# SPACE HEATER DESIGN IN CERAMICS

Thesis by:

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Industrial Designer

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## SUMMARY OF THESIS

A 10,000 B. t. u. gas fired domestic space heater was designed in non-critical ceramic material and developed to the point of production in conjunction with the Gladding McBean Co. The heater was designed in several variations to compete in a post-war market as well as to meet an immediate need for small gas heating appliances in the Los Angeles area.

First a market survey was made to determine the size of the wartime replacement market. The survey indicated that 4,000 or more of this type heater could be sold annually in this area under present restrictions.

Following the market survey, studies were made of the physiological and psychological effects of heat, historical developments and present trends in heating, safety codes and public health, and factors influencing the consumer in the purchase of a gas heating appliance.

Finally, a specific type of heater which seemed best adapted to all considerations was selected and a study made of its functional requirements. The completed design represents a synthesis of ideas from various phases of the preliminary research modified by such practical aspects as physical characteristics of the material and manufacturing facilities.

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# MARKET RESEARCH COVERING THE LOS ANGELES AREA

## Summary

A study of the retail market for gas burning domestic space heating units in this area reveals the following:

1. A demand for at least 12,000 space heaters in the fall and winter of 1943, which cannot be filled by dealers' present stocks.
2. Roughly, 4,000 of these would fall into the small unvented bathroom heater class priced at from $3.00 to $5.00.
3. There is no local competition for the market and little chance of any for the duration.
4. By substituting non-strategic material for the sheet metal and cast iron in present models, a superior heater could easily be developed to fill in part the market demands for the duration and compete with post-war units.

All indications point to the inexpensive bathroom heater as being the most likely to compete in a post-war market, the simplest to manufacture, and having a minimum probable demand of 4,000 units per year for the duration.

## Demand

During the fall and winter of 1943 there will be a replacement market for approximately 16,000 household space heating units in Los Angeles area. The present stock on hand is estimated to be between 2,000 and 4,000 units, which would leave a market for at least 12,000 space heaters under the present W. P. B. restrictions in the fall and winter of 1943.

The W. P. B. in Washington has issued two orders which directly affect the sales and manufacture of space heating appliances. The order L31 issued during March, 1942, was primarily a gas conservation measure restricting the sales of all domestic gas heating equipment to replacements of condemned units of the same type and capacity. Order L79, issued July, 1942, prohibited the manufacture of all domestic gas heating equipment except upon special requests approved by the board. Its purpose was to conserve critical labor and material. In April, 1943, the W. P. B. released a certain amount of thin gauge sheet steel for a number of uses including the limited manufacture of space heating equipment. Shortly after this a special request was made for the development of cooking stoves and heating units in ceramics for military purposes. The bulletin mentions similar applications which have proved successful in Europe and encourages further research on ceramic heating units in this country.

Estimates of the 1943 market are based on the following monthly sales made under order L31 as reported to the Southern California Gas Company by its registered dealers who account for 60% to 75% of the total volume of sales in the Los Angeles District.

| Peak Season month | Sales made under W.P.B. order L-31 1942 | Prior to order L-31 1941 |
|---|---|---|
| September | 2,705 units | 2,969 units |
| October | 3,042 units | 5,796 units |
| November | 4,582 units | 7,049 units |
| December | 2,140 units | 6,887 units |
| | total 12,469 units | total 22,701 units |

The above summaries represent the number of unit space heaters (vented and non-vented) sold by Southern California Gas Company registered dealers during the peak season from September to December. Summer sales as reported in 1942 amounted to an average of 250 per month. Similar reports as of February 15, 1943, of stock on hand indicate that only 740 space heaters are held in stock. Reluctance in declaring full stocks might be partially responsible for such a low figure. By using 740 as a base and assuming 260 units held by other dealers not registered with the Gas Company and multiplying by four we arrive at a liberal estimate of 4,000 space heaters in stock February 15, 1943, in the Los Angeles area.

On the basis of sales from September - December in 1942, of 12,469 units as reported to the Gas Company, the total unit sales for the area could be estimated at approximately 16,000 units. With the estimated available stock of 4,000 heaters on hand and no more having been manufactured since July 1942, summer sales of approximately 1,500 units could be neglected and the present stock would last only until the month of October 1943 leaving an unsatisfied demand for about 12,000 units for the rest of the season.

Removal of the W. P. B. restriction L31 would greatly enlarge the potential market. A possibility of relaxing restrictions on the use of natural gas in this area was suggested if the present plan for dry storing natural gas in oil fields at Playa Del Rey proves successful.

Warehouses full of space heating units which might be moved into the market before next season are quite unlikely. A satisfactory unit made from non-critical materials by non-critical labor is necessary to help fill the demands of the large replacement market.

Limited quantities of sheet metal will probably be released at intervals throughout the duration of the war to heater manufacturers in non-critical labor areas.

This will relieve the shortage to a certain extent but is quite unlikely to satisfy the replacement market alone in this area. Any satisfactory heater developed in a ceramic or substitute material would be enthusiastically supported by the W. P. B. and would have tremendous marketing possibilities.

Ceramics have always been the most satisfactory refractory material known. Tile stoves have been used successfully for domestic heating in Europe for several hundred years. Recently stove and heater design in ceramics has been revived. Experiments have been made with glass stoves in this country, and several companies are manufacturing atmospheric gas burners pressed and slip cast in ceramic material. Developments in gas fired industrial furnaces have proven the value of burner design in ceramics incorporating the principle of surface combustion. Resistance to corrosion and low coefficient of heat conduction are properties essential to good burner design and are characteristic of ceramics.

Other physical properties such as shock resistance and weight naturally limit its application and uses. Its advantages must outweigh its limitations in a particular application for ceramics to compete successfully in a post war market.

Competition

Local competition with gas fired space heater manufacturers does not exist. W. P. B. order L29 has prohibited the use of critical material for the manufacture of heating equipment in this area which is also designated as a critical labor zone. By using non-critical material and no additional labor, production could be started on a new all ceramic heater which would help relieve a shortage in this area. There are approximately ten heater manufacturers in this area who are now either engaged in war production or are closed down. These companies may be considered out of the field for the duration but will offer competition for the post war market.

The W. P. B. is permitting a few companies in the Middle West to manufacture limited numbers of domestic space heating units to help alleviate the shortage. Dealers' stocks in this area are now limited to heaters manufactured by these companies. These few manufacturers, and possibly a few ceramic companies who may develop gas heaters, will quite likely be the only competition for the duration. Several ceramic companies were starting to produce atmospheric ceramic gas burners before order L79 was issued in July, 1942. There is no evidence of developmental work on all ceramic heaters available although it is highly probably that the ceramic industry is doing some research work on the problem. The heating industry in general is investigating ceramic substitutions which will permit them to resume manufacturing.

Distribution Channels

The gas heating industry has always been made up of a number of comparatively small manufacturers. This simplifies marketing and distribution problems as most transactions are direct orders from the retailer to the manufacturer. As a general rule, local manufacturers have supplied a major portion of the local market. Dealers' stocks now contain a larger proportion of heaters from mid-western manufacturers because of manufacturing restrictions.

Heaters are sold through a number of different outlets, some of which are:

1. Gas companies
2. Gas appliance dealers (registered and otherwise.
3. Mail order houses
4. Heating and ventilating companies
5. Department stores
6. Furniture stores

7. Hardware stores.

Domestic space heater sales approaches can be classified into several types:

1. To interpret customers' needs and sell a unit which best fits them
2. To meet a specified price range which the customer demands
3. To sell the heater with the best margin of profit

It is maintained that any unit the salesman wishes to emphasize can be sold to the average customer who has no pre-conceived idea of a definite price he can pay. This includes units of different capacities, appearances, efficiencies, and reasonable price variations. Mail order houses do a very large volume of business on the price basis, with a small bathroom heater in the $3.00 price range having the greatest turnover. The gas appliance dealers and gas companies are more interested in filling the customer's needs in the most satisfactory way possible. In all but the higher priced department stores, the small 10,000 B. t. u. bathroom heater at from $3.00 to $5.00 were out-selling all other models.

## GENERAL RESEARCH

### Physiological and Psychological Effects of Heat

Health and physical comfort are the two principal objectives of heating, ventilating, and air conditioning. The combustion of food within the human body releases heat energy which helps to maintain the natural organic functions of the body, build tissue, and provide work energy. Heat is released at a rate which raises the body temperature of the normal human being to 98.6F. and provides energy. This temperature has been conditioned by man's environment over many generations and seems to be the temperature at which human organism functions most efficiently. The temperature regulating system of the body quickly reacts to excessive heat by opening the pores and actuating the sweat glands or in the case of cold, contracting the pores and blood vessels near the surface to conserve heat. When this adjustment is severe enough to become difficult, the body experiences a sensation of discomfort. Conditioned responses can also cause discomfort when the temperature regulating system responds to the sight of an open window or other stimuli. In its present stage the metabolism of the sedentary human being is regulated to generate sufficient heat through the metabolic process to maintain a body temperature of 98.6°F.

and dissipate heat to surroundings at the optimal rate for human comfort when the enviornmental temperature is about 68°F. This temperature varies with people in different climatic zones as well as from winter to summer.

Heat is dissipated from the body by means of three principles:

1. Radiation to cooler surroundings
2. Convection
3. Evaporation

For the average sedentary adult, these transfers take place in the following approximate percentages:

Radiation 46%

Convection 30%

Evaporation 24%

Activity produces a rise in the katabolism and therefore in the amount of heat which must be dissipated.

The practical problem of heating amounts to the control of surrounding temperature conditions so that these three processes can function and heat can be dissipated at the normal rate for comfort. Heating is usually concerned with the adjustment of low temperature surroundings while air conditioning is usually concerned with the adjustment of high temperature surroundings, humidity control, and air purification. Flexibility in regard to the relative amount of heat dissipated by radiation, convection, and evaporation is possible. If the deviations are not too extreme and the total amount of heat dissipated is sufficient, comfortable conditions are still maintained. A simple case would be lowering the moisture content on a hot, humid day to permit more rapid cooling through evaporation when it is not possible to lose heat through radiation because the temperature gradient between the body and the surroundings is in the wrong direction.

Some of the principal environmental factors affecting health and comfort are:

1. Dust content of the aid
2. Temperature of the air
3. Humidity
4. Motion
5. Pressure
6. Temperature of surroundings
7. Distribution of heat
8. Odors
9. Visible light
10. Sound

Human occupancy alters the air in a room by

1. Using up oxygen
2. Increasing the $CO_2$ content
3. Increasing the humidity
4. Increasing the temperature
5. Introducting products of organic decomposition

Discomfort due to breathing stale air has been proven by psychological experiments to be far less important than that due to interference with the normal evaporation from the skin. The carbon dioxide content of the air can be increased to 3% without causing any noticeable effect upon the occupants. The average $CO_2$ content of outside air is only 0.03% while that in the average occupied room is 0.1%.* A much smaller relative change in the moisture content of the air will cause marked discomfort.

The prevention of excessive heat loss from the body which is the objective of heating may be accomplished by:

1. Controlling the air temperature
2. Controlling the temperature of surrounding objects
3. Raising humidity
4. Decreasing air velocities

* F. A. Moss; "Your Mind in Action"

variation of these factors must again be within certain limits for comfort. The following are approximate comfort ranges for the fully clothed sedentary adult:

Temperature air and surroundings 65 - 70 °F.

Relative humidity 50% - 60%

Air velocity 15 - 30 feet per minute

By simulating conditions in nature under which we feel most comfortable and alert, we can set up an objective for heating and ventilating. In the cool, clear air of the mountains or desert, receiving radiant heat from the sun and earth, and with a slight breeze from the front, we have very close to ideal comfort conditions. For long period heating these conditions would suggest a radiant source around the ceiling line of a room which would radiate heat to the floor and surrounding objects from as large a surface as possible. The ventilating requirements would be a supply of fresh, clean air circulating with a velocity of from 15 to 30 feet per minute.

It is logical that mental efficiency should be highest when no bodily sensations tend to distract from the thinking process. This condition can be approached by regulating environment to conditions for maximum comfort and by completely relaxing the body. Some psychological experiments on subjects in controlled atmospheres have suggested that temperature humidity, and the carbon dioxide content of the air can be raised to quite high values before any decrease in mental efficiency is noticed under stimulated learning. Practical results have proven the opposite, that approximately 60% more errors are made on a hot summer day than on an average day.

Historical Developments in Heating

The first application of artificial heat was probably a fire of dry sticks and leaves in a cave or natural shelter. With the advent of tents and huts an opening was left in the roof for smoke to escape. Portable stoves and charcoal braziers without provision for venting were used later by the Romans. Heating by hot water was used first in the Roman baths by running water through brass pipes with wood fires underneath. Fireplaces were used for many years without provision for draft or venting until about the Twelfth Century, when the chimney was introduced. The fireplace has been retained mostly because of its psychological value as it has an efficiency of only ten or fifteen percent acting as a radiant source. Stoves were used for the first time about 1490 in Alsace but did not come into general use for almost three hundred years. Most of the earthenware stoves built in Europe were made in the Seventeenth and Eighteenth Centuries. Many were constructed of rather elaborately designed tile blocks cemented together to form highly decorative rectangular and cylindrical stoves. Most of these stoves were supported by iron legs and occupied a rather large space either in the corner or near the wall so they could be easily vented. Cool green and grey glazes were predominant in the ordinary stoves while the elaborate porcelain stoves were often delicately hand decorated. These stoves were slow to heat up and were only satisfactory for heating over long periods. In 1744, Benjamin Franklin invented a cast iron open heater which projected out from the chimney and radiated heat into the room from all sides. He also made the first attempt to construct a hot air furnace which would supply pure heated air to the room. Steam heat was first proposed in 1750, and a hot water heating system was used in Paris to heat a hot-house about twenty years later. The sheet iron stove was developed in the early Nineteenth Century. Automatic damper control was introduced later and in 1845 a cylindrical stove lined with fire clay was constructed. About the same time the base burner stove into which coal was fed from a magazine above was invented. In 1875, the first oil stoves came out. By 1890, gas stoves were being developed. Electrical heating was the next radical step forward and is still in its early stages. Solar heating has been experimented with but no practical installments have been made. Radiant heating has attracted a great deal of attention lately and is felt to offer a solution to many former heating problems. It is based on the theory of heating surrounding objects to a temperature sufficiently high to prevent excessive heat loss from the body through radiation. Lower air temperatures are possible which it is thought will reduce heating costs. In any case, this trend approaches conditions in nature more closely than any previous attempts in heating and will undoubtedly be developed more thoroughly after the war. Induction heating through the use of ultra high frequency current may also have possible applications.

Ventilation

The history of ventilation parallels that of heating, although very little thought was given to it before the Nineteenth Century. The Egyptians constructed ventilation shafts in their pyramids and the Romans left openings in their roofs for the purpose of ventilation and temperature control but very little serious attention was given to the subject until it came up in connection with mine operation. In 1843, a study of hospital ventilation requirements was made by the French government. Sir Humphrey Davy in 1861 made the first attempt to introduce the need for proper ventilation to the English Parliament. Earliest attempts at securing proper ventilation in the United States were in regard to public assembly halls. Blower systems later supplanted natural ventilation and air conditioning is the latest advancement in the field.

## Types of Space Heaters

The general trend in domestic heating has been toward centralized heating units. In this particular climate, floor furnaces have proven very satisfactory. These units are more economical to install and have higher overall heating efficiencies as there are no conduit losses to contend with. Supplementary heating during abnormally cold spells or in isolated rooms is often provided by portable space heating equipment.

Space heaters may be classified as follows:

Gas - vented and non-vented
circulating
radiant

combination

Electric

circulating

radiant

combination

Stoves (oil, wood and charcoal)

circulating

radiant

combination

Supplementary space heating by gas and electricity has many advantages over stove heating which is used only in rural areas. Electric heating is undoubtedly the most advantageous from the health standpoint. Its two serious handicaps are its cost and its limited heating capacity. Electric heating per B. T. U. of output costs 19 times that of gas at average rates for the medium income domestic consumer. * The maximum output of an electric heater connected to a household circuit designed to carry 15 amperes of current would be about 1,500 watts which is equivalent in heat output to a gas heater of half the capacity of the small 10,000 B. T. U. bathroom heater. A special cord would be required to handle the current and initial costs on electric heaters are also higher than those for gas units.

* See Appendix

Gas heaters of the circulating type are the fastest and most efficient space heaters. They heat the air and set up natural convection currents which distribute the heat throughout the room. Radiant heaters are superior for rapid heating of persons or objects which are near the radiant source and exposed to its direct rays. Gas heaters come in both vented and non-vented types up to the capacities of 40,000 B. t. u.s per hour. Above that capacity they are all vented heaters with the largest heaters rated at about 60,000 B. t. u.s per hour. A 10,000 - 12,000 B. t. u. heater is designed to maintain a room 10 ft. by 10 ft. at a comfortable temperature under average winter conditions. This size heater is used primarily to heat bathrooms and bedrooms for short periods in the morning and evening. Colors are usually white or cream. Prices on these units range from $3.00 to $5.00 and they have a large turnover in sales. A 20,000 B. t. u. heater selling at from $14.00 to $18.00 will heat a room about 12 ft. by 15 ft. and is the next best seller. The larger capacity heaters are usually finished in dark brown and imitation wood patterns to blend with the furniture. Wall heaters require special installations and the imitation log heaters are novel but very inefficient.

Safety Codes and Public Health

Health and Safety Codes have been set up with the purpose of protecting the public. These codes vary from state to state and even from community to community. In regard to gas appliances, the Health and Safety code for the State of California states that every gas-fired appliance, except kitchen gas ranges, which is designed to be a vented appliance shall be provided with a vent pipe or flue leading to outer air. It also states that every gas vent and appliance shall be kept in good repair. Pasadena building codes require that every gas heater with a capacity of 40,000 B. t. u. s or over and every bathroom heater regardless of size be vented as well as provided with intake air.

Carbon monoxide, a product of incomplete combustion, given off from defective gas appliances may prove fatal in an hour at concentrations of 0.4%. Health authorities have set 0.01% as the maximum concentration of carbon monoxide gas which will not give rise to any symptoms. Small quantities of water vapor and carbon dioxide, the principal products of combustion, are not considered injurious in themselves but do increase the toxic effects of any carbon monoxide which might be present. In the early 1920s, the Ohio State Board of Health made the most comprehensive survey of asphyxiation by carbon monoxide which has been published. More than half of the cases were caused by defective domestic appliances. The worst menace was the gas stove left burning in poor homes to heat the room during cold winter nights. Coal and coke stoves, hot water heaters and bathroom heaters were responsible in the order listed for other cases of asphyxiation. Unvented gas heaters of the radiant or circulating types were considered equally dangerous when used for continuous heating. From the standpoint of health and safety providing every heating appliance with a vent and supply of intake air is very desirable but at the same time much of the danger involved in using unvented heaters can be avoided by keeping the appliance in good operating condition.

The American Gas Association sponsored by the gas heating industries for the promotion of gas heating, maintains a series of research and testing laboratories. A number of safety and efficiency requirements have been set up which must be met by any heater submitted to the laboratory before the appliance receives the A. G. A. stamp of approval. These requirements for

A. G. A. approval serve to protect the consumer and at the same time promote the use of gas appliances by helping to overcome fear and prejudice against gas as a fuel for domestic heating.

Consumer Preferences

The validity of a selective consumer survey, even though it covered 10,000 residences, would not be great as this number represents only two per cent of the 500,000 middle income single dwellings in this area. War Production Board restrictions and many other factors affecting the normal consumer market make it almost impossible to conduct a valid survey during this period. It was felt that by interviewing people directly connected with the field of selling and manufacturing gas heating units that a much more valid survey of possible design improvements could be made.

Information on consumer preferences was obtained from salesmen in a variety of retail outlets and from discussions with potential consumers. This material indicated the best selling heaters were found to be the inexpensive bathroom heater in white and cream enamel and the 20,000 B. t. u. circulating or combination radiant circulating heater in dark browns. Variation in the design of several heaters of the same price range and capacities was found to be a very valuable sales factor as the consumer is given an opportunity to choose between several heaters instead of being forced to take the only one shown him. As small and compact a heater as possible was also found to be desirable from the consumer's point of view. Naturally, price is also one of the most important factors.

# DESIGN

## The Problem

The design of a small space heater was chosen as the practical problem. This choice was suggested by a study of the gas appliance market under wartime restrictions which indicated a potential demand for approximately 4,000 low capacity space heating units per year in the Los Angeles area. Ceramic material was chosen as a substitute for critical metals because of its non-priority status, its resistance to corrosion, and its qualities as a refractory material. Gas was selected as a fuel because of its low relative cost, its cleanliness, and its excellent combustion characteristics.

A 10,000 B. t. u. unvented heater seemed best adapted to all practical considerations. The volume of potential sales, competition in the post-war market, the limitations of ceramic material, operating efficiencies, and ease of production were all factors affecting the choice. The functions of this type heater were analized and then a survey of existing heaters designed in sheet metal was studied. A substitution of ceramic material for sheet metal naturally means more careful handling would be necessary to avoid breakage. A permanent gas connection as advocated by the gas companies would greatly reduce the danger of the heater being knocked over on a tile or hardwood floor and broken. The glazed surface will be easy to keep clean and will not change color or fade. The performance of the ceramic burner should be superior to that of a cast iron burner after several years of usage. The ports in ordinary cast iron burners are rapidly corroded and clogged when traces of sulphur are present in the gas while those in a ceramic burner are not affected. Improper combustion with its very dangerous effects is often caused by a badly corroded burner.

The unvented 10,000 B. t. u. heater will warm a room approximately 10' x 10' under average eastern winter conditions. They must heat the space safely, rapidly, and uniformly. In the Los Angeles area, these heaters are usually used as supplementary heating and only for brief periods in the morning or evening. A rubber connecting hose is used in most cases to supply gas from the outlet despite protests from the gas company. The heaters are placed close to the wall and can be moved to outlets in other rooms as supplementary heating units when necessary. A low initial cost permits the purchase of several units to avoid the trouble of moving the heaters from room to room. A case or grill is necessary to prevent curtains, clothing, or any other material from coming in contact with the gas flame. Sufficient air supply must also be provided to permit complete combustion.

## Elements of the Design

Basic elements of this type heater are the orifice, the burner, the case, and the hose connection. These elements must each be designed to fulfil its specific requirements and then be coordinated with the others to fulfil the functional requirements of the heater. After these conditions are met, attention may be concentrated on appearance and sales appeal.

The orifice diameter and the line pressure are main factors which determine the amount of gas flowing into the burner or the maximum capacity of the heater. A slope of 45° tapering from the inside diameter of the gas line to the neck of the orifice prevents excessive turbulence through the orifice. The orifice must be securely located at a certain distance from the burner throat to insure proper mixing. The primary air may be regulated if necessary by adding an adjustable shutter. A metal which does not corrode should be used for the orifice. Brass has been found to be a satisfactory material in this application.

The burner performs the most important function in the heater. The gas and air combination injected into the burner is mixed in the throat and forced out through a number of small ports on the top of the burner where it is ignited and burned in the presence of secondary air. Raised ports are desirable to permit an adequate secondary air supply. These ports should be close enough together to enable the flame to propagate easily when lighting. Temperatures should be comparatively low around the mixing throat to prevent pre-ignition. * A comparison of cast iron and ceramics for use in burner design shows the following:

1. Corrosion resistance of ceramics far superior to cast iron.

2. Heat conductivity of ceramics comparatively low.

3. Proposed ceramic body not a critical material.

4. Ceramics more fragile and porous than cast iron.

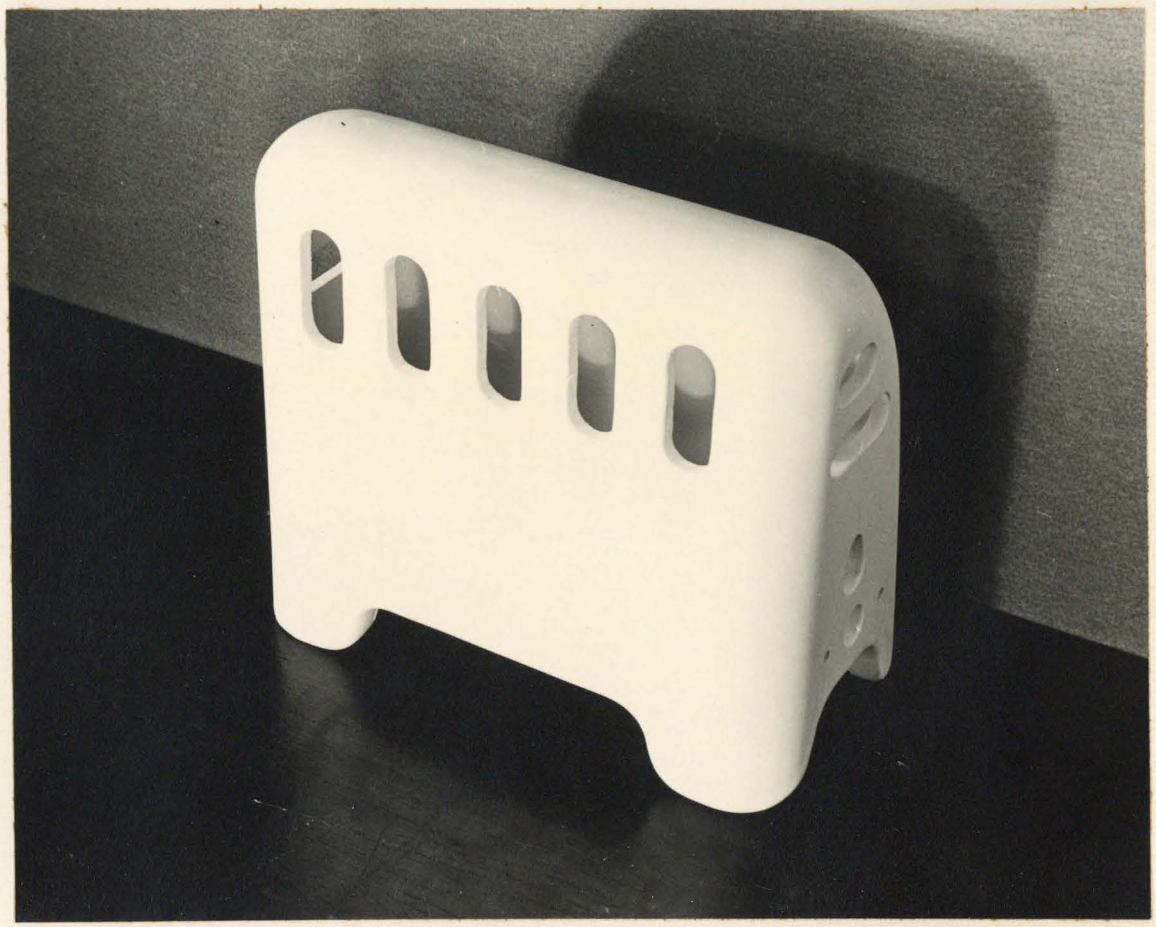
* American Gas Association; "Combustion"

The body of the heater functions as a protective enclosure for the flame, as a low temperature radiating surface and as a circulation directive. The case or body should be sturdy, easily cleaned and, have a low center of gravity. It should be reasonably light and provide some means for carrying. An excess of secondary air should be admitted from the bottom and circulating openings should face forward as a safety means to prevent the charring of curtains or drapes. The top which will be the hottest portion should be slightly further away from the wall and the legs should be sufficiently high to prevent excessive heating of the floor. A hole must be provided for lighting and scratching surface would also be convenient. Provision must be made for securely and accurately locating the burner throat with respect to the orifice.

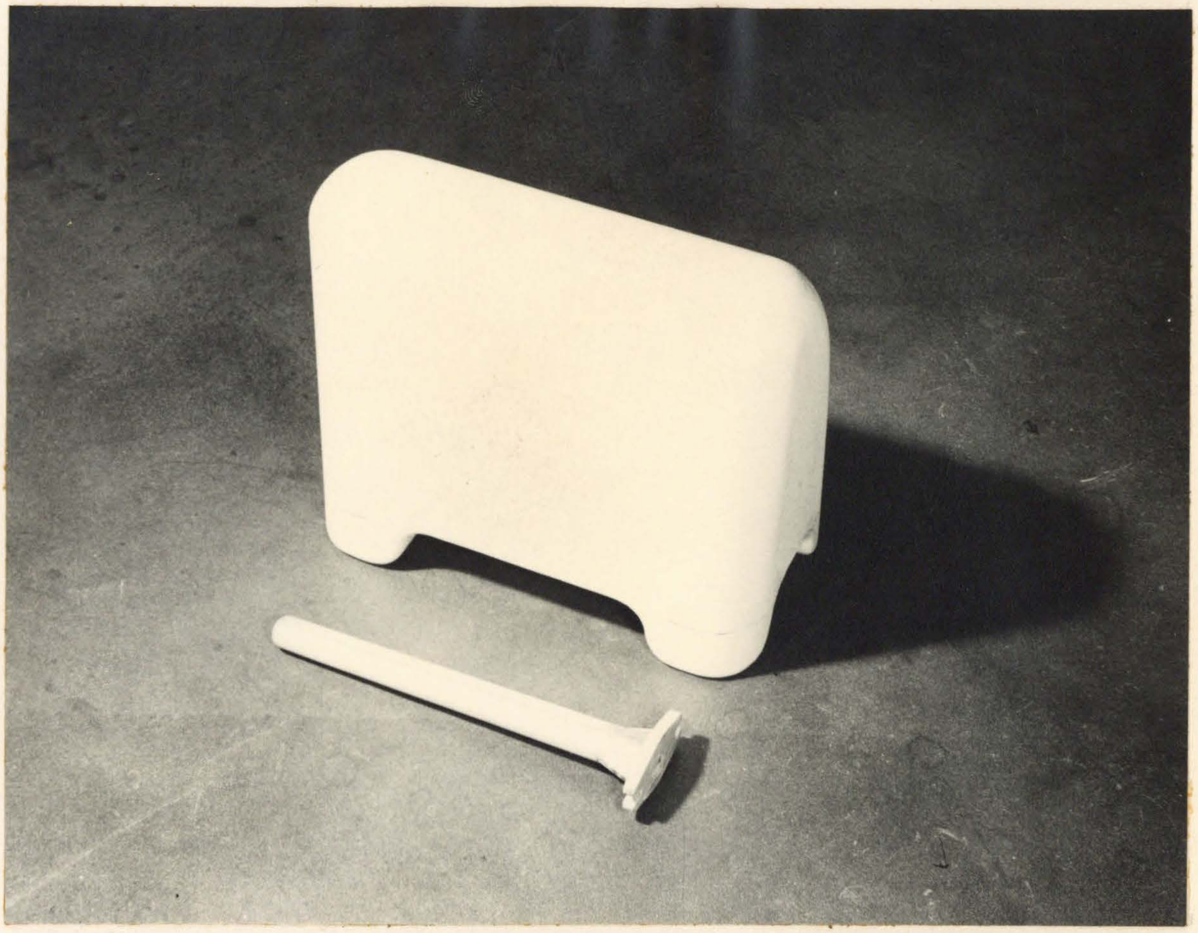
The hose connection should not have a valve. This makes it necessary to regulate the heater from the wall outlet valve which is the safer practice in any case. A connection which would permit either a hose attachment or a pipe joint would be advantageous. In any case, it should be close to the body of the heater and fastened so as to distribute any stress over as large a surface as possible.

variations in appearance may be easily accomplished to stimulate sales and yet cause only slight variation in production methods. By using different cutting templates the sizes, spacing, and arrangement of the circulation vents in the case may be varied.

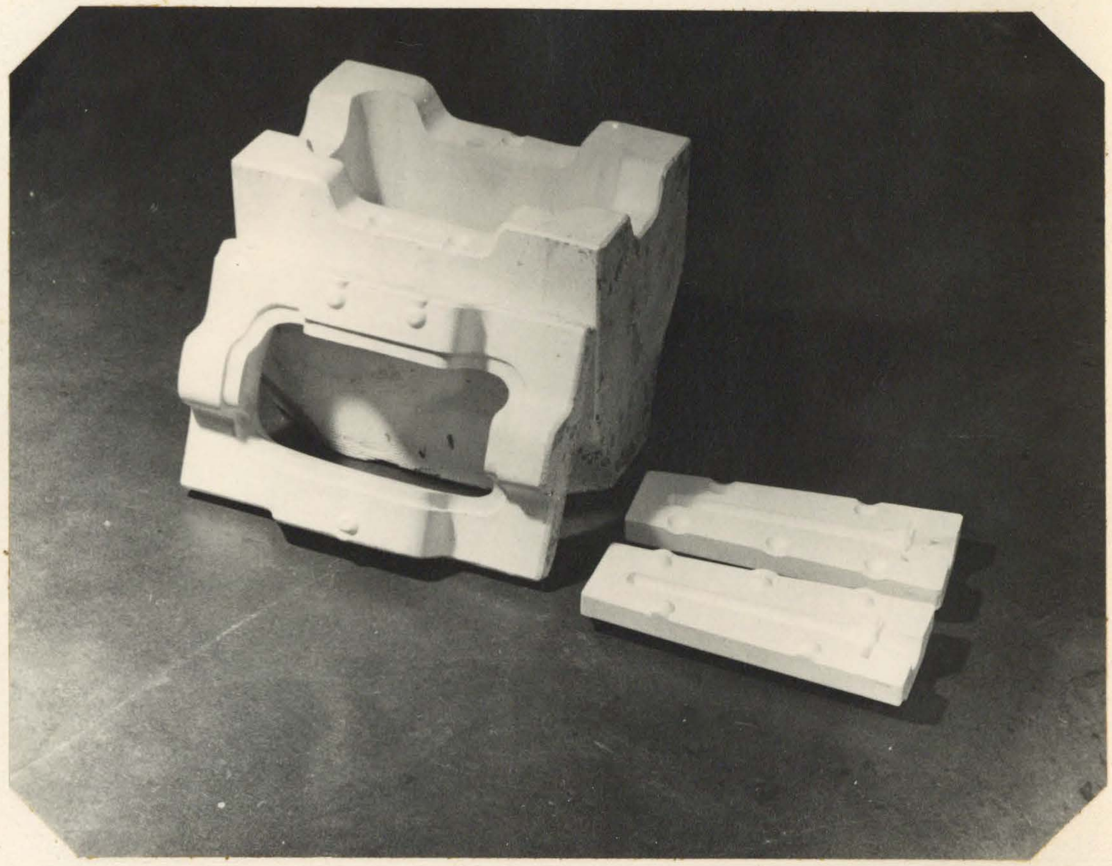
Colored glazes will be possible over a special ceramic body but the market survey indicates that cream and white are the two most popular colors for this type of heater. A rough, dark colored surface would theoretically act as a better radiating surface but practically there is very little difference. These variations in design will give the customer the opportunity of making his own selection and are considered from the sales point of view a very desirable asset for any line of goods.



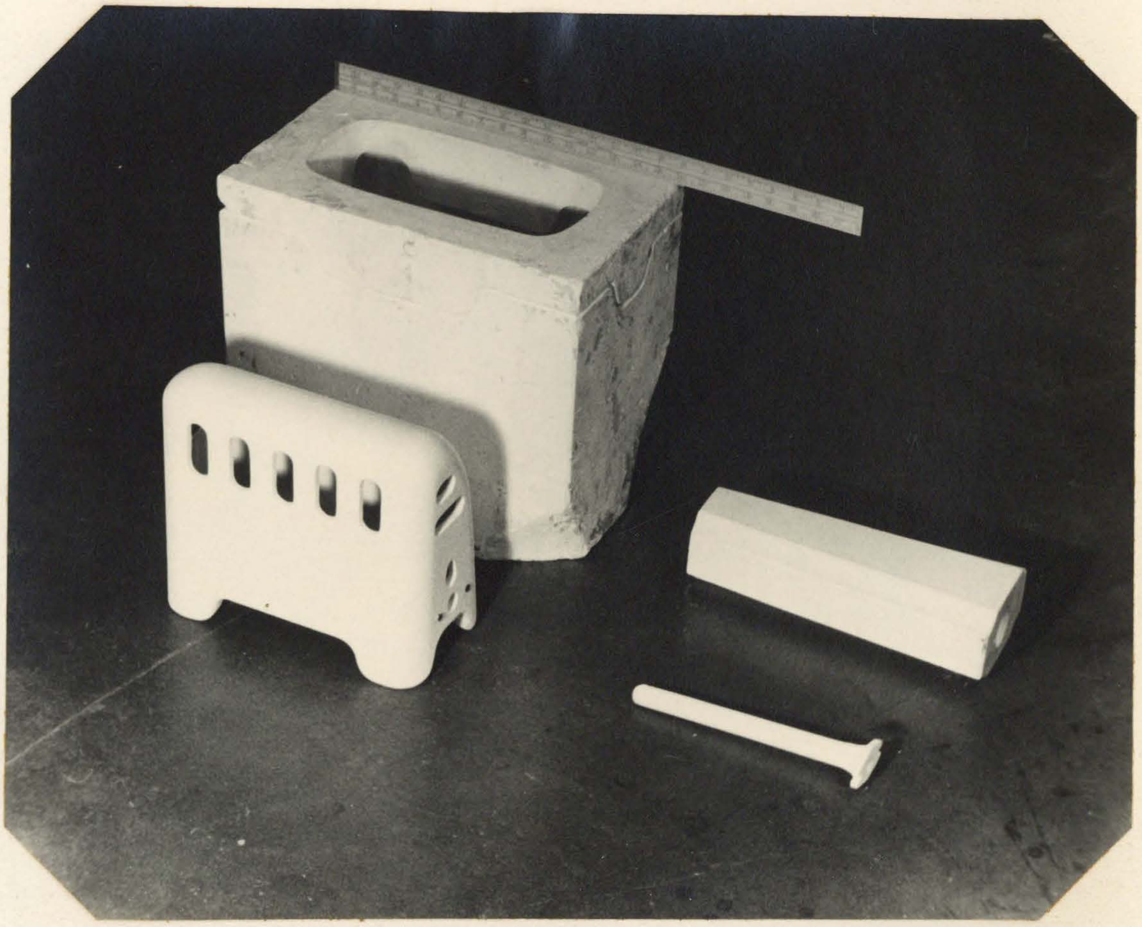
The Heater



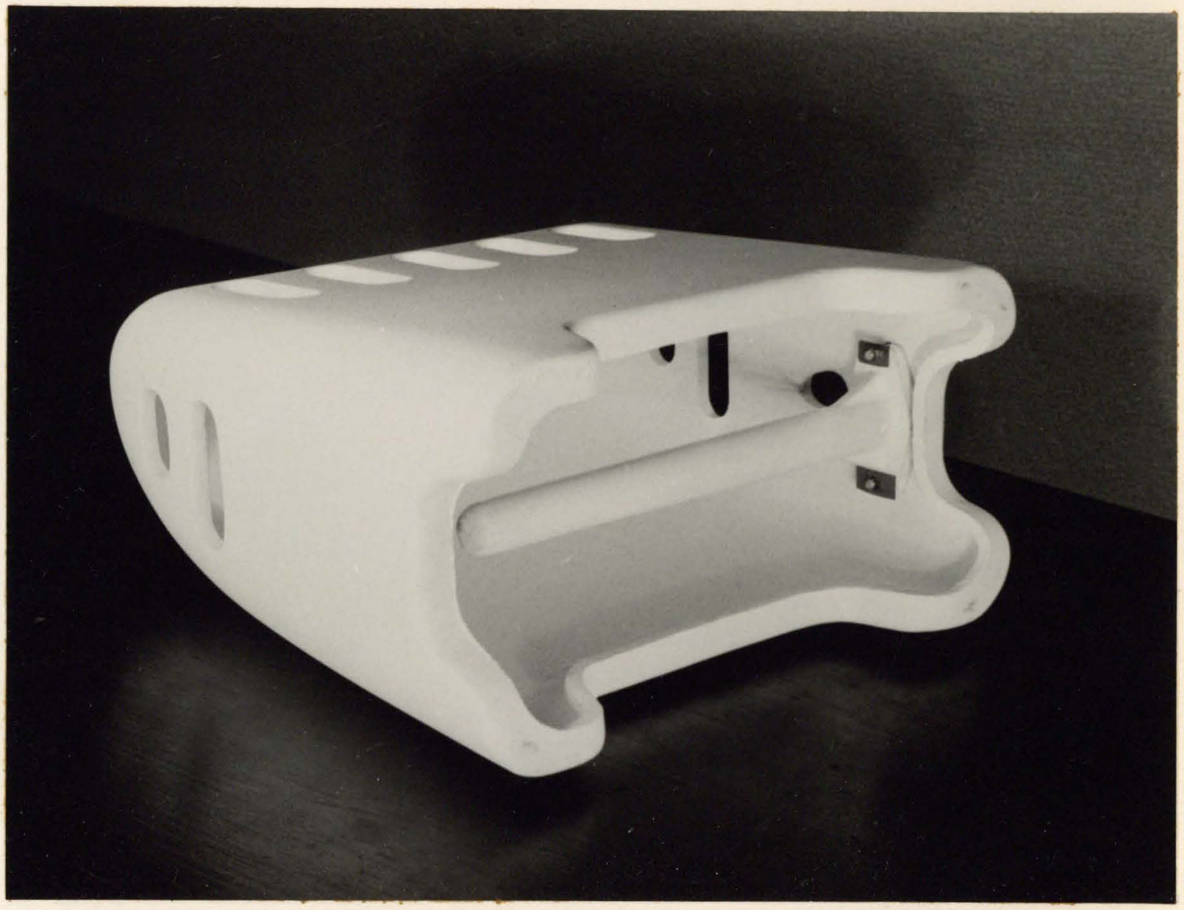
The Models



The Molds

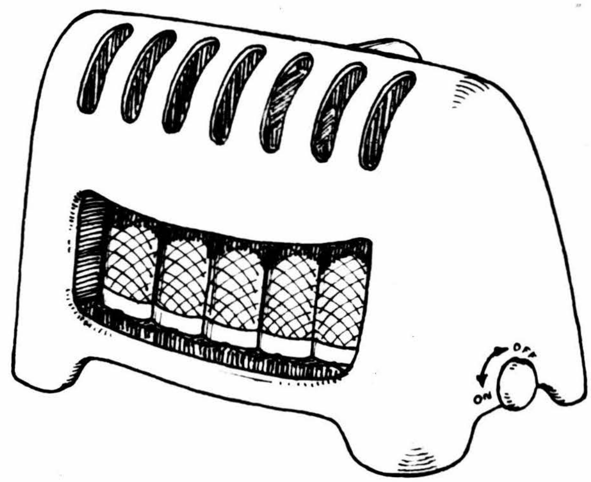


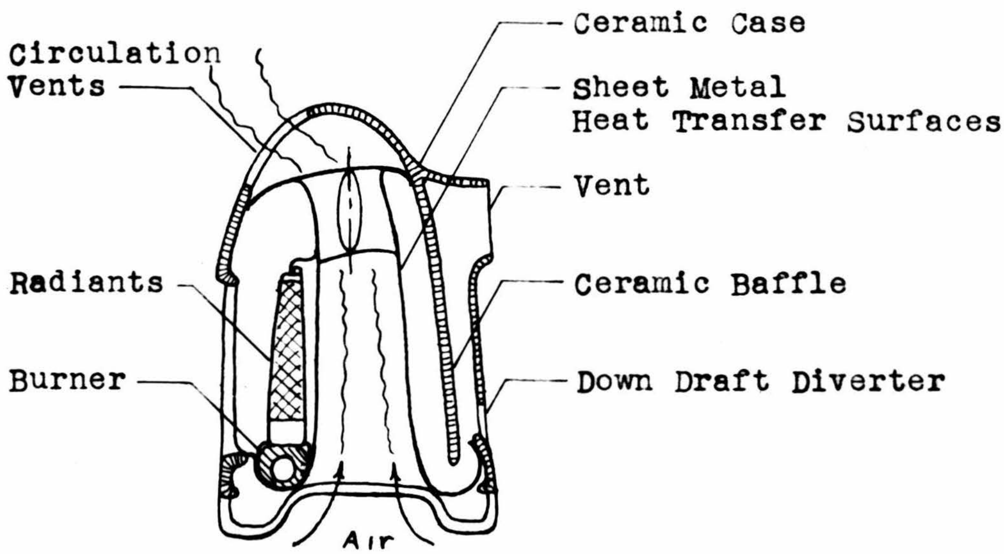
The Molds and Finished Products



The Assembly

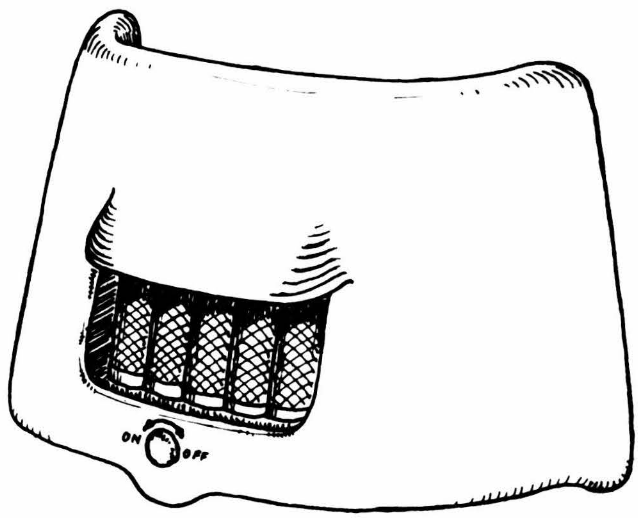
Alternative Designs in Ceramics





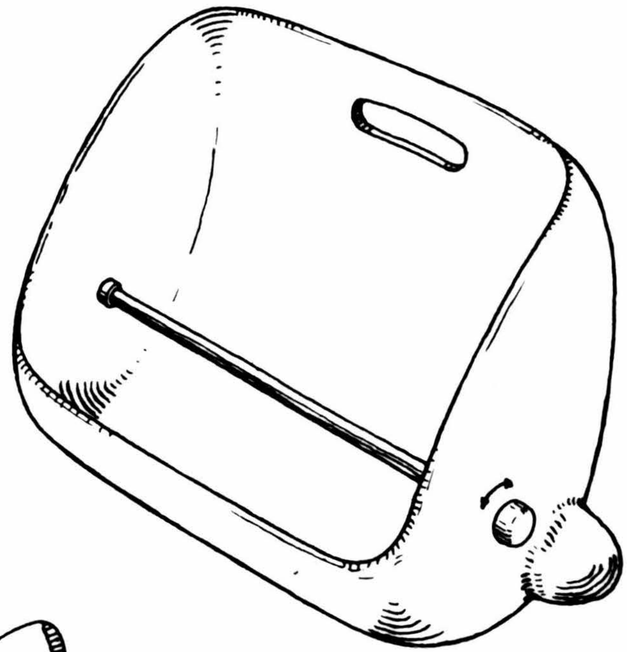

Center Section

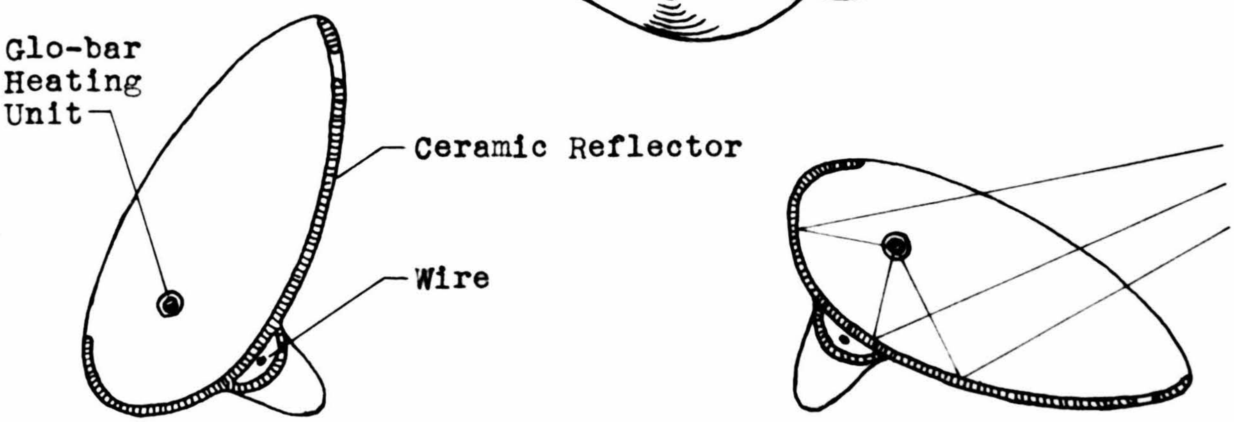
A vented combination radiant-circulating heater utilizing a minimum of sheet metal. By the use of sheet metal only in the most important heat transfer surfaces, efficiences comparable to those of all metal units can be attained.




## A Vented Combination Radiant-circulating Heater

The entire heater is designed in ceramics with the curvature providing low temperature radiating surfaces exposed to all parts of the room and acting as supports for the heater. Products of combustion pass up through the hood, are then diverted through the side wings and finally out of the vent.






Upright     <u>Sectional Views</u>     Horizontal

An electric heater using metal only in the switch and as contacts for the carbon Glo-bar heating unit. The heater may be used in the upright or in the horizontal position depending on the heat distribution desired.

# A P P E N D I X

## COST ANALYSIS

Large scale production does not offer the percentage reduction in manufacturing costs in the ceramic industry that it does in most other fields. The cost of materials is very small in comparison to labor cost, firing expenses, and rejection losses. Round corners, strengthening ribs, and other factors in the design can substantially reduce rejection losses. Simple molds and a minimum of trimming or finishing will reduce labor costs.

Based on the production of several thousand units, the approximate manufacturing costs per heater are as follows:

| | | |
|---|---|---|
| Case | | $1.50 |
| Burner | | .35 |
| Hose connection | | .15 |
| Orifice | | .10 |
| Assembly | | .25 |
| | Total | $2.35 |

Comparison of the cost of heating by gas with the cost of heating by electricity for domestic consumer in the middle income group.

Gas

1 B. t. u. of heat energy costs
$\frac{.0006}{1120} = 0.000000536$ or $53.6 \times 10^{-8}$ dollars

@ \$0.60 per 1000 cu. ft. of natural gas with a heating value of approximately 1120 B. t. u. per cubic ft.

Electricity

1 B. t. u. of heat energy costs $0.000292 \times 0.035 =$ \$0.0000102 or $1020 \times 10^{-8}$ dollars

@ \$.035 per Kw. Hr.
1 B. t. u. = 0.000292 Kw. Hr.

@ \$0.015 per Kw. Hr. 1 B. t. u heat energy costs $0.000292 \times 0.015 =$ $438 \times 10^{-8}$ or $438 \times 10^{-8}$ dollars

:. Heating by electricity is $\frac{1020 \times 10^{-8}}{53.6 \times 10^{-8}}$ or 19 times as expensive as heating by gas for the average domestic consumer in the middle income group.

At a special rate of \$0.015 per Kw. hour, electricity is still eight times as expensive as gas per B. t. u. of heat energy at the average rate for a small domestic consumer.

The approximate weight of flue products per B. t. u. of heat energy released during complete combustion of natural gas with a methane content of 85% are estimated as follows:

Assuming the principal constituent methane to have a heating value close to the heating value of natural gas of 1120 B. t. u. per cubic foot.

$$\underset{16}{\overset{0.00004}{CH_4}} \quad 2O_2 = \underset{44}{\overset{x = 0.00011}{CO_2}} \quad \underset{36}{\overset{Y = 0.0000875}{2H_2O}}$$

1 cubic ft. of $CH_4$ weighs 0.0447#

$\frac{0.0447}{1120} = 0.00004$# of methane per B.t.u. of heating value.

Let x = # $CO_2$ produced per 0.00004 # of $CH_4$

$\frac{0.00004}{16} = \frac{x}{44}$ x = 0.00011 # $CO_2$

Let Y = # $H_2O$ produced

$\frac{0.00004}{16} = \frac{Y}{36}$ Y = 0.00011 # $H_2O$

∴ A 10,000 B.t.u. heater will produce approximately

1.1 # $CO_2$ per hr.

0.875 # $H_2O$ per hr.

About .0738 # of $CO_2$ are exhaled by the average person in one hour. In still air at 68°F. about 0.095 # $H_2O$ per hour are exhaled and evaporated by the average man's body.

This would indicate that a 10,000 B. t. u. unvented heater gives off $CO_2$ at a rate equivalent to 15 persons and $H_2O$ vapor equivalent to nine persons.

Twelve sedentary persons would give off approximately 4,800 B. t. u. of heat energy per hour as compared with the 10,000 released by the gas heater.

# APPENDIX

## Sources of Information and Bibliography

*     used in Market Research section

**    used in General Research section

***   used in Design section

## Personal Contacts

Southern California Gas Company  *   ***

Mr. H. V. Davis - Personnel Manager

Institute of Gas Heating Industries *   **   ***

Mr. F. Suffron

American Gas Association *   ***

Mr. F. Allen

Los Angeles Examiner   *   **

Mr. W. Dover - Market Research Bureau

Los Angeles Chamber of Commerce   *

Mr. G. Marion - Market Research Bureau

Occidental College   **

Dr. G. Brighouse - Psychology Department

Pasadena Board of Health   **

Mr. J. Arthur - Health Officer

"Ideal Heating Corporation ***

Mr. E. Slater

Gem Clay Forming Co. ***

Mr. L. Munchhof

Gladding McBean and Co.

Mr. P. Thornton
Mr. P. Porter
Mr. R. Evans

Pasadena Department of Building Codes **

Gas Appliance salesmen interviewed at:

Sears Roebuck and Company (Pasadena and Los Angeles)
F. C. Nash & Co.
Pasadena Hardware Store
Leader Furniture Co.
Bullock's
The May Co.
J. W. Robinson
Barker Brothers
Benedict and Gingrich Gas Appliances * **

Correspondence

Correspondence was carried on and catalogs or bulletins were obtained from 23 space heater manufacturers and associations * ** ***

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Industrial Furnaces
Trink

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