted system: A moderate increase in distribution cost (piping, radiators) expected. Alternately, the boilers could be provided with heat exchangers so that an air system continues to be used. The weighting factor is medium. Built-in electric units: High cost of additional distribution system involving piping, radiators, chases. The weighting factor is low. Floor, wall or pipeless furnace: Distributed heating
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already exists.

Other means: High cost of additional distribution system involving piping, radiators, chases. The weighting factor is low.

Opportunity Rating: Proportional to the number of units.

Table 5: Number of Floors (New York State Building Stock)

Weighting Factor: Number of floors in a structure is a strong indicator of first cost for distribution system and code compliance problems.

Opportunity Rating: Distribution cost, codes, and customs do not favor structures above 4 floors.

Table 6: Number of Units Grouped According to Number of Floors Per Building

Weighting Factor: Same as Table 5. The data are only for new construction in the Northeast.

Opportunity Rating: Same as Table 5.

Table 7: Gas Availability, Existing Housing Stock

Weighting Factor: Gas availability is a very important factor because without inexpensive access to gas service, decentralized heating cannot be cost-effective.

Opportunity Rating: The cost of connecting decentralized heating system depends on the location of existing gas supply line.

Table 8: Housing Growth (1960 - 1990)

Weighting Factor: Relatively low weighting factor because the older housing stock is more important. Newer buildings are unlikely to need replacement of heating equipment. Therefore, the rate at which new buildings are erected is not as important as the existing housing stock built before 1970.

Opportunity Rating: Rate of growth from 1960 onwards.

Table 9: Newer Housing Stock (1970 - 1990)

Weighting Factor: New housing units do not offer a strong potential for replacement of existing heating systems. As a result, the weighting factor is less than that for Table 3.

Opportunity Rating: Number of units.

Table 10: Gas Availability, New Construction

Weighting Factor: Same as Table 7

Opportunity Rating: Same as Table 7

APPENDIX B
MULTIPLE ATTRIBUTE ANALYSIS FOR DECENTRALIZED HEATING
IN EXISTING MULTIFAMILY BUILDING STOCK IN
NEW YORK STATE
(RENTER OCCUPIED UNITS, 1980)

TABLE 11A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 1

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
1 UNITS PER STRUCTURE	1	5	5	5	3	25	25	25	9	N/A	N/A
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL											
a. OIL	2	2	2	4	5	16	16	64	100	196	4.90
b. GAS	5	2	2	2	2	100	100	100	100	400	10.00
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.40
d. LPG	4	1	1	1	1	16	16	16	16	64	1.60
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL											
a. HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10.00
b. WARM AIR DUCT	3	1	1	1	1	9	9	9	9	36	.25
c. ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11
d. OTHER	1	1	1	1	1	1	1	1	1	4	.03
SUBTOTAL LINE 3a,4a						116	116	689	725	N/A	N/A
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A
TOTAL LINE 1,2,3 AND 4						500	500	1473	1493	N/A	N/A
TOTAL NORMALIZED						3.35	3.35	9.87	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6 NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
7 GAS AVAILABILITY NORMALIZED	5	5	3	1		625	225	25		N/A	N/A
						10.00	3.60	.40		N/A	N/A
GAS AVAILABILITY NORMALIZED	5	5	4	1		625	400	25		N/A	N/A
						10.00	6.40	.40		N/A	N/A

TABLE 12A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 2

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
1 UNITS PER STRUCTURE	1	5	5	5	3	25	25	25	9	N/A	N/A
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL											
a. OIL	3	2	2	4	5	36	36	144	225	441	10.00
b. GAS	5	2	2	2	2	100	100	100	100	400	9.07
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.36
d. LPG	4	1	1	1	1	16	16	16	16	64	1.45
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL											
a.HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10
b.WARM AIR DUCT	3	1	1	1	1	9	9	9	9	36	.25
c.ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11
d.OTHER	1	1	1	1	1	1	1	1	1	4	.03
SUBTOTAL LINE 3a,4a						136	136	769	850	N/A	N/A
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A
TOTAL LINE 1,2,3 AND 4						520	520	1553	1618	N/A	N/A
TOTAL NORMALIZED						3.21	3.21	9.60	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6 NUMBER OF UNITS GROUPED	5	5	2			625	100			N/A	N/A
6 ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
6 ACCORDING TO FLOORS											
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
7 NORMALIZED	5	5	3	1		10.00	3.60	.40		N/A	N/A
NORMALIZED						10.00	3.60	.40		N/A	N/A
GAS AVAILABILITY	5	5	4	1		625	400	25		N/A	N/A
NORMALIZED						10.00	6.40	.40		N/A	N/A

TABLE 13A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 3

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
1 UNITS PER STRUCTURE	1	5	5	5	3	25	25	25	9	N/A	N/A
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL											
a. OIL	2	2	2	4	5	16	16	64	100	196	4.90
b. GAS	5	2	2	2	2	100	100	100	100	400	10.00
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.40
d. LPG	4	1	1	1	1	16	16	16	16	64	1.60
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL											
a. HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10.00
b. WARM AIR DUCT	4	1	1	1	1	16	16	16	16	64	.44
c. ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11
d. OTHER	1	1	1	1	1	1	1	1	1	4	.03
SUBTOTAL LINE 3a,4a						116	116	689	725	N/A	N/A
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A
TOTAL LINE 1,2,3 AND 4						507	507	1480	1500	N/A	N/A
TOTAL NORMALIZED						3.38	3.38	9.87	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6 NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
NORMALIZED						10.00	3.60	.40		N/A	N/A
GAS AVAILABILITY	5	5	4	1		625	400	25		N/A	N/A
NORMALIZED						10.00	6.40	.40		N/A	N/A

TABLE 14A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 4

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)	
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2						
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >			

1 UNITS PER STRUCTURE	1	5	5	5	3	25	25	25	9	N/A	N/A	
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A	
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL												
a. OIL	3	2	2	4	5	36	36	144	225	441	10.00	
b. GAS	5	2	2	2	2	100	100	100	100	400	9.07	
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.36	
d. LPG	4	1	1	1	1	16	16	16	16	64	1.45	
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL												
a. HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10.00	
b. WARM AIR DUCT	4	1	1	1	1	16	16	16	16	64	.44	
c. ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11	
d. OTHER	1	1	1	1	1	1	1	1	1	4	.03	
SUBTOTAL LINE 3a,4a						136	136	769	850	N/A	N/A	
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A	
TOTAL LINE 1,2,3 AND 4						527	527	1560	1625	N/A	N/A	
TOTAL NORMALIZED						3.24	3.24	9.60	10.00	N/A	N/A	

		NUMBER OF FLOORS				NUMBER OF FLOORS						
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE					
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A	
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A	
6 NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A	
TOTAL LINE 5 AND 6						1250	200			N/A	N/A	
TOTAL NORMALIZED						10.00	1.60			N/A	N/A	

		LOCATION OF AVAILABLE GAS LINE				LOCATION						
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS				
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A	
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A	
NORMALIZED						10.00	3.60	.40		N/A	N/A	
GAS AVAILABILITY	5	5	4	1		625	400	25		N/A	N/A	
NORMALIZED						10.00	6.40	.40		N/A	N/A	

TABLE 15A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 5

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
<hr/>											
1 UNITS PER STRUCTURE	2	5	5	5	3	100	100	100	36	N/A	N/A
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL											
a. OIL	2	2	2	4	5	16	16	64	100	196	4.90
b. GAS	5	2	2	2	2	100	100	100	100	400	10.00
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.40
d. LPG	4	1	1	1	1	16	16	16	16	64	1.60
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL											
a. HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10.00
b. WARM AIR DUCT	3	1	1	1	1	9	9	9	9	36	.25
c. ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11
d. OTHER	1	1	1	1	1	1	1	1	1	4	.03
SUBTOTAL LINE 3a,4a						116	116	689	725	N/A	N/A
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A
TOTAL LINE 1,2,3 AND 4						575	575	1548	1520	N/A	N/A
TOTAL NORMALIZED						3.71	3.71	10.00	9.82	N/A	N/A
<hr/>											
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6 NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
<hr/>											
		LOCATION OF AVAILABLE GAS LINE				LOCATION					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
NORMALIZED						10.00	3.60	.40		N/A	N/A
GAS AVAILABILITY						625	400	25		N/A	N/A
NORMALIZED						10.00	6.40	.40		N/A	N/A

TABLE 16A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 6

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
1 UNITS PER STRUCTURE	2	5	5	5	3	100	100	100	36	N/A	N/A
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL											
a. OIL	3	2	2	4	5	36	36	144	225	441	10.00
b. GAS	5	2	2	2	2	100	100	100	100	400	9.07
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.36
d. LPG	4	1	1	1	1	16	16	16	16	64	1.45
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL											
a.HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10.00
b.WARM AIR DUCT	3	1	1	1	1	9	9	9	9	36	.25
c.ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11
d.OTHER	1	1	1	1	1	1	1	1	1	4	.03
SUBTOTAL LINE 3a,4a						136	136	769	850	N/A	N/A
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A
TOTAL LINE 1,2,3 AND 4						595	595	1628	1645	N/A	N/A
TOTAL NORMALIZED						3.62	3.62	9.90	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6 NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
NORMALIZED						10.00	3.60	.40		N/A	N/A
GAS AVAILABILITY	5	5	4	1		625	400	25		N/A	N/A
NORMALIZED						10.00	6.40	.40		N/A	N/A

TABLE 17A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 7

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
1 UNITS PER STRUCTURE	2	5	5	5	3	100	100	100	36	N/A	N/A
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL											
a. OIL	2	2	2	4	5	16	16	64	100	196	4.90
b. GAS	5	2	2	2	2	100	100	100	100	400	10.00
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.40
d. LPG	4	1	1	1	1	16	16	16	16	64	1.60
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL											
a. HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10.00
b. WARM AIR DUCT	4	1	1	1	1	16	16	16	16	64	.44
c. ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11
d. OTHER	1	1	1	1	1	1	1	1	1	4	.03
SUBTOTAL LINE 3a,4a						116	116	689	725	N/A	N/A
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A
TOTAL LINE 1,2 3 AND 4						582	582	1555	1527	N/A	N/A
TOTAL NORMALIZED						3.74	3.74	10.00	9.82	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6 NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
NORMALIZED						10.00	3.60	.40		N/A	N/A
GAS AVAILABILITY	5	5	4	1		625	400	25		N/A	N/A
NORMALIZED						10.00	6.40	.40		N/A	N/A

TABLE 18A : MULTI-FAMILY HOUSING STOCK (OLD-PRE 1970)

run 8

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
1 UNITS PER STRUCTURE	2	5	5	5	3	100	100	100	36	N/A	N/A
2 HOUSING STOCK (1970)	5	3	3	5	5	225	225	625	625	N/A	N/A
3 EXISTING HEATING FUEL REPLACEMENT POTENTIAL											
a. OIL	3	2	2	4	5	36	36	144	225	441	10.00
b. GAS	5	2	2	2	2	100	100	100	100	400	9.07
c. ELECTRICITY	2	1	1	1	1	4	4	4	4	16	.36
d. LPG	4	1	1	1	1	16	16	16	16	64	1.45
4 EXISTING HEATING SYSTEM REPLACEMENT POTENTIAL											
a. HYDRONIC PIPING	5	2	2	5	5	100	100	625	625	1450	10.00
b. WARM AIR DUCT	4	1	1	1	1	16	16	16	16	64	.44
c. ELECTRIC UNITS	2	1	1	1	1	4	4	4	4	16	.11
d. OTHER	1	1	1	1	1	1	1	1	1	4	.03
SUBTOTAL LINE 3a,4a						136	136	769	850	N/A	N/A
SUBTOTAL LINE 3b,4a						200	200	725	725	N/A	N/A
TOTAL LINE 1,2,3 AND 4						602	602	1635	1652	N/A	N/A
TOTAL NORMALIZED						3.64	3.64	9.90	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
5 FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6 NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
7 GAS AVAILABILITY	5	5	3	1		625	225	25		N/A	N/A
NORMALIZED						10.00	3.60	.40		N/A	N/A
GAS AVAILABILITY	5	5	4	1		625	400	25		N/A	N/A
NORMALIZED						10.00	6.40	.40		N/A	N/A

TABLE 11B : MULTI-FAMILY HOUSING STOCK (RECENT AND FUTURE)

run 1

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
8 HOUSING GROWTH (1960-90)	1	5	5	4	1	25	25	16	1	N/A	N/A
9 NEW HOUSING (1970-90)	2	4	2	1	5	64	16	4	100	N/A	N/A
TOTAL LINE 8 AND 9						89	41	20	101	N/A	N/A
TOTAL NORMALIZED						8.81	4.06	1.98	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5R FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6R NUMBER OF UNITS GROUPED ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION OF AVAILABLE GAS LINE					
		PREMISES	STREET	NO GAS		PREMISES	STREET	NO GAS			
10 GAS AVAILABILITY NORMALIZED	5	N/A	3	1		0	225 10.00	25 1.11		N/A	N/A
GAS AVAILABILITY NORMALIZED	5	N/A	4	1		0	400 10.00	25 .63		N/A	N/A

TABLE 12B : MULTI-FAMILY HOUSING STOCK (RECENT AND FUTURE)

run 2

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
8 HOUSING GROWTH (1960-90)	1	5	5	4	1	25	25	16	1	N/A	N/A
9 NEW HOUSING (1970-90)	3	4	2	1	5	144	36	9	225	N/A	N/A
TOTAL LINE 8 AND 9						169	61	25	226	N/A	N/A
TOTAL NORMALIZED						7.48	2.70	1.11	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5R FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6R NUMBER OF UNITS GROUPED	5	5	2			625	100			N/A	N/A
6R ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
ACCORDING TO FLOORS											
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION OF AVAILABLE GAS LINE					
		LOCATION	STREET NO GAS			LOCATION	STREET NO GAS				
10 GAS AVAILABILITY	5	N/A	3	1		0	225	25		N/A	N/A
NORMALIZED							10.00	1.11		N/A	N/A
GAS AVAILABILITY	5	N/A	4	1		0	400	25		N/A	N/A
NORMALIZED							10.00	.63		N/A	N/A

TABLE 13B : MULTI-FAMILY HOUSING STOCK (RECENT AND FUTURE)

run 3

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2					
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >		
8 HOUSING GROWTH (1960-90)	2	5	5	4	1	100	100	64	4	N/A	N/A
9 NEW HOUSING (1970-90)	2	4	2	1	5	64	16	4	100	N/A	N/A
TOTAL LINE 8 AND 9						164	116	68	104	N/A	N/A
TOTAL NORMALIZED						15.77	11.15	6.54	10.00	N/A	N/A
		NUMBER OF FLOORS				NUMBER OF FLOORS					
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE				
5R FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A
6R NUMBER OF UNITS GROUPED	5	5	2			625	100			N/A	N/A
6R ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A
ACCORDING TO FLOORS											
TOTAL LINE 5 AND 6						1250	200			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
TOTAL NORMALIZED						10.00	1.60			N/A	N/A
		LOCATION OF AVAILABLE GAS LINE				LOCATION OF AVAILABLE GAS LINE					
		PREMISES	STREET	NO	GAS	PREMISES	STREET	NO	GAS		
10 GAS AVAILABILITY	5	N/A	3	1		0	225	25		N/A	N/A
NORMALIZED							10.00	1.11		N/A	N/A
GAS AVAILABILITY	5	N/A	4	1		0	400	25		N/A	N/A
NORMALIZED							10.00	.63		N/A	N/A

TABLE 14B : MULTI-FAMILY HOUSING STOCK (RECENT AND FUTURE)

run 4

ATTRIBUTE	W.F. (WF)	MULTI-FAMILY CATEGORIES BY NUMBER OF UNITS IN A STRUCTURE								TOTAL	TOTAL (NORM.)	
		OPPORTUNITY RATING (ORT)				ATTRIBUTE SCORE (S) = (WF X ORT) **2						
		3 TO 4	5 TO 9	10 TO 49	50 & >	3 TO 4	5 TO 9	10 TO 49	50 & >			
8 HOUSING GROWTH (1960-90)	1	5	5	4	1	25	25	16	1	N/A	N/A	
9 NEW HOUSING (1970-90)	3	4	2	1	5	144	36	9	225	N/A	N/A	
TOTAL LINE 8 AND 9						169	61	25	226	N/A	N/A	
TOTAL NORMALIZED						7.48	2.70	1.11	10.00	N/A	N/A	
		NUMBER OF FLOORS				NUMBER OF FLOORS						
		1 TO 3	4 AND ABOVE			1 TO 3	4 AND ABOVE					
5R FLOORS/STRUCTURE (NYS)	5	5	2			625	100			N/A	N/A	
6R NUMBER OF UNITS GROUPE	5	5	2			625	100			N/A	N/A	
6R ACCORDING TO FLOORS	5	5	2			625	100			N/A	N/A	
ACCORDING TO FLOORS												
TOTAL LINE 5 AND 6						1250	200			N/A	N/A	
TOTAL NORMALIZED						10.00	1.60			N/A	N/A	
TOTAL NORMALIZED						10.00	1.60			N/A	N/A	
		LOCATION OF AVAILABLE GAS LINE			LOCATION OF AVAILABLE GAS LINE							
		PREMISES	STREET	NO GAS				PREMISES	STREET	NO GAS		
10 GAS AVAILABILITY	5	N/A	3	1		0	225	25			N/A	N/A
NORMALIZED							10.00	1.11			N/A	N/A
GAS AVAILABILITY	5	N/A	4	1		0	400	25			N/A	N/A
NORMALIZED							10.00	.63			N/A	N/A

APPENDIX C

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APPENDIX E
GAS PIPING TECHNOLOGIES

CORRUGATED STAINLESS STEEL TUBING

The corrugated stainless steel tubing (CSST), which is A.G.A. Labs design certified for use in fuel gas piping systems, is manufactured in both the United States and in Japan. In January 1991, the American National Standards Institute, Inc. adopted ANSI/A.G.A. LC-1 as the ANSI Standard for CSST systems. The system uses semirigid corrugated tubing made of 304 stainless steel. It is currently supplied in coils from 100 to 250 ft in length. The tubing is manufactured in up to four different sizes, 3/8, 1/2, 3/4, and 1 in. internal diameters.

The corrugated tubing is covered with a polyethylene (PE) or a polyvinyl chloride (PVC) coating, approximately 0.63 mm (0.025 in.) thick. The purpose of the coating is threefold: to protect it against household chemicals, abrasion, and to reduce friction while snaking it through stud walls and floor joists. Special mechanical fittings are provided to interconnect the tubing with other components within the overall gas piping system.

There are currently two suppliers of this product, each with slight variations in the tubing size, shape and fitting design. Dimensional specifications for each of the current manufacturers product are shown in Figure E-1. Larger sizes up to 1-1/2 in. diam may be available in the future. Because of these variations, each manufacturer's system requires individual instruction on the proper sizing and installation procedures. A brief description including installation requirements for each manufacturer's system follows.

WARD MANUFACTURING

Ward Manufacturing manufactures an annular shaped tubing with mechanical fittings that can be installed with simple hand tools. The tubing is cut with a conventional tubing cutter supplied by Rigid or other such manufacturer.

The assemble process for the Ward Manufacturing fitting requires that the plastic covering over the tubing be removed near the joint, and the split retainer piece placed around the tubing at a prescribed location (see Figure E-2). The fitting is assembled by hand and tightened with conventional wrenches. The fiber washer must be replaced if the fitting is reused.

	Ward Manufacturing				Titeflex		
Tubing Size (in.)	3/8 (10A)	1/2 (15A)	3/4 (20A)	1 (25A)	3/8 (6A)	1/2 (8A)	3/4 (11B)
Outside diameter OD (in.)	0.56	0.72	0.98	1.21	0.51	0.71	0.92
Inside diameter ID (in.)	0.45	0.59	0.79	0.98	0.40	0.57	0.75
Wall thickness (in.)	0.008	0.008	0.010	0.010	0.011	0.011	0.011
Coil length (ft)	250	250	180	180	100	100	100
Corrugated Tubing Shade (s)	Annular				Annular		
Covering	Polyvinyl chloride				Polyethylene		

Figure E-1. Corrugated Tubing Dimensional Specifications

TITEFLEX

Titeflex also manufactures an annular shaped tubing with mechanical fittings that can be installed with simple hand tools. The tubing is cut with a modified **Rigid** tubing cutter fitted with self adjusting rollers to accommodate different tubing sizes which have different corrugated profiles.

Figure E-2. Fitting Assembly (Ward Manufacturing)

The assemble process for the Titeflex fitting requires that the plastic covering over the tubing be removed near the joint, and the split retainer ring placed around the tubing at a prescribed location (see Figure E-3). The fitting is assembled by hand and tightened with conventional wrenches. If reused, no replacement parts are required.

Most semirigid tubing systems utilize a multiport gas distribution manifold. A system manifold would supply multiple gas appliances in a parallel arrangement from a single distribution point. Figure E-4 depicts several available configurations. The manifolds can be cast malleable iron or assembled from a series of standard tee fittings and pipe nipples.

There are several other unique hardware requirements associated with the use of hybrid pressure and semirigid tubing. These include special metallic striker plates, Maxitrol line regulators, tubing clips, appliance stub-outs and other shielding devices.

Figure E-3. Fitting Assembly (Titeflex)

Figure E-4. Typical Multiport Manifolds (Tokyo and Osaka Gas Companies)

MEPLA AND KITEC TUBING SYSTEM DESCRIPTION

MEPLA TUBING

Technical specifications are shown in Tables E-1 and E-2 for the MEPLA tubing product. Figures E-5 through E-11 show photographs of the tubing, fittings, accessory components, and special installation tools required to install the piping system. Initially, all performance tests and installation assessments were conducted on MEPLA tubing designated for underfloor heating applications (first category). The underfloor heating tubing was initially selected because of its greater flexibility compared to the natural gas tubing. However, it did not perform well when subjected to elevated temperature conditions.

Therefore, additional tests were conducted on MEPLA tubing designated for natural gas applications (fourth category). The metal tubing used in the MEPLA tubing for natural gas applications has a thicker wall and is an aluminum alloy material. The metal tubing used in the MEPLA tubing for underfloor heating applications is of a thinner wall, and pure aluminum material.

KITEC TUBING

Tables E-3 and E-4 give technical specifications for the Kitec tubing product. The photographs in Figures E-12 through E-16 show the tubing, fittings, accessory components, and special installation tools required to install the piping system. Two tubing types, one designated for hot water/central heating applications and one designated for natural gas applications, were selected for evaluation.

Table E-1. MEPLA Pipe Technical Specifications

MEPLA® The metallic multi-

Delivery options

Pipe	Ø	16 mm		20 mm		26 mm	
	Length m	200	100	100	50	100	50
Reels	Height mm	185	200	205	190	240	180
	Ø ext. mm	720	580	800	730	1120	1050
	Ø int. mm	400	400	620	620	900	900
Straight lengths		Upon request		5 m		5 m	

The 50 and 100 m reels are made to fit inside each other, thereby reducing shipment volume.

Technical data

			Pressure		Temperature		Pipe colour			Bursting pressure at 20° C
	Reference	Ø ext./int.	Cont.	Peaks	Cont.	Peaks	Marking	Int.	Ext.	
Underfloor heating PE - AL - PE	0.02.016 MEP 0.02.020 MEP	16/11.5 20/15	6 bar	10 bar	60° C	95° C	White	Black	Burgundy	60 bar
Hot water sanitary XPE - AM - PE	0.01.016 MEP 0.01.020 MEP 0.01.026 MEP	16/11.5 20/15 26/20	10 bar	15 bar	95° C	110° C	Red	White	Black	90 bar
Cold water Drinking water PE - AM - PE	0.03.016 MEP 0.03.020 MEP 0.03.026 MEP	16/11.5 20/15 26/20	15 bar	20 bar	45° C	65° C	Blue	Black	Black	80 bar
Gas - Butane - Propane PE - AL - PE	0.04.016 MEP 0.04.020 MEP 0.04.026 MEP	16/11.5 20/15 26/20	15 bar	20 bar	45° C	65° C	Black	Black	Yellow	70 bar
Industry PE - AM - XPE	0.05.016 MEP 0.05.020 MEP 0.05.026 MEP	16/11.5 20/15 26/20	15 bar	20 bar	100° C	110° C	Yellow	Brown	Black	90 bar
Polyamide PA - AM - PA	0.06.016 MEP 0.06.020 MEP 0.06.026 MEP	16/11.5 20/15 26/20						White	Brown	

Physical data

Pipe	16 mm	20 mm	26 mm
Linear mass	125 g/m	185 g/m	300 g/m
Carrying capacity	0,1038 l/m	0,1767 l/m	0,3146 l/m
Thermal conductivity	0,43 W/m.K		
Linear thermal expansion coefficient	$26 \times 10^{-6} \times K^{-1}$		
Gas diffusion	none		
Absolute roughness of internal pipe	3 µm		
Minimum bending radius (5 × pipe Ø)	80 mm	100 mm	130 mm

Table E-2. MEPLA Pipe Technical Specifications

layer pipe with unique features					
Reference	Designation	5 m	50 m	100 m	200 m
0.02.016 MEP 0.02.020 MEP	Underfloor heating $\varnothing$ 16 x 2.25 $\varnothing$ 20 x 2.5				
0.01.016 MEP 0.01.020 MEP 0.01.026 MEP	Hot water – Sanitary – Heating $\varnothing$ 16 x 2.25 $\varnothing$ 20 x 2.5 $\varnothing$ 26 x 3				
0.03.016 MEP 0.03.020 MEP 0.03.026 MEP	Cold- and drinking water – Food-stuffs $\varnothing$ 16 x 2.25 $\varnothing$ 20 x 2.5 $\varnothing$ 26 x 3				
0.04.016 MEP 0.04.020 MEP 0.04.026 MEP	Gas – Butane – Propane – etc. $\varnothing$ 16 x 2.25 $\varnothing$ 20 x 2.5 $\varnothing$ 26 x 3				
0.05.016 MEP 0.05.020 MEP 0.05.026 MEP	Industry $\varnothing$ 16 x 2.25 $\varnothing$ 20 x 2.5 $\varnothing$ 26 x 3				
0.06.016 MEP 0.06.020 MEP 0.06.026 MEP	Polyamide $\varnothing$ 16 x 2.25 $\varnothing$ 20 x 2.5 $\varnothing$ 26 x 3

Figure E-5. MEPLA Pipe Samples

Figure E-6. MEPLA Pipe Mechanical Fittings

Figure E-7. MEPLA Pipe Multiport Manifolds

Figure E-8. MEPLA Pipe Installation Tool Kit

Figure E-9. MEPLA Pipe Installation Tools

Figure E-10. MEPLA Pipe Bending Tool

Figure E-11. MEPLA Pipe End Preparation Tool

Table E-3. Kitec Tubing Technical Specifications

KITEC

KITEC® ORANGE is a flexible, multi-purpose pressure pipe consisting of an aluminum tube laminated between two layers of plastic. New KITEC eliminates traditional disadvantages of copper, steel and plastic-only pipes.

APPLICATION	Hot water, central heating			
CAN ALSO BE USED FOR	Cold water, underfloor heating, air-conditioning, compressed air			
MATERIAL	XLPE - ALU - XLPE			
CHEMICAL RESISTANCE	Non-corrosive, resists most acids, salt solutions, alkalines, fats and oils			
OXYGEN DIFFUSION	None			
OPERATING TEMPERATURES	Continuous -40°C to +95°C			
OPERATING PRESSURES	150 psi			
CODE NUMBER*	1014 (3/8")	1216 (1/2")	1620 (3/4")	2025 (1")
INTERNAL DIAMETER (in.)	.394	.472	.630	.787
EXTERNAL DIAMETER (in.)	.551	.630	.787	.984
MIN. BENDING RADIUS 5D (in.)	2.76	3.15	3.94	4.92
COMPOSITE WALL THICKNESS (in.)	.071	.075	.089	.089
WEIGHT PER FOOT (lb.)	.054	.066	.097	.124
VOLUME PER FOOT LENGTH (gal.)	.005	.008	.013	.021
SUPPLIED	Coils or straight bars			
SUSPENSION DISTANCE	Horizontal 3.5 ft. Vertical 7 ft.			
FITTINGS	KITEC® (Brass)			
THERMAL CONDUCTIVITY	3.12 B.T.U. in./ft.²/hr./°F			
THERMAL EXPANSION COEFFICIENT	1.3 x 10⁻⁵ in./in./°F			

KITEC is anti-static due to the aluminum core. It can be detected in walls, ceilings, etc. by a simple metal detector.

If exposed to severe sun rays, use KITEC Black type.

KITEC is available in various colours for a number of applications. Contact Scepter for information on the full range.

*CODE NUMBER: First two digits denote internal diameter expressed in millimeters.
Last two digits denote external diameter expressed in millimeters.

Scepter
WHERE INNOVATION IS AN ATTITUDE

Scepter Manufacturing Co. Ltd. 495 Finchdene Square, Scarborough, Ontario M1X 1B7
PHONE: (416) 321-8811 FAX: 416-321-8824
Branches: Vancouver, Edmonton, Calgary, Saskatoon, Winnipeg, Toronto, Montreal, Saint John, Dartmouth

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Kitec® is the trademark of Kitec Technology B.V. used under license by Scepter Manufacturing Co. Ltd.

Table E-4. Kitec Tubing Technical Specifications

KITEC

KITEC® YELLOW is a flexible, multi-purpose pressure pipe consisting of an aluminum tube laminated between two layers of plastic. New KITEC eliminates traditional disadvantages of copper, steel and plastic-only pipes.

KITEC is anti-static due to the aluminum core. It can be detected in walls, ceilings, etc. by a simple metal detector.

If exposed to severe sun rays, use KITEC Black type.

KITEC is available in various colours for a number of applications. Contact Scepter for information on the full range.

APPLICATION	Domestic, gas (butane, propane)			
CAN ALSO BE USED FOR	Compressed air, industrial gases and liquids			
MATERIAL	HDPE - ALU - HDPE			
CHEMICAL RESISTANCE	Non-corrosive, resists most acids, salt solutions, alkalines, fats and oils			
OXYGEN DIFFUSION	None			
OPERATING TEMPERATURES	Continuous -40°C to +40°C			
OPERATING PRESSURES	150 psi			
CODE NUMBER*	1014 (3/8")	1216 (1/2")	1620 (3/4")	2025 (1")
INTERNAL DIAMETER (in.)	.394	.472	.630	.787
EXTERNAL DIAMETER (in.)	.551	.630	.787	.984
MIN. BENDING RADIUS 5D (in.)	2.76	3.15	3.94	4.92
COMPOSITE WALL THICKNESS (in.)	.071	.075	.089	.089
WEIGHT PER FOOT (lb.)	.054	.066	.097	.124
VOLUME PER FOOT LENGTH (gal.)	.005	.008	.013	.021
SUPPLIED	Coils or straight bars			
SUSPENSION DISTANCE	Horizontal 3.5 ft. Vertical 7 ft.			
THERMAL CONDUCTIVITY	3.12 B.T.U. in./ft. ² /hr./°F			
THERMAL EXPANSION COEFFICIENT	1.3 x 10 ⁻⁵ in./in./°F			

*CODE NUMBER: First two digits denote internal diameter expressed in millimeters.
Last two digits denote external diameter expressed in millimeters.

Scepter
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Figure E-12. Kitec Tubing Samples

Figure E-13. Kitec Tubing Mechanical Fittings

Figure E-14. Kitec Tubing Multiport Manifolds

Figure E-15. Kitec Tubing Installation Tools

Figure E-16. Kitec Tubing End Preparation Tool

ANSI/ASHRAE 124P

ASHRAE STANDARD

**PROPOSED AMERICAN
NATIONAL STANDARD**

METHOD OF TESTING
FOR RATING
COMBINATION SPACE
HEATING/WATER
HEATING APPLIANCES

PUBLIC REVIEW DRAFT

March 13, 1987

**The American Society of Heating, Refrigerating,
and Air-Conditioning Engineers, Inc.**

1791 Tullie Circle, NE, Atlanta, GA 30329

NOTICE: COMMENTS ON
DRAFT STANDARD

1. Instructions for Filing Comments

- A. If you wish to make comments on the attached draft standard, they must be submitted by: June 15, 1987

These should be sent to:

Manager of Standards
ASHRAE
1791 Tullie Circle, NE
Atlanta, GA 30329

- B. In making comments the enclosed form must be used. Background documents to substantiate your comments should be included. Do not return marked up copies of the draft.

2. Information on Review and Disposition of Comments

All comments received by ASHRAE are acknowledged and forwarded to the Standards Project Committee (SPC) for its consideration. The SPC will inform commentors of the disposition of their comments.

FORM FOR COMMENTING ON PROPOSED ASHRAE STANDARDS

1. Name _____ Date _____

Organization

Address _____

Telephone Number _____

Number and Title of Standard	124P, "Method of Testing for Rating Combination"

Space Heating/Water Heating Appliances"

2. Section or paragraph _____

3. Recommended changes

4. Substantiating statements

Use separate form for each comment, completing lines 2 - 4 only

Mail To: **Manager of Standards**
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1.0 PURPOSE: The purpose is to establish a method of test to rate the performance of a combination space heating/water heating appliance.

2.0 SCOPE :

2.1 This test method is intended to cover electric, gas-fired or oil-fired combination space heating/water heating appliances.

2.2 This standard covers appliances up to 300,000 Btuh rated input (87.9 kW).

3.0 DEFINITIONS

boiler, low pressure steam or hot water. An electric, gas or oil-burning boiler designed to supply low pressure steam or hot water for space heating application. A low pressure steam boiler operates at or below 15 psig steam pressure; a hot water boiler operates at or below 160 psig water pressure and 250°F water temperature.

combination space heating/water heating appliance. A unit which is designed to produce the total requirements of space heating and water heating from a single primary energy source.

draft hood. A device that is not an integral part of an appliance, and which is connected to the unit by a short length of flue pipe. It is designed to (1) provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft hood, (2) prevent a back draft from entering the unit, and (3) neutralize the effect of stack action of the chimney or gas vent upon the operation of the unit. For the purpose of this Standard, this does not include integral draft diverters.

direct exhaust system. A mechanical appliance venting system supplied or recommended by the manufacturer through which the products of combustion pass directly from the appliance to the outside and which does not employ a means of draft relief. This includes units which have small air passages in the flue which do not allow for air flow through it in excess of 10% of the maximum flue flow.

direct vent system. A system supplied by a manufacturer which provides outdoor air directly to a unit for combustion and for draft relief, if the unit is equipped with a draft control device, and which provides for discharge of all flue gases to the outside atmosphere.

flue. A conduit between the flue outlet of the appliance and the integral draft diverter, draft hood, barometric draft regulator, vent terminal, or any other point of draft relief.

flue collar. A projection or recess provided to accommodate the vent connector or draft hood.

3.0 DEFINITIONS (continued)

flue gases. All gases in the flue during the duration of combustion in the combustion chamber, including reaction products, inerts, and any excess air.

flue outlet (vent). The opening provided in an appliance for the escape of flue gases.

heat trap. A device which can be integrally connected or independently attached to the hot or cold water pipe connections of a water heater such that the device will develop a thermal or mechanical seal to minimize the recirculation of water due to natural thermal convection between the water heater tank and its water supply pipes and thereby reduce the heat loss to the environment from the hot water stored in the water heater.

higher heating value (H). The heat produced per unit of fuel when complete combustion takes place at constant pressure and the products of combustion are cooled to the initial temperature of the fuel and air and when the vapor formed during combustion is condensed. The higher heating value is expressed in Btu/lb or Btu/ft³ for gaseous fuel, or Btu/lb or Btu/gal for liquid fuel.

hot water storage tank. A tank used to store water that is heated indirectly by a circulating water heater or by steam or hot water circulating through coils or other heat exchange methods internal or external to the tank.

instantaneous water heater. A water heater which has an input rate of at least 4,000 Btu per hour per gallon of self-stored water. Automatic control is obtained by (a) water-actuated controls, (b) thermostatic control (c) combination of water actuated control and thermostatic control.

integral draft diverter. A device that is an integral part of an appliance and which is designed to (1) provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft diverter, (2) prevent a back draft from entering the unit, and (3) neutralize the effect of stack action of the chimney or gas vent upon the operation of the unit. For the purpose of this Standard, this does not include draft hoods.

integrated heater. A boiler and an external storage tank in which domestic water, heated by the boiler, is stored.

isolated combustion system. An installation in which a unit is installed indoors and all combustion and ventilation air is admitted through grills or ducts from outdoors and (all such air) does not communicate with air in the conditioned space.

outdoor appliance. A unit intended for installation out-of-doors, equipped with a weatherized jacket and integral venting means, and labeled for outdoor installation.

3.0 DEFINITIONS (continued)

stack. The portion of the exhaust system downstream of the draft diverter, draft hood, or barometric draft regulator.

storage water heater. A closed vessel, in which water is heated by the combustion of fuels, electricity or any other source and is withdrawn for use external to the system at pressures not exceeding 160 psig, including the apparatus by which heat is generated and all controls and devices necessary to prevent water temperatures from exceeding 210F.

tankless heater. A heat exchanger for indirect heating of domestic water which is designed to be used without a storage tank. It may be attached directly to the boiler or installed external to the boiler and connected by piping.

thermostat, tank. A device which senses changes in stored water temperature and controls electrically, by means of separate components, the flow of fuel to the burner(s) to maintain selected temperatures.

vent connector. That portion of the venting system which connects the gas appliance to the gas vent, chimney or single-wall metal pipe.

vent pipe. Passages and conduits in a direct vent system through which gases pass from the combustion chamber to the outdoor air.

water temperature control. A device which senses boiler water temperature and controls the burner.

4.0 CLASSIFICATIONS

Combination space heating/water heating appliances are classified as follows:

- 4.1 TYPE I APPLIANCE - An appliance whose primary function is space heating and which has a secondary function of domestic water heating. The space heating function of this type can be tested for performance and efficiency in accordance to ANSI/ASHRAE Standard 103-1982.⁽¹⁾ Methods of Testing for Heating Seasonal Efficiency of Central Furnaces and Boilers as supplemented by the Federal Register of March 28, 1984 (49 FR 12148).⁽²⁾

Subcategories include:

- 4.1.1 Tankless heater directly in appliance. See Fig. 1.
- 4.1.2 Tankless heater in external tank. See Fig. 3. This includes a tank within a tank where the volume of boiler water is greater than the volume of domestic water.
- 4.1.3 Integrated heater with domestic water in external tank. See Fig. 2. This includes a tank within a tank where the volume of domestic water is greater than the volume of boiler water.

- 4.2 TYPE II APPLIANCE - An appliance whose primary function is domestic water heating and which has a secondary function of space heating. The domestic water heating function of this type can be tested for performance and efficiency in accordance with 10 CFR 430⁽³⁾ - subpart B, appendix E of the Federal Regulations, or where appropriate, ANSI Z21.10.3 - 1984.⁽⁴⁾

Subcategories include:

- 4.2.1 Storage water heater
- 4.2.2 Instantaneous water heater

- 4.3 TYPE III APPLIANCE - An appliance whose primary function is to both heat space and heat water. For the purpose of this standard it can be tested as a Type I or Type II appliance.

5.0 REQUIREMENTS

5.1 SPACE HEATING PERFORMANCE

- 5.1.1 Type I Appliance - The space heating performance shall be determined from tests conducted in accordance to ANSI/ASHRAE Standard 103-1982.⁽¹⁾ Methods of Testing for Heating Seasonal Efficiency of Central Furnaces and Boilers as supplemented by the Federal Register of March 28, 1984 (49 FR 12148).⁽²⁾

5.1.2 Type II Appliance - Space heating performance parameters shall be determined from tests conducted in accordance to ANSI/ASHRAE Standard 103-1982.⁽¹⁾ Methods of Testing for Heating Seasonal Efficiency of Central Furnaces and Boilers as supplemented by the Federal Register of March 28, 1984 (49 FR 12148)⁽²⁾ and the additional provisions of Sect. 6 through 10 of this Standard.

5.1.2.1 Waiver of Space Heating Tests - If the optional procedure for calculating the combined efficiency as defined in Section 11.3.6 is employed for a Type II appliance intended to be installed as an isolated combustion system, the space heating tests prescribed in 5.1.2 do not have to be conducted for that appliance.

5.2 WATER HEATING PERFORMANCE

5.2.1 Type I Appliance - Water heating performance parameters shall be determined from tests conducted in accordance with this standard.

5.2.2 Type II Appliance - The water heating performance shall be determined from tests conducted in accordance with this standard, 10 CFR 430⁽³⁾ - subpart B, appendix E of the Federal Regulations, or ANSI Z21.10.3 - 1984,⁽⁴⁾ as appropriate.

5.3 COMBINED SPACE HEATING/WATER HEATING PERFORMANCE - Combined space heating/ water heating performance of the combination appliance shall be determined from calculations as prescribed in Section 11.

6.0 INSTRUMENTS

6.1 GENERAL

All instruments shall be in working order and be calibrated periodically. Records of periodic calibration shall be kept and they shall contain at a minimum the date of calibration, method of calibration, and reference standard used.

6.2 TEMPERATURE

6.2.1 Thermometers. Thermometers shall have an error no greater than $\pm 1^{\circ}\text{F}$.

6.2.2 Thermocouples. Thermocouples and their read out instrumentation shall have an error no greater than $\pm 2^{\circ}\text{F}$. Thermocouples shall be the bead type having a wire size no greater than No. 24 American Wire Gauge (AWG). Where there is a possibility that the thermocouple(s) could receive direct radiation from the flame, use of a radiation shield is required.

6.2.3 Thermocouple Grid. Thermocouple grid shall be constructed of thermocouples of the type described in 6.2.2. The grid shall be wired in parallel in a test plane perpendicular to the axis of the test flue, stack, or vent pipe (direct vent system) and the thermocouple leads shall be equalized in length before paralleling.

6.3 PRESSURE

Gas, oil, air, water, and steam pressure measuring instruments shall be calibrated so that the error is no greater than the following:

6.3.1 Gas - ± 0.2 inch water column.

6.3.2 Oil - ± 0.5 pounds per square inch.

6.3.3 Air ± 0.01 inch water column.

6.3.4 Steam - ± 0.2 inch mercury column.

6.3.5 Water - ± 0.5 pounds per square inch.

6.4 DRAFT

Draft gauges shall have an accuracy of ± 0.005 inch water column. Minimum divisions on the draft gauge shall be 0.005 inches of water column.

6.5 COMBUSTION PRODUCTS

Stack and flue CO₂ (carbon dioxide) shall be determined with an instrument providing a reading with an error no greater than ± 0.1 percentage points.

6.6 WEIGHT OR VOLUME

The error associated with the measuring instruments shall not exceed ± 0.5 percent of the hourly rate.

6.7 TIME

The error associated with timing instruments shall not exceed ± 0.5 second.

6.8 SMOKE

Smoke-measuring instruments shall comply with requirements for smoke meters as outlined in Method of Test for Smoke Density in the Flue Gases from Burnin⁽³⁾ Distillate Fuels, ANSI Z11.182-1965 (R-1971) ASTM-D-2156-65 (1980).

6.9 ENERGY FLOW RATE

6.9.1 Electricity. The error shall be no greater than one percent.

6.9.2 Gas. The error shall be no greater than one percent.

6.9.3 Oil. The error shall be no greater than one percent.

6.10 ENERGY CONSUMPTION

6.10.1 Electricity. The error shall be no greater than two percent.

6.10.2 Gas. The error shall be no greater than two percent.

6.10.3 Oil. The error shall be no greater than two percent.

6.11 Higher Heating Value

6.11.1 Gas. The error shall be no greater than one percent.

6.11.2 Oil. The error shall be no greater than one percent.

7.0 APPARATUS

7.1 GENERAL

The apparatus described below is used in conjunction with Type I or Type II combination space heating water heating appliances during the testing.

7.2 TYPE I APPLIANCES

7.2.1 Space Heating Function - refer to Section 7 of ASHRAE 103-1982 ⁽¹⁾

7.2.2 Water Heating Function Requirements

7.2.2.1 Flue requirements for gas fired Type I Appliances. For a gas unit having a vertically discharging draft hood outlet, a 5 foot vertical flue pipe extension having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For a gas unit having a horizontally discharging draft hood outlet, a 90 degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A 5 foot length of flue pipe shall be connected to the elbow and oriented to discharge vertically upward. Perform all tests with the natural draft established by this length of flue pipe. Direct vent and direct exhaust gas units shall be installed with venting equipment as specified in the manufacturer's instructions; however, the vertical length of the flue pipe shall be no greater than 5 feet. (See Figure 5.)

7.2.2.2 Flue requirements for oil-fired and power gas fired Type I appliances - The unit shall be provided with a flue pipe and elbows as shown in Figure 4. A length of flue pipe sufficient to establish the manufacturer's recommended draft shall be connected to the elbow fitting and oriented to discharge vertically upward. When ceiling height limits the use of a sufficient length of vertical flue pipe for an oil unit, a mechanical draft inducer may be used during periods of burner firing to establish the specified draft in the flue. Direct vent

and direct exhaust units shall be installed with venting equipment as specified in the manufacturer's instructions.

7.2.2.3 Piping

See Figures 1, 2, and 3 for typical piping arrangements. Provision shall be made to assure constant water temperature and pressure being supplied to the unit.

7.2.2.4 Water Flow Measurement

Provide appropriate weigh tanks and scales, or calibrated meters to measure water flow rate.

7.2.2.5 Fuel or Energy Consumption Measurement

Install one or more instruments which measure, as appropriate, the quantity or rate of energy consumed by the appliance when heating water. Electrical energy consumption is to be expressed in units of Kilowatt-hours. Natural gas and propane consumption shall be expressed in units of Btu. Fuel oil consumption shall be expressed in units of Btu.

7.2.2.6 Room Temperature

Install a thermocouple to measure the ambient temperature with junction shielded against direct radiation from any heat source and positioned at the vertical midpoint of the unit at a perpendicular distance of approximately 24 inches from the surface of the boiler (tankless heater), or 24 inches from both the boiler and tank jacket. Provide an associated temperature measurement and indicator system to assure that the temperature indicated for the thermocouple location is within $\pm 1^\circ\text{F}$ of the actual temperature at that location.

7.2.2.7 Thermocouple Installation

7.2.2.7.1 Thermocouple installation for domestic water storage

tanks of integrated water heaters - Install six thermocouples inside the tank. Position each thermocouple measuring junction along a vertical line at the level of the center horizontal plane of each of six non-overlapping sections of approximately equal volume from the top to the bottom of the tank such that each

thermocouple is surrounded by water and as far as possible from any heat input device, anodic protective device or a tank wall. The anodic protective device may be removed in order to install the thermocouples and all testing may be carried out with the device removed. Install thermocouples in both the cold-water inlet pipe and the hot-water outlet pipe not more than 18" from the connections to the water heater, or where those connections are inaccessible, at the closest accessible point to those connections. Locate the thermocouples downstream of two elbows, or a turbulator, to assure good mixing.

7.2.2.7.1.1 Mean tank temperature measurement - Mean tank temperature of the water in an integrated heater tank, wherever specified shall be the mean of the temperatures determined by using the six heater tank thermocouples.

7.2.2.7.2 Thermocouple installation for gas-and oil-fired tankless water heaters - Install thermocouples in both the cold water inlet pipe and the hot water outlet pipe not more than 18" from the connections to the heat exchange unit. Locate the thermocouples downstream of two elbows, or a turbulator, to assure good mixing. Install a thermocouple to measure the boiler water temperature in the location where the control well is normally installed. The thermocouple shall extend into the boiler water a distance equal to 2/3 the length of the control well supplied with the boiler. The thermocouple may be inside the well, or outside at the same level and within 1" of the well, but not touching the coil.

7.3 TYPE II APPLIANCES

7.3.1 Water Heating Function Requirements - For water heating function of storage type appliances refer to 10 CFR 430⁽³⁾ - Subpart B, appendix E of the Federal regulations. For water heating performance of instantaneous type appliances refer to ANSI Z21.10.3-1984.⁽⁴⁾

7.3.2 Space heating function requirements.

7.3.2.1 Installation - Install the water heater according to the manufacturer's installation instructions on a 3/4-inch thick plywood platform elevated approximately 4" off the floor by three 2" x 4" runners. For water heaters without integral heat traps and with vertical inlet and outlet pipe connections, install the inlet and outlet piping with heat traps at the inlet and outlet ports. Such heat traps may be made using pipe fittings such as elbows connected in such a fashion that the inlet and the outlet piping make vertically upward runs just before turning downward to connect to the inlet and outlet ports. For water heaters with integral heat traps or with horizontal inlet and outlet pipe connections, install the inlet and outlet piping in any convenient fashion.

Sufficient clearance shall be allowed between the water heater surface and the piping (including heat traps, if any) so that when the piping is insulated as specified below, the insulation does not contact any water heater surface except at the location where the pipe connections penetrate the water heater jacket. Insulate the relief valve and the water heater inlet and outlet piping (including heat traps, if any) for a length of four feet from the connection at the water heater with a material having a thermal resistance (R) value of not less than

$$4 \frac{\text{hr F}}{\text{Btu}}$$

7.3.2.2 Flue Requirements

7.3.2.2.1 Gas-Fired Water Heaters - For a gas water heater having a vertically discharging draft hood outlet, a 5 foot vertical flue pipe extension having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For a gas water heater having a horizontally discharging draft hood outlet, a 90 degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A 5 foot length of flue pipe shall be

connected to the elbow and oriented to discharge vertically upward. Perform all tests with the natural draft established by this length of flue pipe. (See figure 8) Direct vent gas water heaters shall be installed with venting equipment as specified by the manufacturer's instructions. If the manufacturer specifies optional or adjustable venting equipment, the arrangement that will result in the highest flue loss shall be used during testing of the direct vent water heater.

7.3.2.2.2 Oil-Fired and Power Gas-Fired Water Heaters - For an oil fueled or power gas-fired water heater, establish a draft at the flue collar equivalent to at least 0.02 inch of water column during periods of burner firing. For a water heater having a vertically discharging flue outlet, establish the draft by using a sufficient length of flue pipe connected to the water heater flue outlet and oriented to discharge vertically upward. For a water heater having a horizontally discharging flue outlet, a 90 degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the flue outlet. A length of flue pipe sufficient to establish the draft shall be connected to the elbow fitting and oriented to discharge vertically upward. Direct vent water heaters should be installed with venting equipment as specified in the manufacturer's instructions.

7.3.2.3 Energy Supply

7.3.2.3.1 Electrical Supply - For an electric water heater and for the auxiliary electrical system, if any, of an oil or gas water heater, maintain the electrical supply voltage to within ± 5 percent of the center of the voltage range specified by the water heater manufacturer on the water heater nameplate throughout the entire operating portion of each test.

7.3.2.3.2 Natural Gas - For a gas water heater utilizing natural gas maintain the gas supply at a normal inlet test pressure immediately ahead of all controls of 7 to 10 inches of water column. Use natural gas with a higher heating value of approximately 1,025 Btu per standard cubic foot. Determine the actual higher heating value, H, in Btu per standard cubic foot, for the natural gas to be used in the test, with an error no greater than ± 1 percent, and use that value for all calculations included herein. Alternatively, the test can be conducted using "bottled" natural gas of a higher heating value of approximately 1,025 Btu per standard cubic foot as long as the actual higher heating value of the bottled natural gas has been determined with an error no greater than ± 1 percent as certified by the supplier.

7.3.2.3.3 Propane Gas - For a gas water heater utilizing propane gas, maintain the gas supply at a normal test pressure immediately ahead of all controls of 11 to 13 inches of water column. Use propane with a higher heating value of approximately 2,500 Btu per standard cubic foot. Determine the actual higher heating value, H, in Btu per standard cubic foot, for the propane to be used in the test, with an error no greater than ± 1 percent, and use that value for all calculations

included herein. Alternatively, the test can be conducted using "bottled" propane of a higher heating value of approximately 2,500 Btu per standard cubic foot as long as the actual higher heating value of the bottled propane has been determined with an error no greater than ± 1 percent as certified by the supplier.

7.3.2.3.4 Oil Supply - For an oil water heater, use fuel oil with a heating value of approximately 138,500 Btu per gallon at 70°F. Determine the actual higher heating value, H, in Btu per gallon for the fuel oil to be used in the test, with an error no greater than ± 1 percent, and use that value for all calculations included herein. Alternatively, the tests can be conducted using a tested fuel oil with a certified higher heating value other than 138,500 Btu per gallon as long as the actual higher heating value of the test fuel oil has been determined with an error of no greater than ± 1 percent as certified by the supplier.

7.3.2.4 Thermocouple Installation

7.3.2.4.1 Tank - Install six thermocouples inside the water heater tank. Position each thermocouple along a vertical line which is centrally located on the approximate center of a section of the tank away from any heat source or other irregularity. The level of each thermocouple measuring junction shall be the center of each of six horizontal sections of approximately equal volume. The anodic protective device may be removed in order to install the thermocouples and all testing may be carried out with the device removed.

- 7.3.2.4.2 Piping - Install thermocouples in both the cold-water inlet pipe and the hot-water outlet pipe not more than 18 inches from the connections to the water heater, or where those connections are inaccessible, at the closest accessible point to those connections. Locate the thermocouples downstream of two elbows, or a turbulator, to assure good mixing.
- 7.3.2.4.3 Ambient - Install a thermocouple with junction shielded against direct radiation from the water heater and positioned at the vertical mid-point of the heater at a perpendicular distance of approximately 24 inches from the surface of the water heater jacket.
- 7.3.2.5 Fuel or Energy Consumption Measurement - Install one or more instruments which measure, as appropriate, the quantity and rate of electrical energy, natural gas, propane and fuel oil consumed by water heater and auxiliary devices.
- 7.3.2.6 Thermocouple installation in Flue Pipe - For determining flue temperatures install a 5 thermocouple grid 12" above the jacket top. Arrange the thermocouples in a grid with one thermocouple in the center of the test stack, and the remaining as shown in Fig. 9. If there is a possibility that the thermocouples could receive direct radiation from the flame, install radiation shields on the flame side of the thermocouple only and position the shields so that they do not touch the thermocouple junctions.

8.0 TEST SETUP

- 8.1 GENERAL - Type I and Type II combination space heating/water heating appliances shall be equipped with the apparatus described in 7, and the instrumentation described in 6 shall be set up for recording data. Refer to Figures 1 through 10 when equipping the Type I and Type II appliances with the apparatus and instrumentation. The equipment shall be adjusted to the test requirements or conditions described in 8.4.

8.1.1 Test Unit - Type I and Type II combination space heating/water heating appliance.

8.1.1.1 Integrated Units - Install the unit according to the manufacturer's directions. Install the connecting piping between the boiler and the storage tank as recommended by the manufacturer.

8.1.1.2 Tankless Units - Tankless water heaters shall be installed in the boiler or in the external tank containing boiler water. The boiler shall be equipped with a pressure relief valve. Expansion of the water during the test shall be provided for.

8.1.1.3 Storage Tank Units - Install the appliance according to the manufacturer's installation instructions. Appliance shall be equipped with a pressure and temperature relief valve.

8.1.1.4 Instantaneous Units - Install the appliance according to the manufacturer's installation instructions.

8.2 AIR, WATER, AND ELECTRICAL

8.2.1 Water Supply - During the entire test maintain the water supply to the appliance inlet at a temperature of between 56F and 60F, and at a gauge pressure of between 40 pounds per square inch and the maximum pressure specified by the manufacturer for the appliance under test. If the water supply pressure varies outside of these limits during testing, the heater shall be isolated by use of a shut-off valve in the supply line with an expansion tank installed in the supply line downstream of the shut-off valve. There shall be no shut-off means between the expansion tank and the water heater inlet.

8.2.2 Room Ambient Temperature - Maintain the ambient air temperature of the test room between 65F and 70F at all times during the test, as measured according to section 7.2.2.6 or 7.3.2.4.3.

8.3 POWER INPUT DETERMINATION - Initiate normal operation of the appliance and determine the power input, Q_{in} , to the main burners (including pilot light power, if any) or heating elements of the appliance under test, in Btu per hour or kilowatts, as appropriate. (Also see 8.3.3)

- 8.3.1 For gas fired appliances, adjust the fuel rate to achieve an hourly Btu input that is within ± 2 percent of the hourly Btu rating specified by the manufacturer as measured 15 minutes after initiation of appliance operation. If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure at normal test pressure shall be within $\pm 10\%$ of the manufacturer's specified manifold pressure.
- 8.3.2 For oil fired appliances, adjust the burner to obtain an hourly Btu rating with the CO_2 reading in accordance with the manufacturer's instructions as measured 15 minutes after initiation of appliance operation. The fuel pump pressure shall be within $\pm 10\%$ of the manufacturer's specified pump pressure.
- 8.3.3 For electric appliances with immersed heating elements, the power input, Q_{in} to the heating element shall be taken to be the design power rating of the heating element as indicated on the appliance rating plate. For an electric water heater with dual immersed heating elements, the power input, Q_{in} to the heating elements shall be taken to be the arithmetic mean of the design power ratings of the heating elements, if, in characteristic operation of the appliance, only one heating element will be energized at any time; otherwise, Q_{in} shall be taken to be the sum design power ratings of the heating elements.
- 8.4 SETTING THE TANK THERMOSTAT, TYPE II APPLIANCES (where applicable)
- 8.4.1 Single Thermostat - Starting with a tank of supply water, initiate normal operation of the appliance. After cutout, determine whether the maximum value of the mean tank temperature is within the range of $135 \pm 5\text{F}$. If not, turn off the appliance, adjust the thermostat, refill with supply water, then initiate normal operation of the appliance, and once again determine the maximum mean temperature after cutout. Repeat this sequence until the maximum mean tank temperature after cutout is within the range of $135\text{F} \pm 5\text{F}$, at which time the thermostat is properly set.

8.4.2 Two Thermostats - If an appliance has two thermostats, the upper thermostat shall be set first to yield a maximum water temperature of 135F $\pm$ 5F as measured by the topmost tank thermocouple after cutout as described in 8.4.1. The lower thermostat shall then be set to yield a maximum mean tank temperature of 135F $\pm$ 5F after cutout as described in 8.4.1.

8.4.3 Non-adjustable Thermostat - Remove the non-adjustable thermostat and replace it with an adjustable thermostat installed at the same location, and follow 8.4.1.

8.5 SETTING CONTROL OF TYPE I INTEGRATED WATER HEATER - Starting with a tank of unheated water, initiate normal operation of the unit. After thermostat cutout, determine whether the maximum mean tank water temperature is within the range of 135F $\pm$ 5F. If not, turn off the unit, adjust the thermostat, empty the tank and refill with unheated water, then initiate normal operation of the unit, and once again determine the maximum mean tank water temperature after cutout. Repeat this sequence until the maximum mean tank water temperature after thermostat cutout is within the range of 135F $\pm$ 5F, at which time the thermostat is properly set. The boiler limit control shall be set not higher than 210F.

8.6 SETTING CONTROL OF TANKLESS WATER HEATER - Starting with a boiler full of unheated water, initiate normal operation of the boiler. After cutout, determine whether the maximum temperature measured by the thermocouple installed at the control well is within the range of 180F $\pm$ 5F, or the nominal setting recommended by the manufacturer's installation instructions, if higher. If not, turn off the boiler, adjust the water temperature control, empty the boiler and refill with unheated water, then initiate normal operation of the boiler and once again determine the maximum temperature at the well after cutout. Repeat this sequence until the maximum temperature at the control well after cutout is within the range of 180F $\pm$ 5F, or the nominal setting recommended by the manufacturer's installation instructions, if higher, at which time the control is properly set. The differential setting of the control shall be set to 10F, or the setting nearest 10F, when a 10F setting is not provided. The boiler limit control shall not be set higher than 210F.

8.7 FLOW RATE FOR SIMULATED - USE TEST - The simulated-use test specifies six equal draws of U/6 gallons each during a 24 hour period. (U=60 gal.)

8.7.1 Systems with Storage of Domestic Water - The flow rate shall be 3 ± 0.25 gpm and the outlet water temperature (T_o) shall not fall below 115 F at any time during a draw. If necessary, the flow rate may be adjusted to a lower value in order that the outlet water temperature does not fall below 115F.

8.7.2 Systems Without Storage of Domestic Water - The flow rate shall be set to achieve a difference between the average outlet water temperature and inlet water temperature (ΔT) of 77F $\pm$ 3F.

9.0 TEST PROCEDURE

9.1 TYPE I APPLIANCES

9.1.1 Space heating - Space heating tests shall be conducted according to ASHRAE 103 - 1982⁽¹⁾ and the Federal Register of March 28, 1984 (49 FR 12148).⁽²⁾

9.1.1.1 There are no test requirements for electric appliances installed in the heated space.

9.1.2 Water heating - Water heating tests shall be conducted according to the following sections.

9.1.2.1 Tank Storage Capacity Determination - Determine the storage capacity, V, of the integrated unit tank, in gallons, according to the method specified in section 2.28 of the American National Standard for Gas Water Heaters, Volume I, designated ANSI Z21.10.1-1984.⁽⁶⁾ No storage capacity measurement is necessary for tankless water heaters.

9.1.2.2 Simulated Use Test

9.1.2.2.1 Initial Conditions - Initiate normal operation of the boiler and heater with the controls set as specified in sections 8.5 or 8.6. After initial cutout, or a subsequent cutout, draw U/6 gallons at the rate determined in 8.7.1 or 8.7.2. Thirty minutes later again draw U/6 gallons at the same rate.

9.1.2.2.2 Simulated Test Conditions - When the burner and circulator (if used) shut off, start the 24 hour test clock following the second preliminary draw. After approximately 18 hours have elapsed, conduct six equal draws of U/6 gallons initiated one hour apart at the draw rate determined in 8.7.1 or 8.7.2.

At the beginning of the test, and at each 15 minute interval, record supply water temperature (T_i), water temperature at the outlet (T_o), air temperature (T_a), and boiler water temperature (T_b). Determine energy input for the 24 hour period (Q_{rs}) and the 18 hour period (Q_{sb}). Collect or meter the water drawn (U_s). The total shall be $U \pm 2\%$. Record the electrical usage for the 24 hour period ($C_{aux.}$) and for the 18 hour period ($C_{aux.sb}$), including a circulator if used. Stop the test after 24 hours have elapsed. For appliances with storage tanks, the mean stored water temperature shall also be recorded at 15 minute intervals throughout the 18 hour standby period.

9.1.2.2.3 Measurements During Draw Periods - Record supply water temperature (T_i) and outlet water temperature (T_o) at the start and at continuing 15 second intervals during all draw periods. Determine the average temperature difference, ΔT , for all the water drawn.

9.1.2.3 First Hour Draw Test

Initiate normal operation of the boiler and heater with the controls set as specified in Section 8.5 or 8.6.

At initial cutout start the test by drawing water at a rate of 3 ± 0.25 gpm. Start readings of outlet water temperature at 15 seconds after start of draw and repeat every 15 seconds until the outlet water temperature drops 20F, or to a minimum of 115F. Stop the draw and read inlet water temperature and boiler water temperature.

Repeat this procedure at each cutout until one hour is completed. Collect and weigh the water drawn, or use a calibrated meter to determine the total water drawn (G).

If the hour terminates during a draw, turn off the burner at the end of the hour but continue the water draw until the outlet water temperature has dropped 20F. If the hour terminates outside a draw, turn off the burner at the end of the hour, and initiate a final draw which is continued until the outlet water temperature has dropped to the lowest level of the previous draw.

9.2 TYPE II APPLIANCES

9.2.1 Space heating - Space heating tests shall be conducted according to the requirements for boilers in ASHRAE 103-1982⁽¹⁾ and the Federal Register of March 28, 1984 (49 FR 12138)⁽²⁾, except as noted below:

9.2.1.1 During the steady state test determine the CO₂F (in the flue) and CO₂S (in the stack) with the draft control device supplied by the manufacturer in its normal position.

9.2.1.2 For determining flue temperatures, consider the units as having an integral draft diverter. Use a 5 thermocouple grid.

9.2.1.3 The normal thermostat setting shall be bypassed and the burner operated manually in order to avoid shutdown of the burner during the test.

9.2.1.4 Begin cool-down test by setting the control of the unit to pilot position or turning the burner to the off position if there is no pilot position, and closing off the supply and water valves.

9.2.2 Water heating - Water heating tests shall be conducted in accordance with Section 9.1.2, or, if appropriate, in accordance with 10 CFR 430 - subpart B, appendix E, or, if appropriate, in accordance with ANSI Z21.10.3 (1984).⁽³⁾

10.0 DATA TO BE RECORDED

10.1 NOMENCLATURE

α	oversize fraction
CAE	combined annual efficiency
C_{aux}	auxiliary electric input, as measured, kWh
$C_{aux.sb}$	standby loss test auxiliary electric input, kWh
DD	degree days, base 65F
DHR	design heating requirement, Btu per hour
EF	energy factor, water heating
E_{FS}	energy factor, summer
E_{FW}	energy factor, winter
E_r	recovery efficiency
E_t	thermal efficiency
$Effy_{hs}$	space heating seasonal efficiency
$Effy_{ss}$	steady state space heating efficiency
F	first hour rating, gallons
G	volume of water drawn during first hour test, gallons
H	fuel higher heating value, Btu per lb., Btu per cu.ft. Btu per gallon
k	specific heat of water, Btu/gal. F
NHLF	non-heating season load factor
Q_{in}	energy input rate, Btu per hour.
Q_{rs}	total energy input, Btu
Q_{sb}	standby loss energy input, Btu
R	ratio of non-heating season hours to heating season hours
S	standby loss (storage type), hr. ⁻¹

SHLF	space heating load factor
T_a	air temperature, F
T_b	boiler water temperature at control location, F
T_i	inlet water temperature, F
T_m	arithmetic mean of outlet water temperature, F
T_o	outlet water temperature, F
ΔT	difference between average outlet water temperature and inlet water temperature, F
ΔT_1	Difference between average outlet water temperature and average inlet water temperature during all draws of the simulated use test, F
ΔT_2	Difference between the mean stored water temperature at the start of the simulated use test to the initiation of the first draw, F
ΔT_3	Difference between the average mean stored water temperature and the average ambient air temperature during the standby portion of the simulated use test, F
U	60 gallons per day of hot water consumption
U_s	gallons drawn during the simulated use test
V	storage volume, gallons
WHLF	water heating load factor

TYPE I and TYPE II APPLIANCES HEATING TEST LOG SHEET

Manufacturer _____ By _____ Date _____

Model No. _____ Fuel _____ Nameplate Input _____

Remarks: _____

☐ Type I ☐ Type II

[illegible]

Time	Tracer Gas		Pilot
	Temp.	Flow	
3:45			
22:30			
45:00			

Barometer

[illegible]

11.0 CALCULATIONS

11.1 TYPE I APPLIANCES

11.1.1 Space Heating Function - Space heating parameters shall be calculated for indoor installation, isolated combustion system installation, or outdoor installation, as applicable, in accordance with the procedures of as specified in Section 11 of ANSI/ASHRAE Standard 103-1982, Methods of Testing for Heating Seasonal Efficiency of Central Furnaces and Boilers as supplemented by Section 4.0 of the Federal Register of March 28, 1984 (49 FR 12148) with the inclusion of the following additional requirements.

11.1.1.1 For electric appliances $Eff_{ys} = Eff_{yh}$

11.1.2 Water heating function - The following calculations shall be performed:

11.1.2.1 First hour rating - Calculated the first hour rating, F, expressed in gallons and defined as:

$$F = G \times \frac{T_m - T_i}{77}$$

where:

F = first hour rating, gal.

G = volume of water drawn, gal.

T_m = arithmetic mean of outlet water temperature, F

T_i = inlet water temperature, F

77 = temperature rise of water, F

11.1.2.2 Energy Factor - The energy factor is calculated by dividing the energy delivered in the hot water draws during the 6 hour draw period by the energy consumption in the total 24 hour test period. This equation is as follows:

$$EF = \frac{(8.25 * U_s * \Delta T_1)}{(Q_{rs} + 3413 * C_{aux})}$$

where:

8.25 = density of water, lb./gal.

U_s = amount of water drawn during the simulated use test, gal.

ΔT_1 = difference between average outlet water temperature and average inlet water temperature during all draws of the simulated use test, F

Q_{rs} = total energy input, Btu

C_{aux} = auxiliary electrical input, kWh

11.1.2.3 Recovery Efficiency - Calculate the recovery efficiency as follows:

For appliances with storage tanks:

$$E_r = \frac{8.25 * U_s * \Delta T_1 + [(h + 6)/h] * 8.25 * V * \Delta T_2}{(Q_{rs} + 3413 * C_{aux}) - [(h + 6)/h] * (Q_{sb} + 3413 * C_{aux-sb})}$$

where:

Q_{rs} = total energy input, Btu

C_{aux} = auxiliary electrical input, kWh

Q_{sb} = energy input during the standby period, Btu

C_{aux-sb} = auxiliary electric input during the standby period, kWh

h = the number of hours from the start of the simulated use test to the initiation of the first draw (the standby period)

V = storage volume in gallons as determined in 9.1.2.1

ΔT_2 = the difference between the mean stored water temperature at the start of the simulated use test and the initiation of the first draw, F.

11.1.2.4 Standby Loss - For appliances with storage tanks, the standby loss in hour⁻¹ shall be determined as follows:

$$S = \frac{U_s * \Delta T_1 * (1/EF - 1/E_r)}{24 * V * \Delta T_3}$$

where:

ΔT_3 = the difference between the average value of the mean stored water temperature and the average value of the ambient air temperature during the standby portion of the simulated use test, F.

11.2 TYPE II APPLIANCES

11.2.1 Space heating function - Space heating parameters shall be calculated for indoor installation, isolated combustion system installation, or outdoor installation, as applicable in accordance with the requirements for boilers as specified in Section 11 of ANSI/ASHRAE Standard 103-1982.⁽¹⁾ Methods of Testing for Heating Seasonal Efficiency of Central Furnaces and Boilers as supplemented by Section 4.0 of the Federal Register of March 28, 1984 (49 FR 12148)⁽²⁾ with the inclusion of the following additional requirements.

11.2.1.1 For electric appliances, $Effy_{ss} = Effy_{hs}$

11.2.2 Water heating function - One of the following calculations shall be performed, depending on the method of test.

11.2.2.1 DOE Procedure - For those heaters covered by DOE rules, 10 CFR 430⁽³⁾ subpart B, appendix E of the Federal Regulations shall be followed to obtain EF.

11.2.2.2 ANSI Z21.10.3 1984⁽⁴⁾ - For instantaneous heaters the value of E_t and S shall be obtained in accordance with paragraph 2.8 THERMAL EFFICIENCY, and 2.9 STANDBY LOSS, ANSI Z21.10.3 1984.⁽⁴⁾

$$EF = \frac{E_t}{1 + \frac{C_{aux} \times 3413}{Q_{in}}}$$

where:

E_t = thermal efficiency, %.

C_{aux} = auxiliary electrical usage, kWh

Q_{in} = fuel input rate, Btu/hr.

11.3 COMBINED SPACE AND WATER HEATING ANNUAL FUEL UTILIZATION EFFICIENCY (CAE)

11.3.1 Heating Season - Space Heating Load Factor (SHLF) shall be obtained from:

$$SHLF = \frac{Effy_{ss}}{Effy_{hs}} \times \frac{65-42}{65-5} \times \frac{DD}{5200} \times \frac{1}{1 + \alpha}$$

where:

DD = the local number of heating degree days with a 65F base

α = the oversize fraction of the space heating output as determined from:

$$\frac{(Q_{in}) (Effy_{ss})}{(DHR)} - 1$$

where:

Q_{in} = the input rate at maximum rated input Btu/h.

$Effy_{ss}$ = the steady state efficiency expressed as a decimal.

DHR = the design heating requirement (Btu/h) from ASHRAE 103-1982, Table C-1

11.3.2 Heating Season - Water Heating Load Factor (WHLF)

Calculate the water heating load factor applicable during the space heating season as:

$$WHLF = \frac{U(77) (8.25) (1.0)}{(Q_{in})(Effy_{ss}) (24)}$$

where:

U = the gallons per day of hot water consumption

77 = temperature rise of water F.

8.25 = density of water at the average stored water temperature (Lb/Gal)

1.0 = specific heat of water (Btu/Lb F)

Q_{in} = the input rate in Btu/h

$Effy_{ss}$ = as determined in 11.1.1 or 11.2.1

24 = hours per day

11.3.3 Non-Heating Season Load Factor (NHLF) - Calculate the non-heating season load factor (for water heating only) as:

$$\text{NHLF} = \frac{(U)(77)(8.25)(1.0)}{(Q_{in})(EF)(24)}$$

where:

U, 77, 8.25, 1.0, Q_{in} , and 24 are defined in 11.3.2.

EF is the water heating energy factor as determined in 11.1.2.2 or 11.2.2.

11.3.4 Calculation of CAE - Calculate CAE, Combined Annual Efficiency, from:

$$\text{CAE} = \frac{(\text{SHLF})(\text{Effy}_{hs}) + (\text{WHLF})(\text{Effy}_{ss}) + (R)(\text{NHLF})(EF)}{(\text{SHLF}) + (\text{WHLF}) + (R)(\text{NHLF})}$$

where:

SHLF as defined in 11.3.1

Effy_{hs} as determined in 11.1.1 or 11.2.1

WHLF as defined in 11.3.2

Effy_{ss} as determined in 11.1.1 or 11.2.1

NHLF as defined in 11.3.3

EF as determined in 11.1.2 or 11.2.2

R = Ratio of non-heating season hours to heating season hours.

11.3.5 Season Efficiencies

11.3.5.1 The heating season efficiency can be obtained from

$$\text{Heating Season Eff.} = \frac{(\text{SHLF})(\text{Effy}_{\text{hs}}) + (\text{WHLF})(\text{Effy}_{\text{ss}})}{(\text{SHLF}) + (\text{WHLF})}$$

11.3.5.2 The non-heating season efficiency is obtained by

$$\text{Non-heating Season Eff.} = \frac{(R)(\text{NHLF})(\text{EF})}{(R)(\text{NHLF})} = \text{EF}$$

11.3.6 Optional Method of Calculating CAE - for combined space heating/

water heating Type II appliances intended to be installed as isolated combustion systems, the CAE term may be optionally calculated as follows:

$$\text{CAE} = \frac{E_r}{1 + \left(\frac{1}{[26.5 U/E_r Q_{\text{in}}] + 0.475 \text{SHLF}_{\text{II}}} - 1 \right) \frac{635 V S}{Q_{\text{in}}}}$$

where:

E_r = recovery efficiency as determined in 11.2.2

P = input rate in Btu/h as determined in 11.2.2

V = storage volume determined in 11.2.2

S = standby loss determined in 11.2.2

U = hot water consumption in gallons/day
from 11.2.2

$$\text{SHLF}_{\text{II}} = (0.225) (DD/5200) [(1.7)/(1+\alpha)] [1/(1-635*v*S/Q_{\text{in}})]$$

and:

$$26.5 = \left(\frac{77 \times 8.25}{24} \right)$$

$$635 = 77 \times 8.25$$

$$0.475 = \left(\frac{8760 - 4600}{8760} \right)$$

$$1.7 \times 0.225 = \left(\frac{65 - 42}{65 - 5} \right)$$

11.3.7 Comparison of Combined Appliance Efficiency with Efficiencies of Single Function Appliances.

For a methodology enabling comparison of a combined appliance with single function appliances see Appendix A.

12.0 REFERENCES

1. "Methods of Testing for Heating Seasonal Efficiency of Central Furnaces and Boilers," ANSI/ASHRAE Standard 103-1982, American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329, 1982.
2. Federal Register , March 28, 1984, 49 FR 12148, U.S. Government Printing Office, Washington, DC 20402, 1984.
3. Federal Regulations, 10 CFR 430, U.S. Government Printing Office, Washington, DC 20402.
4. "Gas Water Heaters Volume III: Circulating Tank, Instantaneous and Large Automatic Storage Water Heaters," ANSI/AGA Standard Z21.10.3-84, American Gas Association, 8501 East Pleasant Valley Road, Cleveland, OH 44131, 1984.
5. "Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels," ANSI/ASTM Standard D2156-80, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, 1980.
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TYPE I APPLIANCES
TYPICAL PIPING ARRANGEMENT
TANKLESS HEATER IN BOILER

FIGURE 1

TYPE I APPLIANCES
TYPICAL PIPING ARRANGEMENT
INTEGRATED WATER HEATER - DOMESTIC WATER IN TANK

FIGURE 2

TYPE I APPLIANCES
TYPICAL PIPING ARRANGEMENT
TANKLESS WATER HEATER - BOILER WATER IN TANK

FIGURE 3

TEST FLUE FOR OIL OR POWER GAS FIRING
FIGURE 4

TEST FLUES AND STACKS FOR ATMOSPHERIC GAS FIRING
FIGURE 5

SUGGESTED OIL BURNER TEST SETUP
FIGURE 6

SUGGESTED ATMOSPHERIC GAS BURNER TEST SETUP
FIGURE 7

TYPICAL TEST SETUP STORAGE TANK WATER HEATER
FIGURE 8

TYPE II COMBINATION SPACE HEATING/
WATER HEATING APPLIANCE

FIGURE 8 A
ALTERNATIVE PIPING ARRANGEMENT

TYPE II COMBINATION SPACE HEATING/
WATER HEATING APPLIANCE

CO_{2s} before blocking draft hood
CO_{2f} after blocking draft hood
and restricting flue

Space heating test setup

FIGURE 9

SUGGESTED ELECTRICAL ARRANGEMENTS

FIGURE 10

APPENDIX A

Allocation of Fuel Consumption to Space Heating and Water Heating

The combined annual efficiency of the combined appliance is expressed by CAE. The annual efficiency for each function of the appliance was not determined explicitly, but an arbitrary allocation of the total annual fuel requirements can be made to establish sets of annual efficiency terms which would yield identical annual fuel consumption. The resulting compatible annual efficiency terms can then be used to indicate compliance with standards based on the performance of individual appliances.

I. Equal Annual Efficiencies for Space Heating and Domestic Water Heating (Type I or Type II Appliances)

If it is desired to designate equal annual efficiencies for space heating and domestic water heating the following relationships apply:

$$\text{Annual Space Heating Efficiency (ASHE)} = \text{CAE}$$

$$\text{Annual Water Heating Efficiency (AWHE)} = \text{CAE}$$

II. Annual Space Heating Efficiency Established at ANSI/ASHRAE Standard 103-1982⁽¹⁾ AFUE Level (Type I Appliances only)

The Combined Annual Efficiency (CAE) of the combination appliance can be defined as:

$$\text{CAE} = \frac{\text{Annual Output}}{\text{Annual Input}} = \frac{\text{ASHL} + \text{AWHL}}{\frac{\text{ASHL}}{\text{ASHE}} + \frac{\text{AWHL}}{\text{AWHE}}} \quad (1)$$

where

ASHL = Annual Space Heating Load in Btu
AWHL = Annual Water Heating Load in Btu
ASHE = Annual Space Heating Efficiency
AWHE = Annual Water Heating Efficiency

Solving this expression for the Annual Water Heating Efficiency (AWHE) gives:

$$\text{AWHE} = \frac{\text{CAE}}{1 + \frac{\text{ASHL}}{\text{AWHL}} \left(1 - \frac{\text{CAE}}{\text{ASHE}}\right)} \quad (2)$$

For a Type I appliance,

$$\text{ASHE} = \text{AFUE} \quad (3)$$

where:

AFUE is determined from ANSI/ASHRAE 103-1982⁽¹⁾

The annual space heating load is determined from

$$ASHL = (4160) (Q_{in}) (SHLF) (Effy_{hs})$$

where:

4160 = National average heating season hours
 Q_{in} = Appliance input in Btu/h
 SHLF = Space Heating Load Factor as determined in 11.3.1
 $Effy_{hs}$ = Heating Seasonal Efficiency as determined from
 ANSI/ASHRAE 103-1982 "

The annual water heating load is

$$AWHL = (U) (365) (8.25) (77)$$

where:

U = Daily hot water usage in gallons
 365 = Days in year
 8.25 = Heat content of water in Btu/gal-F
 77 = Temperature rise of water in F

The ratio of these two loads is

$$\frac{ASHL}{AWHL} = \frac{(Q_{in}) (SHLF) (Effy_{hs})}{(55.74) (U)} \quad (4)$$

Substituting (3) and (4) into (2) gives:

$$AWHE = \frac{CAE}{1 + \frac{(Q_{in}) (SHLF) (Effy_{hs})}{55.74 (U)} (1 - \frac{CAE}{AFUE})} \quad (5)$$

If the type I appliance does not have a standing pilot, then $AFUE = Effy_{hs}$ and (5) simplifies to:

$$AWHE = \frac{8760}{4160/Effy_{ss} + 4600/EF}$$

where:

$Effy_{ss}$ as determined in 11.1.1

EF as determined in 11.1.2

If the Type 1 appliance were used for space heating only and domestic water heating is provided by a separate water heater, it would require a water heater with an Energy Factor (EF) equal to AWHE to provide the same total annual energy consumption as the combination appliance providing both functions. Therefore, the combination appliance can be considered to have an effective domestic water heating EF equal to AWHE.

III. Annual Water Heating Efficiency Established at CFR 10 Energy Factor Level (Type II Appliances Only)

Solving (1) for Annual Space Heating Efficiency (ASHE) gives:

$$ASHE = \frac{CAE}{1 - \left(\frac{AWHL}{ASHL}\right) \left(\frac{CAE}{AWHE} - 1\right)} \quad (6)$$

For a Type II appliance,

$$AWHE = EF \quad (7)$$

where:

EF is determined from CFR 10

Substituting (4) and (7) into (6) yields:

$$ASHE = \frac{CAE}{1 - \frac{(55.74)(U)}{(Q_{in})(SHLF)(Eff_{yhs})} \left(\frac{CAE}{EF} - 1\right)} \quad (8)$$

If the optional method of determining CAE as provided for in 11.3.6 is employed, the space heating efficiency is given by a comparable expression.

$$ASHE = \frac{CAE}{1 - \frac{(55.74)(U)}{(Q_{in})(SHLF_{II})(E_r)} \left(\frac{CAE}{EF} - 1\right)} \quad (9)$$

where:

$SHLF_{II}$ = as determined in 11.3.6

E_r = Recovery Efficiency as determined from CFR 10.

If the water heating Energy Factor (EF) of the type II appliance is based on not having heat traps on the outlet water connection and the inlet water connection as integral parts of the appliance and also is based on not consuming any auxiliary electric energy, then (9) simplifies to:

$$ASHE = \frac{E_r}{1 - (77)(8.25)(S)(V)/Q_{in}}$$

where:

E_r = Recovery Efficiency as determined in 11.2.2

S = Standby Loss as determined in 11.2.2

V = Storage Volume as determined in 11.2.2

Q_{in} = Btu/h Input as determined in 11.2.2

If the Type II appliance were used for domestic water heating only and space heating is provided by a separate furnace/boiler, it would require a furnace/boiler with an Annual Fuel Utilization Efficiency (AFUE) equal to ASHE to provide the same total annual energy consumption as the combination appliance providing both functions. Therefore the combination appliance can be considered to have an effective space heating AFUE equal to ASHE.

APPENDIX B

Determination of Combined Annual Efficiency (CAE) for Installations with Single Function Appliances

The Combined Annual Efficiency (CAE) of an installation consisting of a single function appliance providing the space heating plus a single function appliance providing water heating can be determined from the following expression:

$$\frac{\text{ANNUAL OUTPUT}}{\text{ANNUAL INPUT}} = \frac{\text{ASHL}}{\text{AFUE}} + \frac{\text{AWHL}}{\text{EF}} \quad (1)$$

where:

ASHL = Annual Space Heating Load in Btu
AWHL = Annual Water Heating Load in Btu
AFUE = Annual Fuel Utilization Efficiency of the space heating appliance as determined from ANSI/ASHRAE Standard 103-1982 ⁽¹⁾
EF = Energy Factor of the water heating appliance as determined from DOE procedures outlined in CFR 10

The annual space heating load is

$$\text{ASHL} = [(65-42)/(65-5)] (4160) (\text{DHR}) = (1595) (\text{DHR}) \quad (2)$$

where:

4160 = Hours in heating season
DHR = Space Heating Design Heating Requirement in Btu/h

The annual space heating load can also be expressed as

$$\text{ASHL} = \frac{(1595) (Q_{\text{out}})}{(1 + \alpha)} \quad (3)$$

where:

Q_{out} = Heating capacity of space heating appliance in Btu/h
= Oversize fraction = $(Q_{\text{out}}/\text{DHR}) - 1$

The annual water heating load consistent with the DOE Energy Factor of the water heating appliance is

$$\text{AWHL} = (60) (365) (77) (8.25) = 13,911,975 \quad (4)$$

NATIONAL AVERAGE CONDITIONS

1. National Average SHLF:

$$SHLF = \frac{Effvss}{Effyhs} \times \frac{65-42}{65-5} \times \frac{5200}{5200} \times \frac{1}{1.7}$$

$$SHLF = \frac{Effvss}{Effyhs} \times .3833 \times 1 \times .5882$$

$$SHLF = 0.225 \times \frac{Effvss}{Effyhs}$$

2. National Average R:

$$R = \frac{4600}{8760-4600}$$

$$R = 1.1$$

3. Example:

Assume an appliance with the following:

$$Q_{in} = 50,000 \text{ Btuh}$$

$$\text{Heating Capacity} = 40,000 \text{ Btuh}$$

$$Effy_{ss} = 80\%$$

$$Effy_{hs} = 73\%$$

$$EF = .55$$

From Table C-3, ASHRAE 103-1982 " DHR = 25

$$SHLF = .225 \times \frac{.80}{.73} = .247$$

$$WHLF = \frac{60 \times 77 \times 8.25 \times 1.0}{50,000 \times .80 \times 24} = .04$$

$$NHLF = \frac{60 \times 77 \times 8.25 \times 1.0}{50,000 \times .55 \times 24} = .058$$

$$CAE = \frac{(.247 \times .73) + (.04 \times .80) + 1.1 (.058 \times .55)}{.247 + .04 + 1.1 (.058)} = .7052$$

or 70.52% for national average conditions.

**RETROFIT SAVINGS FOR DUAL INTEGRATED APPLIANCES
IN SMALL COMMERCIAL AND MULTIFAMILY BUILDINGS**

INTERIM REPORT

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INTRODUCTION

A dual integrated appliance is defined as a unit that provides both domestic hot water and space heat to a building. There are generally three types of dual integrated appliances (DIA). The first consists of a boiler which has a primary function of producing space heat, but has either an integral heat exchanger or a separate storage tank, heat exchanger, and pump for producing domestic hot water (DHW). The second type of appliance is a water heater that has the primary function of supplying DHW but includes a separate heating coil and pump for producing space heat. The third type has a primary function of supplying both DHW and space heat. This study examines only a type II DIA, or otherwise called combination heater. For the remainder of the report the term DIA is considered to indicate a type II DIA.

A typical DIA system configuration is displayed in Figure 1. The heater water hot outlet supplies not only DHW but also water to a heating coil. When space heat is required, a pump circulates hot water through the heating coil and returns it to either to the cold water inlet or separate inlet. A check valve is included on the heating coil supply pipe so that cold water is not drawn through the heating coil when there is a DHW draw in the building. The heating coil can be located near the heater or remote and is available in vertical, horizontal, and wall-recessed units. If the proper materials are used, fin tube baseboards can be used in place of a fan coil; however that is not the preferred configuration. The building thermostat typically activates both the blower and circulation pump. Installations can incorporate a time delay relay on the blower which reduces the small period of time that cool air is supplied to the heating registers. The heater is controlled as it would be for a typical heater, by an aquastat inserted in the tank.

A DIA has many advantages compared to a separate furnace and water heater:

- 1) There is only one combustion appliance to maintain or replace.
- 2) Side or vertical venting will typically be easier for a DIA.
- 3) Using a horizontally mounted air handler provides a reduction in the required floor area for the mechanical system.
- 4) The heating supply system is easier to zone and zones are easier to add after the initial installation.
- 5) For comparable heating appliances, the DIA off-cycle losses are lower.

However, a DIA system also has the following disadvantages:

- 1) When the system is recovering from a temperature setback and has a large DHW draw, there will be an increased recovery time for both the DHW and building air temperatures.
- 2) The range of input and efficiency for approved DIA heaters is limited.
- 3) The DIA system is relatively new to the Twin Cities Metropolitan area. There are fewer contractors experienced with installing DIA systems and some cities may be hesitant in allowing them to be installed.

In many cases, the advantages of a DIA system will outweigh the disadvantages.

DIA systems have had a greater market penetration in the warmer climates of the southern states, but there are appropriate selected markets in colder climates. DIA systems are generally best suited to locations which have relatively high DHW loads. In this situation, it may not be necessary to increase the heater size from the level that would have been used with a separate system. Higher loads on the heater will also usually make it cost effective to use a more efficient heater. This study targets two markets as being appropriate for DIA systems: small commercial businesses and multi-family buildings that have space heat and DHW provided on an individual unit basis.

This study is designed to assess the applicability of dual integrated appliances in small commercial and multi-family buildings. Ten systems are installed at five small commercial and five multi-family locations. The savings of the DIA systems are determined by systematically comparing the measured gas use of the DIA systems to that of the existing systems. Two of the systems are more intensively monitored in order to measure their seasonal efficiency. Various methods of computing the combined DIA seasonal efficiency are examined. The field measurements are applied to these methods in order to compare the energy use of the DIA systems to separate systems with different efficiencies. Finally, the field experiences of installing and operating the DIA systems are reported. This section discusses equipment sizing, code issues and city approval, equipment availability, and equipment malfunctions. This interim report presents information on the installed equipment and the preliminary results of the gas use analysis. The final report will be submitted after the 1990/91 heating season.

SITE SELECTION AND DESCRIPTION

This study targeted two markets: multi-family buildings with unit-level heating and DHW equipment and small commercial buildings. 10 sites were selected for the study based primarily on the potential to achieve energy savings using a DIA system and also the capability of demonstrating savings. One of the important factors for achieving savings is the size of the domestic hot water load. The increased usage of the integrated system, compared to a DHW only separate system, usually will make it cost effective to use a heater with a higher recovery efficiency. With a higher recovery efficiency, the absolute savings will be greater for buildings with higher DHW loads. A second source of savings is the reduced off-cycle losses of a single appliance compared to a heater and furnace. However, the reduction in total off-cycle losses may only be realized if the increase in the heater size does not significantly increase the loss rate. Thus, a second factor considered for building selection was the increase in the heater size required to meet both the building DHW and space heat loads.

Another important consideration is the availability of acceptable water heaters. In order to achieve savings for the space heating load, the heater recovery efficiency must be at least as high as the AFUE of the furnace under consideration. The National Appliance Energy Conservation Act (NAECA 1987)

has established a minimum AFUE standard of 78% for furnaces with inputs less than 225,000 Btu/hr manufactured after January 1992. Table 1 lists a total of 34 natural gas heaters from four manufacturers that are specified for use as integrated appliances. 14 of the heaters have recovery efficiencies of 78% or above, but only four of these have inputs greater than 40,000 Btu/hr (at the time of the installations, the authors were not aware of the two units with inputs of 57,500 and 75,500 Btu/hr). The lack of available efficient equipment limited the DIA systems to either sites with low to moderate heating loads or ones with higher loads that could justify the cost of using the expensive (list price of \$3,200), condensing heater with an input of 100,000 Btu/hr.

Small multi-family units meet many of the stated criteria for successful DIA system application. Typically, small multi-family units have heaters with inputs that range from 30,000 to 40,000 Btu/hr. Similar sized heaters, with recovery efficiencies of 78%, can handle heating loads from 19,000 to 26,000 Btu/hr (see later section on equipment sizing). A slightly increased heater size of 55,000 Btu/hr, with a recovery efficiency of 80%, can handle a heating load of 35,000 Btu/hr. This should be sufficient for units with floor areas of 1000 ft² or less that are built to the more recent higher energy efficiency standards. Thus, small multi-family units meet the criteria of having heater sizes that are either sufficient or would be only increased slightly to meet the heating load. Also, there are numerous manufacture approved DIA heaters of the required size that meet the efficiency requirements. Since it is not expected that the level of DHW load would normally be known or considered when selecting a DIA system, DHW use was not used as a selection criteria for the multi-family sites. Consequently, relatively new multi-family units with floor areas less than 1000 ft² were considered for the study.

Certain small commercial businesses are expected to be good candidates for DIA systems. Those with high, but not excessive, DHW loads (e.g. hair salons but not laundromats) or which have heaters that do not require significant increases in heater input are most promising. The following businesses were among those identified as potentially having high DHW loads: sandwich shops, bakeries, dog grooming salons, hair styling salons, and doctors offices. The second selection criteria was the heater input required to meet the heating load. Due to limitations of available equipment, sites were considered which had relatively low heating loads that could be satisfied with only slightly larger heaters and sites with heating loads high enough to require the high input, condensing heater. Sites were also considered if they could demonstrate an innovative use of a DIA system.

The capability of accurately determining the savings from the DIA retrofit was also a consideration. The sites needed to have few or no changes during the previous and upcoming year which would significantly effect the DHW and space heat loads. This required that the building occupants and their activities would not change, the existing equipment was expected to last for another year, and no significant modifications would be made to the building thermal envelope. It was also necessary to select sites which had monthly gas use which was adequately modelled by outdoor temperature. The energy analysis for some of the sites was to be performed by comparing the normalized annual energy use of the existing system to the use of the retrofit DIA system. For these sites, a more stringent selection criteria was applied to the results of the gas use model.

The candidate buildings were found from previous contacts with CEUE and Minnegasco or from listings in the phone directory. A total of 25 multi-family and 26 small commercial sites agreed to be considered for acceptance into the study and had their fuel bills analyzed. Sites were removed from consideration due to poorly modelled gas use, possibilities for future load changes, or incompatible heating load levels. For their participation in the study, the owners received the retrofit equipment for the equivalent cost of three years of savings.

The five multi-family units are all located in a single, two story, eight-plex built in the early 1980. A description of each of the units is contained in Table 2. All of the units have ground entrances and two stories. They are built in a single row with four two-bedroom and four three-bedroom units. The four three-bedroom units occupy the two end and center positions. The three two-bedroom units used in the study have floor areas of 675 ft² and engineering estimated (e.g. heating contractor computed) design heat loss of 20,000 Btu/hr. The design heat loss estimated from the gas use analysis (17,400 to 21,100 Btu/hr) showed good agreement with the contractor computation. The two three-bedroom end units used in the study have floor areas of 930 ft² and engineer heat losses of 27,000 Btu/hr. This loss rate also agreed well with the gas use analysis estimates of 26,600 and 25,500 Btu/hr. The loss rates of 20,000 and 27,000 Btu/hr fell within the range for available equipment. The annual base (DHW and stove) use estimated from the gas use analysis ranged from 30 to 37% (211 to 371 ccf) of the total for all the units, except #72 which had a relatively higher base use of 52% (436 ccf). Each unit had one or two adult occupants and two children - except #64, which had no children.

All of the units had the same furnace and water heaters. The furnaces had inputs and outputs of 55,000 and 42,000 Btu/hr respectively and AFUEs of 60.3% (see bottom of Table 3). They appear to be greatly oversized for the building design heat loss, but were probably the smallest furnaces readily available in the Minneapolis metro area at the time they were installed. The water heaters have an input of 36,000 Btu/hr and storage capacities of 40 gallons.

The five small commercial sites are located in the Minneapolis Metropolitan area. Due to the unanticipated difficulty of finding "ideal" sites, the selection criteria were relaxed in some cases in order to complete the installations during the winter of 1990. The two medical offices (#3920 and #3925) have low annual base loads of 9 and 12% (120 and 164 ccf) consisting almost entirely of DHW use (see Table 4). The design heat losses from gas use analysis for sites 3920 and 3925 are 42,700 and 44,200 Btu/hr respectively and the annual heating usages are 1208 and 1201 ccf. The design and construction of the buildings are similar to single family homes and have floor areas of 2,900 and 3,600 ft² - including basement area. A description of the existing equipment at the small commercial sites is displayed in Table 5. The two medical offices have similar type furnaces with AFUEs of 65.8%. The input for the furnace at #3920 is lower, 110,000 Btu/hr compared to 165,000 Btu/hr for the one at #3925. The heater at #3920 has an input of 33,000 Btu/hr, storage capacity of 30 gallons, and recovery efficiency of approximately 70%. The heater at #3925 is more than double the size. It has an input of 75,000, storage capacity of 63 gallons, and recovery efficiency of approximately 76%.

In contrast to the medical offices, the sandwich shop (#4409) and dog grooming salon (#4207) have relatively large annual base uses of 36 and 40% (496 and 382 ccf) respectively (see Table 4). These base uses are more than a factor of two greater than that usually found for small commercial businesses (German et al. 1988) and provided a better match to the selection criteria than the medical offices. Site 4409 has a floor area of 3,350 ft² and a design heat loss of 54,200 Btu/hr. However, the furnace that is being used for comparison in this study is only used to heat the rear of the shop. A roof-top unit is used to heat the front sandwich preparation and customer service section. Site 4207 has a floor area of 1,400 ft² and a design heat loss of 26,000 Btu/hr. The existing equipment at #4409 consisted of a furnace with an input of 50,000 Btu/hr and AFUE of 71.4%. The water heater had an input of 38,000 Btu/hr, storage capacity of 40 gallons, and recovery efficiency of 73% (see Table 5). The existing equipment at #4207 was comparatively larger. It consisted of a furnace with an input of 80,000 Btu/hr and AFUE of approximately 66%. The heater had an input of 40,000 Btu/hr, storage capacity of 30 gallons, and recovery efficiency of 70%.

The final small commercial site is a combination bagel shop and bakery. The reported annual gas use and design heat loss are somewhat misleading. The furnace and water heater were connected to the same meter that supplies gas to the bagel cooker. Thus, a significant portion of the reported base use is due to the cooker. In addition, it appears that the heat from the cooker and ovens is sufficient to heat the building on most days. Although this site is not a good candidate for obtaining accurate and substantial energy savings, it is useful for demonstrating an innovative DIA application.

INSTALLED SYSTEMS

Dual integrated appliances are a relatively new type of system that do not have an extensive history to guide equipment sizing and system design. Firm guidelines are in the process of being developed. The sizing considerations for DIA systems include the heating coil output, heater output, and heater storage capacity. The standard practices that are used for other systems to determine the heat output based on the design heat loss, safety factor, and pick up load can also be used for sizing the heating coil output. A report has recently been published which uses a simplified model of system operation to recommend guidelines for sizing DIA systems for multi-family and single family applications (Pietsch and Talbert 1989). The authors assumed that an adequately sized integrated system should be able to "recover from a large hot water draw in one hour or less, while also supplying the space heat load". The recommended "rule of thumb", was that the heater output should typically be 1.2 times the rated coil output. In addition, the storage capacity should be between 3 to 5 times the peak hot water draw. For units without laundries this would require a storage of 40 to 50 gallons but 50 to 75 gallons may be required for units with laundries.

The heater output requirement was somewhat more conservative than that specified by a gas utility (EOGC 1987):

$$Q_o = (Q_d + 12,700)/E_r \quad (1)$$

where:

- Q_o = heater output [Btu/hr]
- Q_d = design loss [Btu/hr]
- E_r = recovery efficiency, fraction

However, the recommended heater output was higher than that of one manufacturer which specifies that the heater output should be equal to or greater than the heating coil output (AHHC 1987). The manufacturer also does not recommend increasing the storage capacity above that normally recommended for the building use (but states that the capacity should not be less than 40 gallons). In general, the DIA systems for this study followed the guideline of having heater outputs at least a factor of 1.2 times the heating coil output.

The State of Minnesota has recently adopted several DIA system design guidelines into the plumbing code (SM 1990). The entire code is included in this report as appendix A. In summary, the code requires the following design features:

- 1) A user controlled mixing valve for DHW.
- 2) A drainage port and isolation valves or purge control to prevent stagnation of heater coil water.
- 3) The unit must be specifically approved by the manufacturer as a integrated heater.
- 4) All components in the system must be approved for potable water.

All systems installed for this study met the code specifications outlined in (1), (3), and (4). However, since the installations were performed before the code went into effect, not all the systems included a drain port or intermittent purging of the heating coil. The systems all have similar controls. The existing thermostat was used to activate the pump and blower and the heater burner is controlled by its aquastat, as it would be under normal operation.

One of the difficulties of the study design was specifying the heating coil outputs of the DIA systems. Minnesota State Energy code, at the time of the installations, specified that the rated capacity of a heating system could not exceed 115% of the design load (SM 1985). However, all of the existing systems, except multi-family units 60 and 74, had capacities over 200% of the estimated design load. The system capacities of #60 and #74 were 155% of the design load. It was expected that matching the existing capacities would allow a better comparison to the existing systems, but would not provide a fair test of the DIA systems. A compromise was selected in which some systems were designed to either match the existing furnace output or use the maximum output available which would come as close as possible to the furnace capacity. Other systems used the design heat loss as a guide. One multi-family system was selected to match the output of two of the other multi-family DIA systems.

The five DIA systems installed in the multi-family units are described in Table 3. Each of the heaters has the same storage capacity of the old system, except the heater for #74 which is 10 gallons larger. The systems for the two larger units have coil outputs of 41,500 Btu/hr, which closely match the output of the furnace (42,000 Btu/hr). The recovery efficiencies are both 76%. The heater for #74 has an input of 65,000 Btu/hr and output of 49,400 Btu/hr. The output is nearly a factor of 1.2 times the heating coil output. The heater for #60 was slightly undersized, even by the manufactures guidelines. The heater output of 39,900 Btu/hr is only 96% of the rated coil output. It was decided to test two, recently available, systems which have integral heaters and air handlers. These are installed in two of the smaller units, #70 and #72, and have inputs of 40,000 Btu/hr, outputs of 33,200 Btu/hr, and coil outputs of 29,000 Btu/hr. The heating coil output is the highest available and is a compromise between the furnace output and the design load (145% of the design). The heater outputs are a factor of 1.14 times the coil output rated for the high fan flow. A similar sized unit, with separate heater and air handler, is installed in #64. The heater input and storage capacity is the same as for the integral unit, but the recovery efficiency, heater output, and coil output are all slightly larger. This site is expected to allow a comparison between the two types of DIA systems.

The five systems installed at the small commercial sites are described in Table 6. Sites 3920 and 3925 use the high input (100,000 Btu/hr) condensing heater with the largest available heating coil (67,000 Btu/hr). For #3920 the coil output is still 20% below the furnace capacity and for #3925 it is 47% below. With the high input and recovery efficiency of the heater, the heater output is a factor of 1.4 times the coil output. The heater storage capacity is four gallons more than the existing heater in #3920, but 29 gallons less than that in #3925. However, the gas use analysis indicates a low DHW load that could be satisfied by the smaller storage capacity.

The same system as that installed in multi-family unit #74 is installed in #4409. The coil output is closely matched with the furnace capacity (only 6% above) and the heater output is a factor of 1.19 times the coil output. The storage capacity is 10 gallons larger than the existing heater but both have similar energy factors. Since the recovery efficiency of the DIA heater is only 4.3% above the furnace AFUE, this is expected to serve as a good comparison of DIA and separate systems with similar efficiencies. Site 4207 is used as another test of the recently released integral heater and air handler. The coil output is only 112% of the design load and the heater output is a factor of 1.14 times the heater output. The storage capacity is 10 gallons larger than the existing heater and the energy factor is 31% higher.

The fifth small commercial site (#4412) was selected to demonstrate an innovative application of a DIA system. A single, high efficiency, condensing heater with an output of 94,000 Btu/hr is installed with two separate air handlers, heating, and cooling coils. A two-stage heating/single stage cooling thermostat sequentially activates the two heating coil pumps and air handlers. The system also incorporates a manually controlled outdoor air economizer. The rated coil output of the two coils combined is 134,000 Btu/hr. The over-capacity allows the heating coils to produce as much heat as the heater can generate. This is useful for occasions when maximum heat output is desired, such as recovery from setback. However, the coil over-

capacity will cause the heater temperature to drop when both air handlers and coil pumps are operated. The heater output is 23% less than the furnace but is a factor of 7 times the, somewhat uncertain, design load estimated from the gas use analysis. As previously discussed, the low design loss is probably due to the heat generated from the bakery and the uncertainty in the analysis due to the multiple appliances connected to the one gas meter.

EXPERIMENTAL DESIGN

The primary purpose of this study is to compare the energy use of a dual integrated appliance to that of an existing furnace and water heater. This is performed by analyzing the weekly or biweekly gas use of the two different systems. Two of the sites are also intensively monitored to measure the annual efficiency of the DIA systems. In addition, the final report will examine various methods of computing the combined annual efficiency of the separate and integrated systems and apply the field results to these methods.

Gas Use Analysis

The DIA systems were installed either in parallel with the existing systems or as a complete change out. When possible, the DIA systems were installed in parallel. This allowed alternating mode, or flip/flop tests to be performed on the two systems. This type of test has been successfully used by CEUE to perform various studies of energy retrofits (Hewett et al 1988; Hewett and Peterson 1984). The test is carried out by switching between the two systems every one or two weeks and recording the gas use by the active system. The inactive system is isolated so that it does not contribute to off-cycle losses. Isolation consists of switching water valves so that there is no flow through the heater, turning off pilot lights, and shutting off electrical power.

Due to space limitations, the five multi-family and two of the small commercial installations (#4207 and #4412) had to be complete change outs. At these sites, the existing equipment was completely removed and DIA systems installed in their place. The analysis at these sites is performed by comparing the gas use of the existing system from the previous year to that of the entire year following the installation (i.e. pre/post test). The monthly gas use records for the previous year were obtained from the local gas utility, Minnegasco.

Gas use is normalized for weather (i.e. outdoor temperature) using PRISM, the PRinceton Scorekeeping Method (Fels 1986). PRISM uses meter reading data and a historic weather file to fit a three parameter model of summer non-heating use, a heating slope, and the outdoor reference temperature below which heating is required. These three parameters are used with a table of long-term weather norms to yield an estimate of gas use in an average weather year. This state-of-the-art computer program is considered highly accurate in estimating normalized annual consumption.

Intensive Monitoring

Two of the sites are intensively monitored to measure the seasonal efficiency of the DIA systems. The useful energy output, DHW and heating coil, and

heater input are monitored in order to establish the relationship between the heater energy input and output. Heating and non-heating efficiencies will be computed and combined to estimate an annual system efficiency.

The data logging equipment and sensors have been installed at small commercial site 3920 and will also be implemented at site 4207. Hour averages or totals of each measured variable are recorded using a Hewlett Packard 3421A data acquisition and control unit and MetraByte CTM-05 counter/timer interface board operated by a IBM compatible computer. A complete list of the measured variables is displayed in Table 7 and a schematic of the sensors located on the DIA system is displayed in Figure 2. The data acquisition system monitors the heating coil flow rate, heating coil supply temperature, and return temperature in order to compute the heating coil energy output. The heater inlet water flow rate, inlet water temperature, and DHW supply temperature (after the mixing valve) are monitored in order to compute the DHW energy demand (or DHW output). The water temperatures are monitored using thermocouples placed on the surface of the pipes. In order to more accurately measure the temperature difference across the heating coil, the heating coil supply temperature is used as the reference temperature (i.e. the second thermocouple junction) for the heating coil return temperature. A similar arrangement is used for the DHW inlet and supply temperatures. The percentage of time that the existing heater, DIA heater, and furnace operate are multiplied by the respective energy input rates to compute the average energy input rates of the appliances. If an appliance has a standing pilot, the pilot use rate has been measured and is added to the average energy use of that appliance.

Additional air temperatures are also recorded in order to document the variation in the seasonal space heating load and examine any differences in building temperatures between the two systems. The temperature measurements are made with thermocouples and include the following locations: outdoor air, heating system supply and return air, upstairs and basement air, and data logger case. The number of times the existing heater, DIA heater, and furnace turn on are also recorded to document the cycling behavior of the appliances.

The monitoring system requires approximately one second to monitor a single channel. The complete set of variables is read in no longer than 30 seconds. Every one hour the time and average or total value of each variable are stored to a file on a floppy disk. The computer is connected to a modem and can be remotely accessed for data file transfer and the display of current data values.

RESULTS AND DISCUSSION

Gas Use Analysis

The present results of the gas use analysis are preliminary. Due to possible hysteresis and other seasonal effects, the analysis is most accurate using an entire year of data (Rachlin et al. 1985, Dunsworth and Hewett 1985). All of the systems were installed in the mid to later portion of the 1989/90 heating season and require further heating season data to obtain a full year of data. Gas use data has been collected at the multi-family sites over 2 to 3 week periods during the heating season and one month periods over the summer. The

data at the small commercial sites has been collected on a weekly basis during the heating season and biweekly thereafter. Biweekly gas use will continue to be recorded at all the sites until late March to early May, depending on the actual installation date of the particular system.

A pre/post test procedure is used to estimate the savings of the DIA systems in the five multi-family units. The seven or eight data values for the "pre" year of existing system use span from approximately November 1988 through October 1989. The result of the gas use analysis is displayed in Table 8 and show a good fit to the PRISM model. The standard errors for the normalized annual consumption (NAC) range from 1.1 to 3.7% (8 to 30 ccf/year) - well below the 5 or 10% limit commonly used for screening PRISM results (Dunsworth and Hewett 1985, Reynolds 1990). The NACs of the pre-period range from 705 to 1003 ccf/year with the three smaller units being lower than the two three-bedroom units.

The DIA systems were installed in early February, 1990. PRISM results from the 16 post-period measurements are also displayed in Table 8. Thus far, the savings for all the units except #74 are quite promising. The NACs of units 60, 64, 70, and 72 for the post-period range from 592 to 870 ccf/year and represent savings from 113 to 157 ccf/year or from 13.2 to 19.4%. There is not presently a clear, significant pattern of savings between the different types of DIA systems. It appears that the savings for these four units will be significant. The standard errors of the savings range from a factor of 0.20 to 0.32 of the computed savings. However, it is important to note that the DIA systems are being compared to furnaces with AFUEs of 60.2%. Further analysis, to be presented in the final report, is necessary to compare the energy use of the DIA systems to units that would be installed after the new NAECA standard takes effect in 1992 (NAECA 1987).

There has been a 17.2% increase in the energy use of unit 74. Unfortunately, there was a change of occupants about one month after the system was installed. Studies have shown that indential single family homes with different occupants can have more than a two to one variation in building energy use (Dutt et al. 1986) and that occupants effects are responsible for a significant portion of this variation (Sonderegger 1978). In fact, the two data values obtained with the DIA system while the original occupant was still present (designated "Post1" in Figure 3) show a decrease in the energy use of 13 to 16% from that predicted from the pre-PRISM model. While the two points obviously do not constitute conclusive evidence, they are consistent with savings estimates similar to those obtained in the other multi-family cases. However, each of the values for the second occupant (designated "Post2" in Figure 3) has been above that predicted by the pre-model. The PRISM results using data generated from the DIA system with only the second occupants (designated "Post2 PRISM" in Figure 3), show a base use increase of 14.1%, reference temperature increase of 3.0°F, and increase in the slope of 6.0%. However, the change in any the three individual parameters is not very statistically significant. Changes in the DHW use, indoor temperature, or window opening behavior could all contribute to changes in the energy use. It is likely that the DHW use has increased, since the new occupants have one more child and both children are older than the child of the original occupants.

The two medical offices had DIA systems installed in parallel with the existing systems and are analyzed using the alternating mode data. The DIA system installation was completed in January, 1990. The PRISM results for the existing and DIA system operation during the post-period are displayed in Table 9. The NAC of the existing system at #3920 is 1282 ccf/year and has a low standard error of 51 ccf/year. In comparison, the DIA system shows a savings of 241 ccf/year (18.8%). The relatively low standard error of 63 ccf/year for the savings indicates that they are statistically significant. The base use and heating slope of the DIA system are both comparatively lower than for the existing system. However, the reduction in the base use is not significant compared to the standard errors of the existing and DIA system base uses. The results for site 3925 are very similar. The NAC of the existing system is 1217 ccf/year with a low standard error of 27 ccf/year. The DIA savings are 252 ccf/year (20.7%) and are statistically significant, with a standard error of 45 ccf/year. The DIA system also shows reduced base use and heating slope. Since the existing and DIA systems at these two sites are similar, the similarity of their savings was expected.

The pre and post-period NACs of the existing system at #3920 differ by only 46 ccf/year. However, there is a decrease of 148 ccf/year of the NAC at #3925. This is probably due to the numerous window openings while the building was being partially renovated during the pre-period. There is sufficient heating season data and consistency between the pre and post-periods to indicate that the savings estimates will not change considerably with the addition of more heating season data.

The DIA system at site 4409 was installed in parallel with the existing furnace and water heater in early March, 1990. Since there is little 1989/90 heating season data, the post-period results are very preliminary. The PRISM results, shown in Table 9, indicate a savings of 841 ccf/year (50.5%). However, the post-period NAC for the existing system have increased by an unexpected 20.8%. In addition, the post-period results for the DIA system show a remarkable decrease in the heating slope (88%) and increase in the reference temperature (20.4°F). As indicated by the post-period results displayed in Figure 4, the data for the two systems collected to this date does not appear to be significantly different. Further heating season data is required for accurate results.

The DIA system at site 4207 was a complete change out and was completed in mid April, 1990. The pre-period data, pre-period PRISM model, and post-period data is displayed in Figure 5. There have been 15 measurements made during the post-period; however, this data contains only 184 degree days and only three measurements have average outdoor temperatures below 50°F. The PRISM results for the post-period are inconclusive. The DIA NAC is 4.7% greater than that for the existing system, but the standard error of the difference in use is greater than the actual difference in use. In fact, there does not appear to be any significant difference between any of the pre/post PRISM parameters. Further data is required to draw significant conclusions.

The DIA system at site 4412 was a complete change out and was installed in mid February, 1990. As previously discussed, this system was installed primarily to demonstrate an innovative application of a DIA system. Due to the gas use of the large cooking appliances and the small dependence on outdoor temperature, this site was not expected to show significant energy savings.

The data for the pre and post-periods is displayed in Figure 6 and shows that there is generally an increase of 22.7% in average energy use for the post-period. This increase is entirely due to a statistically significant increase in the base use. However, neither period shows much dependence on outdoor temperature. In fact, the PRISM results for both periods (see Table 9) meet the "flatness index" criteria, with coefficients of about 4%. Data with a coefficient lower than 11% is considered to be unmodelable by PRISM (Reynolds 1990). The inability of PRISM to determine a proper reference temperature for either period confirms that the data is unmodelable.

It is unlikely that the increase in the base use (5.4 ccf/day or 22,500 Btu/hr) could be due to a difference in efficiency of the existing and DIA heaters. It is possible that other factors could be influencing the building energy use. The street in front of the store was under construction during the pre-period and was completed about the time the DIA system was installed. Information on the relative sales volume will be examined as a possible explanation for the increase in building energy use.

CONCLUSIONS

The gas use results for all 10 sites are preliminary and require further heating season data. Gas use measurements will continue to be collected until the mid or end of the 1990/91 heating season. The present results from the multi-family units indicate a 13.2 to 19.4% savings for the DIA systems in the four units that did not have a change in occupant. The energy use in the fifth unit has increased by 17.2%, but this is most likely due to the change in occupants that occurred shortly after the system was installed. It is important to note that the existing equipment included furnaces with AFUEs of 60.3%. The savings demonstrated in this study would be lower if the DIA systems were compared to the more efficient furnaces and heaters that will be required after January, 1992.

The results from two of the small commercial sites (#3920 and #3925) which installed high efficiency, condensing heaters, show savings of 18.8 and 20.7%. Further data are not expected to significantly change these results. The remaining three small commercial sites have more limited heating season data. The results from sites 4409 and 4207 show a savings of over 50% and an increase of 4.7% respectively. Numerous inconsistencies in the modelled data indicate that these results are not yet significant and may change with further heating season data. The final small commercial site (4412) was primarily used to demonstrate an innovative installation of a DIA system. The average energy use at this location has increased by 22.7%. This is most likely due to changes in other uses in the building and does not necessarily reflect the differences in efficiencies of the existing and DIA systems.

The final report will include an examination of possible methods for computing the combined efficiency of the DIA and separate equipment. This should allow a comparison of the DIA system efficiency to more efficient equipment. In addition, the results from the intensive monitoring and a qualitative summary of the field experiences will be reported.

DEFINITIONS

Annual Fuel Utilization Efficiency (AFUE) - A rating of the annual efficiency of an appliance that is based on average input, losses, and on and off cycling using procedures specified by the US Department of Energy.

Dual Integrated Appliance (DIA) - A system that uses a water heater to supply both domestic hot water and space heat to the building. ASHRAE defines a type I appliance as "An appliance whose primary design function is space heating and which has a secondary function of domestic water heating" (ASHRAE 1990). A type II appliance is defined to be "An appliance whose primary design function is domestic water heating and which has a secondary function of space heating".

Energy Factor (EF) - A measure of the overall efficiency of a water heater based on the model's recovery efficiency, standby loss, and energy input.

Recovery Efficiency - The percentage of energy put into the water compared to the total energy used by the water heater.

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APPENDIX A: Minnesota Plumbing Code: Chapter 4715
As in effect July 16, 1990

Section 4715.2190 Combination Water and Space Heating Equipment.

Equipment used for heating domestic or service hot water and for space heating must be installed with a mixing valve to permit the user to control the temperature of the domestic or service hot water regardless of the space heating demand.

The installation must include a drainage port and isolation valve to permit the user to purge the heating coils to waste after the non-heating season, or the system must be designed to automatically prevent stagnation.

The water heater must be specifically designated by the manufacturer for use as a combination hot water and space heater.

All pipes, joints, and appurtenances in the system must be of a type approved for potable water distribution. This provision is not intended to address the wall thickness of heating coils, which must be the responsibility of the manufacturer.

Figure 1

Typical DIA System Configuration

Figure 2

DIA System with DAS Sensors

Figure 3

Residential DIA Gas Use Results

Figure 4

Small Commercial DIA Gas Use Results

Figure 5

Small Commercial DIA Gas Use Results

Figure 6

Small Commercial DIA Gas Use Results

Table 1

Available DIA Heaters

Manufacturer specified for DIA use

Input (BTU/Hr)	Storage Capacity (Gal)	Recov. Eff (%)	Energy Factor	Burner Type	Vent Type	List Price (\$)	Availability
38,000	40	85	0.60	Atmospheric	Vertical	\$250	immediate
38,000	40	76	0.58	Atmospheric	Side	\$308	immediate
38,000	40	NA	0.56	Sealed	Direct	\$387	2 weeks
40,000	40	83	0.64	Power, Sealed	Side	\$445	immediate
40,000	40	80	0.62	Atmospheric	Vertical	\$341	2 weeks
40,000	40	85	0.61	Atmospheric	Vertical	\$625	4 weeks
40,000	50	85	0.60	Atmospheric	Vertical	\$461	2 weeks
40,000	50	85	0.59	Atmospheric	Vertical	\$298	immediate
40,000	40	78	0.59	Atmospheric	Direct	\$738	2-3 weeks
40,000	50	85	0.58	Atmospheric	Vertical	\$730	4 weeks
40,000	40	76	0.57	Atmospheric	Vertical	\$450	4 weeks
40,000	40	76	0.57	Atmospheric	Vertical	\$550	4 weeks
40,000	50	78	0.57	Atmospheric	Direct	\$793	2-3 weeks
40,000	40	85	0.55	Atmospheric	Vertical	\$248	2 weeks
40,000	50	76	0.54	Sealed	Direct	\$431	2 weeks
40,000	40	75	NA	Sealed	Vertical	\$713	4 weeks
40,000	40	76	NA	Atmospheric	Direct	\$787	4 weeks
42,000	50	76	0.57	Atmospheric	Side	\$344	immediate
48,000	50	76	NA	Sealed	Vertical	\$792	4 weeks
48,000	50	76	NA	Atmospheric	Direct	\$892	4 weeks
52,500	40	76	0.54	Atmospheric	Vertical	\$575	4 weeks
52,500	40	76	0.54	Atmospheric	Vertical	\$485	4 weeks
52,500	50	76	0.52	Atmospheric	Vertical	\$605	4 weeks
52,500	50	76	0.52	Atmospheric	Vertical	\$705	4 weeks
55,000	75	80	NA	Atmospheric	Vertical	\$1,075	4 weeks
57,500	40	80	0.59	Atmospheric	Vertical	\$310	2 weeks
60,000	50	76	0.52	Atmospheric	Vertical	\$426	2 weeks
65,000	50	76	0.52	Atmospheric	Vertical	\$655	4 weeks
65,000	50	76	0.52	Atmospheric	Vertical	\$755	4 weeks
75,100	75	76	0.48	Atmospheric	Vertical	\$903	4 weeks
75,100	75	76	0.48	Atmospheric	Vertical	\$953	4 weeks
75,500	62	80	NA	Atmospheric	Vertical	\$533	2 weeks
83,000	100	76	NA	Atmospheric	Vertical	\$1,453	4 weeks
100,000	34	94	0.90	Power, Sealed	Side	\$3,278	immediate

NA - Not Available

Table 2

Building Description Multifamily Units

Building ID	# of Occupants		Floor Area (ft^2)	Unit Location	Design Heat Loss		Annual Gas Use			
	Adults	Children			Engineering (Btu/hr)	Gas Use* (Btu/hr)	Heating		Base	
							(%)	(ccf)	(%)	(ccf)
60	1	2	930	End	27,000	26,600	63	632	37	371
64	1	0	675	Interior	20,000	21,100	70	494	30	211
70	1	2	675	Interior	20,000	22,000	70	566	30	242
72	2	2	675	Interior	20,000	17,400	48	403	52	436
74	2	2	930	End	27,000	25,500	68	609	32	286

* - estimated from PRISM gas use analysis at -19F design temperature

MFTAB1

Table 3

Description of DIA Equipment Multifamily Units

Build. ID	Heater Input (Btu/hr)	Heater Output* (Btu/hr)	Coil Output** (Btu/hr)	Storage Capacity (gal)	Recov. Eff. (%)	Energy Factor	Comb. Eff. (%)	Flue Temp. (F)	Vent Type	Installed Cost (\$)
60	52,500	39,900	41,500	40	76	0.54	77.6	471	vert. nat	2,212
64	40,000	34,000	30,000	40	85	0.61	81.2	310	vert. nat	2,067
70	40,000	33,200	25,000	40	83	0.64	84.5	275	power, side	2,809
72	40,000	33,200	25,000	40	83	0.64	85.6	257	power, side	2,809
74	65,000	49,400	41,500	50	76	0.52	78.3	423	vert. nat	2,212
old equip.	36,000	NA	NA	40	NA	0.49	77.2	494	vert. nat	

* - computed from (heater input) (recovery eff.)

** - rated at inlet temperature = 140F

Old furnace: Input = 55,000 Btu/hr, Output = 42,000 Btu/hr
AFUE = 60.3%

New Furnace	
AFUE (%)	replacement cost
70	\$1,200
80	\$1,350

MFTAB2

Water heater replacement cost = \$400 (EF=0.5)

Table 4

Building Description Small Commercial Buildings

Building ID	Type of Business	Floor Area** (ft ²)	Design Heat Loss* (Btu/hr)	Annual Gas Use			
				Heating		Base	
				(%)	(ccf)	(%)	(ccf)
3920	Doctors Office	2,900	42,700	91	1208	9	120
3925	Dentist Office	3,600	44,200	88	1201	12	164
4409	Sandwich Shop	3,350	54,200+	64	881	36	496
4207	Dog Grooming	1,400	26,000	60	572	40	382
4412	Bagel Shop/Bakery	4,000	13,200	7	592	93	7869

* - estimated from PRISM gas use analysis at -19F design temperature

** - includes first floor and basement area

+ - a portion of heating load satisfied by roof top unit in the front section of the shop

SCTAB1

Table 5

Description of Existing Equipment Small Commercial Buildings

Build. ID	Furnace Input (Btu/hr)	Furnace Output (Btu/hr)	AFUE (%)	Water Htr. Input (Btu/hr)	Water Htr. Output (Btu/hr)	Storage Capacity (gal)	Recov. Eff. (%)	Energy Factor
3920	110,000	84,000	65.8	33,000	23,100	30	70	NA
3925	165,000	126,000	65.8	75,000	57,000	63	76*	0.54*
4409	50,000	39,000	71.4	38,000	27,740	40	73	0.51
4207	80,000	62,000	66*	40,000	28,000	30	70	0.49
4412	160,000	121,600	66*	NA	NA	NA	NA	NA

NA - information not available

SCTAB2a

Table 6

Description of DIA Equipment Small Commercial Buildings

Build. ID	Heater Input (Btu/hr)	Heater Output* (Btu/hr)	Heating Coil Output** (Btu/hr)	Storage Capacity (gal)	Recov. Eff. (%)	Energy Factor	Burner Type	Vent Type	Installed Cost (\$)
3920	100,000	94,000	67,000	34	94	0.90	power, sealed	side	2,850
3925	100,000	94,000	67,000	34	94	0.90	power, sealed	side	2,875
4409	65,000	49,400	41,500	50	76	0.52	atmospheric	vert.	2,809
4207	40,000	33,200	29,000	40	83	0.64	power, sealed	side	2,848
4412	100,000	94,000	134,000	34	94	0.90	power, sealed	side	5,680

* - computed from (heater input) (recovery eff.)

** - rated at inlet temperature = 140F

9-TAR2b

Table 7

Data Acquisition System Channel Description

Sensor Name	Description	Type of Sensor
RTpump	Percent runtime of heating coil pump	Electrical relay Resistance
EVpump	Number of times pump turns on	Electrical relay Resistance
RTfurn	Percent runtime of furnace	Electrical relay Resistance
EVfurn	Number of times furnace turns on	Electrical relay Resistance
Retair	Heating system return air temperature	T-type Thermocouple
supair	Heating system supply air temperature	T-type Thermocouple
RTpolr	Percent runtime of DIA Heater	Electrical relay Resistance
EVpolr	Number of times the heater turns on	Electrical relay Resistance
Fcoil	Heating coil flow rate	Paddle wheel type flow meter
Tclsup	Heating coil supply temperature	T-type Thermocouple
Tclret	Heating coil return temperature	T-type Thermocouple Differential
Ecoil	Heating coil energy output	Calculated from flow and temperature difference
Gasuse	Building gas use	Gas meter switch
RTheat	Percent runtime of existing heater	Pressure differential switch
EVheat	Number of times existing heater turns on	Pressure differential switch
Fdhw	Domestic hot water flow	Nutating disk positive displacement flow meter
Tdhsup	DHW supply temperature	T-type Thermocouple
Tdhinl	DHW cold water inlet temperature	T-type Thermocouple Differential
Edhw	DHW energy demand (output)	Calculated from flow and temperature difference
Tout	Outdoor temperature	T-type Thermocouple
Tbase1	Basement air temperature	T-type Thermocouple
Tupst	Upstairs air temperature	T-type Thermocouple
Thp	DAS temperature	Internal

Table 8

Results of PRISM Gas Use Analysis

Multifamily Units

Build. ID	Pre*				Post**				NAC Savings	
	NAC	Base	Slope	Tref	NAC	Base	Slope	Tref	(%)	(ccf)
	(ccf)	(ccf/day)	(ccf/F day)	(F)	(ccf)	(ccf/day)	(ccf/F day)	(F)		
60	1003 (23)	1.01 (0.11)	0.105 (0.008)	56.7 (3.2)	870 (12)	0.97 (0.04)	0.082 (0.004)	58.0 (1.2)	13.2	133 (26)
64	705 (8)	0.58 (0.05)	0.084 (0.003)	56.0 (1.6)	592 (35)	0.60 (0.08)	0.084 (0.016)	49.3 (3.5)	16.0	113 (36)
70	808 (30)	0.67 (0.17)	0.083 (0.008)	60.0 (4.5)	651 (23)	0.67 (0.07)	0.061 (0.008)	59.7 (3.1)	19.4	157 (38)
72	839 (10)	1.19 (0.06)	0.070 (0.004)	55.9 (2.4)	703 (32)	0.77 (0.07)	0.092 (0.015)	49.8 (2.9)	16.2	136 (34)
74+	895 (12)	0.78 (0.06)	0.100 (0.004)	57.2 (1.9)	1049 (31)	0.89 (0.07)	0.106 (0.010)	60.2 (2.1)	-17.2+	-154+ (33)

* - period spans November 1988 to October 1989

** - period spans February, 1990 to November 1990

+ - change of occupant, March 1990, post results for second occupant

Values in () are standard errors

Table 9

Results of PRISM Gas Use Analysis Small Commercial Buildings

Build. ID	Existing System				DIA System				NAC Savings	
	NAC	Base	Slope	Tref	NAC	Base	Slope	Tref	(%)	(ccf)
	(ccf)	(ccf/day)	(ccf/F day)	(F)	(ccf)	(ccf/day)	(ccf/F day)	(F)		
3920 Pre	1328 (36)	0.35 (0.19)	0.154 (0.009)	64.0 (2.4)						
Post	1282 (51)	0.31 (0.21)	0.198 (0.016)	56.3 (2.2)	1041 (36)	0.21 (0.17)	0.153 (0.012)	58.1 (2.5)	18.8	241 (63)
3925 Pre	1365 (36)	0.47 (0.20)	0.163 (0.009)	62.3 (2.7)						
Post	1217 (27)	0.44 (0.09)	0.194 (0.012)	54.2 (1.6)	965 (53)	0.11 (0.15)	0.147 (0.017)	58.0 (2.7)	20.7	252 (45)
4409 Pre	1377 (88)	1.73 (0.35)	0.262 (0.052)	43.0 (5.1)						
Post	1664 (153)	1.23 (0.06)	0.410 (0.081)	40.6 (1.6)	823 (105)	1.30 (0.23)	0.050 (0.027)	61.0 (10.9)	50.5	841 (186)
4207	954 (29)	1.04 (0.17)	0.107 (0.009)	53.7 (3.5)	999 (79)	0.98 (0.07)	0.116 (0.025)	54.6 (3.1)	-4.7	-45 (84)
4412+	8461 (219)	21.64 (1.27)	0.038 (0.028)	85.0*	10386 (81)	27.05 (0.48)	0.034 (0.012)	86.0*	-22.7	-1925 (234)

* - PRISM could not determine a proper reference temperature

+ - gas use includes cooking appliances

Values in () are standard errors

POLARIS®

MOR-FLO® / AMERICAN®
Comfort Systems™

Recovery Efficiency: +94 percent.

Stainless steel tank assures long life. No glass lining necessary.

Foam insulation with R-16 factor minimizes heat loss; meets California Title 24 requirements.

Stainless steel coiled flue transfers heat from flue gases to the water resulting in 94% recovery efficiency.

Bullet-shaped submerged stainless steel combustion chamber reduces conventional water heater heat loss, lime build-up and noise.

Burner generates intense heat that is forced through the combustion chamber and coiled flue by a powered combustion air blower.

Plastic vent pipes, which can be installed through the wall or roof at distances up to 40 ft., serve as combustion air inlet and flue gas outlet.

Negative pressure gas valve maintains uniform gas/air mixture for even, efficient combustion for a variety of inlet pipe applications.

Other features/benefits:

- Solid state electronic thermostat assures precise temperature control.
- LED indicator for Power, Igniter, Burner displays heater operation, simplifies troubleshooting.
- All flue connections are at the bottom of the water heater eliminating standby flue heat loss.
- Submerged combustion chamber allows for water heater to be installed with zero clearance to combustible building materials.
- Silicon carbide hot surface igniter heats to 2600° F to light burner flame. Solid state electronic control eliminates pilot flame and automatically shuts off gas should flame go out.
- All water connections, including additional side taps, are 1-in. nipples.
- Supplied condensate trap, wall-termination kit and tempering valve.

MOR-FLO / AMERICAN POLARIS

Gas Combo Comfort For Every Home

- TOTAL COMFORT FOR CUSTOM HOMES
- PENNY-PINCHING POWERHOUSE
- THE GAS ANSWER FOR ALL-ELECTRIC HOMES
- VERSATILITY
- GREAT FOR COMMERCIAL APPLICATIONS

POLARIS

Total Comfort For Custom Homes

Penny-Pinching Powerhouse

The Mor-Flo/American POLARIS is the only energy source you need for total home heating comfort — both space and water. With its power, versatility and quick recovery, the POLARIS is ideal for meeting the heating needs of any family in large, custom-built homes — in any climate. A single POLARIS with multiple Air Heaters™ brings consistent comfort to those hard-to-heat homes.

Richmond, Virginia:

A single POLARIS installed in a garage with 66-gallon storage tank provides all the hot water for this family's domestic use (including a whirlpool bath) and space heating.

POLARIS system with dual air handlers — one in the attic and one in the crawlspace — ensures comfortable zoned heat for this 4000+ sq-ft home.

POLARIS has the power and efficiency to economically satisfy all the space and water heating requirements of any home. With a condensing efficiency of +94%, the simple fact is there is no more efficient gas-fired system than POLARIS. This means plenty of hot water — more than 2 gallons per minute — with only 1/3 the standby heat loss of the best energy-efficient gas water heaters.

Pewaukee, Wisconsin:

These three homes, featured in the 1989 Parade of Homes in suburban Milwaukee, range from 2,873 to 3,400 sq ft. In each a single POLARIS water heater provides for all space and water heating requirements. Dual Air Heaters™ provide zoned heat. Since the POLARIS provides unmatched efficiency for

both space and water heating, it is the perfect system for energy-conscious homes.

The Gas Alternative All-Electric Homes

Versatility

POLARIS brings economical gas comfort to all-electric homes. Its condensing, low-temperature flue gases can be vented through an outside wall or roof with plastic pipe. When you choose POLARIS, you automatically convert both space and water heating to gas. Since it is a single gas appliance doing the job of a conventional furnace and water heater, the POLARIS can be the easiest, most economical conversion choice. This means one flue and one gas line instead of two. With POLARIS you can even utilize an existing air handler. POLARIS is environmentally friendly because it draws outside air for combustion, uses a low-NO_x burner and uses clean-burning gas.

POLARIS gives you construction options: Flexible venting — through a wall or roof — with no chimney needed; use it with new baseboard or radiant floor heating systems; install the compact POLARIS just about anywhere; use multiple Air Heaters or fan convectors for hard-to-heat, remote areas. In short, POLARIS gives you more ways to make your homes more economical, livable and desirable.

Bellevue, Washington:

Electric conversion became easy with POLARIS. Because it can be vented up to 40 feet with sealed

combustion through an outside wall or roof, this all-electric home was converted easily and economically with a POLARIS. In many applications, the existing air handler can be converted by merely inserting a hot water coil, attaching a pump package and installing a POLARIS to heat all the hot water necessary for both space and water heating. And the POLARIS Comfort System™ delivers consistent, warm air at unmatched economy of operation.

Columbus, Ohio:

This home replaced five flames — a water heater, furnace and three space heaters — with the single flame of the POLARIS.

Hard-to-heat areas, such as basements, can be heated with small fan convectors that draw hot water from a POLARIS.

Great for Commercial Applications, Too

POLARIS is ideal for office/warehouse complexes, food service, barber shops, beauty salons — anyplace where both water and space heating are needed. Once you have installed a POLARIS system, you have the right system for any tenant.

Birmingham, Alabama:

George A. Jackins, Jr., P.E. of Engineering Resource Group, Inc., solved the water and space heating problem of a 8,690 sq-ft office/warehouse complex with a POLARIS Comfort System. The system consists of two POLARIS water heaters tied into five air handlers matched to five condensers that provide a total of 22 tons of cooling. The total water and space heating gas consumption for the year beginning August 6, 1987 was 372 CCF. This innovative design is so energy efficient that Engineering Resource Group won the 1988 ASHRAE Region VII CRC Energy Award.

Office/warehouse complex.

George Jackins, Jr., P.E. with POLARIS water heaters.

Five split-system condensing units.

POLARIS

MOR-FLO/AMERICAN

Available from

AMERICAN APPLIANCE MFG. CORP
1752 Cloverleaf Blvd.
Santa Monica, CA 90404-3996
(213)829-1755, (213)870-8541
1-800-333-4109

INDUSTRIES, INC.
South Miles Road
OH 44128-4296
(663)7300
937-1037

Inc 1991

PA 011

POLARIS

Heats both homes and water in any climate.

Mor-Flo/American Comfort Systems™, utilizing a Polaris water heater as a single energy source, will heat homes, the hot water used in those homes — and in any climate.

These reliable and energy-efficient systems, designed primarily for use with forced-air heating, combine the Polaris with Mor-Flo/American Air Heaters™.

Compact ceiling, wall and closet Air Heaters come in space heating capacities of 14,000 Btu/hr, and higher. In addition, Air Heaters are supplied with a DX cooling coil for air conditioning during warmer months.

After having proven themselves in extensive laboratory and in-the-field tests, Polaris water heaters are now providing +94% recovery efficiency in installations nationwide.

With its compact size — 22 inches in diameter, 47 1/2 inches tall (34 gal.) and 61 1/2 inches tall (50 gal.) — the Polaris is engineered with inputs of 100,000 Btu/hr and will provide more than enough hot water to heat homes and the water used in those homes. The Polaris also can be used in many large-usage, residential water-heating only applications.

There are a number of reasons why these reliable, high-efficiency water heaters provide

optimum energy efficiency. The submerged stainless steel combustion chamber is completely surrounded by water. This eliminates bottom heat loss and reduces energy consumption. The design provides almost noiseless operation.

When the thermostat calls for heat, the igniter is activated. The power blower and negative pressure gas valve force air and gas into the combustion chamber and the burner ignites. The combustion heat is forced into the flue coil. However, the flue, rather than exiting at the top of the tank, coils down and around the combustion chamber and exits the bottom of the tank.

The water in the tank continually draws heat from the hot gases in the flue coil. Normal flue losses are eliminated during standby because the heat cannot descend without being forced by the power blower.

Another significant advantage is that these condensing, low temperature flue gases can be vented through an outside wall or roof, at distances up to 40 ft., using 2-inch ABS or CPVC pipe. Additionally, outside combustion air can be provided with 2-inch ABS or CPVC pipe. In short, the Polaris can be installed in homes or light commercial buildings without chimneys.

POLARIS SPECIFICATIONS

SPECIFICATIONS								
MODEL NUMBER	DATA PROCESS NUMBER	TANK CAP. (gal.)	NATURAL GAS		LP GAS		RECOVERY EFF (%)	SHIPPING WGT (lb)
			INPUT (Btu/hr)	RECOVERY 90° rise (gph)	INPUT (Btu/hr)	RECOVERY 90° rise (gph)		
*PR 34	Nat: 0310002 LP: 0310003	34	100,000	125.4	100,000	125.4	94	136
PR 50	Nat: 0310004 LP: 0310005	50	100,000	125.4	100,000	125.4	94	190

DIMENSIONS (in.)						
MODEL NUMBER	EXTERIOR		1" WATER CONNECTIONS		T&P HGT.	1/2" GAS SUPPLY
	A	B	C	D	E	F
PR 34	47 1/2	22	16 3/4	39 3/4	40 3/4	5 3/4
PR 50	61 1/2	22	16 3/4	53 3/4	54 3/4	5 3/4

*Call for availability

10-year Limited Tank Warranty

Specifications are subject to change without notice.

Input, output and recovery may vary depending upon air inlet and vent outlet installations. Length and number of bends in inlet and outlet pipes may reduce input, output and recovery efficiency.

Mor-Flo Industries is recognized as the leader in the development of new, energy efficient water heating products. As a result of this on-going commitment, new and innovative water heating technologies have been established and incorporated into a series of proven products that include energy saving residential commercial water heaters; the first water heater with a submerged combustion chamber; solar water heating systems; heat pump water heaters; and now Polaris — the first in a series of space/water heating Comfort Systems.

MOR-FLO®/AMERICAN®
Comfort Systems™

MOR-FLO INDUSTRIES, INC.
18450 South Miles Road
Cleveland, OH 44128-4296
(216)663-7300
1-800-937-1037

Available from:

AMERICAN APPLIANCE MFG. CORP.
1725 Cloverfield Blvd.
Santa Monica, CA 90404-3996
(213)829-1755, (213)870-8541
1-800-333-4109

INTEGRA

MOR-FLO[®]/AMERICAN[®]
Comfort Systems™

**Q: WHAT HEATS BOTH SPACE AND
WATER WITH GAS, NEEDS NO
CHIMNEY, INCREASES LIVING
SPACE AND DOESN'T COST MUCH?**

A: INTEGRA™

Mor-Flo / American's New, Integrated Gas-Combo Heater For Apartments, Condos And Small Homes

- **Low Cost** — To buy, to install and to operate
- **Compact** — Increases living space
- **Vents through-a-wall** as far as 25 feet away with up to four elbows
- **Brings gas heating to apartments, condos and small homes**
- **Sealed combustion**
- **High efficiency**

Inexpensive to Buy, Install and Operate

The INTEGRA is a low-cost gas combo heater. Since one appliance does the work of two, there is one gas line, one burner and one plastic flue. And because the INTEGRA Air Heater™ and INTEGRA Water Heater quick-connect together, installation costs are kept to a minimum. INTEGRA heated residences are in high demand because of low operating costs.

More Space for Living

With INTEGRA, you can offer a more livable home. One appliance does the work of two in a single compact footprint reducing equipment space by 50% or more. With zero clearance to walls and floors for Water Heater and Air Heater, the INTEGRA may be installed as far as 25 feet from an outside wall with up to four elbows, no chimney needed. And with its quiet operation, the INTEGRA may be installed almost anywhere. Because the INTEGRA has sealed direct venting, no inside air is used for combustion. With a slide-in cooling coil that matches your air conditioner or heat pump for cooling, the INTEGRA provides for heating, cooling and water heating in a single self-contained comfort package.

Brings High-Efficiency Gas Water and Space Heating to Apartments, Condos and Small Heat-Loss Homes.

Designed in conjunction with the gas industry, the INTEGRA makes gas water and space heating affordable for smaller heat-loss living units. Warmth, comfort, reliability, economy, quiet — all reasons why INTEGRA heated residences are preferred by consumers everywhere.

Mor-Flo/American COMFORT SYSTEMS™ A Growing Family of Total Home-Heating Appliances

INTEGRA is the latest addition to the Mor-Flo/American line of Comfort System home and water-heating

products. By using any one of a number of efficient Mor-Flo/American gas energy sources, a Comfort System

can be sized to meet the heating needs of almost any home.

SPECIFICATIONS

INTEGRA WATER HEATER

Product Number	0101184 PVVN463S-V, nat. gas 0101185 PVVN463S-V, LPG
Input	40,000 Btuh, nat. gas 37,000 Btuh, LPG
Output	33,200+Btuh, nat. gas 30,710+Btuh, LPG
Recovery @90°F Rise	44.4+ US gal/hr, nat gas 41.1+ US gal/hr, LPG
Recovery Efficiency	83% +
Tank Size	40 US gal
Weight	160 lb
Electrical	120V less than 7A

INTEGRA AIR HEATER

Product Number	0900414 MF870PM
Heating Capacity*	@ 600 cfm: 25,000 Btuh @ 700 cfm: 27,200 Btuh @ 800 cfm: 29,000 Btuh
Weight	85 lb
Electrical — blower motor	120V 1/5hp 1075 rpm 2.7A

INTEGRA COOLING COIL

Product Number	0900415 DX870
Cooling Capacity	1, 1-1/2 or 2 tons
Weight	15 lb

* INTEGRA Air Heater two-speed blower pre-wired at low speed. May be field wired to high speed. CFM varies with static pressure and with presence of heating coil only, or both heating and cooling coils.

MOR-FLO®/AMERICAN®
Comfort Systems™

MOR-FLO INDUSTRIES, INC.
18450 South Miles Road
Cleveland, OH 44128-4296
(216) 663-7300

AMERICAN APPLIANCE MFG. CORP.
2341 Michigan Avenue
Santa Monica, CA 90404-3996
(213) 829-1755 • (213) 870-8541

MCR-FLO / AMERICAN INTEGRA

The Gas Combo Heater In A Closet

Ideal for All Multi-Family and Small Heat-Loss Homes

Fits Anywhere

Mor-Flo/American's INTEGRA is the perfect heating source for domestic space and water where space is at a premium. With its single, small footprint, INTEGRA only requires the space of a small closet. Homeowners and tenants will not be aware of the INTEGRA—even if it is in the same room—as it silently and consistently delivers comfortable warm-air heating and plenty of hot water. And it's also a snap to install with flexible venting that allows the INTEGRA to fit neatly into almost any floorplan.

Wherever there are a few square feet of floorspace, even with zero clearance to construction materials, an INTEGRA can be installed. Venting, with plastic pipe, can be through a roof or outside wall as far away as 40 feet. Return air can either be ducted or through a central-return air grill—whichever best fits your needs. Because its Air Heater™ sits right on top of the water heater, heating with an INTEGRA gives you a bonus—more living space to make your homes more desirable.

New York City:

The INTEGRA is ideal for small heat-loss homes such as this home on Staten Island. This INTEGRA was installed in the basement in the same location as the original gas furnace.

Fort Wayne, Indiana:

The through-the-roof venting of the INTEGRA proved most economical in these Fort Wayne apartments.

Both through-the-roof and through-the-wall venting may be made at distances of up to 40 feet with sealed combustion.

Fort Collins, Colorado:

These apartments have INTEGRA units located in small closets. The single footprint of the INTEGRA

means more of the apartment can be used for living and less for equipment.

Alexandria, Virginia:

A 184-unit high-rise proved no problem for the INTEGRA. Through-the-wall venting eliminated costly multiple-story venting.

For Rehabs

Because of its space-saving flexibility, INTEGRA is ideal for those hard-to-heat rehabs. Use it with or without air conditioning (cooling can be easily added later) or use it without an Air Heater for water heating only. INTEGRA is also the best answer for converting from an old, centrally-metered system to up-to-date, individually metered systems. With INTEGRA you save up-front because of its low installed cost and you save down the road because of its low maintenance requirements, thanks to a proven, uncomplicated, rugged design.

Chicago, Illinois:

When a centrally metered building in Chicago was converted to a 2C-unit, individually

metered apartment house for homeless families, the INTEGRA provided affordable high-efficiency water and space heating.

North Bay, Ontario:

To convert the Empire Hotel in North Bay from a central system to individually metered apartments, ICG

Utilities found the venting and installation versatility of the INTEGRA to be the perfect space and water heating system.

For Electric Conversions

Now, with INTEGRA, you can bring the comfort and economy of gas heating to all-electric homes. INTEGRA draws outside air for combustion, has a low NO_x burner, requires zero clearance to construction materials and often fits in the same space as the original electric equipment. For comfort and economy nothing beats INTEGRA — it is the easiest way to convert both electric water and space heating.

Ottawa, Ontario:

The INTEGRA is a quiet, economical gas alternative to electric PTAC units and electric water heaters.

INTEGRA units are so safe and quiet they are installed in kitchen pantries in these apartments.

Tampa, Florida:

The INTEGRA often can fit in the same area as the original electric water heater and furnace as was the case in this electric conversion in Tampa. Zero clearance and chimneyless sealed combustion venting are only two of the many reasons that the INTEGRA is the ideal gas combo heater for electric conversions.

For Any Climate

For Energy Efficiency

From Canada to California, INTEGRA is right whatever the climate. In the coldest weather, INTEGRA is ideal for apartments, condos and even for small, single-family homes with a net heating loss of 29,000 Btu/hour, or less. For cooling flexibility, with just a simple orifice change, INTEGRA can utilize either a 1, 1-1/2 or 2-ton condenser.

Las Vegas, Nevada:

The heavy cooling load of these Las Vegas apartments proved to be no problem for the INTEGRA Air

Heater™. With a simple orifice change the INTEGRA cooling coil matches 1, 1-1/2 or 2-ton condensing units and is heat-pump compatible.

North Bay, Ontario:

A Canadian developer chose INTEGRA water heaters as the energy source for radiant floor heating systems in an individual strip complex. And, as in all INTEGRA installations, high-efficiency water heating is also provided.

Thanks to its unique, submerged combustion chamber, INTEGRA is extremely energy efficient. With an +80% space heating efficiency, and very high water-heating efficiency, INTEGRA exceeds the 1992 Federal energy standards. Total gas comfort and economy in a compact, easy-to-install and maintain integrated appliance. This is the competitive advantage you'll enjoy when you heat with the Mor-Flo/American INTEGRA.

Vermillion, South Dakota:

This student housing project at the University of South Dakota posed a difficult energy problem — high water consumption (2, 3 and 4-bedroom apartments), space and venting restrictions and the need for energy-efficient equipment in a severe climate. The INTEGRA solved all these problems and proved to be the right answer to this space and water-heating challenge.

MOR-FLO/AMERICAN®

MOR-FLO INDUSTRIES, INC.
18450 South Miles Road
Cleveland, OH 44128-4296
(216)663-7300
1-800-937-1037

Available from:

AMERICAN APPLIANCE MFG. CORP.
1752 Cloverleaf Blvd.
Santa Monica, CA 90404-3996
(213)829-1755, (213)870-8541
1-800-333-4109

EnergyMate™

ADVANCED
HOME HEATING
TECHNOLOGY

QUALITY DESIGN FEATURES

When you compare brands of integrated water and space heating systems, compare specific features. Like the materials used in manufacturing and the accessibility of major controls and components. You'll find Rheem's quality construction and common-sense approach to engineering make the most sense for your home heating requirements.

EnergyMate Air Handler Features

The Rheem EnergyMate Air Handler was designed especially for use with the EnergyMate Water Heater. Available for upflow, downflow or horizontal airflow applications, these versatile air handlers allow contractors to meet virtually any installation requirement from basement to attic. The design features of the air handler unit include:

HEAVY DUTY PUMP

The water is transferred from the water heater to the air handler via a heavy duty circulating pump. When heat is required in the home, the pump is activated automatically. The pump transfers and returns the water from the water heater to the air handler.

COPPER TUBE ALUMINUM FIN HEAT TRANSFER COIL

The EnergyMate Air Handler features a copper tube aluminum fin heat transfer coil which is mechanically bonded to maximize heat transfer. The coil is leak-tested prior to leaving the factory.

REUSABLE AIR FILTER

Dirty filters restrict airflow and can reduce operating efficiency. The Rheem EnergyMate Air Handler features a reusable filter. The filter is easy to remove for cleaning and regular maintenance will help keep your system operating at peak performance.

HIGH QUALITY COPPER TUBING

All Rheem tubing is made from copper. It has become a lasting trademark of Rheem's commitment to quality.

HIGH-EFFICIENCY BLOWER

The blower unit forces the air over the heat transfer coil and through the air ducts to each room in the home. The blower unit includes a direct-drive blower assembly and a multi-speed motor. The direct-drive system eliminates belts and pulleys which tend to wear out and can require frequent adjustment. The multi-speed motor responds efficiently to provide proper airflow under varying operating conditions. The blower is slide-mounted which makes it easier to inspect and service. And the blower compartment is insulated to minimize noise.

EnergyMate Water Heater Features

The Rheem EnergyMate Water Heater line is designed to be matched with the EnergyMate Air Handler to provide optimum performance and efficiency. The line offers a full range of Energy Efficient or High Performance models with tank capacities from 40 to 62 gallons. The High Performance models feature Thermal Efficiency ratings of 80% and above. Vertical vent and direct vent models are available to meet virtually any installation requirement. Natural and LP gas models are available. The line features a five-year tank and parts warranty. Your Rheem contractor can provide a full and complete description of warranty terms.

The EnergyMate Water Heater features the following quality components:

THERMOSTATIC GAS VALVE

EnergyMate Water Heaters feature a Robertshaw adjustable thermostat control which can be easily adjusted to satisfy the needs of your home.

ALUMINIZED STEEL BURNER

Most EnergyMate Water Heaters feature a special aluminized steel burner. The GasMaster™ burner is designed to provide efficient, quiet operation. The burner features precision port alignment for even heat transfer and is easy to light.

RHEEMGLAS® TANK

EnergyMate Water Heater tanks are lined with an exclusive porcelain formula called Rheemglas. This process results in a smooth, tough, glasslike lining that effectively resists the corrosive attacks of water chemicals which can shorten the life of the water heater.

UNITIZED HEAT EXCHANGER CORE

High Performance™ EnergyMate models feature a patented unitized heat exchanger core. The heat exchanger features Rheem's exclusive multi-tube core, which is welded before glass lining. This provides more heat transfer surface than a conventional single flue, and much higher BTU inputs can be used which increases hot water delivery.

FOAM INSULATION

R-Foam® insulation surrounds the EnergyMate for improved economy and fuel savings. In a patented process, the rigid polyurethane foam is injected directly between the tank and outer jacket to minimize the possibility of heat loss caused by uninsulated areas.

INTEGRATED HOME HEATING:

The Smart Choice For Many Homeowners

If you're in the market for a new central heating system for your home, you should consider the Rheem EnergyMate, an integrated space and water heating system. The EnergyMate Water Heater works with the EnergyMate Air Handler to provide both the hot water and space heating your home requires.

In the traditional home, a water heater supplies hot water throughout the home and a separate electric air handler or gas furnace heats the home. Most of the time, the water heater stands idle. By utilizing the excess capacity of the water heater to heat your home you could realize an overall increase in the efficiency of your home heating system.

How The EnergyMate System Works

The water heater and the air handler units are connected by two copper pipes, which transfer water between the units. When space heating is required, the wall thermostat in the home activates a small pump in the air handler unit which transfers the water from the water heater to the air handler. There, the hot water is circulated through a copper tube aluminum fin coil located in the air handler. The air handler's high efficiency blower pulls return air from the home and blows it over the heated coil. This warm air is then transferred throughout the

home via the conventional duct system. The water in the air handler coil is pumped back into the water heater for reheating. The water will usually only lose 15 to 25 degrees in temperature while being circulated through the air handler.

The Rheem EnergyMate system can also be used to cool your home with the addition of a cooling coil and air conditioning or heat pump system.

HIGH EFFICIENCY COOLING:

The Rheem EnergyMate space and water heating system can be combined with a high efficiency Rheem air conditioning or heat pump system to meet your home's cooling requirements. Rheem manufactures a complete line of air conditioning systems with S.E.E.R. ratings up to 12.0. Rheem's heat pump line has S.E.E.R. ratings up to 12.20 and H.S.P.F. ratings up to 8.70.

It Pays To Install Rheem

Rheem is one of the largest manufacturers of central heating, cooling and water heating products in North America. For over 50 years, the Rheem brand has been a standard in the industry. The company has earned its reputation by building affordable, dependable, efficient products that provide homeowners with lasting value.

Your neighborhood Rheem contractor is knowledgeable about what heating and cooling systems are best for homes in your area, and he'll happily answer any questions you may have about properly heating and cooling your home.

1. All Thermal Efficiency ratings presented in this brochure have been calculated in accordance with 1977 Department of Energy procedures.
2. All EnergyMate Water Heater models have been tested according to Department of Energy procedures and meet or exceed the energy efficiency requirements of ASHRAE STANDARD 90, BOCA Code and all state energy efficiency performance criteria for energy consuming appliances.
3. Before purchasing this appliance, be sure to read important energy cost and efficiency information available from your Rheem dealer.
4. Design specifications subject to change without notice.

AIR CONDITIONING SYSTEMS

HEAT PUMP SYSTEMS

RHEEM WATER HEATER DIVISION

5780 Peachtree Dunwoody Road, N.E.
Atlanta, GA 30342
404-256-2037

RHEEM AIR CONDITIONING DIVISION

5600 Old Greenwood Road
P.O. Box 6444
Fort Smith, AR 72903
501-646-4311

HOT WATER SPACE HEAT FURNACES

Indoor unit shown for upflow application.
Unit may also be field modified for either
downflow or horizontal
application.

HOT WATER SPACE HEAT FURNACES

RHWA- SERIES

Two Basic Models

Cooling Capacities
from 1-1/2 thru 3 Tons.

Heating Capacities
from 30,000 to 45,000 BTUH.

The Rheem® RHWA- Hot Water Space Heat Furnace is designed for use in residential and multifamily heating and cooling applications. The unit is also available for heating only applications.

The units can be installed for either vertical (upflow or downflow) or horizontal airflow applications.

The unit is designed to be connected to a water heater incorporating recirculation loop connections. If the water heater does not have these connections, a kit (RXHW-A01) is required.

The RHWA Hot Water Space Heat Furnace can be combined with Rheem Condensing units and coils to achieve cooling efficiencies of up to 12.00 S.E.E.R. (Seasonal Energy Efficiency Ratio). The RHWA can also be field-installed with Rheem Heat Pumps.

"CERTIFIED UNDER THE
A.R.I. CERTIFICATION
PROGRAM - A.R.I. STANDARDS
210/240-84"

Features

RHWA- Series Hot Water Space Heat Furnaces

The following features, plus its installation flexibility, make it an excellent choice for new construction or replacement/Add-on.

- Available upflow, downflow, or horizontal airflow applications.
- Cooling coils mount inside the cabinet.
- Cleanable air filter furnished standard.
- Direct drive blower both statically and dynamically balanced.
- All models are U.L.® listed for either attic or closet installation.
- Insulated blower compartment furnished standard.
- Heavy Duty Pump with replaceable cartridge furnished standard.
- All models feature copper sweat connections for heating and cooling coils.
- All models are U.L. listed at 115 volt, 60 Hz, single phase.

Engineering Features

1. Insulated cabinet for cooling section standard on all units (units may have cooling coil added later in space provided).
2. Wide selection of cooling coils fit inside the cabinet for either upflow, downflow, or horizontal applications.
3. Direct drive blower assemblies are mounted on a slide-out rail for ease of service.
4. Blower compartment is factory insulated for thermal and sound benefits.
5. Cleanable air filter furnished standard, for bottom return only.
6. Direct drive blower assembly with motor factory lubricated does not require periodic maintenance.
7. Ease of access through front panel for electrical controls and components and blower-air filter access.
8. Sweat fittings standard on all models (cooling and heating).
9. All units feature copper tube/aluminum fin heat transfer coils.
10. All units are 115 volt, 60 Hz, single phase.
11. Heavy duty pump is mounted for easy service access.

Optional Equipment

- De-pneumatic Kit (RXHW-A01)

Rheem Hot Water Space Heat System

How the Hot Water Space Heat Furnace Works

The water heater and the furnace units are connected by two copper pipes, which transfer water between the units. When space heating is required, the wall thermostat in the home activates a small pump in the furnace which transfers the water from the water heater to the furnace. There, the hot water is circulated through a copper tube aluminum fin coil located in the furnace. The furnace's high efficiency blower pulls return air from the home and blows it over the heated coil. This warm air is then transferred throughout the home via the conventional duct system. The water in the furnace coil is pumped back into the water heater for reheating. The water will usually only lose 15 to 25 degrees in temperature while being circulated through the furnace.

The Rheem RHWA can also be used to cool your home with the addition of an air conditioning or heat pump system.

Table 6—Unit Airflow Data

Model Number	Coil Application	Blower Speed	CFM/External Duct Static Inches of Water				
			.10	.20	.30	.40	.50
RHWA-08	RCAB-A021	HI	815	785	740	690	630
		LO	625	615	595	565	505
RHWA-08	No Coil	HI	825	805	780	750	700
		LO	625	615	610	590	550
RHWA-12	RCAB-A037	HI	1110	1040	950	870	780
		LO	1050	980	915	810	710
RHWA-1'	No Coil	HI	1280	1200	1120	1020	910
		LO	1100	1060	990	900	840

Table 8

Unit Model	Weight, Lbs	
	Net	Ship
RHWA-08	90	95
RHWA-12	100	105

Table 7—Unit Dimensions

Dim.	RHWA		Dim.	RHWA	
	08	12		08	12
	Inch	Inch		Inch	Inch
A	42 ¹ / ₂	47 ¹ / ₄	P	34 ³ / ₄	39 ¹ / ₂
B	18 ¹ / ₈	18 ¹ / ₈	Q	35 ¹ / ₄	41
C	19 ⁷ / ₈	22	R	6 ¹ / ₄	8 ³ / ₈
D	16 ⁵ / ₈	16 ⁵ / ₈	S	8	10 ¹ / ₄
E	18	20 ¹ / ₈	T	10 ⁵ / ₈	12 ⁷ / ₈
F	15 ⁵ / ₈	15 ⁵ / ₈	U	14 ¹ / ₄	14 ¹ / ₄
G	17 ³ / ₈	19 ¹ / ₂	V	25 ¹ / ₂	28
H	12 ¹ / ₄	12 ¹ / ₄	W	31 ⁷ / ₈	34 ³ / ₈
J	9 ⁵ / ₈	9 ⁵ / ₈	X	34 ¹ / ₂	37
K	4 ¹ / ₈	4 ¹ / ₈	Y	2 ¹ / ₈	2 ¹ / ₈
L	2 ⁷ / ₈	2 ⁷ / ₈	Z	2 ⁵ / ₁₆	2 ⁵ / ₁₆
M	17 ¹ / ₄	19 ³ / ₈	AA	40 ⁷ / ₈	45 ⁵ / ₈
N	14 ¹ / ₄	16 ³ / ₈	—	—	—

NOTES:

1. All drain fittings are 3/4" male pipe thread.
2. Hot water connections are 3/4" (O.D.) sweat connections.
3. Horizontal units with factory-installed cooling coils are shipped for right hand airflow.

Before proceeding with installation,
refer to installation instructions
packaged with each model, as well as
complying with all Federal, State, and
Local codes, regulations, and practices.

**RHEEM
AIR CONDITIONING
DIVISION**

P.O. Box 17010, Fort Smith, Arkansas 72917-7010

"In keeping with its policy of continuous progress and product improvement, Rheem reserves the right to make changes without notice."

PRINTED IN U.S.A.

11-90 BP

FORM NO. H11-507 REV. 1
Supersedes Form No. H11-507 Rev. 0

HYDROHEAT

HYDROHEAT 5010 Residential Gas Water Heater with Foam Insulation

40, 50 and 75 Gallon Storage Capacity
Natural and Propane (L.P.) Gas

Input BTU/Hr: 35,500 through 75,100 Natural and Propane (L.P.) Gas
Five-year Limited Warranty on Tank and One-year on Parts

Compared to a standard fiberglass insulated water heater of the same capacity, the HydroHeat 5010 models furnish more hot water per hour and offer 76% recovery efficiency.

Apollo Comfort Products offers this HydroHeat 5010 gas water heater for any system requiring the addition of recirculating hot water loop.

Check these Quality Features

- Competitively Priced
- Foam Insulation retains heat 2½ times better than standard fiberglass insulation.
- Aluminized Steel Multi-Port Burner for quiet, efficient combustion.
- Energy-Saving Pilot.
- Nylon Drain Valve eliminates electrolytic corrosion.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- A.G.A. Design Certified E.C.O. (Energy Cut-Off).
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited tank warranty. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure Relief Valve.
- Side mounted tapping for recirculating system.
- Optional recirculating loop assembly — part # 9001262
- Optional Hot check valve — part # 9001378
- Optional Cold check valve — part # 9000948

A Complete System

Matched Components

Apollo Air Handlers are designed for use with The Apollo HydroHeat 5010 water heaters.

apollo
HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

HydroHeat 5010 Residential Gas Water Heater with Foam Insulation

Model Number	Gallon Capacity	Dimensions in Inches									Shipping Weight (Lbs.)
		A	B	C	D	E	F	G	H	J	
A5-40-35.5NBRT	40	60	56½	18	3	51	15	8	52¾	15½	132
A5-40-40.0NBRT	40	62½	58	18	†3-4	52¾	15	8	60¾	24½	154
A5-40-52.5NRRT	40	63¼	59½	18	4	53¾	15	8	62¼	24½	162
A5-50-52.5NRRT	50	62½	58¾	20	4	52¾	15	8	61¼	24½	183
A5-50-65.0NRRT-5	50	63¾	60	20	4	53¾	15	8	62¾	25½	183
A5-75-75.1NRRT	75	64	60	24	4	54	15	8	62	25¾	244
A5-40-35.5PBRT	40	60	56½	18	3	51	15	8	52¾	15½	132
A5-40-40.0PBRT	40	62½	58	18	†3-4	52¾	15	8	60¾	24½	154
A5-40-52.5PRRT	40	63¼	59½	18	4	52¾	15	8	62¼	24½	162
A5-50-52.5PRRT	50	62½	58¾	20	4	52¾	15	8	61¼	24½	183
A5-50-65.0PRRT-5	50	63¾	60	20	4	53¾	15	8	62¾	25½	183
A5-75-75.1PRRT	75	64	60	24	4	54	15	8	62	25¾	244

Model Number	Gallon Capacity	BTUH Input	Recovery Degree Rise			First Hour Rating	Recovery Efficiency	BTUH Output	Energy Factor
			100°	80°	60°				
A5-40-35.5NBRT	40	35,500	33	36	55		76%	26,980	.56
A5-40-40.0NBRT	40	40,000	37	41	61	69	76%	30,400	.57
A5-40-52.5NRRT	40	52,500	48	54	81	80	76%	39,900	.54
A5-50-52.5NRRT	50	52,500	48	54	81	87	76%	39,900	.52
A5-50-65.0NRRT-5	50	65,000	60	67	100	98	76%	49,400	.52
A5-75-75.1NRRT	75	75,100	69	77	115	122	76%	57,076	.48
A5-40-35.5PBRT	40	35,500	33	36	55	65	76%	26,280	.56
A5-40-40.0PBRT	50	40,000	37	41	61	69	76%	30,400	.57
A5-40-52.5PRRT	40	52,500	48	54	81	80	76%	39,900	.54
A5-50-52.5PRRT	50	52,500	48	54	81	87	76%	39,900	.52
A5-50-65.0PRRT-5	40	65,000	60	67	100	98	76%	49,400	.52
A5-75-75.1PRRT	75	75,100	69	77	115	122	76%	57,076	.48

Recoveries are rounded to nearest gallon.
†Provision for 3" or 4" flue pipe.

Water Heater/Air Handler Sizing

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

HYDROHEAT

HYDROSWIRL 5050 Residential Gas Water Heater with Foam Insulation

40, 50 and 75 Gallon Storage Capacity
Natural and Propane (L.P.) Gas
Input BUT/Hr: 40,000 through 75,100 Natural and Propane (L.P.) Gas
Five-year Limited Warranty on Tank and Parts

Compared to a standard fiberglass insulated water heater of the same capacity, the HydroSwirl 5050 models furnish more hot water per hour and offer 76% recovery efficiency.

Apollo Comfort Products offers this *HydroSwirl 5050* gas water heater for any system requiring the addition of recirculating hot water loop. All models are equipped with side-mounted recirculating taps and valves.

Energy-efficient water heaters don't always stay energy-efficient. Deposits of lime and other sediments can accumulate on heat transfer areas of the tank, affect tank life, and gradually decrease the water heater's recovery efficiency. But the **HydroSwirl 5050** features a specially designed HydroSwirl Dip Tube that creates turbulence inside the tank to help prevent harmful sediment from collecting.

Check these Quality Features

- HydroSwirl Dip Tube.
- Side-mounted tapping and valves for recirculating system.
- Foam Insulation retains heat 2½ times better than standard fiberglass insulation.
- Aluminized Steel Multi-Port Burner for quiet, efficient combustion.
- Energy-Saving Pilot.
- Nylon Drain Valve eliminates electrolytic corrosion.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- A.G.A. Design Certified E.C.O. (Energy Cut-Off).
- Zinc-Coated Plasticert Nipples reduce electrolytic action.
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited tank and parts warranty. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure Relief Valve.

A Complete System

apollo
HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

HydroSwirl 5050 Residential Gas Water Heater with Foam Insulation

Model Number	Gallon Capacity	Dimensions in Inches									Shipping Weight (Lbs.)
		A	B	C*	D	E	F	G	H	J	
A5-40-40.0NART	40	62½	58	18	†3-4	52¾	15	8	60¾	24½	154
A5-40-52.5NQRT	40	63¼	59½	18	4	53¾	15	8	62¼	24½	162
A5-50-52.5NQRT	50	62½	58¾	20	4	52¾	15	8	61¼	24½	183
A5-50-65.0NQRT-5	50	63¾	60	20	4	53¾	15	8	62¾	25½	183
A5-75-75.1NQRT	75	64	60	24	4	54	15	8	62	25¾	244
A5-40-40.0PART	40	62½	58	18	†3-4	52¾	15	8	60¾	24½	154
A5-40-52.5PQRT	40	63¼	59½	18	4	53¾	15	8	62¼	24½	162
A5-50-52.5PQRT	50	62½	58¾	20	4	52¾	15	8	61¼	24½	183
A5-50-65.0PQRT-5	50	63¾	60	20	4	53¾	15	8	62¾	25½	183
A5-75-75.1PQRT	75	64	60	24	4	54	15	8	62	25¾	244

Model Number	Gallon Capacity	BTUH Input	Recovery Degree Rise			First Hour Rating	Recovery Efficiency	BTUH Output	Energy Factor
			100°	90°	60°				
A5-40-40.0NART	40	40,000	37	41	61	69	76%	30,400	.57
A5-40-52.5NQRT	40	52,500	48	54	81	80	76%	39,900	.54
A5-50-52.5NQRT	50	52,500	48	54	81	87	76%	39,900	.52
A5-50-65.0NQRT-5	50	65,000	60	67	100	98	76%	49,400	.52
A5-75-75.1NQRT	75	75,100	69	77	115	122	76%	57,076	.48
A5-40-40.0PART	40	40,000	37	41	61	69	76%	30,400	.57
A5-40-52.5PQRT	40	52,500	48	54	81	80	76%	39,900	.54
A5-50-52.5PQRT	50	52,500	48	54	81	87	76%	39,900	.52
A5-50-65.0PQRT-5	50	65,000	60	67	100	98	76%	49,400	.52
A5-75-75.1PQRT	75	75,100	69.0	77	115	122	76%	57,076	.48

Recoveries are rounded to nearest gallon.

†Provision for 3" or 4" flue pipe.

*The "C" dimension will be 2" larger on heaters manufactured to meet CEC requirements.

HydroSwirl dip tube makes sure that the money-saving performance lasts!

The HydroSwirl is equipped with the exclusive, patented **HydroSwirl dip tube**. It creates a "vortex" of turbulence inside the tank, which prevents sediment accumulation. In ordinary water heaters, lime and their sediments can accumulate on heat transfer areas, affect tank life, and decrease the water heater's efficiency. But **HydroSwirl** water heaters clean themselves, so they're energy efficient and **stay** that way! **No other gas water heater saves homeowners this much on operating costs!** The Energy Guide label found on all water heaters tells consumers how much it costs to heat water. And the HydroSwirl label tells a powerful story. Homeowners can **save** more money on operating cost with the HydroSwirl over the life of the water heater, compared to less efficient models. HydroSwirl has the lowest operating cost of any gas water heater made!

Water Heater/Air Handler Sizing

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

H-10-3-89

HYDROHEAT

HYDROSWIRL SUPER 5050 Residential Gas Water Heater

80-85% Recovery Efficiency for the industry's
lowest operating cost
40,000-55,000 BTU natural gas input for high recovery
40 and 50 Gallon Storage Capacity

Five-year Limited Warranty on Tank and Parts

Apollo offers a gas residential water heater with **80-85% recovery efficiency** for low operating costs and **high recovery** for plenty of hot water.

Apollo Hydro Heat offers this *HydroSwirl Super 5050* gas water heater for any system requiring the addition of recirculating hot water loop. All models are equipped with side-mounted recirculating taps and valves.

Energy-efficient water heaters don't always stay energy-efficient. Deposits of lime and other sediments can accumulate on heat transfer areas of the tank, affect tank life, and gradually decrease the water heater's recovery efficiency. But the **HydroSwirl Super 5050** features a specially designed HydroSwirl Dip Tube that creates turbulence inside the tank to help prevent harmful sediment from collecting.

Check these Quality Features

- HydroSwirl Dip Tube.
- Side-mounted tapping and valves for recirculating system.
- Foam Insulation retains heat 2½ times better than standard fiberglass insulation.
- Heat Traps prevent heat loss at inlet and outlet.
- Aluminized Steel Multi-Port Burner for quiet, efficient combustion.
- Energy-Saving Pilot.
- Nylon Drain Valve eliminates electrolytic corrosion.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- A.G.A. Certified E.C.O. (Energy Cut-Off).
- Zinc-Coated Plasticert Nipples reduce electrolytic action.
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited tank and parts warranty. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure (T&P) Relief Valve.

A Complete System

HB Series
Air Handler

VB Series
Air Handler

Matched Components

Apollo Air Handlers are designed for use with the Apollo HydroSwirl Energy Efficient 5050 self-cleaning water heaters.

apollo
HydroHeat & Cooling

500 By Pass Rd., Ashland City, TN 37015-1296
A DIVISION OF STATE INDUSTRIES ASHLAND CITY, TN

the Smart way to heat

Specifications

HydroSwirl Super 5050 Residential Gas Water Heater

•Lowest Operating Cost

•High Recovery

•Patented, sediment-fighting HydroSwirl dip tube

Model Number	Gallon Capacity	Dimensions in Inches									Shipping Weight (Lbs.)
		A	B	C	D	E	F	G	H	J	
A5-40-40.0NXRT	40	64½	60	18	†3-4	54¼	15¼	8	63	29	166
A5-50-40.0NXRT	50	64	59½	20	†3-4	54¼	15¼	8	62¼	31	188
A5-40-40.0PXRT	40	64½	60	18	†3-4	54¼	15¼	8	63	29	166
A5-50-39.0PXRT	50	64	59½	20	†3-4	54¼	15¼	8	62¼	31	188
A5-40-55.0NXQT	40	64½	60	18	†3-4	54¼	15¼	8	63	29	166
A5-50-55.0NXQT	50	64	59½	20	†3-4	54¼	15¼	8	62¼	31	188
A5-40-48.0PXQT	40	64½	60	18	†3-4	54¼	15¼	8	63	29	166
A5-50-48.0PXQT	50	64	59½	20	†3-4	54¼	15¼	8	62¼	31	188

†Provision for 3" or 4" flue pipe.

Model Number	Gallon Capacity	BTUH Input	Recovery Degree Rise			First Hour Rating	Recovery Efficiency	BTUH Output	Energy Factor
			100°	90°	60°				
A5-40-40.0NXRT	40	40,000	41	46	69	73	85%	34,000	.61
A5-50-40.0NXRT	50	40,000	41	46	69	80	85%	34,000	.58
A5-40-40.0PXRT	40	40,000	41	46	69	73	85%	34,000	.61
A5-50-39.0PXRT	50	39,000	40	45	67	79	85%	33,150	.58
A5-40-55.0NXQT	40	55,000	53	59	89	109	80%	44,000	.52
A5-50-55.0NXQT	50	55,000	53	59	89	109	80%	44,000	.52
A5-40-48.0PXQT	40	48,000	44	48	73	83	80%	38,400	.52
A5-50-48.0PXQT	50	48,000	44	48	73	83	80%	38,400	.52

Recoveries are rounded to nearest gallon.

Water Heater/Air Handler Sizing

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

HydroSwirl dip tube makes sure that the money-saving performance lasts!

The HydroSwirl is equipped with the exclusive, patented **HydroSwirl dip tube**. It creates a "vortex" of turbulence inside the tank, which prevents sediment accumulation. In ordinary water heaters, lime and their sediments can accumulate on heat transfer areas, affect tank life, and decrease the water heater's efficiency. But **HydroSwirl** water heaters clean themselves, so they're energy efficient and **stay** that way! **No other gas water heater saves homeowners this much on operating costs!** The Energy Guide label found on all water heaters tells consumers how much it costs to heat water. And the HydroSwirl label tells a powerful story. Homeowners can **save** more money on operating cost with the HydroSwirl over the life of the water heater, compared to less efficient models. HydroSwirl has the lowest operating cost of any gas water heater made!

HYDROHEAT

DIRECT VENT 5050 Residential Gas Water Heater

A new alternative to electric water heating in multi-unit buildings, basements, garages and other applications. A gas water heater that vents horizontally, directly through an exterior wall, without complicated, costly venting. Specially-designed vent kits adjust for wall thickness up to 48". Also available with four different vertical vent heights. 40-gallon and 50-gallon storage capacities.

Apollo fills a need...

Until now, architects and builders have hesitated to include more economical gas water heaters in multi-unit, multi-story apartment and condominium buildings, as well as in some kitchens, garages and other complex residential applications. To do so required complex, costly multiple venting systems to vent the products of combustion through the roof of the building. But Apollo's direct vent gas water heater can be easily installed in an apartment closet or utility space, and features a dual-channel contained combustion vent system that vents horizontally, directly through the building wall. Because of this through-the-wall design, the availability and lower costs of gas water heating compared to electric make the building more attractive to prospective renters or buyers.

Check these Quality Features

- HydroSwirl Dip Tube.
- Side-mounted tapings and valves for recirculating system.
- Foam Insulation retains heat 2½ times better than standard fiberglass insulation.
- Aluminized Steel Multi-Port Burner for quiet, efficient combustion.
- Energy-Saving Pilot.
- Nylon Drain Valve eliminates electrolytic corrosion.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- A.G.A. Design Certified E.C.O. (Energy Cut-Off).
- Zinc-Coated Plasticert Nipples reduce electrolytic action.
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited tank and parts warranty. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure Relief Valve.

A Complete System

apollo
HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN.

Specifications

Direct Vent 5050 Residential Gas Water Heater

The Direct Vent 5050 Gas Fired Water Heater comes with a standard vent kit (#9000687) unless otherwise specified when ordering.

In addition to the standard kit (#900687) there are three optional kits which telescope to give adjustments up to 48" horizontally and 122¼" (50 Gallon) vertically.

Each kit is listed below and outlines the minimum and maximum dimensions it covers. There is no distinction between a kit being used horizontally or vertically. However, only one kit can be used horizontally or vertically. If optional kits are required, specify when ordering.

Horizontal Length (Extension Kit)

To determine the horizontal length and extension kit needed, simply plug the dimensions "A" and "B" into the equation below. The answer "C" should then be located in chart to the side. The size range in which "C" dimensions falls, indicates the kit that should be used horizontally to obtain the desired length.

"A" = The wall thickness

"B" = The distance wanted between the edge of the water heater and the **inside** edge of the wall

"C" = The distance the extension kit must be able to extend

The Equation

$$A + B = C$$

Model Number	Gal. Cap.	Dimensions in Inches				Shipping Weight (Lbs.)
		E	F	H	D	
A5-40-40.0NADS	40	49	42	21	50	185
A5-50-48.0NADS	50	61½	54¼	21	62¼	226

Dimensions shown above apply to equivalent Propane (L.P.) models.

Vertical Vent Extension Kit Number	"A" Dimension Maximum Wall Thickness	"C" Dimension	
		Min	Max
9000687 (Std.)	10"	3½"	10"
9001246 (Opt.)	15½"	10"	15½"
9001247 (Opt.)	26½"	15½"	26½"
9001248 (Opt.)	48"	26½"	48"

Water Heater Model No.	Gal. Cap.	BTUH in 1000	GPH Recovery 100° F	Overall Height of Water Heater "G" Dimension							
				"G" Dimension							
				Kit 9000687 (Std.)	Kit 9001246 (Opt.)	Kit 9001247 (Opt.)	Kit 9001248 (Opt.)	Kit 9001246 (Opt.)	Kit 9001247 (Opt.)	Kit 9001248 (Opt.)	Kit 9001248 (Opt.)
A5-40-40.0 NADS	40	40/40	36	63¼"	72"	77½"	77½"	88½"	88½"	110"	110"
A5-50-48.0 NADS	50	48/44	44	76"	84¼"	89¼"	89¼"	100¼"	100¼"	122¼"	122¼"

Dimensions shown above also apply to equivalent Propane (L.P.) models.

Water Heater/Air Handler Sizing

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

HydroSwirl dip tube makes sure that the money-saving performance lasts!

The direct vent is equipped with the exclusive, patented **HydroSwirl dip tube**. It creates a "vortex" of turbulence inside the tank, which prevents sediment accumulation. In ordinary water heaters, lime and their sediments can accumulate on heat transfer areas, affect tank life, and decrease the water heater's efficiency. But **HydroSwirl** equipped water heaters clean themselves, so they're energy efficient and **stay** that way! **No other gas water heater saves homeowners this much on operating costs!** The Energy Guide label found on all water heaters tells consumers how much it costs to heat water. And the HydroSwirl label tells a powerful story. Homeowners can **save** more money on operating cost with the HydroSwirl over the life of the water heater, compared to less efficient models. Direct Vent has the lowest operating cost of any gas water heater made!

DV-11-989

HYDROHEAT

DIRECT VENT 5010 Residential Gas Water Heater

A new alternative to electric water heating in multi-unit buildings, basements, garages and other applications. A gas water heater that vents horizontally, directly through an exterior wall, without complicated, costly venting. Specially-designed vent kits adjust for wall thickness up to 48". Also available with four different vertical vent heights. 40-gallon and 50-gallon storage capacities.

Apollo fills a need...

Until now, architects and builders have hesitated to include more economical gas water heaters in multi-unit, multi-story apartment and condominium buildings, as well as in some kitchens, garages and other complex residential applications. To do so required complex, costly multiple venting systems to vent the products of combustion through the roof of the building. But Apollo's direct vent gas water heater can be easily installed in an apartment closet or utility space, and features a dual-channel contained combustion vent system that vents horizontally, directly through the building wall! Because of this through-the-wall design, the availability and lower costs of gas water heating compared to electric make the building more attractive to prospective renters or buyers.

Check these Quality Features

- Side mounted tapping for recirculating system.
- Optional recirculating loop assembly — part # 9001262
- Foam Insulation retains heat 2½ times better than standard fiberglass insulation.
- Aluminized Steel Multi-Port Burner for quiet, efficient combustion.
- Energy-Saving Pilot.
- Nylon Drain Valve eliminates electrolytic corrosion.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- A.G.A. Design Certified E.C.O. (Energy Cut-Off).
- Zinc-Coated Plasticert Nipples reduce electrolytic action.
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited tank warranty. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure Relief Valve.

A Complete System

apollo
HydroHeat & Cooling

500 By Pass Rd., Ashland City, TN 37015-1296
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Direct Vent 5010 Residential Gas Water Heater

The Direct Vent 5010 Gas Fired Water Heater comes with a standard vent kit (#9000687) unless otherwise specified when ordering.

In addition to the standard kit (#9000687) there are three optional kits which telescope to give adjustments up to 48" horizontally and 122 1/4" (50 Gallon) vertically.

Each kit is listed below and outlines the minimum and maximum dimensions it covers. There is no distinction between a kit being used horizontally or vertically. However, only one kit can be used horizontally or vertically. If optional kits are required, specify when ordering.

Horizontal Length (Extension Kit)

To determine the horizontal length and extension kit needed, simply plug the dimensions "A" and "B" into the equation below. The answer "C" should then be located in chart to the side. The size range in which "C" dimensions falls, indicates the kit that should be used horizontally to obtain the desired length.

"A" = The wall thickness

"B" = The distance wanted between the edge of the water heater and the inside edge of the wall

"C" = The distance the extension kit must be able to extend

The Equation

$$A + B = C$$

Model Number	Gal. Cap.	Dimensions in Inches				Shipping Weight (Lbs.)
		E	F	H	D	
A5-40-40.0NBDS	40	49	42	21	50	185
A5-50-48.0NBDS	50	61 1/4	54 1/4	21	62 1/4	226

Dimensions shown above apply to equivalent Propane (L.P.) models.

Vertical Vent Extension Kit Number	"A" Dimension Maximum Wall Thickness	"C" Dimension	
		Min	Max
9000687 (Std.)	10"	3 1/2"	10"
9001246 (Opt.)	15 1/2"	10"	15 1/2"
9001247 (Opt.)	26 1/2"	15 1/2"	26 1/2"
9001248 (Opt.)	48"	26 1/2"	48"

Water Heater Model No.	Gal Cap.	BTUH in 1000 Nat/LP	GPH Recovery 100° Rise	Overall Height of Water Heater "G" Dimension							
				Kit 9000687 (Std.)	Kit 9001246 (Opt.)		Kit 9001247 (Opt.)		Kit 9001248 (Opt.)		
					Min.	Max.	Min.	Max.	Min.	Max.	
A5-40-40.0 NBDS	40	40/40	36	63 3/4"	72"	77 1/2"	77 1/2"	88 1/2"	88 1/2"	110"	
A5-50-48.0 NBDS	50	48/44	44	76"	84 1/4"	89 3/4"	89 3/4"	100 3/4"	100 3/4"	122 1/4"	

Dimensions shown above apply to equivalent Propane (L.P.) models.

Water Heater / Air Handler Sizing

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

HYDROHEAT

HYDROSWIRL ENERGY EFFICIENT 5050 Residential Gas Water Heater

80% Recovery Efficiency
55,000-BTU natural/propane (L.P.) gas input for high recovery
75 Gallon Storage Capacity
Five-year Limited Warranty on Tank and Parts

Apollo offers a gas residential water heater with **80% recovery efficiency** for low operating costs and **high recovery** for plenty of hot water.

Energy-efficient water heaters don't always stay energy-efficient. Deposits of lime and other sediments can accumulate on heat transfer areas of the tank, affect tank life, and gradually decrease the water heater's recovery efficiency. But the **HydroSwirl Energy Efficient 5050** features a specially designed HydroSwirl Dip Tube that creates turbulence inside the tank to help prevent harmful sediment from collecting.

Check these Quality Features

- HydroSwirl Dip Tube.
- Foamite Insulation retains heat 2½ times better than standard fiberglass insulation.
- Heat Traps prevent heat loss at inlet and outlet.
- Aluminized Steel Multi-Port Burner for quiet, efficient combustion.
- Energy-Saving Pilot.
- Nylon Drain Valve eliminates electrolytic corrosion.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- A.G.A. Certified E.C.O. (Energy Cut-Off).
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited tank and parts warranty. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure Relief Valve.

A Complete System

apollo
HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

HydroSwirl Energy Efficient 5050 Residential Gas Water Heater

- Lowest Operating Cost
- High Recovery
- Patented, sediment-fighting HydroSwirl dip tube

Model Number	Gallon Capacity	Dimensions in inches							Shipping Weight (Lbs.)
		A	B	C	D	E	F	G	
A5 75 55.0NXRT	75	63¾	60	24	4	53½	15	8	240
A5 75 55.0PXRT	75	63¾	60	24	4	53½	15	8	240

Model Number	Gallon Capacity	BTUH Input	Recovery Degree Rise			First Hour Rating	Recovery Efficiency	BTUH Output	Energy Factor
			100°	90°	60°				
A5 75 55.0NXRT	75	55,000	53	59	89	109	80%	44,000	.49
A5 75 55.0PXRT	75	55,000	53	59	89	109	80%	44,000	.49

Recoveries are rounded to nearest gallon.

Water Heater/Air Handler Sizing

The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

HydroSwirl dip tube makes sure that the money-saving performance lasts!

The HydroSwirl is equipped with the exclusive, patented **HydroSwirl dip tube**. It creates a "vortex" of turbulence inside the tank, which prevents sediment accumulation. In ordinary water heaters, lime and their sediments can accumulate on heat transfer areas, affect tank life, and decrease the water heater's efficiency. But **HydroSwirl** water heaters clean themselves, so they're energy efficient and stay that way! **No other gas water heater saves homeowners this much on operating costs!** The Energy Guide label found on all water heaters tells consumers how much it costs to heat water. And the HydroSwirl label tells a powerful story. Homeowners can **save** more money on operating cost with the HydroSwirl over the life of the water heater, compared to less efficient models. HydroSwirl has the lowest operating cost of any gas water heater made!

HYDROHEAT

OIL-FIRED 5010 Residential Oil-Fired Water Heater with Foam Insulation

40 Gallon Storage Capacity
#2 Fuel Oil
Input BUT/Hr: 90,000

Five-year Limited Warranty on Tank
One-year Limited Warranty on Parts

Compared to a standard fiberglass insulated water heater of the same capacity, the Oil-Fired 5010 models furnish more hot water per hour and offer 76% recovery efficiency.

Apollo Hydro Heat offers this *Oil-Fired 5010* oil water heater for any system requiring the addition of recirculating hot water loop. All models are shipped with depneumatic assembly in carton.

Energy-efficient water heaters don't always stay energy-efficient. Deposits of lime and other sediments can accumulate on heat transfer areas of the tank, affect tank life, and gradually decrease the water heater's recovery efficiency. But the **Oil-Fired 5010** features a specially designed HydroSwirl Dip Tube that creates turbulence inside the tank to help prevent harmful sediment from collecting.

Check these Quality Features

- HydroSwirl Dip Tube.
- Foam Insulation retains heat 2½ times better than standard fiberglass insulation.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- Zinc-Coated Plasticert Nipples reduce electrolytic action.
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited warranty on tank and two-year limited warranty on parts. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure Relief Valve.
- Fuel unit single stage standard, two stage optional.
- Electrical requirement—115 volts/60 cycles/single phase, total load 12 amps or less.
- Brass Drain Valve.
- Combustion chamber—one piece of light weight refractory.
- Hand hole cleanout.
- Primary safety control—cadmium cell for flame detection.
- U.L. listed burner designed to fire at 0.65 gallons of oil per hour.

A Complete System

HB Series
Air Handler

VB Series
Air Handler

Matched Components

Apollo Air Handlers are designed for use with the Apollo HydroHeat Oil-Fired 5010 self-cleaning water heaters.

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HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
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the Smart way to heat

Specifications

Oil-Fired 5010 Residential Oil-Fired Water Heater with Foam Insulation

Model	Firing Rate g.p.h.	Tank Storage	Recovery Input BTU/hr.	First Hour Rating	Rate 100° Rise	Shipping Weight	Dimensions in Inches					Power Required	Ampe
							A	B	C	D	E		
A5-40.90.00KRS6	0.65	40	90,000	125	83	195	55 $\frac{7}{8}$	50 $\frac{7}{8}$	20	22 $\frac{7}{8}$	5	115V 60CY 1PHJ	4.5

150 lbs. Hydrostatic working pressure.
UL listed burner shipped unattached.

HydroSwirl dip tube makes sure that the money-saving performance lasts!

The HydroSwirl is equipped with the exclusive, patented **HydroSwirl dip tube**. It creates a "vortex" of turbulence inside the tank, which prevents sediment accumulation. In ordinary water heaters, lime and their sediments can accumulate on heat transfer areas, affect tank life, and decrease the water heater's efficiency. But **HydroSwirl** water heaters clean themselves, so they're energy efficient and **stay** that way! **No other oil water heater saves homeowners this much on operating costs!** The Energy Guide label found on all water heaters tells consumers how much it costs to heat water. And the HydroSwirl label tells a powerful story. Homeowners can **save** more money on operating cost with the HydroSwirl over the life of the water heater, compared to less efficient models. HydroSwirl has the lowest operating cost of any oil water heater made!

Water Heater/Air Handler Sizing

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Barometric Draft Regulator

Since chimneys natural draft can vary greatly, a barometric draft regulator must be installed whenever the chimney height is over 8 feet vertical. The function of the draft regulator is to maintain a stable or fixed draft to the water heater within the limits of available draft of the chimney. This allows the oil burner air shutters to be set for maximum combustion efficiency consistent with clean burning of the oil. The 5 inch draft regulator is for use on the 5 inch flue, 40 gallon short residential or SBT40-90 OESF commercial oil-fired water heater only. Larger draft regulators, suitable for the other commercial oil-fired water heaters, can be obtained.

HYDROHEAT

HydroHeat 5010 Residential Gas Water Heater with Foam Insulation

100 Gallon Storage Capacity
Natural and Propane (L.P.) Gas
Input BTU/Hr: 83,000 BTU Natural, 77,000 BTU Propane (L.P.) Gas

Five-year Limited Warranty on Tank and One-year on Parts

Compared to a standard fiberglass insulated water heater of the same capacity, the HydroHeat 5010 models furnish more hot water per hour and offer 76% recovery efficiency.

Check these Quality Features

- Competitively Priced
- Foam Insulation retains heat 2½ times better than standard fiberglass insulation.
- Aluminized Steel Multi-Port Burner for quiet, efficient combustion.
- Energy-Saving Pilot.
- Nylon Drain Valve eliminates electrolytic corrosion.
- Glasslined Tank for years of rust-free operation.
- Automatic Temperature Control, with four settings for plenty of hot water at a desired temperature.
- A.G.A. Design Certified E.C.O. (Energy Cut-Off).
- Maximum hydrostatic working pressure is 150 psi.
- Five-year limited tank warranty. Complete details on these warranties available at your nearest Apollo sales office.
- Temperature-Pressure Relief Valve.

A Complete System

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HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

HydroHeat 5010 Residential Gas Water Heater with Foam Insulation

Model Number	Gallon Capacity	Dimensions in Inches							Shipping Weight (lbs.)
		A	B	C	D	E	F	G	
A510083.0 NRRT	100	70 $\frac{1}{4}$	66 $\frac{1}{2}$	26 $\frac{1}{4}$	4	60	16 $\frac{3}{4}$	8	580
A510077.0 PRRT	100	70 $\frac{1}{4}$	66 $\frac{1}{2}$	26 $\frac{1}{4}$	4	60	16 $\frac{3}{4}$	8	580

Model Number	Gallon Capacity	BTUH Input	Recovery Degree Rise			Recovery Efficiency	Output (GPH)
			100°	80°	60°		
A510083.0 NRRT	100	83,000	76	85	127	76%	63,080
A510077.0 PRRT	100	77,000	69	77	115	76%	58,520

Water Heater/Air Handler Sizing

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

HYDROHEAT *M Series Heating Only* **Multi-Position Heating Systems**

The M Series is the most economical answer to the builder's needs for heating. Compact design and airflow capabilities for 2½ and 3 ton cooling systems make the M Series ideal for the replacement market. This superior new heating system has fewer parts than any other heating system, making it virtually maintenance free.

Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing. Front mounted for ease of access.
- Pump relay and blower relay.
- Two speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Painted, insulated zinc coated steel cabinet (one piece wraparound).
- Copper sweat connections for heating coil.
- Service/isolation valves for pump.
- Reusable Filter
- Ten-year Limited Warranty on Heating Coil.
- One-year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown below.

A Complete System

ARL

SBCCI

BOCA

IAPMO

UL

500 By Pass Rd. Ashland City, TN 37015-1296
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Nom. Htg. Cap. BTUH*	Nom. CFM	Blower Motor HP	Pump Motor HP	Elec. Char.	Rated Amps	Min. Circuit Ampacity	Water Conn. I.D.	Supply Conn.	Return Opening	Ship. Wt. Lbs.
M-45-H	45,000	1200	1/3	1/20	1-60-115V	6.5	15	3/4	12 x 16	18.5 x 9	75

*3 GPM NOM. CFM, 65°F Entering Air Temperature

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

Form M45-18/1190

HYDROHEAT *M Series*

Multi-Position Heating Systems

Upflow, Horizontal
Heating Capacities 42,000-46,000 BTUH
Cooling Capacities 30,000-48,000 BTUH

The M Series is the most economical answer to the builder's needs for heating, with cooling coils available. This superior new heating system has one-third as many parts as a heat pump, making it virtually maintenance free. It is designed and tailored with heating and cooling capacities to fit from single family homes up to the multi-family market.

Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing. Front mounted for ease of access.
- Pump relay and blower relay.
- Multi-speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Painted, insulated zinc coated steel cabinet (one piece wraparound).
- Copper sweat connections for heating coil, cooling coil.
- Service/isolation valves for pump.
- Ten-year Limited Warranty on Heating Coil.
- Five-year Limited Warranty on Evaporator Coil.
- One-year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown below.

A Complete System

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500 By Pass Rd. Ashland City, TN 37015-1296
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

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Specifications

Model	Nom. Hg. Cap. BTUH*	Nom. Cool Cap. BTUH**	Nom. CFM	Blower Motor HP	Pump Motor HP	Elec. Char.	Rated Amps	Min. Circuit Amperacity	Water Conn. I.D.	R-22 O.D.		Supply Conn.	Return Conn.	Blow-off
										LI	RI			
M-42-2.5	42,000	30,000	1000	1/3	1/20	1-60-115V	6.5	15	3/4	3/8	7/8	12 x 16	18.5 x 19	115
M-45-3.0	45,000	36,000	1200	1/3	1/20	1-60-115V	6.5	15	3/4	3/8	7/8	12 x 16	18.5 x 19	120
M-46-4.0	46,000	48,000	1600	1/2	1/20	1-60-115V	7.9	15	3/4	3/8	7/8	12 x 16	18.5 x 19	135

Model	Heating Capacities			
	130°F	140°F	150°F	160°F
	BTUH			
M-42-2.5	25,890	42,000	47,330	53,090
M-45-3.0	28,890	45,000	50,930	57,150
M-46-4.0	40,000	46,000	52,500	59,000

*3 GPM, Nom. CFM, 65°F entering shaded area indicates recommended water heater temperature range

**Nom. cooling @ 48° suction temp. 80°DB, 67°WB, return air, rated CFM.

Model	ESP	CFM				
		.1	.2	.3	.4	.5
M-42-2.5	HI	1350	1270	1200	1110	1030
	LO	1130	1075	1015	950	885
M-45-3.0	HI	1315	1245	1165	1080	995
	LO	1115	1065	1010	945	875
M-46-4.0	HI	1770	1695	1615	1534	1450
	MED	1550	1490	1430	1365	1310
	LO	1225	1200	1170	1140	1095

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure. The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater. Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

Form M-17-1090

HYDROHEAT *VB Series*

Vertical-Position Heating Systems

Vertical-Upflow unit
Heating Capacities 20,000 through 30,000 BTUH
Evaporator (Cooling Coil) Available in 1, 1½ or 2 Ton Capacities

The VB Series is the most economical answer to the builder's needs for heating, with cooling coils available. This superior new heating system has one-third as many parts as a heat pump, making it virtually maintenance free. It is designed and tailored with heating and cooling capacities to fit from single family homes up to the multi-family market.

Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing. Front mounted for ease of access.
- Pump relay and blower relay.
- Two speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Painted, insulated zinc coated steel cabinet (one piece wraparound).
- Copper sweat connections for heating coil, cooling coil.
- Service/isolation valves for pump.
- 1" throwaway type air filter.
- Ten-year Limited Warranty on Heating Coil.
- Five-year Limited Warranty on Evaporator Coil.
- One-year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown below.

A Complete System

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Cumberland Street, Ashland City, TN 37015

A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Nom. Htg. Cap., BTUH*	Nom. Cool Cap., BTUH**	Nom. CFM	Blower Motor HP	Pump Motor HP	Elec. Char.	Rated Amps	Min. Circuit Ampacity	Water Conn. I.D.	R-22 O.D. LL/SL	Supply Conn.	Return Opening	Filter Size	Ship. Wt. Lbs.
VB2012-1	20,000	12,000	425	1/5	1/20	1-80-115v	2.5	15	1/2"	1/4x1/4"	12"Wx17"D	9 1/2"x19"	14"x20"x1"	87
VB2418-1	24,000	18,000	650	1/4	1/20	1-80-115v	3.0	15	1/2"	1/4x1/4"	12"Wx17"D	9 1/2"x19"	14"x20"x1"	89
VB2618-1	26,000	18,000	650	1/4	1/20	1-80-115v	3.0	15	1/2"	1/4x1/4"	12"Wx17"D	9 1/2"x19"	14"x20"x1"	92
VB3024-1	30,000	24,000	800	1/4	1/20	1-80-115v	4.0	15	1/2"	3/8x3/8"	12"Wx17"D	9 1/2"x19"	14"x20"x1"	96

Heating Capacities*					
E.W.T.	130°F	140°F	150°F	160°F	170°F
Model	BTUH				
VB2012-1	16,700	20,000	21,700	23,300	24,500
VB2418-1	20,200	24,000	26,500	29,100	31,200
VB2618-1	22,200	26,000	29,200	32,100	34,700
VB3024-1	25,100	30,000	34,200	38,200	43,200

*3 GPM, Nom. CFM, 65°F entering shaded area indicates recommended water heater temperature range

**Nom. Cooling @45° suction temp. 80°DB, 67°WB, return air rated CFM.

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

CFM vs Static									
Model	ESP	.05	.10	.15	.20	.25	.30	.35	.40
VB2012-1	LO SPD	450	440	435	430	425	420	415	410
VB2418-1	LO SPD	750	730	705	680	655	635	630	600
VB2618-1	LO SPD	750	730	705	680	655	635	630	600
VB3024-1	LO SPD	750	730	705	680	655	635	615	600
	HI SPD	835	805	775	740	710	680	650	625

With 14" x 20" x 1" Filter Installed

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

VB-3-1-88

HYDROHEAT *HB Series*

Horizontal-Position Heating Systems

Left* or Right-Hand Air Flow
Heating Capacities 20,000 through 30,000 BTUH
Evaporator (Cooling Coil) Available in 1, 1½ or 2 Ton Capacities

The HB Series is the most economical answer to the builder's needs for heating, with cooling coils available. This superior new heating system has one-third as many parts as a heat pump, making it virtually maintenance free. It is designed and tailored with heating and cooling capacities to fit from single family homes up to the multi-family market.

*Shipped standard for left hand air flow, field convertible to right hand air flow.

A Complete System

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Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing. Front mounted for ease of access.
- Pump relay and blower relay.
- Two speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Painted, insulated zinc coated steel cabinet (one piece wraparound).
- Copper sweat connections for heating coil and cooling coil.
- Service/isolation valves for pump.
- External filter rack available.
- Ten-Year Limited Warranty on Heating Coil.
- Five-Year Limited Warranty on Evaporator Coil.
- One-Year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown.

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HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015

A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Nom. Htg. Cap., BTUH*	Nom. Cool Cap., BTUH**	Nom. CFM	Blower Motor HP	Pump Motor HP	Elec. Char.	Rated Amps	Min. Circuit Ampacity	Water Conn I.D.	R-22 O.D. LL/SL	Supply Conn.	Return Conn.	Filter Size***	Ship. Wt. Lbs.
HB2012-1	20,000	12,000	425	1/5	1/20	1-60-115v	2.5	15	1/2"	3/8"	12"Wx17"D	12"x18 1/4"	14"x20"x1"	87
HB2418-1	24,000	18,000	650	1/4	1/20	1-60-115v	3.0	15	1/2"	3/8"	12"Wx17"D	12"x18 1/4"	14"x20"x1"	89
HB2618-1	26,000	18,000	650	1/4	1/20	1-60-115v	3.0	15	1/2"	3/8"	12"Wx17"D	12"x18 1/4"	14"x20"x1"	92
HB3024-1	30,000	24,000	800	1/4	1/20	1-60-115v	4.0	15	1/2"	3/8"	12"Wx17"D	12"x18 1/4"	14"x20"x1"	96

Heating Capacities***					
E.W.T.	130°F	140°F	150°F	160°F	170°F
Model	BTUH				
HB2012-1	16,700	20,000	21,700	23,300	24,500
HB2418-1	20,200	24,000	26,500	29,100	31,200
HB2618-1	22,200	26,000	29,200	32,100	34,700
HB3024-1	25,100	30,000	34,200	38,200	43,200

*3 GPM, Nom. CFM, 65°F entering air temp. shaded area indicates recommended water heater temperature range

**Nom. cooling @45° suction temp., 80°DB, 67°WB return air, rated CFM.

***Shaded area indicates recommended water heater temperature setting.

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

CFM vs Static									
Model	ESP	.05	.10	.15	.20	.25	.30	.35	.40
HB2012-1	LO SPD	450	440	435	430	425	420	415	410
HB2418-1	LO SPD	750	730	705	680	655	635	630	600
HB2618-1	LO SPD	750	730	705	680	655	635	630	600
HB3024-1	LO SPD	750	730	705	680	655	635	615	600
	HI SPD	835	805	775	740	710	680	650	625

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

HYDROHEAT *HB Series Heating Only* Multi-Position Heating Systems

**Vertical (upflow or downflow), Horizontal (right or left) or Counter flow
Heating Capacities 20,000 through 30,000 BTUH**

The HB Series is the most economical answer to the builder's needs for heating. This superior new heating system has one-third as many parts as a heat pump, making it virtually maintenance free. It is designed and tailored with heating capacities to fit from single family homes up to the multi-family market.

A Complete System

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Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing. Front mounted for ease of access.
- Pump relay and blower relay.
- Two speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Painted, insulated zinc coated steel cabinet (one piece wraparound).
- Copper sweat connections for heating coil
- Service/isolation valves for pump.
- External filter rack available.
- Ten-Year Limited Warranty on Heating Coil.
- One-Year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown.

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HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Capacity (GPM)	Water Temp. (°F)	Air Temp. (°F)	Power (W)	Flow (GPM)	Pressure (PSI)	Supply (Duct)	Return (Duct)	Weight (LBS)
HB2400-1	24,000	1/4	1/20	1-60-115v	3.0	15	12"Wx17"D	12"x18 1/8"	79
HB3000-1	30,000	1/4	1/20	1-60-115v	4.0	15	12"Wx17"D	12"x18 1/8"	86

Model	Capacity (GPM)	Water Temp. (°F)	Air Temp. (°F)	Power (W)	Flow (GPM)	Pressure (PSI)	Supply (Duct)	Return (Duct)	Weight (LBS)
HB2400-1	24,000	1/4	1/20	1-60-115v	3.0	15	12"Wx17"D	12"x18 1/8"	79
HB3000-1	30,000	1/4	1/20	1-60-115v	4.0	15	12"Wx17"D	12"x18 1/8"	86

*3 GPM, 65°F entering air temp. shaded area indicates recommended water heater temperature range.
 ***Shaded area indicates recommended water heater temperature setting.

Model	Capacity (GPM)	Water Temp. (°F)	Air Temp. (°F)	Power (W)	Flow (GPM)	Pressure (PSI)	Supply (Duct)	Return (Duct)	Weight (LBS)
HB 2400-1	High Speed	910	900	855	805	715			
HB 3000-1	Low Speed	800	765	725	690	600			

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure. The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater. Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

HYDROHEAT

H Series Horizontal Heating Systems

Heating Capacities 20,000-36,000
Evaporator (Cooling Coil) Available in 1, 1½, 2, or 2½ Ton Capacities

The H Series is designed for the builder who has a need for overhead installation, above dropped or fired-down ceilings. This unit is the most economical answer to applications such as apartments, townhouses, motels, etc.

A Complete System

Check these Quality Features

- Integral return filter grille.
- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing.
- Pump relay and blower relay.
- Multi speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Zinc coated steel cabinet housing.
- Copper sweat connections for heating coil and cooling coil.
- Full coverage condensate drain pan. Primary & Secondary drains.
- Service/isolation valves for pump.
- Ten-Year Limited Warranty on Heating Coil.
- Five-Year Limited Warranty on Evaporator Coil.
- One-Year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown

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HydroHeat & Cooling

500 By Pass Rd., Ashland City, TN 37015-1296
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Nom. Htg. Cap. BTUH*	Nom. Ctg. Cap. BTUH**	Nom. CFM	Blower Motor HP	Pump Motor HP	Elec. Char.	Rated Amps	Min. Circuit Ampacity	Water Conn. I.D.	Supply Duct Conn.	Ship. Wt. Lbs.	R-22 Conn. O.D.	
												LL	SL
H-20-1.0	20,000	12,000	400	1/5	1/20	1-60-115V	3.5	15	1/2"	28 x 6 3/4	75	5/16	5/8
H-24-1.5	24,000	18,000	600	1/5	1/20	1-60-115V	3.5	15	1/2"	28 x 6 3/4	75	3/8	5/8
H-33-2.0	33,000	24,000	800	1/3	1/20	1-60-115V	5.5	15	1/2"	28 x 6 3/4	85	3/8	5/8
H-36-2.5	36,000	30,000	1,000	1/3	1/20	1-60-115V	5.5	15	1/2"	28 x 6 3/4	85	3/8	5/8

Heating Capacities***					
E.W.T.	130°F	140°F	150°F	160°F	170°F
Model	BTUH				
H-20-1.0	17,400	20,000	23,000	25,800	28,600
H-24-1.5	21,000	24,000	27,800	31,200	34,700
H-33-2.0	28,300	33,000	37,500	42,000	46,700
H-36-2.5	30,900	36,400	40,900	46,000	51,000

*3 GPM, Nom. CFM, 65°F entering air temp.

**Nom. cooling @ 45° suction temp., 80°DB, 67°WB return air, rated CFM.

***Shaded area indicates recommended water heater temperature setting.

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

CFM vs Static									
Model	ESP	.05	.10	.15	.20	.25	.30	.35	.40
H-20-1.0	HI	820	790	760	720	665	615	575	535
H-24-1.5	LO	625	615	585	565	530	500	465	430
H-33-2.0	HI	1130	1115	1060	1035	985	940	880	825
	MED	1055	1035	980	955	910	860	800	735
	LO	930	915	870	895	805	755	710	655
H-36-2.5	HI	1075	1060	1020	975	930	885	825	760
	MED	1010	995	950	910	860	815	740	670
	LO	895	885	850	815	770	725	675	625

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure. The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater. Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

Form H15-6-89

HYDROHEAT

W Series In-The-Wall Heating Systems

The W Series is the most economical answer to the builder's needs for heating, "In-the-Wall" with cooling coils available. This superior new heating system has one-third as many parts as a heat pump, making it virtually maintenance free. It is designed and tailored with heating and cooling capacities to fit from single family homes up to the multi-family market.

Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing. Front mounted for ease of access.
- Pump relay and blower relay.
- Two-speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Insulated zinc coated steel cabinet (one piece wraparound).
- White enamel service panel and louvered return grille.
- Optional decorative panels available white, textured finish. W-20, W-26, W-30-#9001610 W-42, W-45-#9001611
- Copper sweat connections for heating coil, cooling coil and condensate drains.
- Service/isolation valves for pump.
- 1" throwaway type air filter.
- Ten-year Limited Warranty on Heating Coil.
- Five-year Limited Warranty on Evaporator Coil.
- One-year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown below.

A Complete System

SHOWN WITH
OPTIONAL DECORATIVE
WALL PANEL

500 By Pass Rd., Ashland City, TN 37015-1296
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Nom. Htg. Capacity BTUH	Nom. Ctg. Capacity BTUH**	Nom. CFM	Blower Motor HP	Pump Motor HP	Elec. Characteristics	Rated AMPS	Min. Circuit Ampacity	Water Connections I.D.	R-22 Conn. O.D./S/L	Supply Connection	Filter Size	WT
W-20-1.0	22,000	12,000	400	1/8	1/20	1-60-115v	2.5	15	1/2"	1/4 3/8	12W x 10 1/4D	16 x 20 x 1	90
W-26-1.5	26,000	18,000	600	1/4	1/20	1-60-115v	3.0	15	1/2"	1/4 3/8	12W x 10 1/4D	16 x 20 x 1	92
W-30-2.0	30,000	24,000	800	1/4	1/20	1-60-115v	4.0	15	1/2"	3/8 5/8	12W x 10 1/4D	16 x 20 x 1	96
W-42-2.5	42,500	30,000	1000	1/2	1/20	1-60-115v	4.4	15	1/2"	3/8 7/8	16W x 12D	25 x 20 x 1	115
W-45-3.0	45,000	36,000	1200	1/2	1/20	1-60-115v	4.7	15	1/2"	3/8 7/8	16W x 12D	25 x 20 x 1	120

HEATING CAPACITIES*					
E.W.T.	120° F	130° F	140° F	150° F	160° F
MODEL	BTUH				
W-20-1.0	15,500	19,000	22,000	24,500	28,000
W-26-1.5	19,300	23,900	26,000	30,500	35,000
W-30-2.0	22,200	27,500	30,000	34,700	40,000
W-42-2.5	N/R	36,900	42,500	48,100	53,700
W-45-3.0	N/R	40,000	45,000	52,187	58,250

*3 GPM, Nom. CFM, 65°F entering air temp. shaded area indicates recommended water heater temperature range

**Nom. cooling @ 48 suction temp., 80°DB, 67°WB return air, rated CFM.

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing through the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

Form W-6/1190

Form W-6/1190

CFM - VS - STATIC									
Model	ESP	.05	.10	.15	.20	.25	.30	.35	.40
W-20-1.0	HI	525	490	465	445	425	400	375	350
	LO	300	295	290	280	278	275	260	250
W-26-1.5	HI	905	880	855	820	770	740	720	710
	LO	725	700	685	675	665	650	630	610
W-30-2.0	HI	920	900	880	855	795	750	735	725
	LO	765	735	715	700	685	675	655	620
W-42-2.5	HI	1340	1310	1280	1250	1210	1180	1145	1110
W-45-3.0	LO	1245	1205	1150	1150	1120	1090	1060	1025

Framing Opening: 20-1.0 — 19½ x 41
26-1.5
30-2.0

42-2.5 — 27 x 41
45-3.0

Panel Size: 20-1.0 — 42 x 22
26-1.5
30-2.0

42-2.5 — 42 x 29½
45-3.0

	W-20-1.0 W-26-1.5 W-30-2.0	W-42-2.5 W-45-3.0
A	17	19
B	21	28½
C	10¼	12
D	12	16

HYDROHEAT *CBC Series*

Multi-Position Heating Systems

Left or Right Hand Airflow or Vertical-Upflow
Heating Capacity 30,800 BTUH
Evaporator (Cooling Coil) Available in 1½ or 2 Ton Capacities

The CBC Series is the most economical answer to the builder's needs for heating, with cooling coils available. This superior new heating system has one-third as many parts as a heat pump, making it virtually maintenance free. It is designed and tailored with heating and cooling capacities to fit from single family homes up to the multi-family market.

Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing.
- Pump relay and blower relay.
- Two speed direct drive blower/motor assembly.
- 115/24 volt transformer
- Painted, insulated zinc coated steel cabinet
- Copper sweat connections for heating coil and cooling coil.
- Service/isolation valves for pump.
- External filter rack available.
- Ten-Year Limited Warranty on Heating Coil.
- Five-Year Limited Warranty on Evaporator Coil.
- One-Year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown below.

A Complete System

apollo
HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Nom. Htg. Cap., BTUH*	Nom. Cool Cap., BTUH**	Nom. CFM	Blower E.S.P.				Motor HP	Pump Motor HP	Elec. Char.	Rated Amps	Min. Circuit Ampacity	Water Conn. I.D.	R-22 O.D.		Ship Wt. Lbs.	Unit Dim.	Supply Conn.	Return Conn.
				0.1	0.2	0.3	0.4							LL	SL				
CBC-8A	30,800	—	LOW SPD	820	780	740	690	¼ HP 2 SPD	1/20	1-60-115v	4.0	15	½"	—	—	78	14"W x 20½"D x 26"H	12" x 17"	12½" x 17"
E-24-CBC-8A	30,800	18,000/24,000	HIGH SPD	830	770	700	630	¼ HP 2 SPD	1/20	1-60-115v	4.0	15	½"	¾"	¾"	106	14"W x 20½"D x 40"H	12" x 17"	12½" x 17"

Heating Capacities***					
E.W.T.	130°F	140°F	150°F	160°F	170°F
BTUH	28,000	30,800	35,000	39,500	44,000

*3 GPM, Nom. CFM, 65°F entering air temp. shaded area indicates recommended water heater temperature range

**Nom. cooling @ 45° suction temp., 80°DB, 67°WB return air, rated CFM

***Shaded area indicates recommended water heater temperature range.

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

CBC-2-3-89

E-24-CBC-8A

CBC-8A

HYDROHEAT *HH Series*

Multi-Position Heating Systems

Multi-Position unit
Heating Capacities 14,700 through 19,300 BTUH
Add-On Evaporator (Cooling Coil) Available in 1 Ton Capacity

The HH Series is the most economical answer to the builder's needs for heating, with cooling coil available. This superior new heating system has one-third as many parts as a heat pump, making it virtually maintenance free. It is designed and tailored with heating and cooling capacities to fit from single family homes up to the multi-family market. Ideal for rehabilitation and replacement.

Check these Quality Features

- Heating coils with copper tubes and aluminum fins.
- Circulator pump with stainless steel or plastic impeller and bronze housing. Front mounted for ease of access.
- Pump relay and blower relay.
- 115/24 volt transformer
- Painted, insulated zinc coated steel cabinet (one piece wraparound).
- Copper sweat connections for heating coil and cooling coil.
- Service/isolation valves for pump.
- Ten-Year Limited Warranty on Heating Coil.
- Five-Year Limited Warranty on Evaporator Coil.
- One-Year Limited Warranty on Parts.
- All models are listed under one or more of the organizations shown below.

A Complete System

apollo
HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

Model	Nom. Htg. Cap. BTUH*	Nom. Cig. Cap. BTUH**	Nom. CFM	Blower Motor HP	Pump Motor HP	Elec. Char.	Min. Circuit Ampacity	Water Conn I.D.	Supply Duct Conn.	Return Duct Conn.	Ship. Wt. Lbs.	R-22 Conn O.D.	
												LL	SL
HH 2000-1	19,000	—	480	1/5	1/20	1-60-115v	15	1/2"	6" x 12"	7" x 21 1/2"	45	—	—
HH 2000-1 with EH12	17,250	12,000	400	1/5	1/20	1-60-115v	15	1/2"	6" x 12"	7" x 21 1/2"	55	1/4	5/8

Model HH2000-1/HH2000-1 w/EH12 Heating Capacities* (BTUH)				
E.W.T.	130°F	140°F	150°F	160°F
300 CFM	12,716	14,723	16,739	18,764
350 CFM	13,863	16,058	18,263	20,480
400 CFM	14,885	17,247	19,622	22,010
450 CFM	15,804	18,318	20,846	23,389
500 CFM	16,639	19,292	21,960	24,645

*3 GPM, Nom. CFM, 65°F entering air temp.

Shaded area indicates recommended water heater temperature range
 **Nom. cooling @ 45° suction temp., 80° DB, 67° WB return air, rated CFM.

Model HH2000-1/HH 2000-1 with EH12 CFM vs Static						
ESP* (both)	.05	.10	.15	.20	.25	.30
HH 2000-1	515	500	490	480	465	435
HH 2000-1 with EH12	440	430	410	400	390	370

*ESP must include filter and duct pressure drop.

How Does The Apollo Air Handler Work?

The HydroHeat Air Handler is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump in the air handler begins circulating the warm water from the water heater through the finned tube heating coil of the air handler. The air handler's blower has also been activated and the air passing over the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

Air Handler/Water Heater Sizing

The air handler's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the air handler's heating coil, when divided by the recovery efficiency of the water heater.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

HYDROHEAT *RFC Series* Multi-Position Heating Systems

**Vertical or Horizontal Air Flow
Heating Capacities up to 57,500 BTUH**

The RFC Series is the most economical answer to today's needs for heating. This superior new heating system is virtually maintenance free. It is designed and tailored with heating capacities to fit from single family homes up to the multi-family market. Ideal for the retrofit market.

A Complete System

Check these Quality Features

- Copper/Aluminum construction
- Built in control relay
- Drive cleats supplied on short side of coil
- 3/4" F.P.T. pipe connections
- Built in manual air vent
- Isolation valves on pump
- Ten-Year Limited Warranty on Heating Coil

apollo
HydroHeat & Cooling

Cumberland Street, Ashland City, TN 37015
A DIVISION OF STATE INDUSTRIES, ASHLAND CITY, TN

the Smart way to heat

Specifications

RFC AIR FLOW/PRESSURE DROP (INCHES OF WATER)						
COIL MODEL	AT 500 CFM	AT 750 CFM	AT 1000 CFM	AT 1250 CFM	AT 1500 CFM	AT 1750 CFM
RFC 1520T	.039	.081	.135	.201	—	—
RFC 2025T	.016	.033	.054	.082	.112	.148
RFC 2030T	.011	.024	.039	.060	.084	.115

Coil/Water Heater Sizing

The coil's heating capability must equal or exceed the (ACCA Method J) heat loss of the structure.

The water heater should be a minimum of 40 gallon capacity. The water heater's input (BTUH) must equal or exceed the capacity of the heating coil, when divided by the recovery efficiency of the water heater.

Assistance in sizing can be obtained from your Apollo Distributor. In addition, the Apollo Systems Handbook which includes installation and operation information, can be found under the "Installation Information" tab of the Apollo Catalog.

How Does The Apollo Coil Work?

The HydroHeat Coil is connected to a conventional heating or heating/cooling thermostat. When the thermostat calls for heat, the circulating pump on the coil begins circulating the warm water from the water heater through the finned tube heating coil. The blower has also been activated and the air passing through the heating coil is heated and blown into the home through the duct system. When the thermostat is satisfied, the pump and blower both stop.

Dimensions (Inches)					Weight in Lbs.	
Model	H	W	D	OW	Water Conn. F.P.T.	Unit Ship Wt. Wt.
RFC 1520T	15	20	6 1/8	29 1/8	3/4"	27 34
RFC 2025T	20	25	6 1/8	34 1/8	3/4"	33 40
RFC 2030T	20	30	6 1/8	39 1/8	3/4"	36 43

In keeping with our policy of continuous product improvement we reserve the right to make changes without prior notice.

New Models Added for 1992!

AquaTherm®

By FIRST CO.

***Combo Air Handlers
...the ultimate heating system***

High Efficiency Space Heating... The **AquaTherm**[®] System...by

The "Integrated" Appliance has Arrived!

Tested for over 16 years in the laboratory and in the field, the AQUA THERM System — a FIRST CO. air handler — converts any properly sized gas or oil-fired water heater into a highly efficient, dual-purpose appliance that can heat your home as well as provide hot water for domestic purposes. And it doesn't make any difference where you live!

Any properly sized water heater (for heating) and split system type condensing unit (for cooling) will work with FIRST CO. AQUA THERM air handlers. **No special water heater is required.** NOTE: FIRST CO. only supplies the AQUA THERM Air Handler.

AQUA THERM air handlers consist of a fan motor for air circulation, hot water circulating pump, hot water heating coil, air purge valve, check valve, components for low voltage control, and most include a cooling coil for air conditioning. All components in the water piping are approved for potable water use.

Sequence of Operation (Heating mode)

When space heating is needed, the wall thermostat energizes a small pump which circulates hot water (135 to 140 degrees) from the water heater to the hot water coil in the air handler. As the fan motor forces the cool return air from the home over the hot water coil, the air absorbs heat from the hot water and this warm air (about 105 to 110 degrees) is then circulated throughout the duct system and into the home. **IMPORTANT** . . . in most applications the water will lose only 15 to 25 degrees in temperature while circulating through the hot water coil and will **RETURN** to the water heater at about 120 to 130 degrees to be reheated!

High Efficiency from your Water Heater

Laboratory and field tests have proven that the more a water heater is used the more efficient it is. While the "recovery efficiency" (maximum operating efficiency) of most water heaters is from 76 to 85%, their "annual efficiency" is only 50 to 60% because of standby and other miscellaneous losses. However, when used for SPACE HEATING as well as domestic water heating the "annual efficiency" is increased dramatically. The equivalent A.F.U.E. of this system will be 2 to 3 percentage points above the recovery efficiency of the water heater.

Compared to the standard heat pump system with an electric water heater, the AQUA THERM System from FIRST CO. can cut the utility bills **IN HALF** and can save even more when compared to straight electric heat! The AQUA THERM System can even save over 16% compared to a standard gas furnace with a gas water heater.

Water heater efficiency information may be obtained from the water heater manufacturer or the latest Gas Appliance Manufacturers Association (GAMA) Directory.

Additional Benefits

Low maintenance costs: The AQUA THERM System is extremely simple and uncomplicated compared to other high efficiency heating systems. Normal maintenance and service on the heating system can be performed easily and quickly because of the lack of sophisticated controls.

Consistently warm air: A properly sized AQUA THERM System will provide warm, comfortable air temperatures no matter what the temperature is outside. Heat pumps, however, tend to blow cooler air as the temperature outside drops.

No venting or gas piping of the air handler is required: The AQUA THERM air handler can be installed virtually anywhere without worrying about costly venting or gas piping.

Compatible with most condensing units: All AQUA THERM air handlers with cooling coils are completely compatible with most major brands of condensing units manufactured by Carrier, Rheem, Lennox, etc. Contact the factory for capacity and efficiency information on specific combinations.

Compatible with ALL gas or oil-fired water heaters and boilers: This allows you to package the most efficient heating and cooling system together at the best possible price. **NO SPECIAL WATER HEATER IS REQUIRED.**

Longer water heater life: Water heaters used for space heating in conjunction with AQUA THERM air handlers have shown dramatically less internal scaling and corrosion due to the gentle increase in water circulation caused by the pump.

Reduced electrical service requirements: All AQUA THERM air handlers operate on 120 volts and only draw 2 to 13 amps. In addition to being inexpensive to operate, the AQUA THERM System will save even more money on overall electrical installation costs — smaller distribution panels and less wiring for electric water heaters and electric heating elements.

Flow Control
Module

Air Handlers for Every Application

FIRST CO. has been building AQUA THERM air handlers since 1974 and now offers *Ten* different air handler models plus an add-on hot water coil.

MAQ, VAQ and RAQ Series air handlers have factory installed circulating pumps and controls while all other air handlers and add-on hot water coils feature the FIRST CO. exclusive external "flow control module" for flexible field installation anywhere between the water heater and air handler.

from a Water Heater!

FIRST CO.

Direct Vent Water Heater

The "flow control module" is a U.L. listed device that consists of the circulating pump, check valve, pump relay, and 6' plug-in line cord and is designed to circulate a precise amount of hot water between the water heater and air handler or coil.

All air handlers and/or "flow control modules" include large air purge valves for faster air purging during start-up.

Equipment sizing

(For complete installation and application manual, order catalog number "IAM").

Air handler

Select an air handler with a heating output that exceeds the space heat loss and that has a cooling coil matched to the outdoor condensing unit.

Please note that the heating output of the air handler (BTUH) will not be greater than the NET BTUH of the selected water heater ($BTUH \text{ INPUT} \times \text{RECOVERY EFFICIENCY}$).

Water Heater

Add 10 to 20% to the structure's heat loss to obtain the minimum **OUTPUT** of the required water heater ($\text{Output} = \text{Input} \times \text{Recovery Efficiency}$).

A minimum 40 gallon high recovery and/or high efficiency gas or oil-fired water heater is recommended. In addition to the above formula, the following volume sizing guide is satisfactory in most parts of the country:

600-800 CFM air handlers — minimum 40 gallon water heater

1000-1200 CFM air handlers — minimum 50 gallon water heater

1400-1600 CFM air handlers — either two 40 gallon water heaters piped together, one high input 50 gallon (63,000 to 75,000 BTU input), or one 72 to 75 gallon.

2000 CFM air handlers — any combination of water heaters having at least 98,000 BTU Output.

For additional assistance in water heater sizing contact the factory or a qualified professional engineer.

Condensing unit

Selection of the condensing unit size should be determined by the "Manual J" method or other approved heat load/gain calculation procedure.

Approved cooling capacities and efficiency information are available upon request from FIRST CO. once the manufacturer name and model number of the outdoor condensing unit are provided.

Thermostat

Any 24 volt thermostat having positive heat and cool fan cycle control should be used. This is usually called an "electric heat" thermostat. A gas furnace thermostat will only work with Series **MAQ**, **VAQ** and **RAQ** air handlers.

Water piping

Water piping between the water heater and air handler should be 3/4" (1" on 60 MAQ) nominal copper or other approved material and should be insulated to prevent freezing and to minimize heat loss if penetrating an unconditioned space.

To prevent air lock of the pump, the piping connections to and from the air handler *must* come from the horizontal connections of the "T" fittings in the vertical hot and cold water supply lines at the water heater. (See diagram above.)

Maximum distance between the water heater and air handler should not exceed 100 feet (one way).

AquaTherm®

VAQ Series Upflow/Horizontal Air Handler

Features:

- Installed circulating pump and check valve
- Large air purge valve
- Copper tube/aluminum fin heating and cooling coils
- Piston type metering on cooling coil
- Factory installed filter
- Primary and secondary drain connections
- Manual air vent on hot water coil
- Blower door safety switch
- Attractive beige baked-on finish

Model	Heating BTUH (1)	Nom. Clg. (Tons)	Dimensions (H-W-D)
18 VAQ - 2	21,800	1.5	40" x 14" x 20"
18 VAQ - 3	27,600		
30 VAQ - 3	41,500	2.5	42" x 20" x 20"
42 VAQ - 4	60,200	3.5	48" x 21 1/4" x 28"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT.
2. Consult factory for boiler applications.
3. Accessories: (Field installed)
 1. **Horizontal Drain Pans** (Air flow right to left)
 #935-1 fits 24 through 36 VAQ (not 18 VAQ)
 #935-2 fits 42 and 48 VAQ
 2. **Freeze Protector** - #941-1 brings on pump below 38°

MAQ Series Upflow/Horizontal Air Handler

Features:

In addition to all of the above VAQ features, the MAQ Series has:

- Extra large high efficiency cooling coil for proper matching with today's higher efficiency condensing units.
- Field installable expansion valve kit for more efficient cooling performance.
- Factory installed horizontal drain pan (right to left airflow).
- Slide out hot water coil assembly for easier service.

Model	Heating BTUH (1)	Nom. CLG (Tons)	Dimensions (H-W-D)
18 MAQ-2	26,800	1.5	40" x 20" x 20"
18 MAQ-3	33,900		
30 MAQ-3	43,600	2.5	42" x 20" x 23"
48 MAQ-4	66,800	3.5-4.0	48" x 21 1/4" x 28"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT.
2. Accessories: (Field installed)
 1. **Expansion valve kits** - (Contact factory for Kit #'s).
 2. **Freeze protector** - #941-1 brings on pump below 38°.

AquaTherm®

RAQ Series Wall or Closet Vertical Air Handler

Features:

- Installed circulating pump and check valve
- Large air purge valve
- Blower door safety switch
- Cap Tube metering on cooling coil (piston type optional)
- Copper tube/aluminum fin heating and cooling coils
- Optional wall panel for recessed wall mounting
- Factory installed filter
- Primary and secondary drain connections
- Manual air vent on hot water coil
- Completely serviceable from the front

Model	Heating BTUH (1)	Nom. Clg. (Tons)	Dimensions (H-W-D)
18 RAQ - 2	20,200	1.5	39 1/4" x 20 1/8" x 16 1/8"
18 RAQ - 3	26,000		
30 RAQ - 3	43,000	2.5	44 1/4" x 24 1/8" x 21 1/8"

Notes: 1. BTUH capacities are based on 140° EWT, 70° EAT.

2. Consult factory for boiler applications.

3. Accessories: (Field installed)

Wall Panels (Req'd for recessed wall mounting)

1. #961 - Fits 18/24 RAQ

2. #962 - Fits 30/36 RAQ

Hanger Bracket - attaches to inside closet wall for air handler hanging - #919-2

RCUA-HW Series Cased Horizontal Air Handler

Features:

- Completely cased
- Factory installed filter
- Bottom return air (Rear Return Optional)
- Completely serviceable from below the unit
- Unit shipped with access/return air panel
- Primary and secondary drain connections
- Manual air vent on hot water coil
- Compact size — only 11" high
- Copper tube/aluminum fin heating and cooling coils
- Mounting brackets furnished with unit
- Piston-type metering device on cooling coil
- Shipped with exclusive U.L. listed "Flow Control" module

Model	Heating BTUH (1)	Nom. Clg. (Tons)	Dimensions (H-W-D)
18 RCUA-2HW	20,000	1.5	11" x 35½" x 24¼"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT, and FIRST CO. Flow Control Module.
2. Consult factory for boiler applications.

HBC-HW Series Uncased Horizontal Air Handler

Features:

- Copper tube/aluminum fin heating and cooling coils
- Insulated drain pan
- Primary and secondary drain connections
- Manual air vent on hot water coil
- Compact size — only 10" high
- Shipped with exclusive U.L. listed "Flow Control" module

Model	Heating BTUH (1)	Nom. Clg. (Tons)	Dimensions (H-W-D)
12 HBC-HW	14,600	1.0	10" x 36½" x 21"
24 HBC-HW	23,900	2.0	10" x 46½" x 21"
36 HBC-HW	31,600	3.0	10" x 59½" x 21"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT, and FIRST CO. Flow Control Module.
2. Consult factory for boiler applications.

XVAQ Series Upflow, Downflow, Horizontal Heating only Air Handler

Features:

- Installed circulating pump and check valve
- Large air purge valve
- Blower door safety switch
- Copper tube/aluminum fin heating coil
- Factory installed filter
- Attractive beige baked-on finish
- Compact size — max 27" tall

Model	Heating BTUH (1)	CFM (@ .1 ESP)	Dimensions (H-W-D)
XVAQ 22-2	21,800	710	25" x 14" x 20"
XVAQ 50-3	49,500	1320	27" x 20" x 23"

Notes:

1. BTUH capacities are based on 140° EWT and 70° EAT.

HAQ Series Upflow, Downflow, Horizontal Heating only Air Handler

Features:

- Installed circulating pump and check valve
- Large air purge valve
- Blower door safety switch
- Copper tube/aluminum fin heating coil
- Attractive beige baked-on finish
- Compact size — only 10" high

Model	Heating BTUH (1)	CFM (@ .1 ESP)	Dimensions (H-W-D)
HAQ 18-2	19,000	380	10" x 23 1/4" x 18 1/4"

Notes:

1. BTUH capacities are based on 140° EWT and 70° EAT.

HWF Series Upflow, Downflow, Horizontal Heating only Air Handler

Features:

- Copper tube/aluminum fin heating coil
- Factory installed filter
- Manual air vent on hot water coil
- Attractive beige baked-on finish
- Blower door safety switch
- Shipped with exclusive U.L. listed "Flow Control" module
- Blower delay relay

Model	CFM Range	Heating BTUH (1)	Dimensions (H-W-D)
HWF 32-3	710-990	32,000	24 3/4" x 17 1/2" x 20 1/4"
HWF 60-4	1020-1780	60,500	28 3/4" x 21 1/2" x 28 1/4"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT and FIRST CO. Flow Control Module.
2. Consult factory for boiler applications.

HWC Series Add-on Heating Coil for Duct Mounting

Features:

- Copper tube/aluminum fin heating coil
- Can be mounted in new or existing duct
- Vertical or horizontal mounting
- Shipped with exclusive U.L. listed "Flow Control" module
- Completely insulated cabinet
- Manual air vent on hot water coil

Model	CFM Range	Heating BTUH (1)	Face Area	Dimensions (H-W-D)
HWC 1520	800-1200	38,300	15 x 20	17" x 3 7/8" x 24 1/2"
HWC 2030	1800-2200	64,000	20 x 30	22" x 3 7/8" x 34 1/4"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT, FIRST CO. Flow Control module, and average air flows.
2. Consult factory for boiler applications.

AquaTherm®

VDX-HW Series Upflow/Horizontal Air Handler

Features:

- Copper tube/aluminum fin heating and cooling coils
- Factory installed filter
- Primary and secondary drain connections
- Manual air vent on hot water coil
- Blower door safety switch

Model	Heating BTUH (1)	Nom. Clg. (Tons)	Dimensions (H-W-D)
18 VDX - 2 HW	22,000	1.5	40" x 14" x 20"
18 VDX - 3 HW	28,200		
30 VDX - 3 HW	41,000	2.5	42" x 20" x 20"
42 VDX - 4 HW	60,500	3.5	48" x 21 1/4" x 28"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT and FIRST CO Flow Control Module.
2. Consult factory for boiler applications.
3. Uses same accessories as VAQ Series (see page 4).

- Attractive beige baked-on finish
- Horizontal drain pan available for 2.0 through 4.0 ton models
- Shipped with exclusive U.L. listed "Flow Control" module

MAX-HW Series Upflow/Horizontal Air Handler

Features:

In addition to all of the above VDX-HW features (1 through 6), the MAX-HW Series has:

- Extra large high efficiency cooling coil for proper matching with today's higher efficiency condensing units.
- Field installable expansion valve kit for more efficient cooling performance. (Piston type metering is standard)
- Factory installed horizontal drain pan (right to left airflow).
- Slide out hot water coil assembly for easier service.

Model	Heating BTUH (1)	Nom. CLG (Tons)	Dimensions (H-W-D)
18 MAX-2HW	25,900	1.5	40" x 20" x 20"
18 MAX-3HW	33,000		
30 MAX-3HW	42,100	2.5	42" x 20" x 23"
48 MAX-4HW	71,500	3.5-4.0	48" x 21 1/4" x 28"

Notes:

1. BTUH capacities are based on 140° EWT, 70° EAT.
2. Accessories: (Field installed)
 1. Expansion valve kits — (Contact factory for kit #'s).
 2. Freeze protector — #941-1 brings on pump below 38°.

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APPENDIX G
APPLIANCE VENTING

AN OVERVIEW OF GRI'S VENTING RESEARCH PROGRAM AND PRACTICAL IMPLICATIONS OF REVISED APPLIANCE VENTING GUIDELINES

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ABSTRACT

The appropriate American National Standards Institute groups are currently considering substantially updating the venting guidelines in the National Fuel Gas Code including new vent sizing tables for Appendix G. These new standards are expected to include improved methods of categorization which will ensure that the vent design is consistent with the appliance operating characteristics. The technical background for these changes was developed by the Gas Research Institute's Venting/Flue Gas Management Project.

This paper will begin by providing an overview and status report of the entire Venting/Flue Gas Management Project. Then, it will illustrate the practical effects in the field that are expected to result from these revisions. First, the expected changes to appliance design will be discussed. Then, a comparison of the new and revised venting guidelines will be used to show how vent sizing and material selection will be modified. Throughout, the rationale motivating these changes will be explained.

INTRODUCTION

Objective

The purpose of this paper is to provide an overall briefing on the purpose, accomplishments, and plans of the Gas Research Institute's (GRI) Venting/Flue Gas Management project ("the venting project"). Additionally, a brief technical rationale for the proposed changes and their expected implications in the field will be presented.

Industry Challenge

The most significant result of the venting project thus far are improved vent sizing tables for fan-assisted, Category I appliances. These tables, along with improved, generic venting and installation instructions, have already been introduced into the field. Local servicemen, installers, and code officials need to be supplied with this information so that the transition will proceed with a minimum of confusion.

VENTING PROJECT ORGANIZATION

Purpose

The purpose of the GRI venting project is to address the need to change the methods for venting the products of combustion from modern gas appliances. Most of the current venting recommendations, as

embodied in the National Fuel Gas Code¹(NFGC), were developed in the 1950's for the appliances available at that time. Since the energy crisis of the 1970's, significant changes in appliance design have occurred. In light of changing appliance technology, the ANSI subcommittee for central furnaces(Z21.47) and other gas industry groups requested GRI support to make a thorough review of all the issues concerning gas venting and recommend changes as necessary. GRI responded by funding the venting project.

Principals

The venting project was organized by GRI in 1987. The project is conducted jointly by The American Gas Association Laboratories(A.G.A.L.) and Battelle.

The venting project has a critical need for constant review and guidance from the different segments of the gas industry. For this reason, GRI organized a Technical Advisory Group(TAG) to monitor the progress of the project. The TAG includes members representing gas utilities, appliance manufacturers, and gas venting product manufacturers. Most of the members are also active in standards committees covering their area of the industry. Thus, the TAG provides an avenue for direct dialogue between the researchers, the standards bodies, and the affected industry group. The TAG has proven to be very effective in expediting industry consensus when new venting recommendations are under development.

Project Tasks

The following tasks have been active during the project:

1. Vent Oversizing,
2. Combustion Air Supply,
3. Common Venting,
4. Multistory Venting,
5. Corrosion Test Methods,
6. Categorization,
- 7 . F i e l d Investigations,
8. Masonry Chimneys, and
9. Technology Transfer.

Initially, the highest priorities were placed on vent oversizing, categorization, and corrosion test methods. Each of these tasks are now substantially completed. Therefore, the focus of the project is currently concentrated on a thorough investigation of masonry chimneys, combustion air supply, and multistory venting. The remainder of the paper will concentrate on the areas of vent sizing and categorization, installation instructions, masonry chimney issues, corrosion test methods, and multistory venting.

VENTING PROJECT RESULTS

Vent Sizing and Appliance Categorization

Traditional gas appliances were designed with a draft hood and depended on natural buoyancy to vent their products of combustion. The operating characteristics of many different types of appliances were quite similar. Therefore, generic venting and installation guidelines were developed "for any gas appliance" and were embodied in the NFGC. Individual

appliances could simply refer in their installation instructions to the NFGC for detailed installation and vent sizing guidelines. The venting guidelines were structured as vent sizing tables.

The current NFGC vent sizing tables list "maximum capacities" for a given vent configuration. The maximum capacity is defined as the largest appliance input rating which can safely vent using a certain vent diameter and geometry. The maximum value is derived by requiring that no spillage will occur at the draft hood and that, the vent system will operate at a nonpositive static pressure. Naturally, the development of these tables required making general engineering assumptions about the vent gas temperatures and the amount of excess combustion air and draft hood dilution air.

The introduction of mid-efficiency (AFUE = 78%-83%) and high-efficiency (AFUE > 90%) appliances, many of which use fan-assisted combustion systems, meant that the assumptions underlying the vent sizing tables might not always be valid. For example, condensing appliances clearly are not meant to be vented with traditional venting products. It became necessary to develop a method to determine which appliances could still be vented using the NFGC. This led to the current ANSI categorization method which is schematically shown in Figure 1. The categorization method was designed in such a way that Category I appliances could still use the generic guidelines of the NFGC. This category includes traditional, draft hood-equipped appliances as well as most mid-efficiency, fan-assisted models.

Appliances in the other three categories must be vented using the manufacturer's specific instructions.

After several years of field experience, the Z21.47 subcommittee requested GRI support to reevaluate the categorization method. Concurrently, they requested research on eliminating the possibility of "vent oversizing", which was perceived as a possible source of vent or appliance corrosion. The initial research led to the conclusion that the categorization method could be improved and that, new vent sizing tables were needed. Most importantly, it was shown that the two separate topics should be treated as one. This makes it possible to design categorization tests and vent sizing tables using identical engineering assumptions. The recommendations for categorization² and vent sizing tables³ are detailed in the references cited. In summary, the results and recommendations are:

1. New vent sizing tables and categorization criteria should both use a steady-state appliance efficiency of 83% as a worst case design assumption;

2. New venting tables were developed for fan-assisted appliances having both maximum and minimum capacities. The minimums are designed to reduce condensation and corrosion; and

3. The test setup for the categorization test, along with the defined boundaries of

ANSI CATEGORIZATION CRITERIA

Figure 1 - Current ANSI Categorization Criteria

Category I should be altered to reflect the assumptions used for the table development.

These new tables have already been introduced into the field by members of the Gas Appliance Manufacturers Association (GAMA). An example of a portion of one table is shown in Figure 2. The column labelled "NAT MAX" is for draft hood-equipped appliances. The "FAN MIN" and "FAN MAX" columns form a range of acceptable inputs for fan-assisted appliances. In 1992, the tables are expected to be incorporated into the NFGC.

Additional information about the new tables may be obtained through GAMA or A.G.A.L.

A schematic of the recommended alterations to the categorization criteria is shown in Figure 3. The change to temperature criteria is intended to make sure that appliances in Category I operate at less than 83% steady state efficiency and are therefore compatible with the sizing tables. The categorization recommendations are expected to be adopted by the Z21.47 subcommittee.

The introduction of new vent

NEW TABLE

Example Of Common Vent Connector Table

Vent Connector Capacity

Vent Height H (FT)		Connector Rise R (FT)		Vent Connector Diameter - D								
				3"			4"		5"			
				Appliance Input Rating Limits In Thousands of Btu Per Hour								
				FAN		NAT	FAN		NAT	FAN		NAT
				MIN	MAX	MAX	MIN	MAX	MAX	MIN	MAX	MAX
10	1	22	43	28	34	78	50	49	123	78		
	2	23	47	33	36	86	59	51	136	93		
	3	24	50	37	37	92	67	52	146	104		
15	1	21	50	30	33	89	53	47	142	83		
	2	22	53	35	35	96	63	49	153	99		
	3	24	55	40	36	102	71	51	163	111		
20	1	21	54	31	33	99	56	46	157	87		
	2	22	57	37	34	105	66	48	167	104		
	3	23	60	42	35	110	74	50	176	116		

FIGURE 2 - EXAMPLE OF NEW VENT SIZING TABLES

PROPOSED CATEGORIES

Flue Gas Temperature (F)

Figure 3 - Proposed Categorization Criteria

sizing and appliance categorization criteria have several implications to appliance design and installation practices. First, the modified categorization test rig will require an appliance to use a slightly larger diameter flue outlet. Of course, flue outlets generally come with diameters that are multiples of one inch so that the available venting products will fit. So practically, Category I appliances whose vent pressures were previously near neutral will increase their flue outlet diameters by one inch. For

example, a 75,000 Btuh furnace with a 3 inch diameter will probably now use 4 inches instead. The vent sizing tables will help reduce occurrences of excessive condensation. The primary affect on installation practice will be to encourage the use of Type B vent for vent connectors in preference to single wall galvanized pipe.

Installation Instructions

At the time the venting project was organized, there was a perception in the industry that the installation instructions for

Category I fan-assisted appliances had unwarranted differences from manufacturer to manufacturer. This could potentially create confusion in the installation community. Therefore, the venting project conducted a literature review of manufacturer's installation instructions to assess the situation.

With the cooperation of GAMA, the venting project obtained samples of the installation instructions and supplementary technical bulletins from 15 brands of Category I, fan-assisted furnaces. These were analyzed for content and scope. In all, 25 specific topics pertinent to venting were identified. Examples of these topics include, "Do the instructions define the meaning of appliance categories?" or "Do the instructions explain the need for clean combustion air?" Each installation instruction was analyzed to catalog how the topic was covered.

In fact, wide discrepancies in both what was covered and how it was covered were documented. These findings formed the basis for a set of recommendations⁴ supplied to the Z21.47 subcommittee. This report lists recommended topics pertaining to venting which ought to be covered consistently in each installation instruction.

The Z21.47 subcommittee is currently in the process of requiring a consistent format for furnace installation instructions. At least one major manufacturer has already rewritten their instructions in anticipation of this standards change. Of course, the venting recommendations being distributed

by GAMA furnace manufacturers will also help to make venting installation practice more uniform.

Masonry Chimneys

Thus far, the vent sizing tables being distributed cover metallic venting systems such as Type B double wall and single wall galvanized vent pipe. However, in some parts of the country, many homes use an existing masonry chimney for venting. Therefore, related recommendations for masonry chimneys are currently under development. The development has included theoretical modelling, experimental observations, and field investigations.

To obtain practical information on masonry chimney condition, over 160 chimneys were inspected. It was found that the primary mechanism for chimney damage is excessive condensation. This can be exacerbated by freeze/thaw cycles or combustion air contamination. In the course of these inspections, it was found that chimney inspection procedures vary widely depending on the knowledge and experience of the inspector. The procedures observed were synthesized into a consistent field inspection procedure for masonry chimneys⁵. This reference also includes sizing tables for flexible metallic chimney lining systems.

Initial comparisons between VENT-II⁶ predictions and experimental measurements made in masonry chimneys showed that the assumption of uniform flow implicit in the model was not correct. This caused the overall heat transfer in the chimney to be under-predicted. Two full-scale experiments were built to

support the development of an improved masonry chimney model. At Battelle, an instrumented masonry chimney was built that meets the specifications of the applicable NFPA standard⁷. At A.G.A.L., a chimney was constructed of a transparent, high temperature thermoplastic for flow visualization⁸. Both chimneys have confirmed that two zones of non-uniform flow exist. They are caused by jet impingement at the breaching where the flue gases enter and unsteady recirculation at the chimney top. VENT-II is being enhanced to account for these effects.

Current recommendations concerning masonry chimneys are:

1. Masonry chimneys require substantial amounts of dilution air to reduce condensation. Therefore, fan-assisted appliances should not be vented using a tile-lined masonry chimney unless a source of dilution air exists; and

2. Typical common venting systems including a fan-assisted appliance and a draft hood-equipped water heater can be vented into tile-lined chimneys using new sizing tables similar to those discussed above.

Research on masonry chimneys is currently the top priority of the venting project. Research areas include:

1. Materials testing to determine which damage mechanisms are most destructive,

2. The possible need for codes to regulate venting of

engine-driven systems in masonry chimneys,

3. Finalizing the sizing tables for masonry chimneys,

4. Alternate methods for supplying dilution air, and

5. Field testing of the inspection procedure.

Tests For Corrosion Resistance

When the first higher-efficiency, near-condensing appliances were introduced (some with AFUE's approaching 90%), some problems with corrosion of heat exchangers or vents occurred. Therefore, GRI has conducted research into the causes of this corrosion since 1983. It was determined that the corrosion was caused by chlorides in the flue gas condensate. The presence of chlorides points to combustion air contamination as the ultimate source of the problem. During 1983-1985, a field survey confirmed this and produced a statistical distribution of chloride levels found in normal field installations⁹.

Practically speaking, the homeowner controls (perhaps, without knowing it) the amount of combustion air contamination in the home. The appliance designer cannot rely on warnings to provide clean sources of air to the appliance. After all, this in effect asks the homeowner to alter their lifestyle. Therefore, appliances and vents need to have corrosion resistance designed to meet real-world levels of contamination. To meet this need, GRI has provided technical support to assist in the

development of a standard ANSI performance test for corrosion resistance. This work began as a task of the Gas Appliance Technology Center (GATC)¹⁰ and was later spun off into the venting project.

The corrosion test methodology under development¹¹ is based on artificially creating corrosive flue gases in a controllable manner. The corrosivity of the flue gases is controlled by introducing trace amounts of CFC R-11 (Freon) into the fuel gas supply. In the combustion zone, the R-11 disassociates into chloride and fluoride ions, in approximately the ratio observed in the field study. Note that the R-11 is destroyed in the process, eliminating any environmental concerns.

The furnace under test is cycled 12,000 times on a 4 minute ON, 8 minute OFF cycle. At the end of the test, the appliance is expected to operate properly with no perforations of the heat exchanger. Thus, this is a go/no-go test, similar to the thermal cyclic test for furnaces which is already in use. Tests of this type require severe conditions to properly differentiate units which pass or fail. Therefore, the level of spiking chosen is much higher than the average found in the field study.

Thus far, 34 furnaces representing 11 models have been tested at different spiking levels. These furnaces include condensing and non-condensing models which may be draft hood-equipped or fan-assisted systems. The purpose of these tests is to determine through experience what spiking level will reliably differentiate between appliances which have good corrosion

records, as opposed to those which do not. At the time of this writing, the recommended spiking level for appliances which use indoor combustion air is 150 ppm Cl⁻ in fully condensed condensate. A similar test methodology for boilers which uses 4800 cycles (10 minutes ON, 20 minutes OFF) is also under development.

Multistory Vents

Many low rise garden apartments feature individual gas appliances in each suite. They are typically placed in dedicated furnace rooms and are common vented into one vertical vent. There has been a need to assess whether fan-assisted appliances can be successfully retrofit into these existing installations. For this study, a full-scale experiment has been constructed at A.G.A.L. (see Figure 4).

The multistory test facility¹² is three stories high with separate furnaces and water heaters in each alcove. The venting system was designed to code as if 60,000 Btuh, draft hood-equipped furnaces were originally installed. However, 40,000-45,000 Btuh, mid-efficiency furnaces were actually used to simulate the retrofit. The entire vent system is fully instrumented and controlled by computer. Normally the system vents into the test bay. However, the vent may be extended out through the roof of the laboratory to cause significant depressurizations with respect to the vent outlet. Facilities are also available for studying the possibility of supplying outdoor combustion air through a manifolded downcomer to relieve this depressurization.

Tests have been conducted by

Figure 4 - Multistory Venting Facility

cycling different combinations of appliances and monitoring for any undesirable conditions. Failure modes have been studied by creating worst case situations such as total blockage. Some preliminary conclusions are:

1. The large amount of dilution air entrained by this vent system provides a good buffer against excessive condensation; and

2. The worst case failure modes applied equally to the

draft hood-equipped appliances and were not caused by the retrofit operation.

Overall, our conclusion is that retrofitting fan-assisted appliances into a multistory vent which meets the code does not introduce any additional risks for venting failure.

Conclusion

The GRI venting research program has provided significant

technical support for updating the existing venting guidelines. These guidelines are expected to help utilities and installers to practice more consistent venting methods in the field. In turn, this will promote venting system installations of uniform, high quality and safety.

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