THE RECUPERATOR OF FLUE GAS HEAT

GRANT NO : DE - FG42 - 93R215469

FINAL REPORT

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The following is a summary of works done in the project RECUPERATOR OF FLUE GAS HEAT, Grant No: DE-FG42-93R215469, during the period from May 1, 1993 to April 30, 1995.

References are made to the tasks listed and described in the Statement of Work (Recommendation No. 469).

Re TASK 1

Within the scope of the above task, the following partial tasks were carried out:

SELECTION OF SHEET METAL MATERIAL:

The polished aluminum, aluminized steel, polished stainless steel and galvanized steel were considered for their suitability from the standpoint of availability, cost, heat reflectivity, and manufacturing:

The polished aluminum was rejected, because of its susceptibility to deformation in light gauges. The heavier gauges are more expensive, and would require additional operations in manufacturing.

The aluminized steel was rejected because of its high cost, and poor availability.

Selected:

28 Ga. galvanized steel was selected as the optimum material for use in RFGH.

In view of the fact, that the metal parts constitute only a small part of the heat reflecting surface, the lower heat reflectivity of galvanized steel vis-a-vis the polished aluminum or stainless steel is a minor shortcoming, which is outweighed by the low cost of galvanized steel and its other advantages in manufacturing.

Alternative:

30 Ga. polished stainless steel, namely for its high heat reflectivity and appearance.

It is however substantially more expensive than the galvanized steel.

SELECTION OF FLEXIBLE TUBING:

The products were considered for their suitability from the standpoint of heat reflectivity, flammability, availability and cost.

The products made of a heat reflecting material were exposed to a combine effect of convection and radiation and tested.

Selected:

Thermaflex S-LD by Flexible Technologies, Inc. is, at the present time*, the most suitable flexible tubing for use in RFGH.

Sizes 8", 10" and 12" dia. for the respective sizes of 5", 7" and 9" of RFGH.

Alternative:

Flexmaster NI-35 or NI-65 by Flexmaster U.S.A., Inc. is more expensive than Thermaflex, and has a lower heat reflectance. Sizes 8", 10" and 12" dia. for the respective sizes of 5", 7" and 9" of RFGH.

*)Considering, that the development of new products continues, a periodical survey for other suitable material can be useful.

SELECTION OF MATERIAL FOR FLANGE:

The materials were considered for their suitability from the standpoint of casting, flexibility, heat resistance, flammability, availability and cost.

Selected:

Teflon® was selected as the most suitable material for use in RFGH.

Alternative:

Nylon 101

SELECTION OF FASTENERS:

The fasteners were considered for their suitability from the standpoint of scale production, availability and cost.

Selected:

Stimpson C-E® 100 rivets, or equivalent.

SELECTION OF TEMPERATURE INDICATORS:

The application of temperature indicators was considered as an inexpensive aid to a prospective user for ascertaining that the flue gas temperature generated by his furnace is high enough to justify the installation of RFGH, and further, to assure that the temperature of flue gas, downstream from the installed RFGH, remains above the dew point, or if necessary, to help the user to adjust appropriately the length of RFGH.

Selected:

Cole-Parmer® Irreversible Temperature Indicators, or equivalent.

Re TASK 2

Within the scope of the above task, the following partial tasks have been carried out:

DETERMINATION OF OPTIMUM DISTANCE BETWEEN FLUE GAS CONDUIT AND HEAT REFLECTIVE SLEEVE:

The distance was designed for the required through flow, common sizes of flue gas conduit, and available sizes of flexible tubing.

Designed:

Distance of 1.5"

DETERMINATION OF OPTIMUM SIZES OF RFGH:

In order to accommodate the newer furnaces which have smaller flue collars, and in view of the available sizes of flexible tubing forming the heat reflective sleeve, the originally proposed sizes of RFGH have been reconsidered.

Designed:

The RFGH is now designed in three sizes, 5", 7" and 9" dia., which, with use of standard increasers and decreasers, are adaptable to all furnaces with flue collars from 3" to 9" dia., and which further opens an option of substituting a flue pipe of a larger diameter in cases where a longer flue pipe would be impractical.

DESIGN OF COIL SPRINGS:

The material, and wire and coil size were designed for the required spacing function, easy installation, availability and cost.

Designed:

0.049" SS x 1.45" OD Extension Springs

DESIGN OF CLOSURE MECHANISM FOR SPLIT SHEET METAL CYLINDER:

The closure mechanism was designed to be simple, inexpensive, easy to operate, and enabling the cylinder to be tighten to the flue gas conduit through its spacers.

Designed:

Double .75" x 16 Ga. 90° angle c/w Southco No.12 Quick-Opening Captive Screw Fasteners.

DESIGN OF AIR DUCT CONNECTING RFGH WITH FURNACE DUCT OR PLENUM:

In order to prevent the flue gas conduit from being exposed to a negative external static pressure, the size of the air duct was designed for a maximum outlet through flow without exceeding the inlet through flow through the annular openings of RFGH.

The duct was further designed for easy installation, minimum heat loss and uniformity of material.

Designed:

Flexible tubing as selected above for the particular size of RFGH.

DESIGN OF BAFFLE:

The baffle was designed individually for each size of RFGH in order to proportion the amount of air entering the furnace through the regular return air duct and the recuperator. It was further designed with regard to the size and shape of the opening, made in the return air duct or plenum for the earlier mentioned connecting air duct, which also provides the necessary installation access for the baffle.

Designed:

28 Ga. galvanized steel sheet providing a flow restricting area of 37, 47 and 56 sqin. for the respective 5", 7" and 9" RFGH models.

Re TASK 3

With reference to the Task 2, shop drawings were elaborated for three models of RFGH designed for 5", 7" and 9" dia. flue pipes.

Re TASK 4

Two prototypes (5" and 7" dia.) were manufactured for the purpose of "safety" and "efficiency" tests.

Re TASK 5

The installation and operation instructions for RFGH were elaborated with respect to:

ANSI/NFPA 31 - Installation of Oil Burning Equipment
ANSI/NFPA 54 - National Fuel Gas Code
ANSI/NFPA 90B - Warm Air Heating and Air Conditioning Systems
ANSI/NFPA 211 - Chimneys, Fireplaces, Vents and Solid Fuel
Burning Appliances, and

variety of the existing home-heating equipment.

The instructions give a prospective user the overall information about the principles and operation of RFGH and provide a guide for selecting a suitable model of RFGH for a particular home-heating equipment.

The instructions further provide a step by step guide for a proper installation, operation and maintenance of RFGH.

In order to establish guidelines for operating RFGH under various conditions in view of the wider applicability of RFGH resulting from use of the flue pipe "increasers and decreasers" discussed in Task 2, and in view of the introduction of "temperature indicators" discussed in Task 1, the second part of this task was modified.

Instead of the originally planned testing of RFGH in three lengths, an in-house testing was carried out to the purpose of determining a ratio between the temperature of flue gas and the surface temperature of a flue pipe under the steady state operation.

Re TASK 6

To the purpose of an independent testing of RFGH concerning "safety" and "efficiency", was necessary to acquire and contract the following:

Supplies:

Oil fired furnace, BDP Model No. 362AAN036105, Serial No. 4394V00072, input 104.2 MBTUH, and
Gas fired furnace, CARRIER Model No. 58WAV111-12, Serial No. 3894A26029, input 110.0 MBTUH.

The acquired forced air heating furnaces, represent the most efficient non-condensing technology on the market, and were purchased instead of the originally planned Sears furnaces, which were no longer available.

The cost of the purchased furnaces was under \$ 1,000.- each.

Testing:

Concerning the independent testing of RFGH for "safety", ETL Testing Laboratories Inc. determined a scope and elaborated test procedures designed to investigate RFGH and its operation under various "normal" and "abnormal" conditions in order to ascertain that RFGH and its use does not constitute a hazard.

The testing focused on the areas of concern in operation of any combustion heating equipment, namely whether there is a potentiality of:

- contamination of indoor air by CO,
- excessive drop of flue gas temperature causing condensation, or
- inadequate access of combustion air.

Re TASK 7

Concerning the independent testing of RFGH for "efficiency", ETL Testing Laboratories Inc. tested both furnaces with and without RFGH according to ANSI/ASHRAE 103-1988 "Methods of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers".

The said standard was followed in all respects, with the exception of the point of T.C. grid measuring the temperature of exiting flue gas.

In order to measure the effect of the recuperator, the temperature of exiting flue gas from the aggregate had to be measured at the exit from the recuperator instead of the exit from the furnace.

The testing of RFGH in combination with the above specified gas and oil furnaces proved, that the recuperator lowered the temperature of exiting flue gas by 132°F, and 191°F, increased the Output Heating Capacity by 4,100 Btu/hr, and 4,460 Btu/hr, and consequently increased the Annual Fuel Utilization Efficiency by 3.6%, and 4.4% respectively.

The results demonstrate, that RFGH can significantly enhance efficiency even of the most efficient furnaces on the market. This is a clear indication how substantial improvement can RFGH bring to the older, less efficient furnaces, which are in use in a large majority.

Re TASK 8

The shop drawings, specifications, and installation and operating instructions were revised and amended.

Re TASK 9

Three final prototypes of RFGH in sizes 5", 7" and 9" dia. were manufactured.

Re TASK 10

According to our estimate, the RFGH models 5", 7" and 9" dia. could be manufactured and brought on the market for \$ 41.00, \$ 43.50 and \$ 46.00 respectively.

The installation is simple, and described step by step in the installation instructions, which makes the product suitable for do-it-your-selfers.

Alternatively, it requires about 1.50 hr to be completed by a professional, and 3 hr if the measuring of temperatures is included.

Re TASK 11

According to the American Housing Survey for the United States in 1991 by U.S. Department of Housing and Urban Development, there is over 49 million of year-round occupied housing units heated by warm-air furnaces.

Considering further, that the "condensing" furnaces, which RFGH is not designed for, are relatively new and expensive technology, it may be safely assumed that there is more than 40 million of potential RFGH users.

In view of this market, our preferred marketing strategy is to offer RFGH for licensing to the existing manufacturers and distributors of heating equipment, and a business plan, based on the said marketing strategy, was drafted.