Retrofitting Natural Gas Service into Existing Multifamily Buildings

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There are many obstacles preventing the conversion of existing multifamily buildings from centralized space and water heating to individual apartment services. The conversion from electric and/or fuel oil to natural gas for individual apartments can be cost prohibitive. Although there are significant potential energy and cost savings in undertaking these types of conversions, institutional, financial and technical obstacles have prevented wide scale implementation. Three critical issues must be addressed in the conversion of centralized heating services to individualized apartment sized natural gas systems:

- Metering: A single master meter must be replaced by individual apartment meters which require additional floor space, isolation, venting and access for reading and maintenance.

- Gas Distribution: Large diameter steel pipe to a central boiler must be replaced with smaller runs of pipe to each apartment unit.

- Appliances: Small capacity apartment sized units must be introduced which require floor space, distribution ducts/baseboards, and venting.

The dual integrated appliance combines space and water heating in a single unit which saves floor space, operates at a high efficiency, and requires only a single vent. Flexible gas piping consisting of corrugated stainless steel tubing and mechanical joints operating at 2 psi can be retrofitted for significantly lower cost than rigid steel pipe. Compact gas meters with remote reading capabilities permit meter installation almost anywhere within the structure. All of these technologies have one thing in common: they have been developed to reduce the cost of installation and improve the utilization of natural gas.

A research project was completed which evaluated many of these new technologies and investigated the cost impact of their installation in typical multifamily buildings. The results indicated that there are potential cost savings to both the building owner and the consumer with the new individual equipment installed, compared to centralized space and water heating practices. The energy savings achievable solely as a result of the decentralized configurations are substantial, ranging from 7 to 17 percent.

Metering

State of the Art

Until recently, gas metering technology (as applied to residential and commercial applications) has remained essentially unchanged since the turn of the century. The diaphragm type gas meter is still the overwhelming choice by gas utilities for residential applications. It is a time proven device that is accurate over a large range of flows, and has proven reliability over its expected service life of 20 years. Coupled with the fact that it is also a low cost item, it is hard to find an equivalent replacement. However, by today's standards it has two distinct drawbacks: its relatively large size and the method it utilizes for measurement, i.e., flow based on "volume" instead of "mass" or "energy."

There are several gas meter technologies currently under investigation and/or development including:

- Small diaphragm meter
- Digital electronic flowmeter
- Domestic compact turbine meter

- Fluidic flowmeter
- Ultrasonic meter

However, at this time, none of the non-diaphragm types have been commercialized to the point where they can be given serious consideration as replacements for the diaphragm meter.

Automatic Meter Reading Systems

By far the biggest change in metering has been in the development of Automatic Meter Reading (AMR) technology. AMR promises to help solve several problems for the gas utilities regarding multifamily residential/ commercial meter reading including:

- 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 vary substantially 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 AMRs 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 as often as desired to the host computer. 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 its customers' current phone numbers.

A simple diaphragm meter can be easily adapted with a remote terminal unit for signal transmission regarding real-time or cumulative gas flow data. 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. Most of the electronic devices for these meters 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.

How does this apply to multifamily buildings? First, if the building is submetered with each tenant having their own 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 available on the market that not only read the gas, electric, and water meters, but phone the utility with the data as well.

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 of 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, and will include features to:

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

Present meter sets, consisting of the pipe riser, shut-off valve, pressure regulator, meter, and associated pipe fittings, are rather bulky and are considered unsightly assemblies in many applications. 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 sq ft of wall space. Compact meters would substantially reduce this space requirement. Although there may not be a truly compact gas meter commercially available at this time, there are smaller lightweight residential meters available which represent a major improvement over existing models. The typical overall dimensions for this class of meters range between: width - 8 to 10 in., height - 11 to 12 in., depth -5 to 10 in.

Gas Piping Technologies

Piping 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 as being both safe and reliable. In the last few years, some plumbing contractors have taken a closer look at the benefits of installing copper tubing gas piping systems as a replacement for steel pipe in residential and commercial buildings. Primarily, the benefits are economic and ease of installation.

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" or "vertical main." 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. The National Fuel Gas Code, NFPA 54, 1992 allows threaded fittings to be used on steel pipe sizes up to and including 4 in. Larger pipe sizes must be joined as welded joints. 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. Most vertical risers use pipe larger than 4 in. because the systems are typically designed for low pressure service (7 in. of water) and carry large capacities of gas to service the entire building.

Semirigid Tubing Systems

The use of semirigid tubing for natural gas distribution within residential and commercial buildings has been going on for many years. Until recently, the tubing used was exclusively copper. In 1988, corrugated stainless steel tubing (CSST) was introduced to the United States plumbing industry. Corrugated stainless steel tubing is an acceptable code listed material for natural gas piping systems in the National Fuel Gas Code, Standard Gas Code, Basic/National Mechanical Code and One- and Two-Family Dwelling Code.

The design of corrugated stainless steel tubing used for gas piping is similar to flexible appliance connectors used by the gas industry for over 30 years. The CSST is manufactured from 304 stainless steel and is fabricated with annular corrugations. The number of convolutions per inch and the amplitude of each convolution are both much smaller than that 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.

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 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 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 length required. CSST uses simple mechanical fittings for joining, requiring only hand tools for assembly. 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 run through steel studs as easily as through wooden wall 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 with 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 test buildings, both low pressure steel pipe and elevated pressure corrugated tubing systems were designed and installed. The data were analyzed for both installation labor (man-hours) and total cost (labor plus materials). The results, summarized in Table 1, have been calculated using a labor rate and material prices which have been found to reflect average costs in the United States (Torbin, Belkus, Campbell, Valentine 1989). 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.

Distribution Networks

Traditionally, when gas piping systems are installed in multifamily buildings, they are 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 typical advanced gas distribution network for a multifamily structure is 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 1). Total gas supplied to the building would be monitored by a conventional gas meter equipped with AMR. This portion of the piping system is called the gas entrance header. From that point, the gas would be distributed via a steel pipe 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.

Table 1. Results From Piping Field Tests Installation Labor and Cost Comparison (CCST versus Steel Pipe)

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

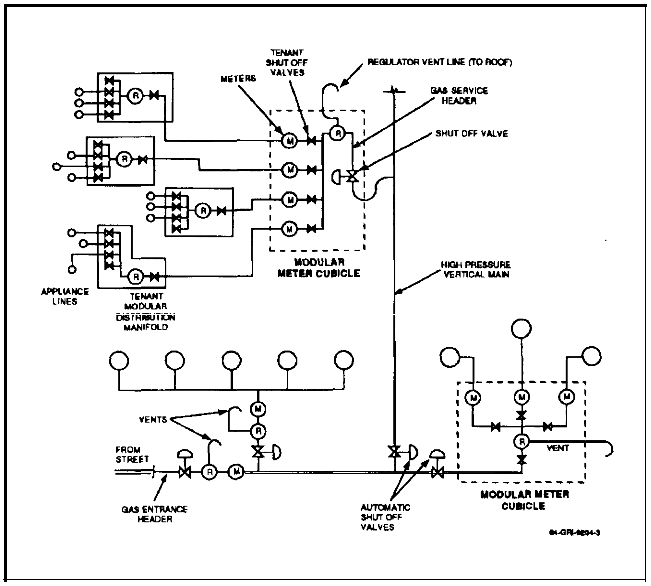


Figure 1. Gas Distribution Network—Typical Residential-Commercial Building

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 apartment unit. This portion of the piping system is called the gas service header. The compact gas meters, required valves, and hardware to connect the components could be installed in pre-assembled modular cubicles. Finally, the gas would be distributed within each tenant unit via the modular distribution manifold. This is essentially a second subnetwork which includes a regulator to reduce the pressure from 2 to 1/4 psi, and a multiport manifold for delivery of the gas to the appliances or a gas outlet. This approach will 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 gas distribution network into the main control system of a fully automated building.

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 buildings 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. This is particularly important for retrofit applications.

Baseboard channels 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, but in a separate compartment from these other services. Several companies already manufacture prefabricated plastic baseboard molding systems capable of carrying CSST. This becomes an ideal solution when rehabilitation of existing multifamily buildings does not require extensive structural or cosmetic changes.

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, is only cost-effective for buildings with three to four stories, especially if there are more than two gas appliances per unit. Buildings with more than four stories may not benefit from meter groupings on the ground floor, and will require meter sets on each or alternate floors.

Space and Water Heating Systems

Dual Integrated Appliances

The early 1990s has been 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 (Actual Fuel Utilization Efficiency) 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.

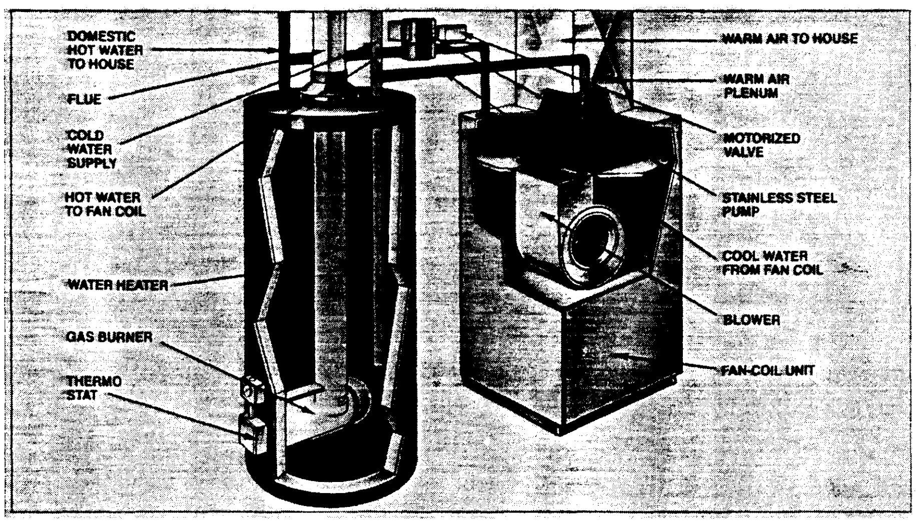
One class of gas furnaces has been devastated by the new standard. Conventional atmospherically vented furnaces cannot meet the new standard. The problem is the NAECA defines the AFUE for these appliances based on the assumption that the furnaces are installed indoors and all combustion air is supplied 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 atmospherically vented furnaces. Only one manufacturer 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 has resulted in lower increased costs for the electric heat pump than for the equivalent gas-fired system. The answer to this situation for the southern gas utilities has been the hydro-heat system, which is commonly referred to as the combo or dual integrated appliance system (DIA). These systems were developed in the 1970s. As depicted in Figure 2, combo systems basically consist of a gas water heater and air handler.

An 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).

A typical integrated system includes:

- Water Heater—A high efficiency water heater is used to satisfy both 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 he air



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 2. Combination Space and Water Heating System

handler. The pump may be integrally mounted in the air handler or may be mounted in the piping.

- Controls—The control system is relatively simple and includes typical controls such as a cooling/heating thermostat, pump and fan relays, 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 the OEM.

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, approximately 375,000 units have been installed in starter homes and multifamily buildings. If water heaters are properly sized, they work 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. None of the water heaters sold currently meet the boiler standards.

Since combination space and water heating appliances are an integrated system comprised of components from several different manufacturers, a means to determine overall system efficiency was needed. To address this need, an ASHRAE Standard, ANSI/ASHRAE 124P entitled: "Method of Testing for Rating Combination Space Heating/Water Heating Appliances" was developed. The standard covers electric, gas-fired and oil-fired combination space and water heating appliances up to a rated input of 300,000 Btu/hr.

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 of 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.

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.

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.

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. However, current research results indicate 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 1 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.

Energy/Cost Savings

Multifamily units have been studied in various manners to identify factors that affect fuel savings and consumption. Various studies have concentrated on centralized versus decentralized heating in an attempt to pass the responsibility and reward for energy savings directly to the tenant. These studies range from individual unit billing allocation schemes for central heating systems to the complete changeout of centralized heating systems to individual heating units and controls.

The individual unit billing allocation study charged each building unit relative to floor area and realized 6 percent savings. It is important to note that this billing structure may not effectively maintain an overall savings. This is because one tenant's efforts/savings will be divided among all the units. Tenants may notice that their efforts do not appreciably affect their energy bill, and therefore, reduce or abandon their conservation efforts causing usage to increase.

In metering studies, where master meters are replaced by individual meters, submeters, or individual consumption monitors, savings vary from 5 to 77 percent. The savings variations are partially a result of differences in the building structures, climates, heating system types, and type and use/non-use of weatherizing.

Table 2 gives a summary of the energy savings achieved through decentralization of heating. The Palermini and Hewitt 1991 study contained two units where the central gas-fired boiler systems were converted to individual gas space heating units. In these instances, savings of 69 percent and 77 percent were obtained. These savings were directly influenced by increased tenant control of interior unit temperatures, the use of weatherizing, and the replacement of old heating systems with more efficient systems.

Use of DIA systems, where space heating and domestic hot water systems are combined, are another way savings may be realized. A study by Bohac et al. 1990 of the effects of installing DIA systems in place of conventional systems showed savings on fuel use between 13 and 19 percent. In this study, the DIA systems (with minimum AFUE values of 76 percent) replaced furnaces with AFUE

Table 2. Summary of Energy Savings Achieved by Changing from Centralized to Decentralized Heating with a Shift in Responsibility for Energy Use to the Tenant

Study	Building Type	Year	Type	Savings (%)
Palermini, D. and Hewitt, D.	Multifamily building	1991	Conversion from Central oil to individual electric	28
			Conversion from Central gas to individual gas	69 to 77
			Central gas with allocation added	6 to 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 two-story	1990	Decentralized heating DHW	13 to 19
Byrene and Fay	Multifamily building 3-story	1989	Computer modeling	20
McClelland, L.	Multifamily buildings	1983	Metering	14

values of 60.2 percent. Further analysis of these systems is needed to compare the savings of DIA systems with conventional systems of the same AFUE.

Based on the information available, significant savings can be achieved by shifting from centralized to decentralized systems. In all the cited studies, energy/cost savings were realized. Table 3 provides data on the fuel savings in typical multifamily residential applications for DIA systems versus systems with a separate water heater and furnace. The multifamily units were built in the early 1980s.

Each unit contained the same heating appliances:

- A furnace with 55,000 Btu/hr input, 42,000 Btu/hr output, and an AFUE of 60.3 percent
- A 40 gal water heater with an input of 36,000 Btu/hr

These systems were completely changed out and replaced with DIAs. The typical yearly savings for these units were arrived at by obtaining the gas use for the year previous to the DIA system installation and by recording gas use for approximately 10 months after the installation.

The study indicates that the fuel consumption savings alone would not provide a quick payoff (less than three years) of the installed DIA system cost. Therefore, the next logical step in this analysis was to compare the replacement costs of the conventional systems to the DIA systems and add (or subtract) any differences in the annual DIA fuel savings costs. The study reveals savings for the installation and use of DIA systems. A comparison of the installed costs between these types of systems is shown in Table 4.

The values for the installed costs of a conventional system (i.e., the equivalent updated versions of the separate water heater and furnace) were obtained through industry estimates. The value for the residential units referred to as "family" is the average estimate of the four units cited in Table 3. In most cases, the initial comparison shows that the costs for the DIA installations are less than for separate conventional installations of water heaters and furnaces. Finally, when the yearly fuel savings are added to the DIA installation costs, a significant cost reduction is realized for the use of DIA units.

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Table 3. DIA Savings

Building ID No.	DIA Installed Cost$	DIA Heater: Input Btu/Hr	DIA Heater: Output Btu/Hr	NAC Pre ccf	NAC Post ccf	NAC Savings: %	NAC Savings: ccf	Yearly Fuel Savings*$
60	2,212	52,500	39,900	1003	870	13.2	133	55.86
64	2,067	40,000	34,000	705	592	16	113	47.46
70	2,809	40,000	33,200	808	651	19.4	157	65.94
72	2,809	40,000	33,200	839	703	16.2	136	57.12

*Based on $0.42/ccf
DIA - Dual Integrated System
NAC - Normal Annualized Cost
ccf - 100 cubic feet of gas

Table 4. Overall Cost Savings

Building ID	Installed DIA Cost $	Installed Conv. Cost* $	Yearly DIA Fuel Savings** $	Total 1st Year DIA Savings $
3920	2,850	2,900	101	151
3925	2,875	3,125	106	356
4409	2,809	2,460	353	4
Family	2,224	2,500	57	333

*All values have been reduced by $200, the estimated value for disposal of the old equipment. This cost was not included in the DIA installation costs.
**Based on $0.42/ccf

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