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VARIABLE FIRING RATE POWER BURNER FOR HIGH EFFICIENCY GAS FURNACES

FINAL REPORT

H.H. FULLER, R.L. DEMLER, E. POULIN

February 1980

Prepared by
FOSTER-MILLER ASSOCIATES, INC.
350 SECOND AVENUE
WALTHAM, MASSACHUSETTS 02154

for
BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UPTON, NEW YORK 11973

UNDER CONTRACT NO. DE-AC02-76CH00016 WITH THE

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

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ABSTRACT

One method for increasing the efficiency of residential furnaces and boilers is to retrofit a burner capable of firing rate (FR) modulation. While maximum FR is still attainable, the average FR is significantly lower, resulting in more effective heat exchanger performance. Equally important is the capability for continuous firing at a very low rate ("simmering") which eliminates off-cycle loss, a heavy contributor to inefficiency. Additional performance can be gained by reducing the excess air required by a burner.

Based on its previous experience, Foster-Miller Associates, Inc. has designed and tested a low excess air (about 15 percent) variable firing rate (VFR) burner.

This report describes the theory of operation and the construction of the test burner. Test results are given along with a conclusion/recommendation. A Phase II plan is outlined which suggests methods and steps for fabrication and field testing of a number of prototype units.

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VARIABLE FIRING RATE POWER BURNER

Summary

Under contract number 455983-S from Brookhaven National Laboratory, Foster-Miller Associates, Inc. (FMA) successfully completed the design, fabrication, and testing of a Variable Firing Rate (VFR) power burner for a high efficiency gas furnace. This burner is intended for use as a retrofit system for existing forced draft gas or oil-fired furnaces and boilers, and was not designed to match any particular heat exchanger. The firing rate range is from 100,000 Btu/hr down to 10,000 Btu/hr and is controlled by a novel gas/air proportioning valve. The important features of the burner are complete gas/air mixing before combustion, no secondary air, and control of excess air between 10 and 20 percent over the firing range. This results in maximum combustion efficiency; the system efficiency remains dependent on furnace heat exchanger effectiveness and off-cycle losses (which the VFR burner minimizes due to its small air passages).

Background

FMA has been working with combustion systems for many years, during which several high performance, high intensity burners were developed. These designs were based on premixed combustion where fuel and air were supplied in controlled proportions, through a mixing zone to a specially developed flameholding device. This system, which specifically eliminates the usual secondary air requirement, required the development of the flameholding system which provided stability over a wide flow rate range, low noise, and low pressure drop. After complete mixing, the fuel/air mixture passes through the flameholder on which it is ignited and stabilized - flashback and blowoff are prevented. The combustion gases then pass on through the heat exchanger in the usual manner.

The premix and flameholding system operates with gaseous fuel/air mixtures, and the FMA burner has operated on propane and natural gas, with butane a minor variation. FMA has also developed liquid fuel vaporizing systems which allow use of gasoline, kerosene, No. 2 diesel fuel, and home heating oil with the same blower, flameholder, and no-secondary-air system. In this case, it has also been run with percentages of inert gas, or combustion gas recirculation, for fuel vaporization requirements and for control of oxides of nitrogen (NO_x) in high temperature applications. The result in all cases is blue flame combustion

with the same low flame noise normally observed in one's home gas stove. The largest burner to date was designed for 2,000,000 Btu/hr with a 20 to 1 turndown ratio operating on gasoline. The smallest burners were flameholder test plates operating perhaps at only a few thousand Btu's per hour.

The premix combustion system also offers emission advantages. The complete fuel/air mixing minimizes unburned hydrocarbon (UHC) and carbon monoxide (CO) formation since a homogeneous mixture is burned. There are no rich or lean spots. Because of the short, blue flame characteristic, the local droplet evaporation/burning at high local temperatures (which occur in yellow flames) do not exist and the formation of oxides of nitrogen (NO_x) is reduced. Further reduction in NO_x can be accomplished with a flame quenching and CO burnout geometry which matches the short and uniform flame pattern. This is accomplished in practice by positioning a portion of the furnace heat exchanger relatively close to the flameholder, not possible with yellow flame, nonhomogeneous combustors due to soot formation on the cooled surfaces.

System Description

The objective of the program was to develop a simple, low cost gas burner which could provide the advantages of variable firing rate particularly when applied to high efficiency gas furnaces (indicating units of compact configuration most likely having extended surface heat exchangers).

The FMA no-secondary-air system already takes a large step toward increasing combustion efficiency especially compared to existing atmospheric burner designs. The remaining hurdle was to design a control system which would meter the required amounts of natural gas and air, keeping a rather precise fuel/air ratio over a flow rate change of 10 to 1.

One basic option for the control of firing rate was to use a variable speed blower. However, this approach has three drawbacks:

- a. When running at the lower speeds, the pressure rise level would be significantly reduced. A 10 to 1 reduction in flow rate would result in a 100 to 1 drop in pressure; this would render the burner susceptible to disturbance by even slight pressure variations such as drafts, or even slamming of boiler room doors.
- b. Either a universal (that is, brush) motor or a special (that is, controllable) induction motor would be required, both of which are more expensive than the standard induction motor.

- c. A controllable voltage or frequency power supply would be required in the case of variable speed motors. This would be heavier and more expensive than a variable signal device needed to control, for example, the throttle valve systems under study.

The selected method for control of firing rate was to use a throttle and a blower with a constant speed. The important point in the design concept was the combining of the air valve throttle with that of the gas valve, using one variable element. The general layout is shown in Figure 1. This required the use of a negative pressure regulator, also called a zero regulator, to deliver the gas to the mixing manifold. The effect now is that both the air and the gas see the same source pressure, namely atmospheric, and both are drawn into the blower by the blower's suction head. From there, the fuel/air mixture passes through and is ignited and held on the flameholder.

The solitary valve disc controls both flows as shown in detail in the sketch in Figure 2. The pivot point of the disc is on the edge of the air valve seat to provide the required fuel/air ratio without using an inordinately large air tube or small gas tube. Once the valve's seat areas are set (the tube diameters fixed), and the position of the gas tube with respect to the air tube is set, the fuel/air ratio is fixed. Opening the valve disc merely increases the flows of gas and air in constant proportion.

Originally, a blower was used which had a head rise of approximately 0.8 in. water column; the later test unit employed a blower producing about 2.5 in. water column. The wheel of the former was 3.8 in. diam by 1.9 in. wide, turning at about 3000 rpm; the latter's wheel was about 7 in. diam by 0.6 in. wide turning at about 3200 rpm. Local flow conditions around the entrance zones of the air and gas tubes caused disturbances which reduced the attainable turndown ratio when the lower pressure rise blower was used. The higher pressure rise blower required less actual valve disc motion to achieve the full ratio of 10 to 1 without the previously observed secondary effect problems.

The major portion of the effort spent on the project was directed toward the development of the gas/air valve. This included sizing the air and gas tubes and establishing the correct geometric position of the gas tube within the air tube. Once it was ascertained that the higher blower pressure would be beneficial, the replacement blower worked as intended. From the beginning, a commercially available Direct Spark Ignition (DSI) system was employed which functioned with no problems during

Figure 1. System schematic

Figure 2. Gas/air throttle valve

experimental testing. It performed the basic system control - energizing the spark system, allowing gas flow, igniting the flame, and maintaining flame surveillance. The FMA developed, interrupted pattern flameholder was used with complete success; no further variation of it was needed.

FMA did not undertake the design of the thermostat or heat demand logic system which would match the firing rate of the burner to the heating requirements (heat loss) of the house. In that regard, the options range from a simple manual selector knob (which might point to a range of seasons) to be manipulated by the owner or user to a sophisticated indoor/outdoor temperature sensor combined with an indoor temperature rate of change sensor. For the test unit, a manually adjusted screw was provided to open and close the valve disc; any linear actuator having a motion of about 1/4 in. and a force of about 3 oz will do the job. Photographs of the unit are shown in Figures 3 through 8, including the last which was taken during operation. A parts and specification list follows, as well as two sheets of descriptive drawings.

Testing

The main burner feature of operation over a wide range of firing rates was monitored by measuring the fuel flow rate. Gas/air valve geometry was adjusted until an acceptable range of operation was achieved, then the amount of excess air introduced into the combustion mixture versus firing rate was examined to evaluate the overall performance of the burner configuration. Restricted emissions levels were also measured in order to verify that they were below the applicable limits.

The gas flow rate was determined by timing a volumetric gas meter, similar to residential units which register hundreds of cubic feet but adapted to allow readings in the cubic foot range. In addition, instantaneous flow rates could be observed on an inclined manometer driven by an orifice meter in the gas line calibrated against the timed gas meter.

For complete combustion of natural gas, the proportioning valve should admit approximately ten times as much air as gas to the burner. If less air is introduced to the mixture, a large amount of CO will be produced and UHC may be detected in the combustion products. On the other hand, if a large percent of excess air is admitted, the process of carbon and oxygen combining to form CO₂ is inhibited and again the result is high levels of CO. Initially the combustion mixture quality was approximated by observation: a blue-green indicated a fuel-rich mixture, and a

Figure 3. Flameholder view

Figure 4. Outside face view

Figure 5. Left side view

Figure 6. Right side view

Figure 7. Air gas orifices

Figure 8. In operation

PARTS/SPECIFICATIONS LIST

Blower: Torin Corporation, Model SC-7.1

Up to 25 cfm

Up to 2.8 in. WC

Separate Cooling Fan

7.1 in. diam wheel

3000-3300 rpm

115 Vac

Ignition/Control System: Fenwal, Inc.

D.S.I. Model 05-162426

24 Vac

Transformer: 120 Vac to 24 Vac, 40 VA

Gas Valve: Honeywell V859A Negative Pressure Regulator

1/2 NPT Inlet

3/4 NPT Outlet

2 to 25 in. WC inlet pressure

Flameholder: FMA interrupted row 5/1/1/1 hexagonal pattern

26 ga. Type 304 Stainless Steel

0.033 in. diam holes

17 percent open area

SYMBOL	PART NO	DESCRIPTION	SPECIFICATION
PARTS LIST			
DESIGNED BY	DATE	BY	POSTER-MILLER ASSOCIATES
DESIGNED BY	JUNE 79	HF	222 SECOND AVENUE WALTHAM MA 02154
APPROVED BY			GAS/AIR VALVE - MANIFOLD
APPROVED BY			W/ COMB. GAS CONTROL
APPROVED BY			C 7844 VER GAS BURNER
APPROVED BY			
APPROVED BY			
APPROVED BY			
APPROVED BY			

feathery pale blue flame suggested a lean mixture. If the mixture was very lean, the flame tended to lift off from the flameholder. When a deep blue flame was observed over a reasonable range of firing rates, the burner was fired inside a Ducane furnace. The stack gas was then continuously sampled and analyzed with a Scott Research Emissions Test Console. This console included Beckman Infrared CO and CO₂ analyzers, a Beckman Model 741 Oxygen Analyzer, a Scott Model 116 Total Hydrocarbon Analyzer, and a Scott Model 125 Chemiluminescence NO_x Analyzer.

Alternatively, and as a means of verification, readings were also taken with the common hand-held Bacharach CO₂ Indicator and the Bacharach Universal Gas Sampler with CO indicator tubes. While the stack gas was being sampled, the furnace combustion chamber was maintained at a slight positive pressure by means of a fuel damper, so that secondary air could not leak in and cause the rate of air induction by the valve to be overestimated. The proportion of air to gas at a given firing rate was therefore derived from the percentages of O₂ and CO₂ in the stack gas assuming complete combustion of the fuel.

As expected, significant amounts of CO were detected only when the mixture was rich or very lean. As long as the excess air was maintained between 10 and 50 percent, the CO reading was always less than 20 ppm, which is well below the AGA limit of 400 ppm.

The emissions of NO_x are highly dependent on the residence time and temperature of the combustion gases before they pass through the heat exchanger and cool off. Thus, the actual design of the furnace or boiler is highly influential; because the heat exchanger design was not part of the project, NO_x readings were not considered.

Final adjustments to the valve geometry were aimed at obtaining consistently low levels of excess air over the entire firing range. In the final burner configuration, this was achieved by adding a small diameter gas pilot orifice to the gas tube. This introduced sufficient fuel at low firing rates to reduce the excess air level without affecting the mixture at high firing rates. The progress toward constant excess air is illustrated in Figure 9.

Component testing was carried out during the development of the gas/air valve and the evaluation of the blowers. This consisted primarily of air flow tests resulting in data indicating pressure variations across the gas/air valve and through the blower versus valve position.

a) GAS ORIFICE DIAMETER = 0.422 in. 1, NO PILOT

b) GAS ORIFICE DIAMETER = 10.422 in. 1, 0.026 in. PILOT DIAMETER

c) GAS ORIFICE DIAMETER = 0.438 in. 1, 0.26 in. PILOT DIAMETER

Figure 9. Excess air versus firing rate

The initial system was assembled with a relatively low rise blower (up to 0.8 in. water column rise and about 100 cfm at free delivery); testing showed nonlinear operating characteristics at the extreme positions of gas/air valve opening; excess air did not remain relatively constant over the firing range.

The new and current blower was searched for and acquired. It had a significantly higher pressure rise (up to 2.8 in. water column) and a flow capacity (about 20 cfm), which were more appropriate to the burner's requirement. The higher pressure available allowed the required gas/air valve opening to be reduced, reduced the effect of pressure variations due to outside sources (wind, doors shutting, etc.), and lessened the change of shape of the gas/air valve opening.

As expected, the flameholder functioned quite like FMA's past experience. The flame was steady and remained attached at the top of the firing range and prevented flashback at the low end of the range. Flame "screech" or "hoot" did occur on a cylindrical flameholder surface but was eliminated with the adaptation of the conical shape known to be quiet.

The zero regulator also operated without any problem, substantiating past experience. It is a servo-operated regulator and maintains a very flat (stable) delivery pressure, in this case, -0.2 in. water column, as set by the manufacturer.

Some problem was experienced with the ignition electrode arcing to ground rather than at the proper gap. This appears to be a problem of geometry, particularly maintaining adequate distance between the live electrode and ground. Some breakdown of the ceramic insulator has been observed as well, predominantly surface breakdown due to dirt, carbon, or moisture. Overheated ceramic appears to lose some of its dielectric resistance. Since the combustion gases of the FMA burner are at higher temperature than atmospheric burners, due to the lower excess air level and no secondary air, it may be that a higher level insulating medium must be employed. The high temperature ignitor and sensor rods seem to cope adequately with the higher temperatures.

After assembly of the final components, the major testing of the burner was done with the unit fitted in a hot water boiler. In all cases, the excess air used, as measured by CO₂ and O₂ concentrations, was in the range of 10 to 20 percent. This can be set to the lowest amount compatible with meeting the AGA 400 ppm CO limitation. The burner operated over its turn-down range of 10 to 1 with approximately constant percentage of excess air. Test data from the final burner configuration is listed in Figure 10.

	Firing Rate, Btu/hr						
	20,000	34,000	38,000	46,000	60,000	67,000	95,000
O ₂ , %	2.5	4.0	3.0	2.25	3.5	2.25	2.25
CO ₂ , %	10.5	9.25	10.75	11.5	10.0	10.75	10.25
CO, ppm	Less than 5 ppm →						
Excess Air, %	12	24	12	7	18	10	13

Furnace or boiler efficiency was not calculated since it will vary from unit to unit. With a typical stack temperature of 350°F, the operating efficiency based on excess air is about 85 percent. The seasonal efficiency which includes off time again depends on the installation.

Figure 10. Example from test data

PHASE II PLAN

FMA proposes the following Phase II plan to implement development of the commercial/production version of the variable firing rate gas burner. The laboratory model of this system was completed at FMA and sent to Brookhaven National Laboratory at the end of June, 1979 for testing and evaluation. This particular test unit has operated at firing rates from under 10,000 to over 100,000 Btu/hr at an excess air level between 10 and 20 percent. The fuel/air ratio is set by geometry and the firing rate is controlled by the air/gas valve opening.

Task 8 of the current Phase I contract (455983-S/AMND No. 1) calls for the preparation of the Phase II plan, and it will cover the following details.

- a. Specifications for the production burners
- b. Prototype/production design
- c. Pilot quantity fabrication
- d. Field demonstration and evaluation
- e. Mapping of commercialization plans with the Carlin Company.

It is proposed to add some preliminary work to the above list to check out the following:

- a. The present test unit uses a somewhat nonstandard and therefore expensive blower. From a production point of view, there is no reason the blower wheel, shroud housing, and motor cannot be brought to a layout which would lend itself to a high-production, low cost system. In addition, the present unit delivers a higher pressure than what might be required for production units, hence it is proposed to evaluate more completely the actual pressure requirements of the burner *and* the furnace or boiler to which it is fitted.
- b. While the FMA burner lends itself to a long-life design, one component in the ancillary area needs further investigation. Current ignition control systems use a relatively weak spark, since they are usually intended for lighting pilots or atmospheric burners which have a locally rich (high fuel/air ratio) mixture and are consequently easy to light. As the fuel/air ratio is

reduced, or leaned out, the stock spark ignition has shown some tendency to misfire causing system lockout. Stock systems which have been modified to give a stronger spark have corrected this problem for the most part, but the hard-to-light gas test required by AGA, using the 1400 Btu butane/air fuel mixture, may extend the problem. It is again proposed to evaluate spark systems in regard to difficult ignition conditions; specifically, a substantially stronger direct spark may be used or an intermittent pilot system (currently available stock items are now being evaluated by FMA) can be employed.

- c. Either of the above ignition systems uses components which are presently available but are positioned in such a way in standard installations to run at relatively low temperatures. In the case of the high performance, high efficiency burner developed by FMA, the combustion is by nature more intense and hotter; there is no inherent cooling due to secondary air that exists in conventional systems. Thus, either the ignitor and flame sensor rods now used in direct spark systems or pilot burners would be subject to more severe operating conditions than they are designed for. Again, it is proposed to investigate the life expectancy of existing equipment by extended testing and/or develop design solutions by placing ignitors in protected (shielded) locations or providing a cooling arrangement.

The Phase II work would include the above preliminary work following the schedule shown in Figure 11 and be outlined as follows:

A. Component Verification

A laboratory burner would be fabricated on which would be tested several candidate blowers to determine the allowable range of pressure rise. It is likely that two or three blower designs could be designated to match different designs of heat exchanger. It is estimated that the burner itself requires about 1.5 in. water column pressure (comprising about 1 in. for the valve to desensitize it from outside disturbances, about 0.2 in. for mixing, about 0.2 in. for the flameholder pressure drop, and perhaps 0.1 in. for duct losses). Existing furnaces generally have very low pressure drops, say below 0.2 in., and at the same time new high performance heat exchangers might be designed for 1 in. or more. The latter would require more sophisticated blowers which might not be economically justifiable on the old retrofitted systems.

Figure 11. Phase II schedule

The laboratory burner would also be used to find initial life expectancy figures for the ignitor components. These will dictate if alternative locations or cooling means will be required for these components. Included in this testing will be operation of the burner on AGA's 1400 Btu test gas mixture. An examination of the final tentative design will insure that it meets remaining AGA design requirements.

It is expected that this part of Phase II will require about 3 months at a four-person (two engineers, two technicians) level of effort.

B. Set Production Design Specifications

Once the laboratory unit has progressed to the stage of meeting candidate requirements, the designation of component parts can be set with a high degree of certainty. Specifically, the five major parts (the blower (motor, wheel and shroud), the gas/air valve, the combination gas valve (CGV), the flameholder, and the control system (includes ignitor)), will be described with their individual requirements (for example, blower: speed, wheel size, power consumption, etc.).

Part B may require 1 month for one person (engineer).

C. Production Design

This part will get down to the brass tacks of the production layout, with detail drawings as necessary to permit straightforward fabrication. It is here that cost reducing techniques and mass-production design aspects will be integrated with the laboratory version. The gas/air valve operator and the design of the burner control/thermostat interface logic will also be selected.

This part may take 1 month primarily involving a draftsman, and an engineer together.

D. Fabrication of Pilot Quantity

Since three of the major components (blower, CGV, control) will be off-the-shelf equipment with few, if any, changes required, these can be ordered in advance. Longer lead items, particularly the flameholder material which is well proven and needs no further development, can be ordered far enough ahead to meet the fabrication schedule. This part primarily involves the fabrication of the gas/air valve, the assembly of the flameholder manifold, and the possible alteration of the ignitor/pilot device.

It is proposed to construct ten units which will be designated for field testing. Time for fabrication is estimated to be about 2 months, with the suggestion that two or three units be completed first and checked out before the remainder are finished. During this time, one unit will be delivered to AGA for certification (a place in the testing queue having been established in advance). Outside vendors will fabricate component parts for assembly at FMA. Two technicians are contemplated with assistance of an engineer.

E. Field Demonstration

The first series of units will be placed in selected field locations and run under "normal residential conditions" to prove performance and durability. If possible, the units will be installed in furnaces or boilers that are currently oil fired or fitted with a gas conversion power burner, and have an operating history recording fuel consumption on a weekly basis. This would allow direct appraisal of efficiency improvement. For a more exact evaluation, the test facilities at Brookhaven could be used.

Data from testing will be studied to verify performance improvements and to pinpoint places or methods for further development. Details and schedules for field testing can be set up concurrently with the other parts of Phase II, a tentative schedule for which is shown in Figure 11.

Numerous field test opportunities have been identified through prior associations and joint projects. Some of the significant testing possibilities are discussed below.

Several FMA engineering personnel are conducting energy consumption studies, oil-to-gas burner conversions, and periodic tuning of their own equipment. These homes are available as understanding consumers.

The Energy Office of the Commonwealth of Massachusetts is actively seeking demonstration hardware and has expressed a strong interest in supporting this program.

FMA has a working relationship with gas utilities that have historically been active in new product development or demonstration: Boston Gas, Commonwealth Gas (MA) and Consolidated Natural Gas (OH).

The Carlin Company and the parent company, Ford Products, have testing access through the state of Connecticut, their distributors and local contractors.

F. Commercialization Plan

The development of the commercialization plan in Phase II hinges on an assessment of the best application and market size for this technology. In a sense, commercialization has already started in fixed firing rate simplified versions. The Carlin Company is applying the technology to a fixed firing rate powered gas burner for retrofit of oil fired furnaces and boilers. FMA is also supplying fixed firing rate powered gas burners to Smith Jones, Tappan Division as a part of another Brookhaven/DOE contract to Thermacore, Inc., for a heat pipe furnace. The practical development of ignition and interface logic is thus already underway.

Carlin is pleased to report successful development of the fixed firing rate power gas burner. Designs have been frozen and tooling ordered for the major housing and allied components. The basic components can be used from 30,000 to 160,000 Btu/hr inputs.

Preliminary discussions have been held with the American Gas Association and a tentative testing date has been established for June 1980. It is expected that actual production models will be available for controlled field testing as early as July or August of 1980 with limited sales during October or November. It is expected that full production will be underway by January 1981.

Commercializing the variable firing rate version is more complicated both in development and in system integration. The practical burner development was discussed in the prior section. The system integration decisions require a better understanding of the performance benefits of a range of turndown ratios, retrofit potential in the existing boiler and furnace population and degree of automation needed to capitalize on variable firing rate. The ultimate in fuel savings on the other hand would be obtained with a new heat exchanger and burner package designed to capitalize on variable firing rate.

The likely path to commercialization would proceed in the following phases:

- a. Single knob manual control - retrofit market - This low development cost step would provide a burner that the installer could simply adjust for a wide range of fixed firing rate applications. The owner would have the option of manual adjustment, over a limited range, to match seasonal demands.

- b. Low fire - automatic stack damper add-on - A shutdown solenoid can be added to set the air/gas valve throttle plate to the minimum firing rate at shutdown. The very small throttle opening will provide the benefits of a stack damper with a substantial safety benefit in that the burner will run safely at this low air flow should the "stack damper solenoid" fail.
- c. Load following controls - The next production step would provide automatic firing rate control based on the indicated or actual demand. The air/gas valve actuator could be either a stepping motor or a series of throttle stops. Indicated demand could be derived from an outdoor air temperature sensor with a firing rate schedule driven by this signal.

The actual demand control would have a theoretical and perhaps an actual efficiency advantage in that the actual demand is also a function of changes in heating zone control changes, night time set back, occupancy level, and solar passive or active gains. The simplest actual demand signal is provided by the indoor thermostat but interpretation and conditioning of this signal are fairly complex. An instantaneous derivative of the thermostat reading is potentially unstable and difficult to integrate with zone controls. A well damped approximation of actual demand can be made from zoned thermostats by a firing rate control system that hunts to minimize thermostat off time. Development of this concept requires empirical as well as analytic surveys and studies of residential demand and hardware implementation.

- d. Integrated variable firing rate heating system - Maximum heating efficiency can be obtained with an integrated heat exchanger, variable firing rate burner and control system. The very compact flame and forced draft features of this power burner allow an integrated lightweight and efficient heat exchanger. One example of this possibility is represented in the Thermacore heat pipe furnace program. Commercialization of an integrated system is a longer term goal due to both development time and marketing limitations. The first three retrofit steps can have an immediate impact and rapid market penetration as replacement/retrofit is currently about 90 percent of the powered gas and oil burner market. The integrated system market is limited to new construction and complete furnace or boiler replacements and therefore limited in sales volume and penetration.

The commercialization process is thus a simple building block process - fixed firing rate baseline product (already in production engineering), manual adjustment option, "stack damper" option, load following controls package, and finally, an integrated system package. Development and production can be largely financed by the manufacturers over a period of time with the final step of integrated system sales requiring approximately 5 years if internally financed.

The Government can accelerate product introductions and market penetration by two methods. Continued cost sharing support of the development programs, such as in the present program, can reduce the commercial financial risk and provide field test feedback. Of equal importance, continuation of the Brookhaven Burner-Boiler/Furnace Efficiency Test Program provides the only source of objective performance and application information in this country and is beginning to have a major impact on the entire heating industry through its realistic cost benefit data for equipment design and sales.

APPENDIX

ORIGINAL CONTRACTUAL STATEMENT OF WORK FOR

CONTRACT NO. 455983-S

The Contractor shall furnish all personnel, materials, equipment, facilities, and services necessary to perform and shall perform the work described in Brookhaven's RFP, dated 5 May 1978, and Pages 3-1 through 3-20 of the Contractor's Technical Proposal, No. P-78107, dated 26 June 1978, entitled "Variable Firing Rate Power Burner for High Efficiency Gas Furnaces," which are incorporated herein by reference.

The work shall include the following tasks:

- Task 1 - Prepare Phase I Project Plan
- Task 2 - Preliminary Testing
- Task 3 - Component Search
- Task 4 - Furnace Characterization
- Task 5 - Preprototype Design
- Task 6 - Preprototype Fabrication and Test
- Task 7 - Prototype Demonstration
- Task 8 - Prepare Phase II Project Plan.