The Design of
A Commercial Coffee Maker

Thesis

by

James Harvey Crate

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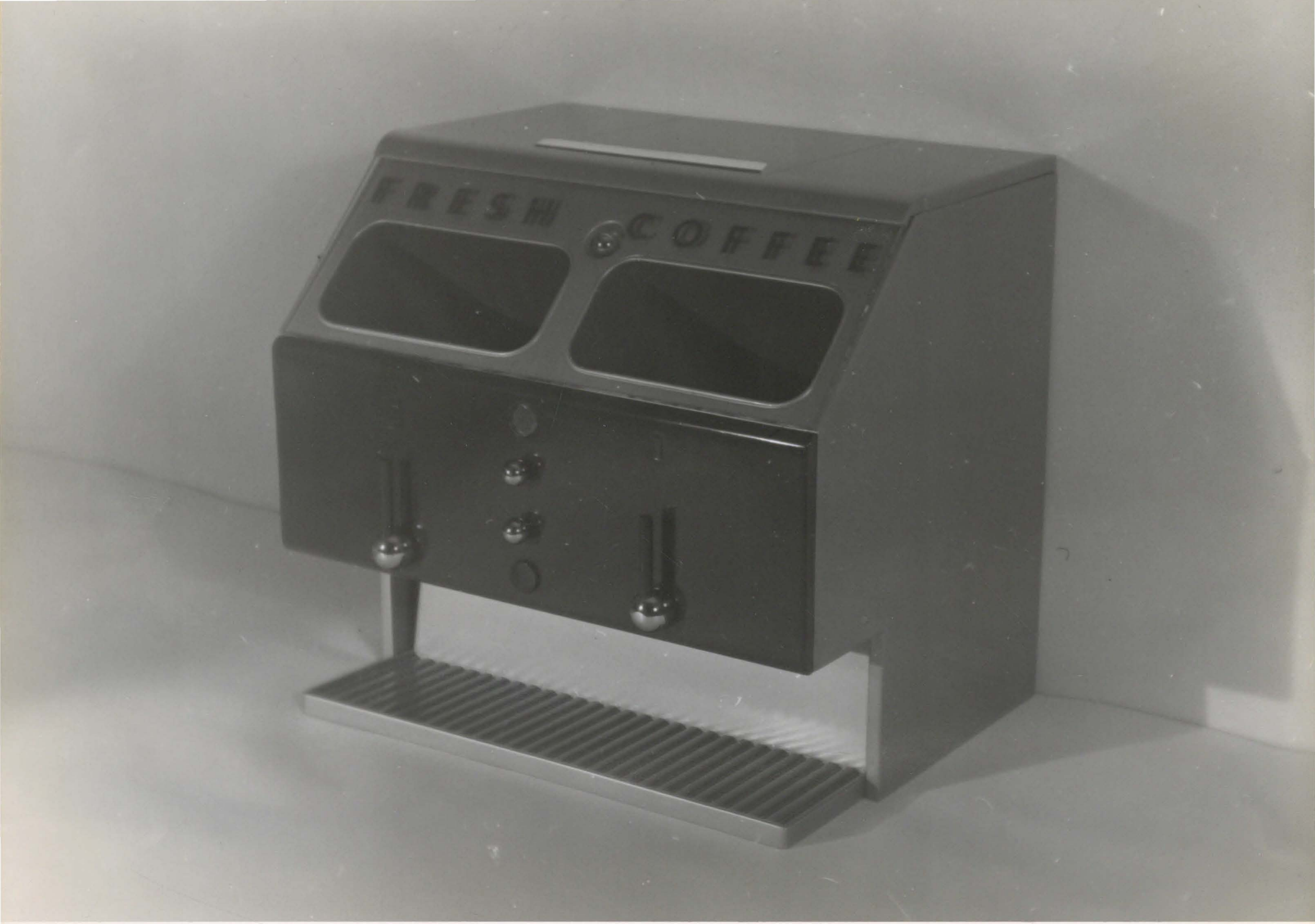
FRESH COFFEE

ABSTRACT

The lack of new and constructive developments in the coffee maker field during the past twenty years and the present great demand for improved commercial cooking equipment evidenced the need for an improved coffee maker.

An ideal brewing cycle was established by analysis of the factors controlling and affecting the brewing process. The features, fabricating methods and materials incorporated in units now on the market were studied. Interviews with representatives of various types of eating establishments and reference to national surveys showed a desire for a coffee maker as automatic as possible that would reduce labor costs, increase safety of operation, and maintain a constant quality of coffee.

These factors were integrated to form the final design. The unit has a capacity of 350 cups per hour, is heated electrically by immersion units, has an automatically controlled brewing cycle, is easy to clean and service, is priced in the range of present coffee makers, occupies a space the same or smaller than that required by present coffee makers, and has an appearance that is conducive to selling both the coffee maker and the beverage it produces.

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INTRODUCTION

THE SCOPE OF THE PROBLEM

The commercial coffee maker as a problem for the industrial designer seemed an appropriate one as it involved an understanding of engineering, materials, production methods and styling. It also was required that these factors be integrated in a manner such that the resulting design would be acceptable to the manufacturer, the distributor, the ultimate user and his clientele.

Developments in this field during the past twenty years have been stagnated by first a depression and then a period of war years. As a result of this slow development of commercial restaurant equipment, present coffee makers, with a few notable exceptions, still reflect the manufacturing processes and appearance prevalent during the 1920's. The disadvantages of inadequate equipment and the high level of his costs have forced the restaurateur to look for improved means of coffee preparation.

Investigation brought to light many factors which suffered from the lack of fresh thinking and the use of "old-fashioned" principles of design and production. Little thought has been given to the safety of the operator, particularly in the transfer of boiling water from the boiler to the urn and in serving the beverage. Few units have been endowed with any outstanding sales points in the way of appearance and unique features that would help in selling the unit to the ultimate consumer or improve the coffee sales of the user. Though a number of manufacturers stress the "automatic" aspects of their products, the term generally applied to only one or two steps of the coffee making process. Coffee as a beverage is taken for granted by so many people that it is difficult to impress one with its importance to the restaurateur. However, the great majority of his clientele choose coffee with their meals, and he realizes the necessity to maintain the quality of this beverage. Only by using freshly roasted and ground coffee, by maintaining careful control of the brewing process and the cleanliness of the apparatus, and by properly serving the beverage can he be certain of customer satisfaction.

DESIGN SUMMARY

The coffee maker will brew up to three gallons of coffee at one time. Though a working model would be needed to determine the actual capacity, it is estimated that it would be approximately 350 cups per hour.

Operation of the unit is simplified to the point where the "human element" is eliminated. A pound of coffee is placed in the unit and a control knob is operated. Measurement of the water, delivery of the water and maintenance of temperatures are cared for automatically. A green light on the front of the cabinet indicates when the water is at the proper brewing temperature of 212 degrees F., and a red light is illuminated until the grounds are disposed of.

The used grounds need not be removed from the machine between batches of coffee as this is taken care of by an automatic wash-out. By moving a lever, the coffee brewing chamber and the filter are cleaned and the used grounds removed.

Cleaning of the unit has also been simplified. All controls on the front panel are recessed to provide a smooth, easily cleaned surface. Gauge glasses are not required as the amount of coffee in the reservoirs is measured on a scale on the back walls of the containers. Spigots are removed by a twisting action and the filter is easily lifted from the brewing chamber. The jacket scaling problem does not exist as the coffee in the reservoirs is held at the serving temperature by individual heating units beneath each container.

The exterior is finished in stainless steel with accents of warm brown on the control panel, levers and handles. The surface is free from crevices and sharp corners and presents a look of cleanliness. All of the controls have been grouped at a convenient point on the front of the coffee maker to eliminate any chance of the unit impressing one as a machine of great intricacy. The coffee reservoirs are covered with a glass panel etched with the words "FRESH COFFEE" as a stimulus to the clientele of the restaurant.

This design presents one solution to the problem. Though certain changes would be required to suit the production techniques of any one manufacturer, and further model work would be necessary to ascertain the critical dimensions affecting the brewing process, the features outlined in the summary above add up to a definite improvement over coffee makers now on the market.

THE COFFEE BREWING PROCESS

COFFEE BACKGROUND

The process of changing the coffee fruit into a granulated product suitable for brewing is carefully controlled to insure that only the finest ground coffee is available to the consumer. It is important to keep this in mind when designing the brewing apparatus as irrespective of how much care has gone into the preparation of the bean, the acceptability of the coffee will depend wholly on the quality of the coffee making equipment.

The best grades now obtainable are grown at an altitude of approximately 6,000 feet in the tropical sections of the world. These grades are classified either as "Brazils" or "milds". The latter includes beans from such diverse sections of the world as Abyssinia, Arabia, Brazil, Colombia, Costa Rica, Guatemala, Hawaii, Haiti, Nicaragua, Java, El Salvador, and Santo Domingo. The physical characteristics of the bean grown in these various places differ considerably; the waxy bluish bean of Guatemala, the greenish bean of rich mellow flavor of Colombia, the small to large blue green bean of strong flavor of Southern India. (1)*

The coffee fruit resembles a cherry. It has an outer wrapping or skin called the pulp covering a gummy substance of mucilagi-

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*Numbers in parenthesis refer to references in Appendix (1).

nous consistency. This substance surrounds two flat-sided beans. Each bean has an additional wrapping comprised of an outer, tough-textured "parchment", and an inner delicate "silver skin". (2)

The size of the coffee plantation or "fazenda" ranges from those of Brazil which produce up to 5,000 bags a season to the smaller ones of Colombia, the "fincas", where the usual production is 5 to 10 bags. Processing is taken care of by the "beneficios" or mills which are generally affiliated with the larger "finceros". (3)

The fruit is usually picked by hand about eight or nine months after blossoming. In some cases the beans are picked separately, and in others the fruit, leaves and all are stripped from the branches. (4)

Two methods are employed to extract the coffee bean from the enclosing coverings of skin and pulp. The more widely used is the "wet" method, the other the "dry" method. (5)

The first step in the "wet" method is the separation of the berries to be processed from undesirable matter. This is accomplished by placing the crop in a large water vat, after which the good berries sink to the bottom and the unripe and malformed fruit, the leaves and twigs float to the top where they are skimmed off. The fruit to be processed is then run through a pulping machine which removes the outer skin and gummy substance, revealing the two beans. These are then allowed to ferment and later dried in the sun. The final step is the de-hulling of the beans which is done by machine.

The "dry" method, though it produces a better quality of coffee, requires a longer time interval for processing and continuance of warm clear weather. After picking, the berries are taken directly to the patios where they are spread in a thin layer and allowed to dry in the sun. Here they remain for a period of three weeks, being turned occasionally to insure proper drying. After drying, they are stored and the skin and husks removed at a later date by either machine or threshing.

The extracted beans are cleaned in a pneumatic and gravity coffee-cleaning machine called the "Catador" and automatically sorted. Before going to market, each bean is checked to insure that only the ripe, correctly formed product is shipped to the roaster.

The individual roasters then process the bean into the form one buys for brewing. During the roasting about 90% of the water is removed, leaving a product with a content of about 1.2% caffeine, 15% fat, 15% protein, 20% crude fiber and 50% nitrogen free extract. Approximately 25% of the total is soluble in water. (6)

METHODS USED, PAST & PRESENT

The history of coffee relates that one of the first groups to use the coffee bean for its food value were the Galla, a tribe of Africa. They depended on coffee for its nutritive value

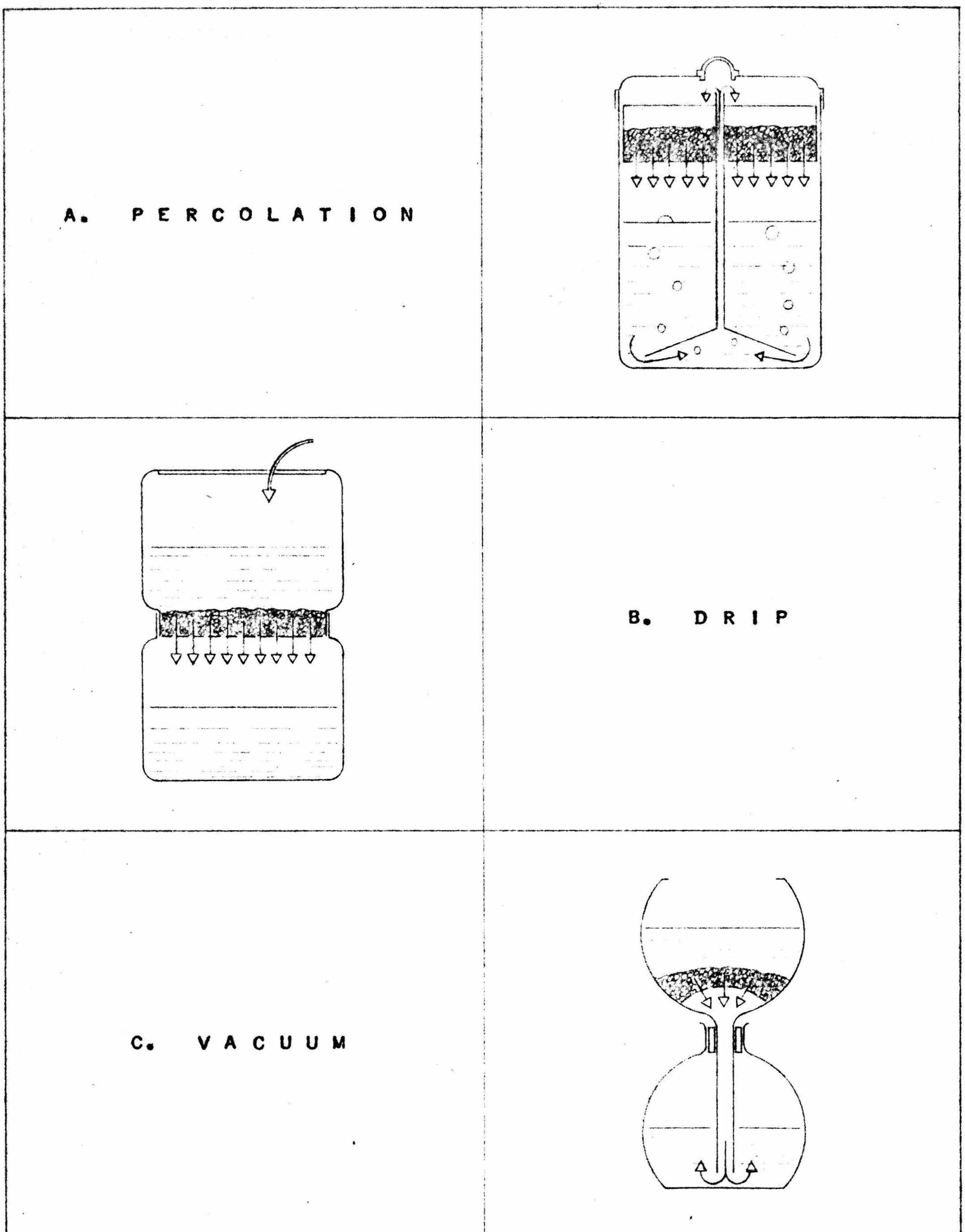

FIG. 2 DIAGRAMS OF THREE POPULAR METHODS OF BREWING COFFEE

during their war campaigns. It was carried in a form that resembled a billiard ball and consisted of a mixture of pulverized coffee and fat. Nowadays, such a use of coffee is frowned upon, for civilized peoples no longer consider coffee as a food but rather as a refreshment whose qualities of delicate aroma and flavor are best appreciated when the bean is prepared in the form of a beverage. (7)

New ways and means for carrying out the brewing process have been found and developed constantly since the discovery of the beverage. These methods were based on the flavor and aroma desired rather than on an established formula, hence, the acceptance of the method was dependent upon the individual involved. Some of the devices employed produce a brew of extremely bitter qualities, others a beverage more easily consumed with the aid of a spoon due to the syrupy consistency. (8)

In the United States, the contrivances in popular use are based on three different principles; percolation, drip, and vacuum. All of these have been commercially successful during the past thirty years.

The first method to achieve popularity was that of percolation (Fig. 2-a). The coffee grounds are placed in the perforated metal basket which is suspended on a metal tube standing on the base of the coffee pot. On boiling, the water in the pot bubbles up through the tube, reaches the upper end and flows down onto the coffee grounds. The water seeps through the grounds, collecting the coffee oils and carrying them below to the pot.

As this percolating action continues, more and more of the coffee oils are extracted. Because of this, the strength of the brew can be determined by the length of percolation.

The second method in most common use today is the drip method (Fig. 2-b). In this arrangement the water is initially brought to a boil in some other container. The coffee grounds are held in a perforated metal pan which is fitted over the receiving utensil. The boiling water is then poured over the grounds. It seeps through the coffee, picking up essential oils and carrying them to the lower pot. The strength of the brew is a function of the speed at which the water filters into the pot, and therefore dependent on the number and size of the holes in the filter. For this reason, it is difficult to vary the strength of brew produced by any one pot.

The third type of coffee maker most widely used today is that based on the vacuum principle (Fig. 2-c). The proper amount of water is placed in the lower bowl and brought to a boil. The upper bowl, containing the coffee grounds, is then placed on the lower and the two sealed by means of a rubber gasket or a precision glass fit. As boiling continues, the water is forced up the stem of the upper bowl by steam pressure and vigorously mixed with the coffee grounds. The heat is removed, and, as the pressure is reduced in the lower bowl, the coffee is forced through the filter and down the stem by the atmosphere. The used coffee grounds are retained in the upper bowl by a filter of either glass, ceramic, or cloth. The time of infusion can be varied on this device and is determined by the point at which the source of heat is removed from the lower bowl.

Though these examples describe only three of the many ways available to brew coffee, they serve to illustrate the complexity of arrangement that may be required to carry out the brewing process.

THE BASIC PRINCIPLE

The basis of the brewing process is the release of aroma and flavor bearing oils from the coffee grounds. Only a limited amount of these oils may be released in order to obtain coffee of a quality preferred by any one individual. During infusion, a definite order exists in which the oils are released; first bitter ones, then sweet ones, and then again bitter ones. If the infusion time allows the release of all the sweet oils, the resulting brew will be acceptable. However, if an insufficient amount of sweet oils is present or additional bitter oils are released beyond the amount initially extracted, the brew will have a bitter flavor. (9)

The quality of the coffee produced is not dependent on how complicated a method is used to carry out the infusion, rather, it depends upon how well the unit under consideration adheres to certain prescribed factors that will be discussed in the following section. As long as these factors are complied with, and providing the original coffee was freshly ground and roasted and that the resulting brew was freshly prepared, the beverage will be acceptable.

FACTORS TO BE CONSIDERED IN BREWING

The ideal brewing process might be defined as a procedure whereby a prescribed amount of water at a temperature of 200 degrees F. to 210 degrees F. is brought into intimate contact with a pound of coffee for a period of seven minutes and then separated from the coffee grounds and maintained at a temperature of not less than 165 degrees F. for a period of time not exceeding one hour. (10) This definition cannot prescribe the exact amount of water as it varies considerably throughout the United States.

To insure a prescribed quality of coffee, accurate control of the brewing process is essential. Dr. Prescott* states the Situation thus:

> "Since beverage coffee is an infusion it follows that the composition of the liquid after infusion will depend upon the amount of the various soluble constituents which are removed by the water treatment, and therefore directly related to the duration of the infusion, the temperature employed, the concentration of relative amounts of ground coffee and water used, the solubility of the various constituents in the ground coffee, and to the character of the materials and apparatus used. Coffee brewing, therefore, is a complex chemical reaction rather than a mechanical process of mixing or compounding inert ingredients." (11)

The factors may be outlined as follows:**

(1). The coffee itself-its freshness, degree of roast, and fineness of grind.

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*Dr. S. C. Prescott, Dean of Science, Head of the Department of Biology and Public Health, Massachusetts Institute of Technology Boston, Massachusetts.

(2). The character of the water.

(3). The temperature of the water.

(4). The character of the container used in infusing.

(5). The infusion time.

(6). The strength of the infusion.

(7). The effect of the addition of other substances. (12)

The coffee itself-its freshness, degree of roast, and fineness of grind is the responsibility of the owner of the coffee making equipment. His choice of brand is determined by his customers preference and what he can afford. Its freshness depends on how frequently he can receive shipments and how well he is able to schedule its use. Custom grinding for each batch of coffee brewed is an excellent means of insuring a maximum amount of aroma and flavor in the cup and will provide an added impetus to sales.

Just as there is a noticable difference in the taste of hard and soft waters, so there is also a difference in the flavor of the coffee brewed with waters of either high or low alkalinity. The recommended type of water is that with a low alkaline content as it more easily dissolves the coffee oils and adds no alkaline flavor to the brew as would hard water. The freshness of the water is important as stale water would produce a flat and brackish element in the coffee flavor. Likewise, water that has been preheated in a central boiler is likely to impart

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**See Appendix (2), Results of Studies by Dr. S. C. Prescott.

an undesirable taste to the brew.

Though there is some variation in the temperature of the water to be used, it is now quite generally accepted that the water, when put in contact with the coffee, should be boiling and held between 200 degrees F. and the boiling point during the infusion. In this temperature range, the proper amount of oils is released.

Any highly reactive metal will affect the flavor of the coffee, and the result will be an undesirable bitterness. Partial cause of this is that some metals form compounds with caffeine and other coffee constituents. The metals most likely to affect the flavor are tin-plate, aluminum, copper, and silver. (13) Those least affecting the flavor are stainless steel, monel metal, and nickel. (14) In regard to the use of stainless steel, the National Coffee Association states that the use of type 304 18-8 has been accepted by them, however, care must be used in fabrication so that no pure iron accumulates on the surface of the stainless steel. (15) Materials other than metal that are recommended for use in parts which come in contact with the coffee are glass, porcelain, stoneware, agate, and vitrified enamel (absolutely free from pin-holes).

The infusion time or period of contact of water and coffee grounds varies considerably in the opinions of coffee experts and restaurant operators. One expert says that the time of infusion should be brief. In general it should not exceed two minutes at the proper temperature. (16) One minute is even better, as long infusion, even at the lower temperatures, increases the bitter taste and decreases the flavor and aroma. A chain of coffee shops on the West Coast uses a seven minute period as a standard infusion time. (17) This variation exists because of the physical requirements of different coffee making devices. In some, the grounds are continuously agitated during the infusion period, thereby increasing the rate at which the oils are released and shortening the length of time needed to extract the standard amount. The time will also be shortened if, after the infusion, the brew is separated from the grounds by filtering it through the grounds; this is the case in a drip-pot or a vacuum unit. However, if the coffee brew is poured off of the grounds instead of through them, the time of infusion must be longer; this is the case in an ordinary ceramic coffee pot.

The strength of the infusion or the relative amounts of coffee and water used is the point left as a variable in the coffee brewing process. As stated, the variety of individual tastes prevents the establishment of a set ratio. A recent survey by the Joint Committee of the Restaurant and Coffee Industries shows that this ratio ranges from less than two gallons per pound or approximately 40 cups, to as high as four gallons per pound or approximately 80 cups. (18) The data they present indicates that 39% of the operators surveyed used two and one half gallons of water per pound of coffee, and the majority, or 76%, made coffee weaker than the two and one half gallon minimum ratio recommended by the National Coffee

Association.*

The effect of other substances, while not directly concerning the brewing procedure, should be mentioned. It has been found that the popularity of adding cream and sugar to coffee has occurred as the result of the distasteful flavor of most coffee sold commercially and the desire of the drinker to make the beverage palatable. As a result, it has become common practice to provide these substances along with the coffee if the consumer desires them. Even in the case of properly brewed coffee, a person in the practice of using cream and sugar will do so as he has learned to accept that as the proper method to prepare the beverage, and finds it more appetizing so prepared. However, the consumer who has learned to appreciate the value of the aroma and flavor of well brewed coffee finds no consolation in the addition of other substances and will patronize the establishment where the coffee is properly prepared.

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*See Appendix (3), for chart of Coffee-Water Ratios used in the United States.

MARKET STUDY

DISTRIBUTION, ADVERTISING AND SALES

Commercial coffee making equipment is distributed through two channels; directly from the manufacturer to the consumer and indirectly through a jobber. The channel that is used by a particular manufacturer depends upon the type of equipment he produces, the area his sales territory includes and the size classification of the consumer.

Direct distribution is generally used by a large manufacturer when he is supplying a group such as a nation-wide drug store or restaurant chain. A local market is also supplied directly in the case of many small manufacturers who have a limited sales territory.

The jobber or hotel and restaurant supply house functions in two ways; as the distributor of products of both the large and the small manufacturer, and as an aid to his customers in the selection of mass-produced equipment and the design and manufacture of custom-built units such as counters, sinks, and cabinetry. The latter are constructed either by the supply house in its own facilities or supplied by a local affiliated fixture concern.

The coffee supplier and his relation to the distribution should also be noted. As a part of his service, he often provides the necessary coffee making equipment. The cost of this service is

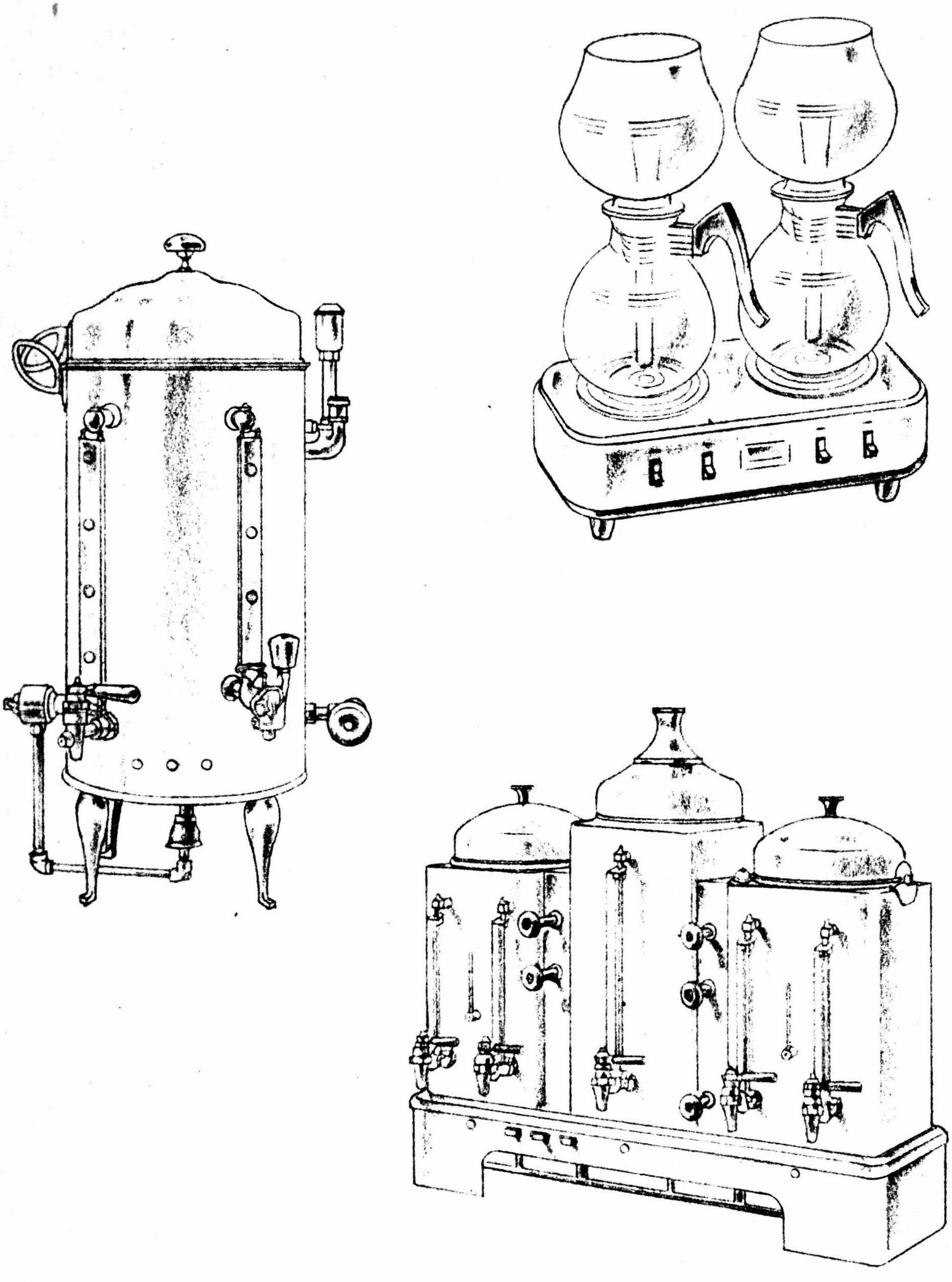

FIGURE 3 TYPICAL COMPETITION

either handled on a monthly basis or charged to sales promotion and advertising.

The most important source of direct consumer contact is through articles and advertisements placed in trade magazines sponsored by restaurant associations, institutional groups, and food processing organizations. Direct mail brochures and pamphlets are another way that is used to create consumer interest. The jobber and the coffee salesman are probably the most influential contact as the consumer depends upon these people for advice concerning their equipment purchases.

The sales possibilities of commercial coffee making equipment will depend upon; its adaptability or its compliance with the needs of the ultimate consumer, the means and degree of advertising used to promote the product, and the customers' satisfaction with the operation and maintenance of the product. Only through cooperation among the manufacturer, the jobber, the coffee supplier, and the restaurant and drug store chains can these requirements be attained.

STUDY OF COMPETITION

In order to determine the features and trends in design of competitive coffee making equipment now on the market, letters of inquiry were addressed to thirty-eight manufacturers* of restau-

*See Appendix (4), List of Manufacturers of Competitive Coffee Making Equipment Studied.

rant equipment and electrical appliances asking for information regarding their products. The literature received indicated that eight produced equipment of the urn-type, three produced vacuum-glass apparatus for commercial use, one manufactured equipment in both of these categories, two produced equipment for large industrial use only, ten manufactured coffee makers for the household only, and the remaining fourteen either did not manufacture coffee making equipment or failed to reply.

To simplify discussion, the following analysis is divided into three sections; urn-type coffee makers, vacuum-glass type coffee makers and a section dealing with special units considered to be outside the range of either of these two groups.

The urn-type of commercial coffee making equipment is probably the one in greatest use by the restaurant industry. This is true because it was the first commercial type to be produced in the country and is available in a great number of models depending upon the capacity, the heat source, materials and filtering means. The principle of operation is similar to that employed in household drip coffee makers only that the equipment is of greater capacity and the heat sources, containers, filters, etc. are altered accordingly.

The operation procedure for the lower priced units is time consuming and often dangerous.* However, on the larger and more

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*See Appendix (5), Procedure for Operating and Cleaning an Urn-Type Coffee Maker.

expensive units, such attachments as thermometers on the water jacket and boiler, thermostatically controlled heating systems that automatically maintain the proper water temperature in the water jacket and boiler, syphoning systems that spray the water over the coffee grounds by boiler pressure, safety release valves and pressure regulators on the boiler, reduce these disadvantages.

Cleaning problems, outside of those connected with the components which come in direct contact with the coffee, are those caused by scaling in the water jacket surrounding the urn liners. The speed of scale formation varies directly with the alkalinity of the water and the frequency of use, but in any case it will eventually form and reduce the efficiency of the unit. Removal often requires that the coffee maker be dismantled or that openings be provided in the jacket for access to the interior.

Fabrication is generally limited to low production techniques in order to keep tooling expense at a minimum. Such operations as bending, shearing, and punching are commonly used. Drawings are frequently found on apparatus of higher production. Complicated castings for spigots, molded plastic parts and other hardware are supplied by specialists in these fields. Urn covers and filter holders are usually spinnings, and urn-liners are deep drawn parts. Assembly is accomplished by arc welding or soldering, and in some cases, seam and spot welding and seaming are employed.

Materials used for the various components differ with each manufacturer and often a choice of materials is offered on any particular model. The large majority of the equipment is finished in stainless steel though a few manufacturers offer finishes in a number of colors of baked porcelain enamel. A producer of small units also offers a choice of aluminum or vitrified china enclosures. Fixtures and hardware such as spigots, handles, legs, and cover hinges are chromium plated cast brass. Urn liners are available in stainless steel, glass, stoneware, or china. Tubing is stainless steel, and in one case lined with glass tubing to prevent a coffee and metal contact.

Heat sources are either electrical, gas, or steam, depending on the buyer's preference. The electrical heating element is the most popular as it is cleaner and more efficient.

Three types of filters are in common use; the muslin cloth filter, the paper filter, and the all metal filter. The cloth filter requires soaking in water when not in use and frequent replacement, but it does the best filtering job of the three types. The paper filter is disposable after use, but necessitates a perforated metal sheet for support that must be washed between batches of coffee. The all metal filter of perforated stainless steel can be used permanently and is simple to clean.

Attachments such as water gauges, spigots, valves, thermostats, and thermometers are mounted on the exterior of the cabinets and cause difficult cleaning problems.

Capacities of urn-type coffee makers range from one gallon to twenty gallon combination units, and greater capacities up to 150 gallons are provided in the large industrial units.

Equipment is available in the form of single coffee urns, twin urns, twin urns with boiler combinations (three piece battery), and single urn and boiler combinations (two piece battery). All of these are manufactured in a variety of sizes and with optional attachments.

The overall dimensions of the equipment vary with the capacity. None are greater in depth than the standard counter depth of 27 inches. The counter length covered varies from 20 inches on the small capacity single urn to 64 inches on the large capacity three piece batteries. The tops of some urns are as much as 50 inches above the counter level or a total of 7 feet, 2 inches above floor level.

The vacuum-glass type of coffee maker was introduced during the early 1930's. It is better suited for small establishments than the urn-type, as coffee may be brewed in the small amounts of six to twelve cups at a time. The principle of operation is the same as that of the household vacuum type coffee maker, but the capacity is increased by larger bowls and the provision for brewing in a number of bowls simultaneously.*

Fabrication processes used in the manufacture of the vacuum-

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*See Appendix (6), Procedure for Operating and Cleaning a Vacuum-Glass Type Coffee Maker.

glass type of coffee maker are more diversified than those employed in the urn-type because of larger production. The manufacturers of this equipment are also in the household appliance field and therefore can afford to use deep drawn and die cast parts. Bowls are usually blown in heat resistant glass though some are spun or deep drawn in stainless steel. Pouring handles, bowl covers, and control knobs are of molded plastic. The stands are either chrome plated sheet steel, stainless steel or aluminum.

A choice of either gas or electric heating units is provided on most models. The units are designed to provide two heats, one for boiling water and another to maintain the brew at the proper serving temperature.

Three types of filters are available; all glass, cloth with a metal support, and cloth with a ceramic support. The all glass type provides good filtering along with permanence and ease of cleaning.

Capacities of the vacuum-glass type coffee makers range from single heater stands up to units with provision for brewing coffee in three bowls at one time.

One manufacturer offers a boiler and stand combination that provides a continuous supply of hot water to speed up service.

Special Units:

Two of the units in this group are similar in appearance to a standard single urn coffee maker. Instead of a single urn liner, two semi-circular liners are provided so that one liner may be filled with fresh coffee while the other is used for serving. The same filter feeds both of these urn liners. Operation is simplified and all that is required for brewing is placing the coffee in the filter, turning a valve and removing the used grounds. This guards against the chance of using the incorrect amount of water. The filter pan of one of these units is accessible from the side of the cabinet, a feature that makes the unit easier to operate and clean.

Another type is similar in appearance to the twin combination urn. Sales literature indicated that any amount up to three gallons could be brewed at one time simply by setting a dial to the desired quantity and pressing a starter button. Water supply, time of infusion, and the temperature of the final beverage are controlled automatically.

A fourth unit is produced by a manufacturer of the vacuum-glass type coffee making equipment. Both its appearance and principle of operation are unique in the field. A stand holding five electrical heating units houses a boiler that provides a constant supply of hot water. A short pylon mounted at the back of the stand holds a small container of hemispherical shape. This container is filled with coffee and covered with a filter cloth. An empty glass bowl is placed on the stand directly beneath the coffee container and a control lever pushed. Water then flows up the pylon, through the coffee grounds and filter cloth and into the bowl. When the bowl is filled, its increased weight trips the control lever and the water flow is stopped. The capacity of the unit is 240 cups per hour, brewed in batches of twelve cups.

CONSUMER REQUIREMENTS

The ultimate consumers of the commercial coffee maker are the owners, operators, or managers of the more than 540,000 commercial and industrial restaurants, cafeteria, lunchrooms, lunch counters, and refreshment stands in the United States. (19) These consumers are doing a $7½ billion business a year and serving 60 million meals per day. (20) They are planning to spend between $142 million and $200 million on replacing inadequate equipment and improving facilities. (21) Because of the high cost of labor, the larger operators are willing to spend as much as $10,000 for a single piece of equipment if it will eliminate the services of one employee. (22) The fact that coffee brewing apparatus is among the first three items that are desired indicated a large market for a unit with the unique features and improvements of this design.*

To obtain information on the desires of the prospective consumer and his criticism of present equipment, two sources of information were investigated; (1) The consumer himself, through personal interviews with the representatives of a drug store chain, a drive-in chain, an industrial cafeteria, a hotel a coffee house chain and various private restaurants;**

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*See Appendix (7), Market Estimate
**See Appendix (8), Personal Interview List

(2) National surveys conducted by restaurant and coffee associations.*

The problem confronting the consumer is that of satisfying his clientele with quality food at low prices and at the same time keeping his costs of operation at a minimum. The latter can be achieved through reduction of labor time, maintaining a large volume, and cutting service and repair costs.

The cost of labor is important in both the brewing of the coffee and in caring for the equipment. In respect to brewing, the owner has two alternatives; one is to hire expensive, dependable help to operate the coffee maker and insure satisfactory coffee, the other is to rely on the bus boy or waitress to tend to the coffee maker in their spare time and risk the danger of serving unsuitable coffee. The first alternative would keep his customers happy but be too expensive for the average restaurateur; the second, which the majority of owners are forced to follow today, would cause dissatisfaction among his clientele though he would save on labor expense. As a compromise, an automatic unit seemed to be the solution. If a few time consuming tasks such as checking water levels, controlling temperatures, and disposing of grounds were controlled by mechanical means, the operator's time would be reduced and the coffee would still be of the highest quality.

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*See Appendix (9), Surveys and Associations Referred To

Cleaning the coffee apparatus is another time consuming job that is a necessity to insure a satisfactory beverage. A typical urn type of coffee maker requires about one half hour to clean, including washing out the urn liners, pipes, spigots, water gauges, filters, and filter holders. Assuming all such components to be essential for brewing, the only way to shorten the length of time needed for cleaning would be by designing them to be more accessible. It is impossible to reach the bottoms of the urns on many units which are located at a standard 36 inch counter height and requires the use of a chair or ladder to inspect the interior and insure its cleanliness. Some spigots are very difficult to disassemble for cleaning and must be removed to gain access to the pipe leading from the urn liner. One spigot design has a knurled knob which, when removed, provides an opening through which a small brush is inserted to clean the tube. However, even this design has a discrepancy in that the knob tends to leak and must be tightened to a point that makes it impossible to remove the knob by hand. Gauge glasses must be scrubbed to eliminate the chance of coffee oil accumulating on the inside wall. Another common dirt catcher that is difficult to clean is the cabinet space below the urn. Coffee is often spilled when pouring at the spigot, and some of this coffee will drain beneath the unit where it lodges on pipes and electrical connections. The exterior cleanliness of the cabinet is vital as it is a direct indication to the customer of the sanitary state of the establishment. The stainless steel shell now so frequently used for cabinet construction is excellent for ease of cleaning. However, dirt catchers such as thermometers, pressure regulators, spigots, and other controls along with "decorative" trim greatly increase the time required to maintain the exterior cleanliness of the cabinet. In glass-vacuum apparatus, cleaning problems occur with narrow necked bowls, complicated cloth filter holders, and openings in the heating elements of gas heated equipment.

Safety in operation is very important to the owner as any injury to an employee while on duty is the employer's responsibility. The cost of unsafe equipment was recently shown when an employee of one of the country's largest drug chains was scalded while repouring coffee, and sued the concern for $7,000 worth of damages. (23) Possible danger points connected with present apparatus are; spilling the brew while serving, lifting boiling water above eye level in repouring, standing on a chair or ladder in order to clean the coffee maker, and coming in contact with hot surfaces of the cabinet while either operating or cleaning the apparatus.

Servicing of the equipment is another costly item for the restaurateur. This cost is the sum of the labor and materials that constitute the repair work plus the inconvenience caused during the time that the apparatus is out of service. Such trouble could be reduced and in some cases eliminated by keeping the components of the unit as simple in construction as possible and by providing convenient access to those parts likely to cause trouble. The problem of scale formation in both the water jacket and the boiler is typical of such servicing.

The capacity requirements vary widely as shown by the survey of competitive units. If the establishment is a lunchroom with a 20-person capacity or a 31-place restaurant, a single vacuum type coffee maker is used. (24) If the restaurant seats 77, a single combination urn is sufficient. (25) A cafeteria serving 156 people at once requires a two urn combination unit. (26) In any case, a desire exists for a flexibility of the amount of coffee that can be brewed at one time in order to schedule for the high and low demand periods during the day without having to run short at one time and wasting an excess at another. After further study it was concluded that the capacity of this design could not be such that it would please all possible consumers, and that to successfully market such a product it would be necessary to include it in a line of coffee makers of various capacities. Some general points were decided upon regarding the size. Since the unit would be designed to substantially reduce labor and upkeep costs, it would be purchased for establishments where such costs are an important factor, the chain drug store or the average restaurant, and not the small refreshment stand or lunch counter. Today the average drug store or restaurant uses a ten gallon combination urn. A large high speed cafeteria line serves up to 12 cups of coffee per minute or approximately 10 gallons per hour. (27) If two units were used for such a demand, they would each need to supply 360 cups of coffee per hour. Present equipment in the price range of

$400 have capacities ranging from 250 to 300 cups per hour, and one of the country's largest manufacturers of the vacuum-glass type of coffee making apparatus is now engaged in the development of an automatic machine that will produce 350 cups per hour. In view of these facts, the capacity of this design was placed at approximately 350 cups per hour.

The quality of the coffee, the perfection of which is the prime function of the coffee maker, is of great concern to the operator. To serve coffee of consistent flavor and aroma is his goal. In present units this depends on the "human element", often an uncertain factor. Besides using freshly ground coffee and clear cold water, the amount of coffee and water, the temperature of the beverage must be carefully regulated to insure customer satisfaction. As stated by one restaurant operator, the coffee maker should be as fool proof and as free from the possibility of human failure as possible. (28)

Costs of operation, including the price of ingredients and power requirements of the units could be substantially reduced by the use of insulating materials and standardized thermostatic controls.

The initial cost that the owner is willing to pay for the equipment is variable, and depends upon which best suits his needs. The average restaurant operator desires to purchase equipment as cheaply as possible, but many of them consider the long-range depreciation (generally a period of from 5 to 10 years) and ultimate replacement in calculating original costs. (29)

The room provided in today's eating places for coffee making apparatus of the capacity of this design is not less than 27 inches deep and 42 inches in length. (30) The figure for depth includes space between the unit and the wall and additional room on the front of the counter for drip pans and serving.

Fine appearance of the coffee making equipment is essential as it aids in selling the unit to the ultimate user and is appealing to his clientele. Operators find that a cabinet of stainless steel is simple to maintain and denotes a well kept establishment to his customers. Such a finish is in harmony with adjoining equipment and, because of its neutral tone, not likely to clash with the color scheme of the restaurant interior. Additional emphasis on the coffee maker as an attraction to clientele could be obtained by the use of a warm color on some part of the unit to indicate the richness of the beverage, or lettering on the cabinet signifying the freshness of the coffee. Applied decoration such as flutes, angular corners, escutcheons, and chrome stripping only add a note of cheapness to the product and make cleaning more difficult.

LEGAL CODES

The following codes were referred to during the course of the design in compliance with many state and local ordinances:

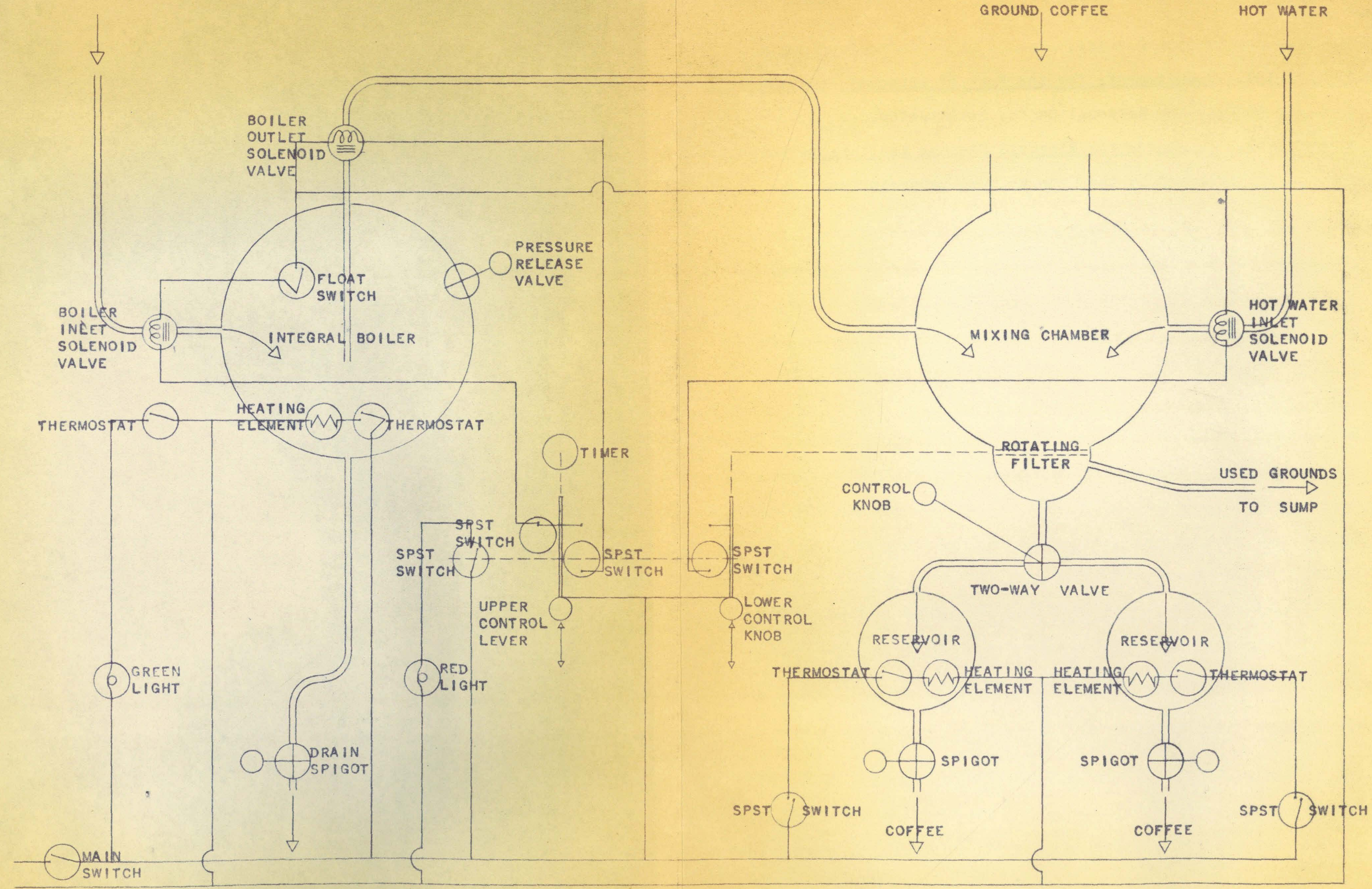
(1). Boiler Construction Code, Section VIII, published by the American Society of Mechanical Engineers.

(2). Ordinance and Code Regulating Eating and Drinking Places, published by the United States Public

Health Service.

(3). <u>Requirements for the Seal of Approval</u>, published by the National Coffee Association.

(4). <u>Standards for Electric Heating Appliances</u>, published by the Underwriters Laboratories.



TUBING	WIRING	MECHANICAL LINKAGE

FIGURE 4

OPERATION DIAGRAM

DESIGN

PROCEDURE

On the basis of previous research, the following criteria were established as the goals of the design:

(1). Adherence to the basic factors of the brewing process.

(2). Simplification of the operation procedure.

(3). Reduction of cleaning and maintenance requirements.

(4). Increased safety of operation.

(5). An appearance with more sales appeal directed at the ultimate consumer and his clientele.

The initial step was to analyze the brewing process and determine the apparatus required. Subsequently, this apparatus was reduced to its simplest form and the components studied with respect to the above criteria. Finally, these components were integrated to produce the final design.

THE COMPONENTS AND THE METHOD OF OPERATION

The components of the design and the controls employed for operation are illustrated schematically in Figure 4. Fundamentally, the process is one of bringing the coffee grounds into intimate contact with hot water from the integral boiler, then separating the two and storing the resulting coffee brew in the reservoirs and depositing the used grounds in a sump.

Before the unit is put into operation at the beginning of the day, all of the manually operated valves are open, the three solenoid valves are normally closed and the boiler is empty. Hence, the first step in preparing the unit for use is to close the drain spigot on the boiler and the serving spigots on the reservoirs.

Next, the main switch is closed. The boiler inlet valve opens and water enters under line pressure to the level of the float switch. At this level, the circuit to the inlet valve is broken by the action of the float switch and the flow ceases. The pressure in the boiler is reduced to five pounds per square inch gage by the pressure release valve. The immersion heating unit is also turned on when the main switch is closed. A thermostat limits the temperature to 212 degrees Fahrenheit, and when this temperature is attained, the green indicator light on the control panel is illuminated. This light signifies that the correct conditions for brewing have been reached in the boiler.

The filter is placed in the base of the mixing chamber and one pound of ground coffee distributed over it.

The brewing cycle begins when the upper control knob is pulled forward. This action breaks the circuit to the boiler inlet solenoid valve and closes the circuit to the boiler outlet solenoid valve. The water is then transferred through the outlet tube to the mixing chamber by the boiler pressure. It is evenly distributed over the coffee grounds by means of a spray ring around the periphery of the chamber. The amount of water transferred is determined by the depth to which the outlet tube penetrates the boiler and may be varied by changing the length of this tube. A red indicator light that is mechanically linked to the control knob is also illuminated at the beginning of the brewing cycle.

When the boiler water has dropped below the outlet tube entrance, the flow to the mixing chamber ceases. The spring loaded control knob is then released by the action of a mechanical timer which was set in motion when the control knob was pulled forward. The movement of the control breaks the circuit to the boiler outlet valve and closes the circuit to the boiler inlet valve. The boiler fills in the same manner as previously described.

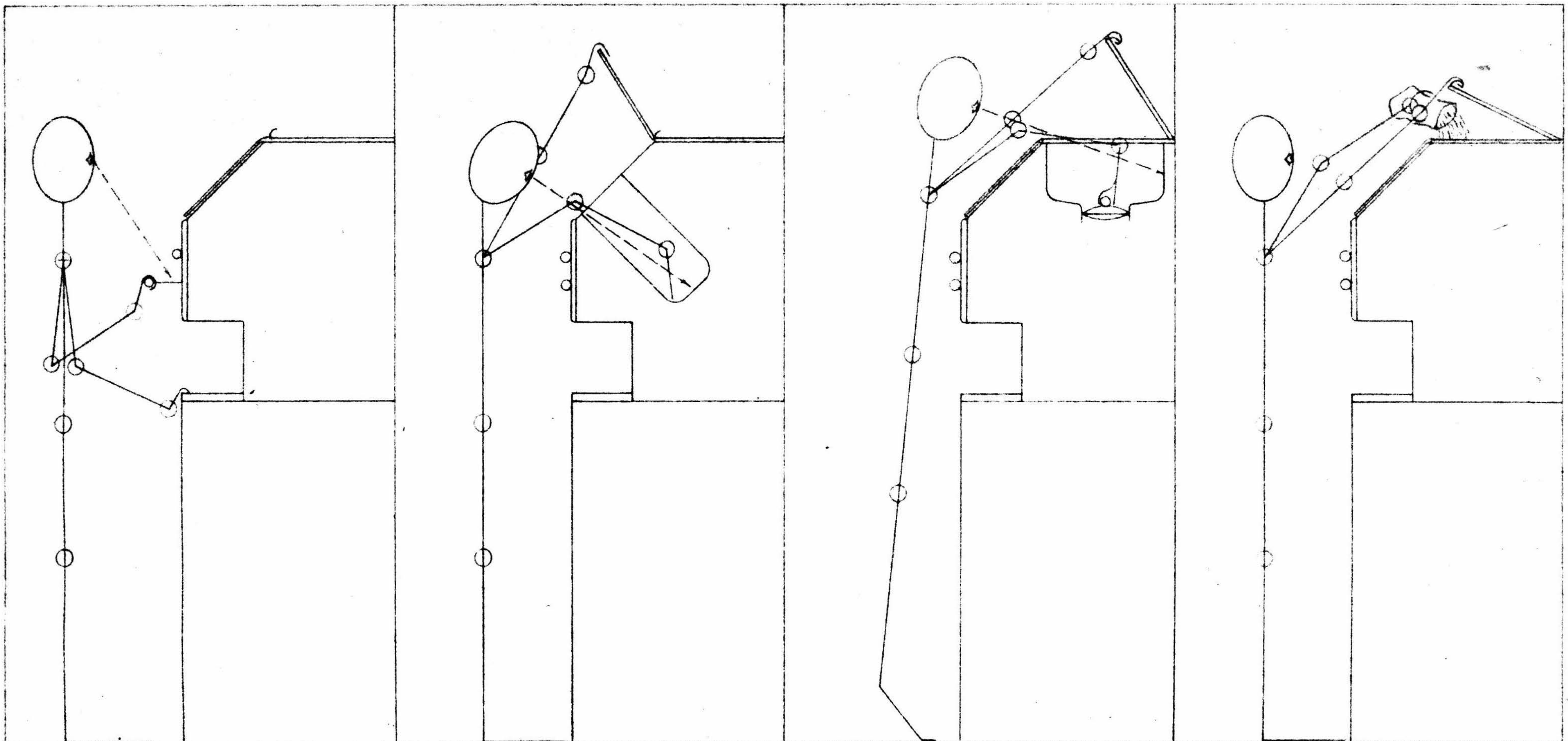
The water that filters through the coffee grounds collects beneath the filter and flows to one of the two reservoirs. This flow is controlled by a two-way valve operated by a knob on the cabinet front. An arrow on the knob points to the reservoir to which the coffee is directed. The reservoir heating element is energized by a switch on the control panel. This element is controlled by a thermostat that maintains the temperature of the coffee at a minimum of 165 degrees Fahrenheit. When the reservoir has filled to an indicated level, the infusion is completed.

At this time, the second control knob is pulled forward. This knob is mechanically linked to the filtering mechanism in such a way that the filter is rotated through ninety degrees to a vertical position. When the knob reaches the end of its travel, it actuates a switch that closes the circuit to the valve on the line from the central hot water supply. This action allows hot water under line pressure to enter the mixing chamber through the spray ring. The water washes the remaining grounds out through the bottom of the chamber to either a sump or a storage bin beneath the coffee maker. The used grounds collect here and are removed at the end of the day. The water also cleans the walls of the mixing chamber and the filter in preparation for the next batch of coffee.

When the control knob is released, the hot water valve closes and the filter returns to the horizontal or brewing position. This action also switches off the red indicator light.

The operator commences with the preparation of another batch of coffee as soon as the green indicator light is again illuminated.

After use, the coffee maker is turned off by opening the main switch. The pressure release valve on the boiler is manually operated and the boiler emptied by opening the drain spigot. The mixing chamber and reservoirs are flushed out with fresh water. The filter and serving spigots are removed, disassembled and cleaned.



OPERATING CONTROL KNOB   WASHING RESERVOIR   REMOVING FILTER   POURING COFFEE GROUNDS

A. THE COFFEE MAKER IS LOCATED AT A HEIGHT OF THREE FEET.
B. THE DIMENSIONS OF THE FIGURES APPLY TO THE AVERAGE FEMALE: STATURE IS FIVE FEET, SIX INCHES.

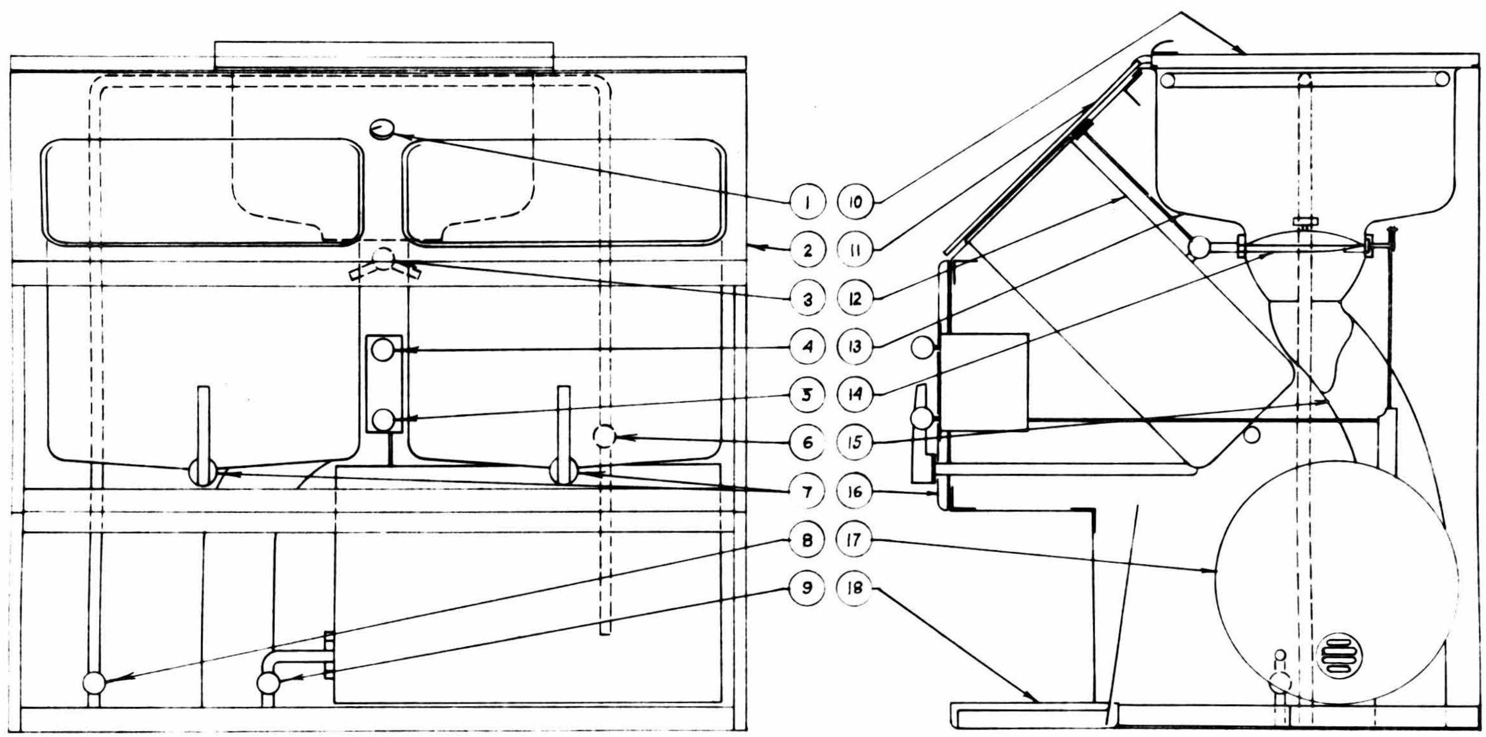
FIGURE 5 DIAGRAMS ILLUSTRATING ACCESS TO THE COMPONENTS OF THE COFFEE MAKER

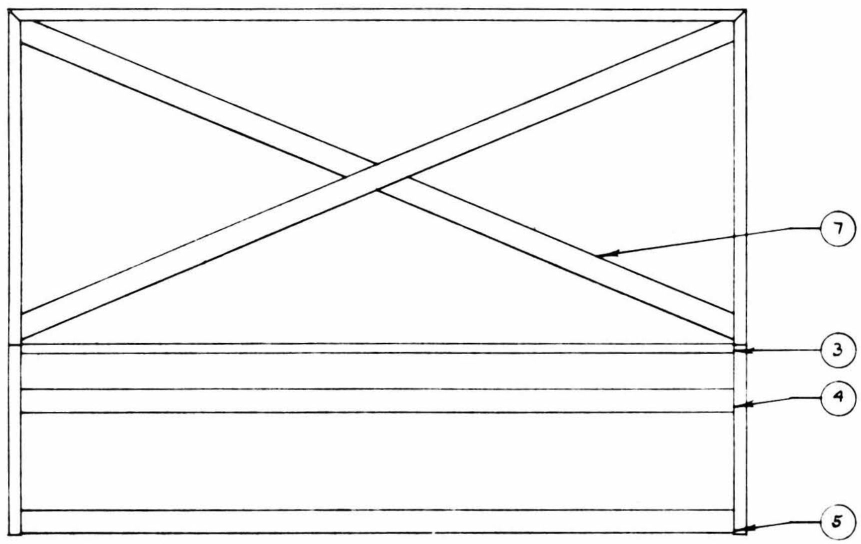
FRONT AND SIDE ELEVATIONS OF THE CABINET SHOWING THE LOCATION OF THE INTERIOR COMPONENTS

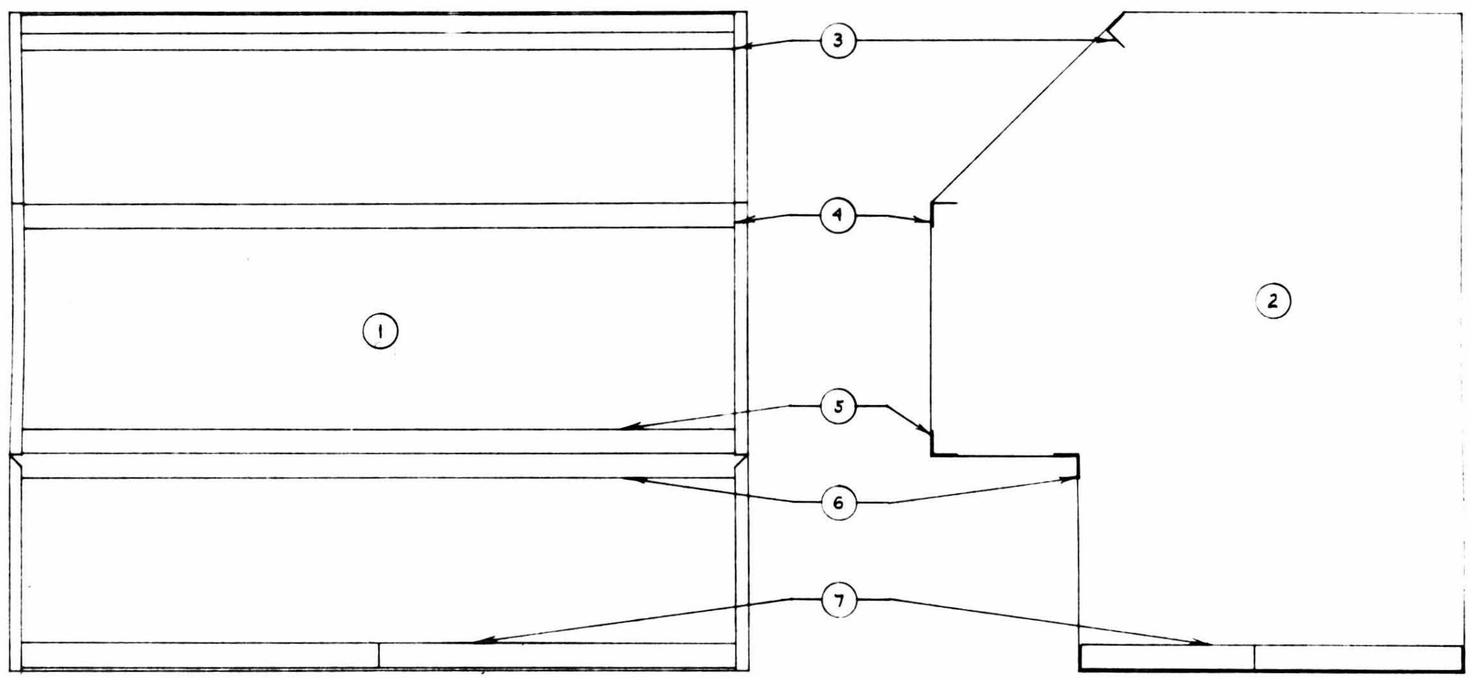
1	KNOB FOR CONTROLLING COFFEE FLOW
2	SUPPORT SHEET FOR RESERVOIRS
3	COFFEE DIRECTION VALVE
4	KNOB FOR CONTROLLING BREWING
5	KNOB FOR CONTROLLING WASH-OUT
6	BOILER OUTLET VALVE
7	SERVING SPIGOTS
8	INLET VALVE - CENTRAL HOT WATER SUP.
9	BOILER INLET VALVE

10	MIXING CHAMBER LID
11	GLASS PANEL COVERING RESERVOIRS
12	RESERVOIRS
13	MIXING CHAMBER
14	FILTER MECHANISM
15	DRAIN PIPE FOR USED GROUNDS
16	CONTROL PANEL
17	BOILER
18	DRIP PAN ASSEMBLY

FIG. 6







1	INSIDE BACK WALL OF WRAP-AROUND
2	INSIDE LEFT WALL OF WRAP-AROUND
3	UPPER TRANSVERSE "L" CHANNEL
4	UPPER FRONT TRANSVERSE "L" CHANNEL
5	LOWER FRONT TRANSVERSE "L" CHANNEL
6	LOWER TRANSVERSE "L" CHANNEL
7	DIAGONAL CHANNELS FORMING BASE

FRONT AND SIDE ELEVATIONS AND TOP VIEW OF THE CABINET BODY

FIG. 7

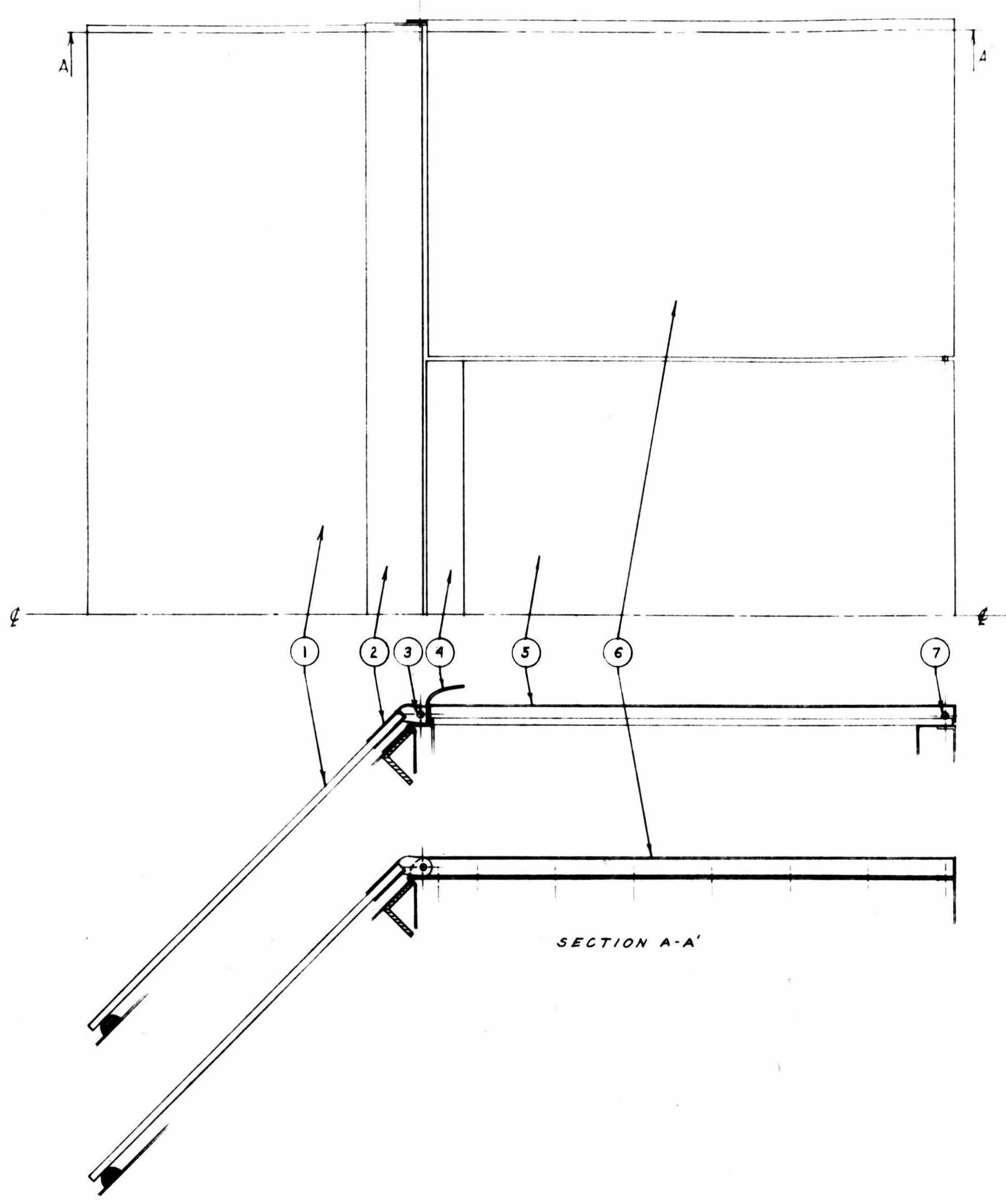


FIG. 8 TOP VIEW AND CROSS-SECTIONS OF THE TOP ASSEMBLY

7	HINGE PIN FOR MIXING CHAMBER LID
6	SIDE PANEL
5	MIXING CHAMBER LID
4	LIFT HANDLE
3	HINGE PIN FOR GLASS COVER
2	METAL SUPPORT FOR GLASS COVER
1	GLASS COVER

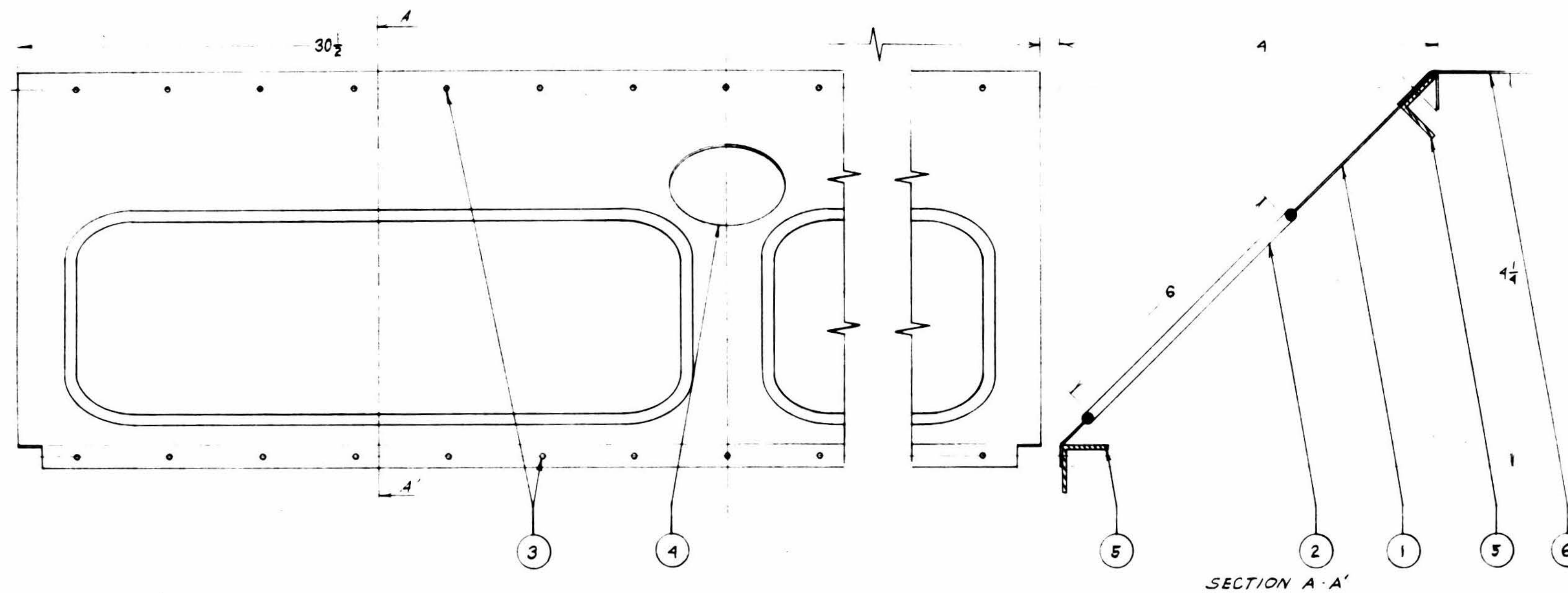
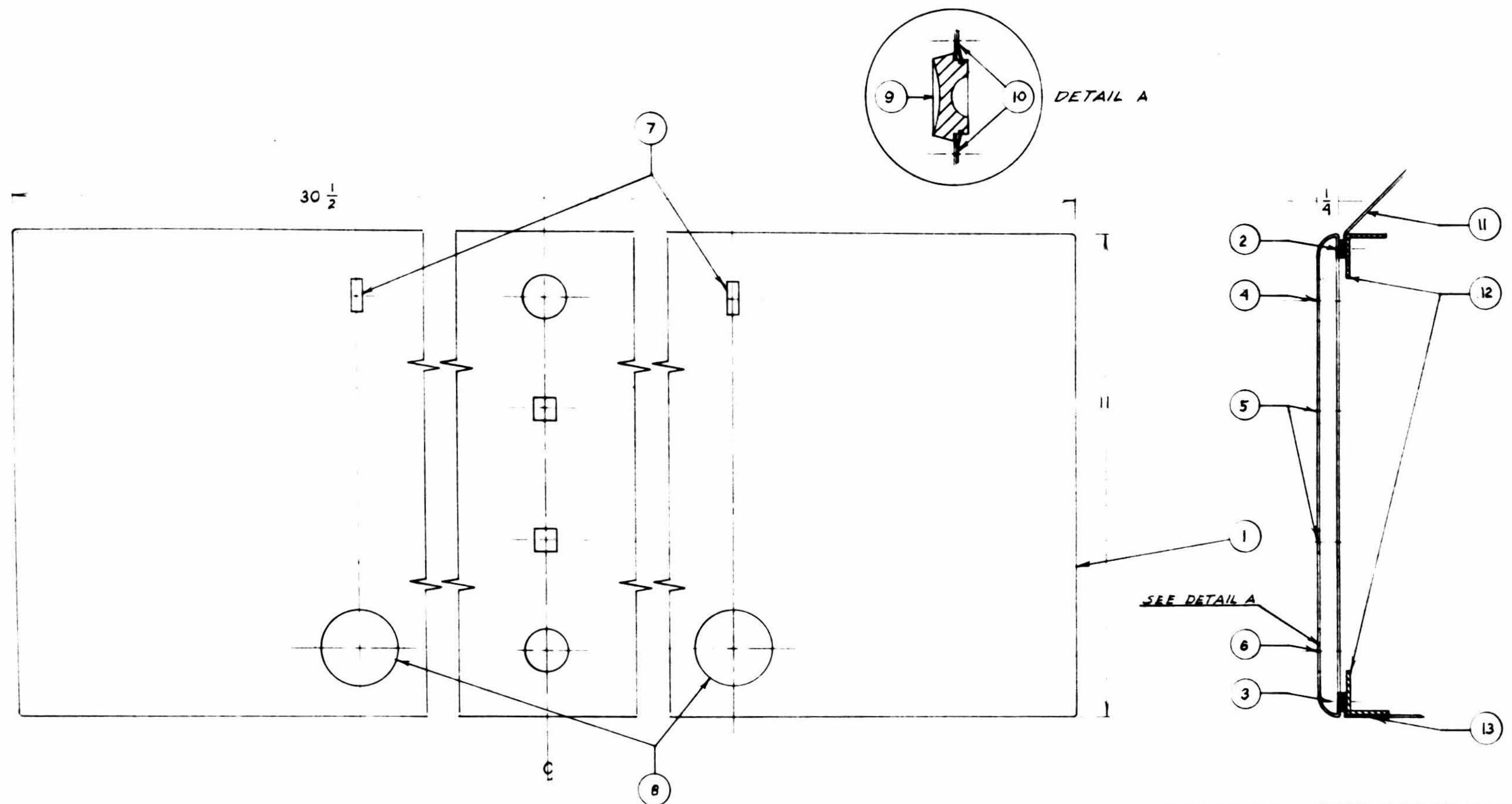


FIG. 9 FRONT AND SIDE ELEVATIONS OF SUPPORT SHEET FOR RESERVOIRS

6	SUPPORT FOR MIXING CHAMBER
5	UPPER TRANSVERSE CHANNEL
4	HOLE FOR CONTROL KNOB
3	SCREW HOLES
2	RUBBER STRIPPING
1	SUPPORT SHEET



13	FLANGE OF BODY WRAP-AROUND
12	UPPER FRONT TRANSVERSE CHANNEL
11	SUPPORT SHEET FOR RESERVOIRS
10	METAL CLIPS ATTACHED TO PANEL
9	GLASS LENS
8	PUNCHED FOR SPIGOTS
7	PUNCHED FOR SWITCHES
6	PUNCHED FOR INDICATOR LENSE (RED)
5	PUNCHED FOR CONTROL RODS
4	PUNCHED FOR INDICATOR LENSE (GREEN)
3	SCREW HOLES
2	RUBBER STRIP
1	FABRICATED PANEL

FIG. 10 FRONT ELEVATION AND CROSS-SECTION OF THE CONTROL PANEL

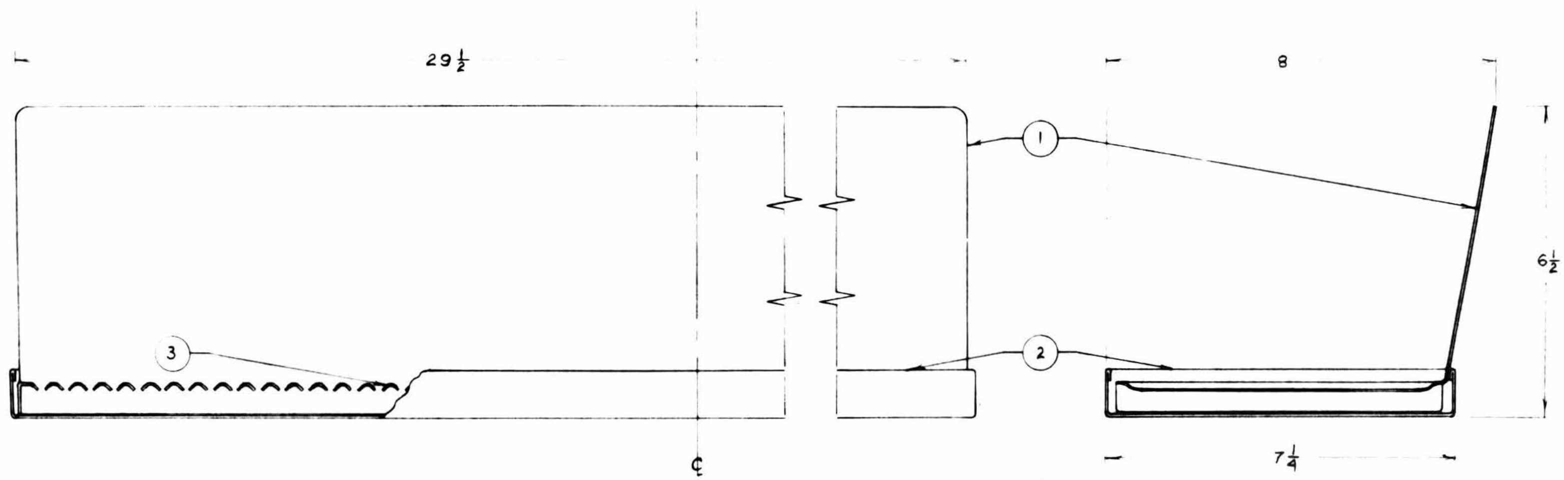
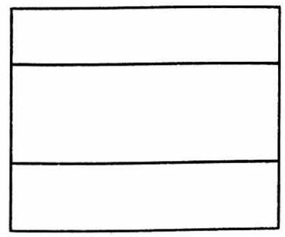


FIG. 11 FRONT ELEVATION AND CROSS-SECTION OF THE DRIP PAN ASSEMBLY

3	SLOTTED RACK
2	PAN
1	BACK PLATE

SPECIFICATIONS

The Cabinet



The basic shape of the cabinet was determined by the position of the elements it encloses and the access required to these elements (Fig. 5 & 6).

The body of the cabinet is made up of a wrap-around of stainless steel sheet that forms the back and the two sides (Fig. 7). This structure serves as both an enclosure and as a mounting for the interior components and the other cabinet panels. The wrap-around is flanged at all edges and is braced by four transverse channels and two channels that cross diagonally at the base. Before assembly, the wrap-around and channels are punched to accommodate fasteners.

The top and the front of the coffee maker are enclosed by four removable sections; the top assembly, the support sheet for the open ends of the reservoirs, the control panel, and the drip pan assembly.

The top assembly includes the lid that covers the mixing chamber, the glass panel that covers the reservoirs and two side panels that cover the remainder of the cabinet top (Fig. 8). These two panels are positioned on the cabinet top by lugs welded to their undersides. A synthetic rubber sealing strip runs along the front edge of these panels to keep water out of the cabinet. The mixing chamber lid is hinged from these two panels at the rear of the assembly. Another sealing strip is attached to the front and the sides of the lid, and the rear is open to allow escape of steam during the infusion. The glass lid covering the reservoirs is hinged from the front outside corners of the two side panels. The glass is mounted between two metal strips that are integral with the hinge. A rubber strip below the lower edge of the glass panel cushions the lid when it is closed and supports it above the open ends of the reservoirs to allow passage of air and prevent fogging. The lettering on the panel is stenciled and baked on the underside.

The support sheet for the open ends of the reservoirs is mounted at an angle on two of the transverse channels, and its edge flanged for bracing (Fig. 9). Three holes are punched in the sheet; two for the reservoirs and a third for the shaft of the valve that controls the direction of coffee flow. The edges of the holes for the reservoirs are lined with rubber stripping to provide a seal.

The control panel is located on the front face of the coffee maker (Fig. 10). Openings are punched in it for the spigots, control knobs, the on-off switches and the indicator lights. Bent metal pieces spot welded to the rear of the panel provide clips that support the colored glass lenses in front of the lights. The spigots and control levers are mounted independently on the cabinet frame.

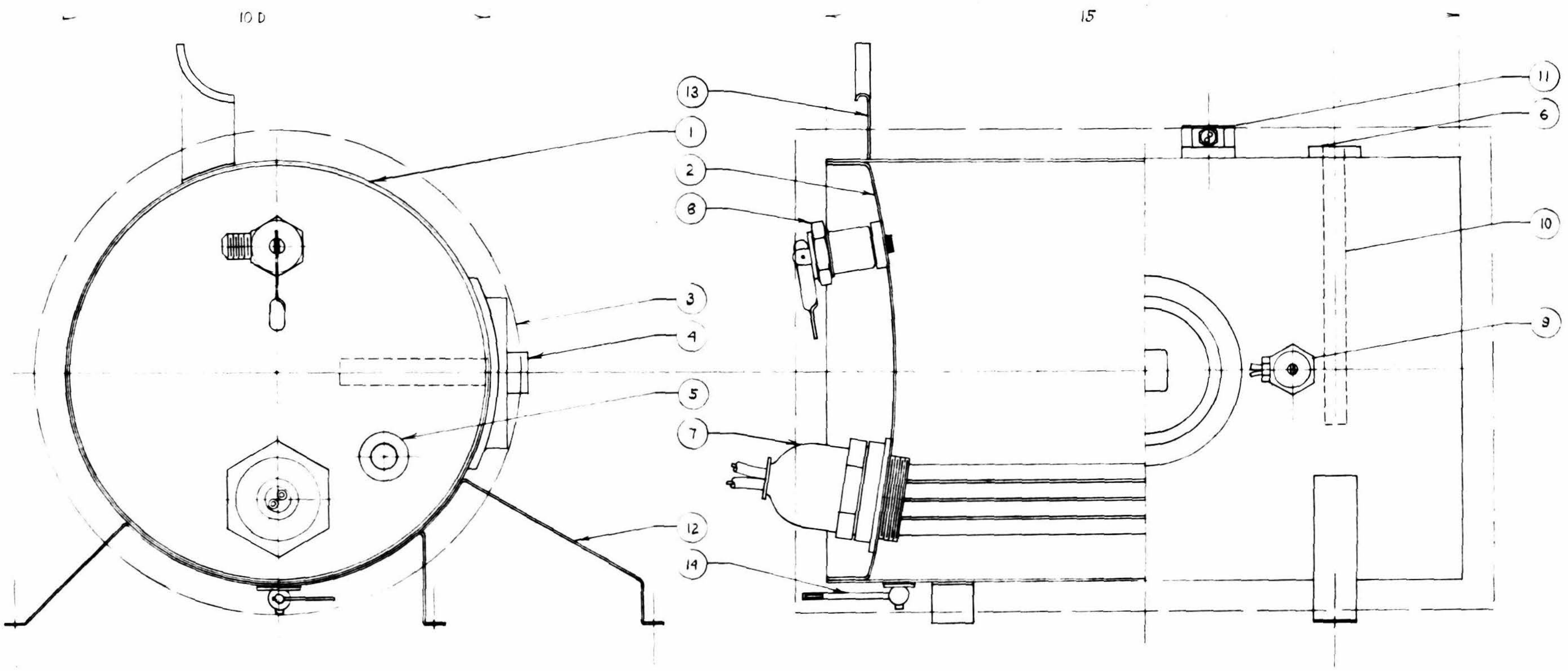


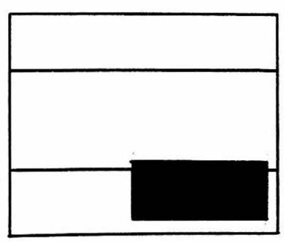
FIG. 12 FRONT AND SIDE ELEVATION OF THE BOILER

14	DRAIN SPIGOT
13	GUIDE FOR CONTROL CABLE
12	SUPPORT BRACKET
11	FLOAT SWITCH
10	OUTLET TUBE
9	IMMERSION THERMOSTAT
8	PRESSURE RELIEF VALVE
7	IMMERSION HEATING UNIT
6	THREADED FLANGE FOR OUTLET TUBE
5	THREADED FLANGE FOR INLET TUBE
4	ACCESS HOLE
3	INSULATION
2	END CAP
1	WRAP-AROUND BODY

The drip pan assembly is situated at the base of the coffee maker (Fig. 11). It consists of two parts; a shallow drawn pan and a slotted support rack. The latter has an extension at the rear that acts as a backing plate to keep liquid out of the cabinet interior. The drip pan assembly rests on the counter surface and may be removed for draining. If a permanent drain is used, the slotted support section that rests in the pan may be removed for cleaning.

The wrap-around section is of 18 gage stainless steel; the drip pan assembly, the reservoir support sheet and the top assembly are of 24 gage stainless steel and the control panel is 24 gage sheet metal. All stainless steel parts are brush finished. This finish affords a rich appearance, and at the same time covers up any slight flaws in the plane surfaces caused by fabrication procedures. The control panel is enameled a warm brown color and the lift handle on the mixing chamber lid and the hinge for the glass cover are chromium plated.

<u>The Boiler</u>



The boiler capacity is sufficient to hold four gallons of water plus approximately three hundred cubic inches of steam. An extra gallon of water is allowed in order that the heating element will always be covered and the possibility of burn-out reduced.

Material investigation showed that stainless steel Type 304 18-8 would be suitable for fabrication of the boiler because of its high resistance to corrosion.

The boiler consists of three parts (Fig. 12); a butt welded wrap-around forming the body and two identical shallow drawn end caps. Before assembly, the wrap-around is punched to accommodate fittings for the outlet water tube, the drain spigot, the thermo-switch, the float switch and the access hole. Two edges of the wrap-around are then butt welded together to form a cylinder. Threaded flanges are welded in place at the points where the fittings are attached, and bent metal brackets are spot welded to the body to support the boiler within the cabinet. The end caps are then pressed into the open ends and seam welded to the body.

The immersion heating unit is rated at seven thousand watts. This size was found to be sufficient to bring the water up to a temperature of 212 degrees Fahrenheit in a ten minute period. The unit is mounted on a two inch header with standard pipe thread.

The completed boiler is enclosed in a mat of glass wool insulating material which is held in position by metal straps. This material was chosen for its excellent insulating qualities and its resistance to the formation of organic growth should water or coffee be absorbed by it.

All attachments on the boiler are accessible through either the top or the front of the coffee maker should replacement or adjustment be necessary. The fresh water inlet tube, the heating ele-

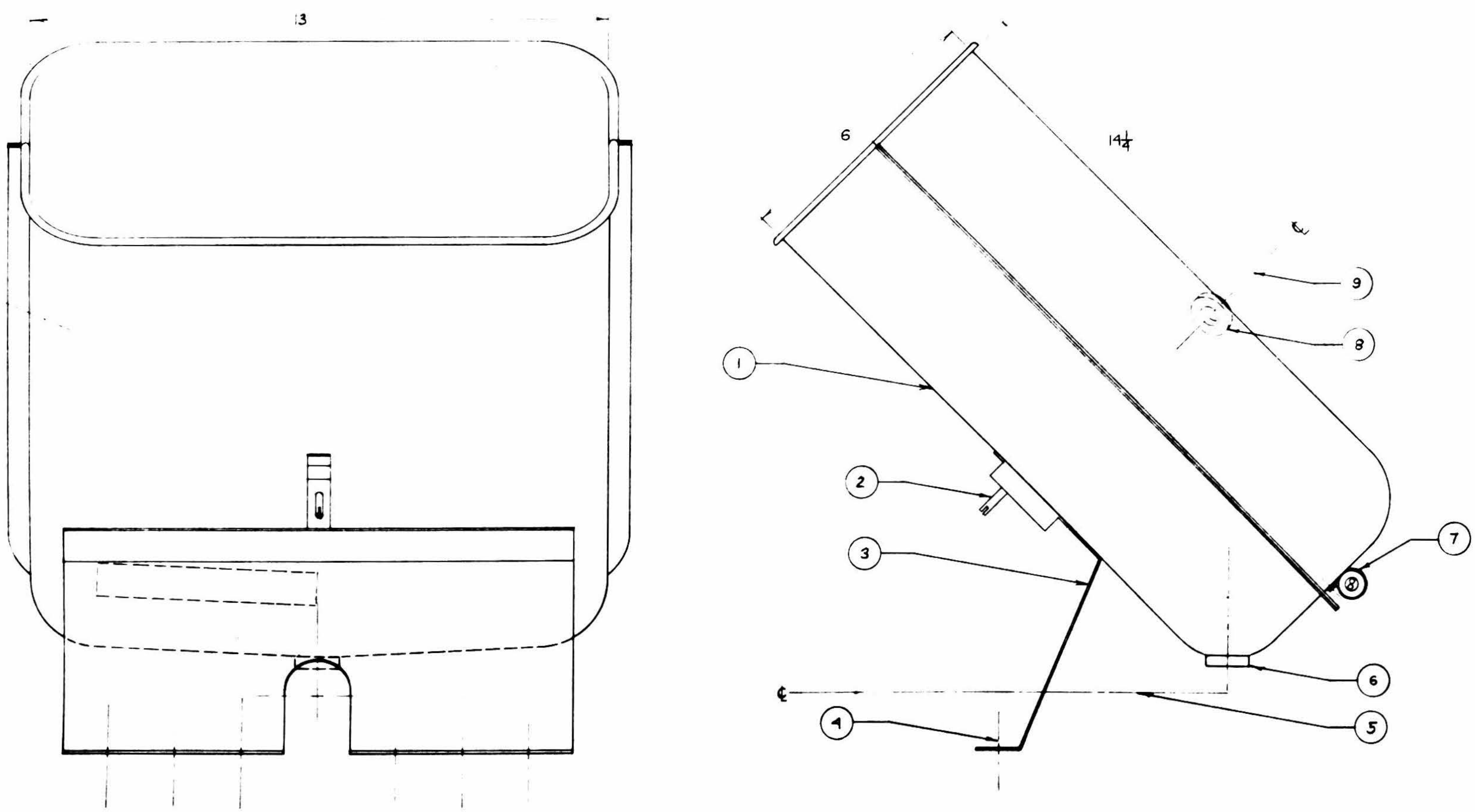


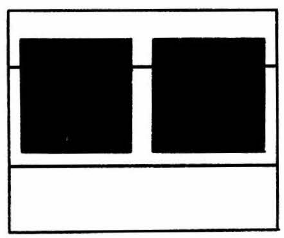
FIG. 13   FRONT AND SIDE ELEVATIONS OF THE RESERVOIRS

9	CENTERLINE OF INLET TUBE
8	THREADED FLANGE FOR INLET TUBE
7	CARTRIDGE TYPE HEATER
6	THREADED FLANGE FOR OUTLET TUBE
5	CENTERLINE OF OUTLET TUBE
4	SCREW HOLE
3	SUPPORT BRACKET
2	THERMOSTAT
1	DRAWN BODY

ment and the pressure release valve are located on the left end of the boiler. The drain spigot is placed on the bottom, near the left end, directly beneath the heating unit. The hot water outlet tube and the float switch enter at the top of the boiler.

The minimum pressure required to transfer the water from the boiler to the mixing chamber was determined by calculation to be 1.65 pounds per square inch gage pressure. The time required to transfer the three gallons of water was determined by test to be four minutes and forty seconds. To insure proper operation, the boiler was designed to maintain a gage pressure of five pounds per square inch.

<u>The Reservoirs</u>



Two reservoirs are provided in order that a continuous supply of coffee may be attained without the need of mixing a freshly made batch with some brewed previously.

The capacity of each reservoir is sufficient to hold three gallons of coffee, and an additional capacity precludes overflow.

The material used for fabrication is stainless steel. This material was chosen on the basis of its inertness to coffee oils and the fact that it is approved for such use by the National Coffee Association.

Each reservoir is made up of two identical parts (Fig. 13).

The two parts are formed as a single shallow draw that is trimmed to provide a flange around its edge. This unit is then split equally and the two identical sections punched to accommodate the coffee inlet and outlet tube fittings. One of the parts is embossed with a scale to indicate the amount of coffee within the reservoir. The two parts are then seam welded together to form a single unit. After assembly, the open end is rolled to provide a smooth edge and a sealing surface when the reservoir is installed in the cabinet. Subsequently, the threaded tube fittings, the bent metal support bracket, and the fittings for the thermostat and the cartridge type heater are welded in place.

The reservoirs are located at an angle in the cabinet. This is done for three reasons; it allows the operator to see into the reservoir from a normal standing position to determine the amount of coffee it contains, it facilitates cleaning, and, since the spigots and controls are situated beneath the inclined reservoir and do not project out in front of it, the counter space needed for the coffee maker is reduced.

The heat to maintain the proper serving temperature of 165 degrees Fahrenheit need only be sufficient to make up for the heat conducted through the reservoir and the surrounding insulation. Calculations showed that a unit of twenty two watts on each reservoir would provide the necessary heat. However, fifty watt cartridge type units are specified to insure that the proper temperature is attained. The units are controlled by thermostats attached to the exterior of each container and may be

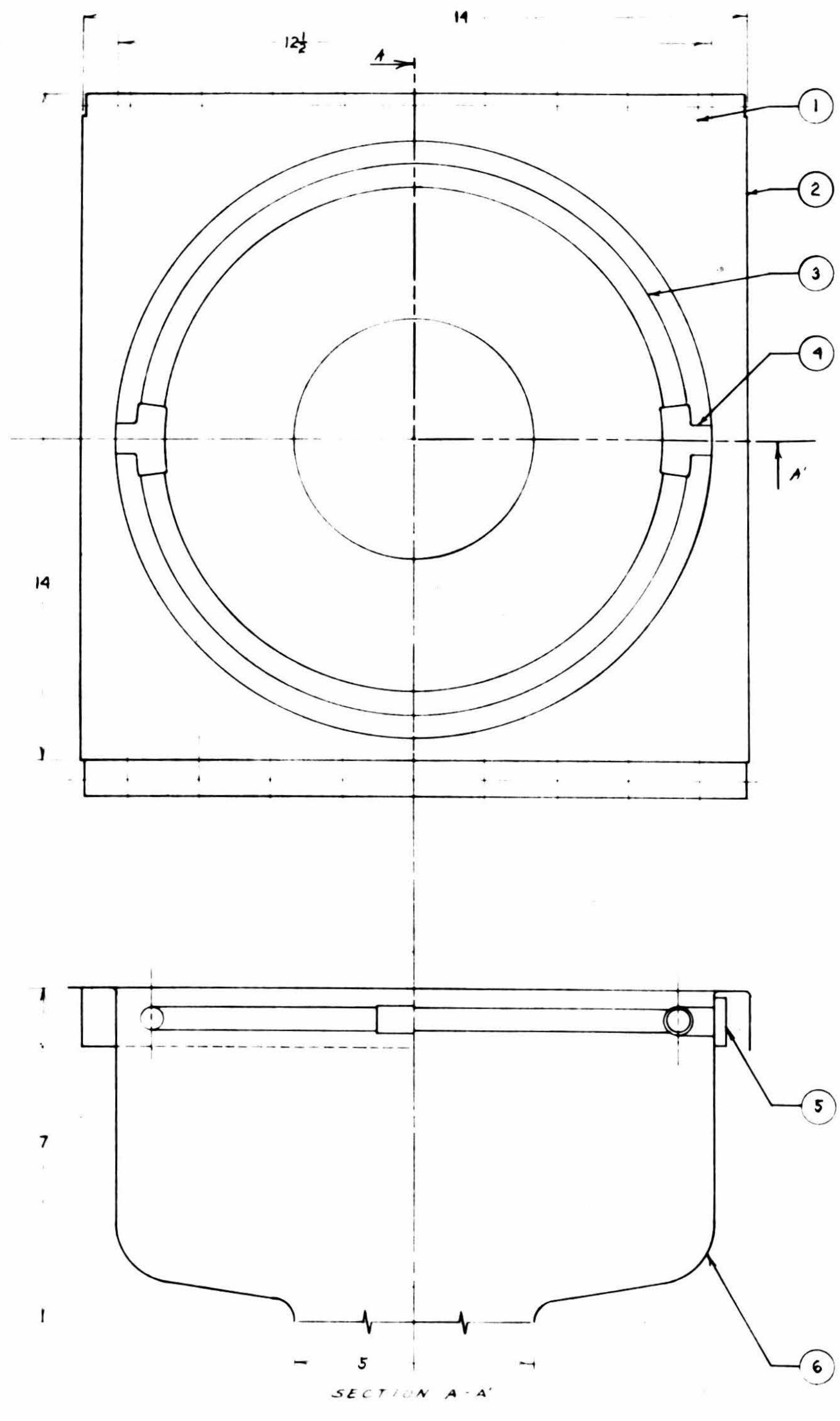


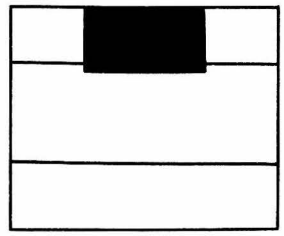
FIG. 14

PLAN VIEW AND CROSS-SECTIONS OF THE MIXING CHAMBER

6	DRAWN BODY
5	FLANG FOR INLET TUBE
4	TEE FITTING
3	SPRAY RING
2	FLANGED SUPPORT SHEET
1	SCREW HOLES

turned off when the reservoir is not in use.

The Mixing Chamber



The capacity of the mixing chamber provides space for three gallons of water and one pound of coffee. Additional volume is provided to prevent overflow.

The mixing chamber is drawn from stainless steel and the base is formed to house the filtering mechanism (Fig. 14). After drawing, the top is trimmed and a formed sheet welded to the chamber to provide a support on the cabinet frame. The upper section is punched to accommodate the fittings for the inlet water tubes from the integral boiler and the central hot water supply of the establishment.

The spray ring located just below the upper edge of the mixing chamber is bent from stainless steel tubing. Eighty orifices are drilled in the ring in order that the water will be evenly distributed over the coffee grounds and that all of the interior surface of the mixing chamber will be covered during the wash-out operation. The spray ring is supported by the fittings for the inlet water tubes. The ring is designed to follow the perimeter of the mixing chamber so that it will be out of the way when the chamber is cleaned by hand.

A mat of glass wool insulating material surrounds the mixing

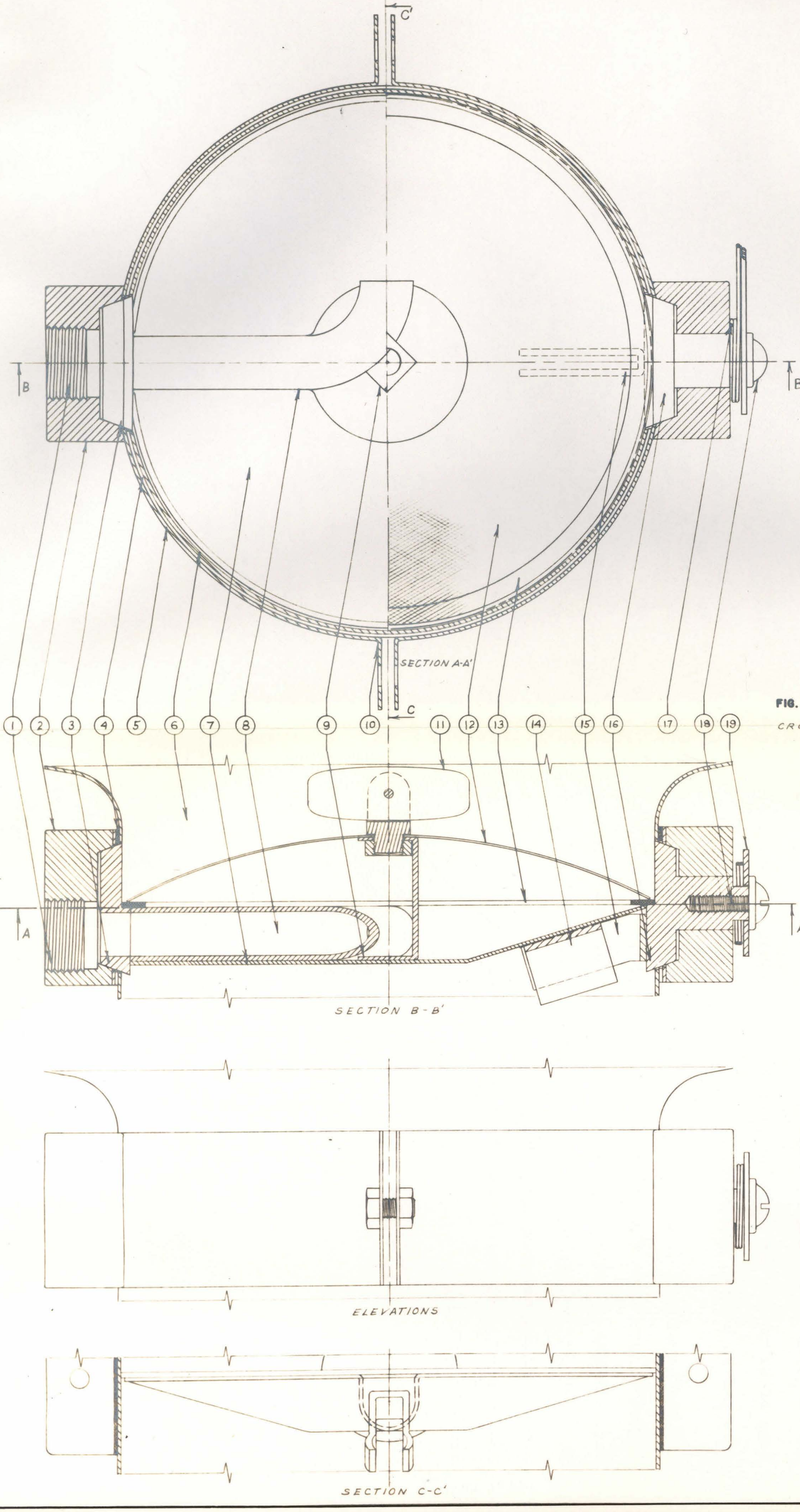
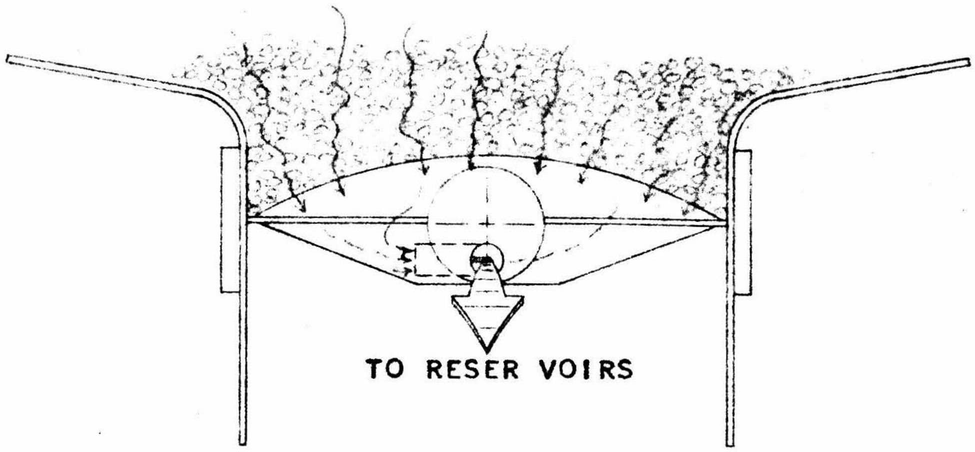


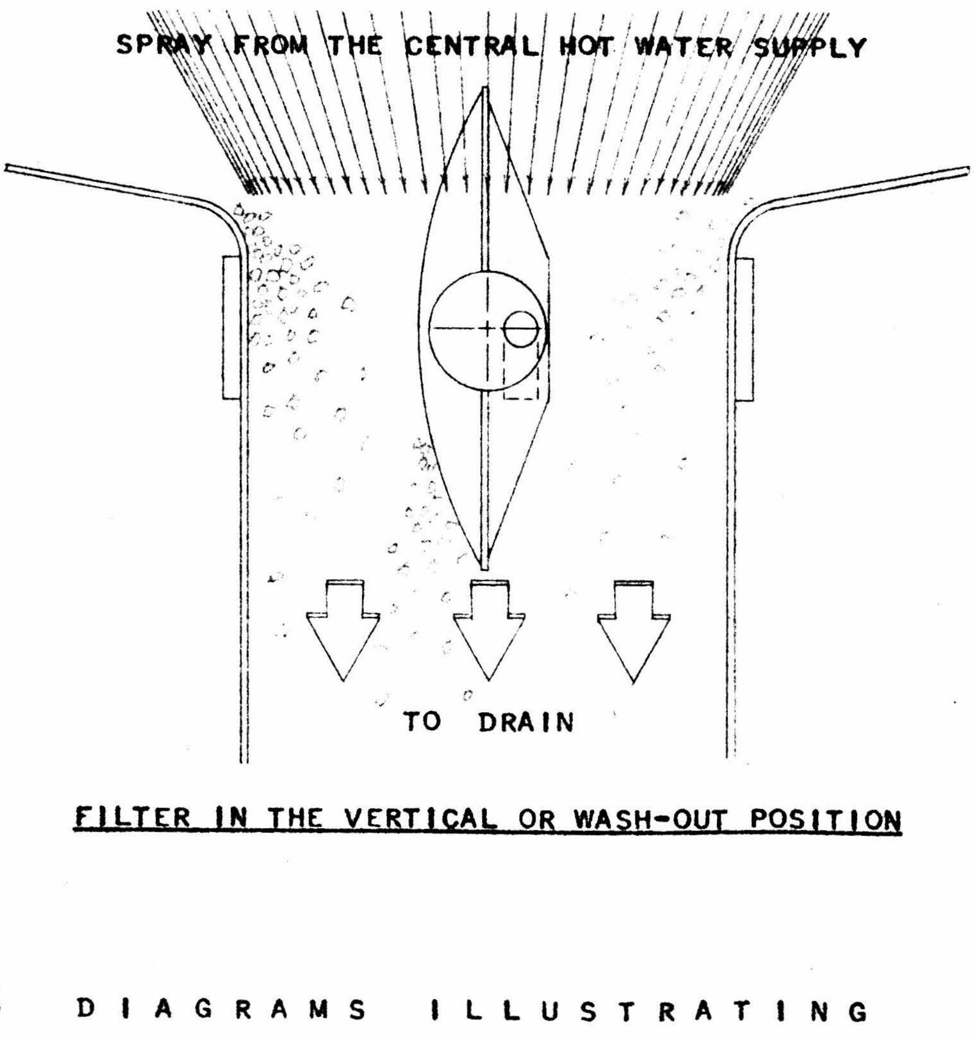
FIG. 15

CROSS SECTIONS OF THE FILTER MECHANISM

19	LEVER ARM
18	FLANGE HEAD MACHINE SCREW
17	TORSION SPRING
16	DRIVING SHAFT
15	BENT METAL KEY TO FILTER
14	BENT METAL KEY TO DRIVING SHAFT
13	SYNTHETIC RUBBER SEAL
12	PERFORATED METAL FILTER
11	THUMB SCREW
10	TIGHTENING FLANGE
9	THUMB SCREW BRACKET
8	TUBE
7	COLLECTING PAN
6	HOUSING
5	SPLIT RING
4	RUBBER SEALING RING
3	CONICAL BEARING AND SEAL
2	BEARING BLOCK
1	THREADED FOR COFFEE DIRECTION VALVE

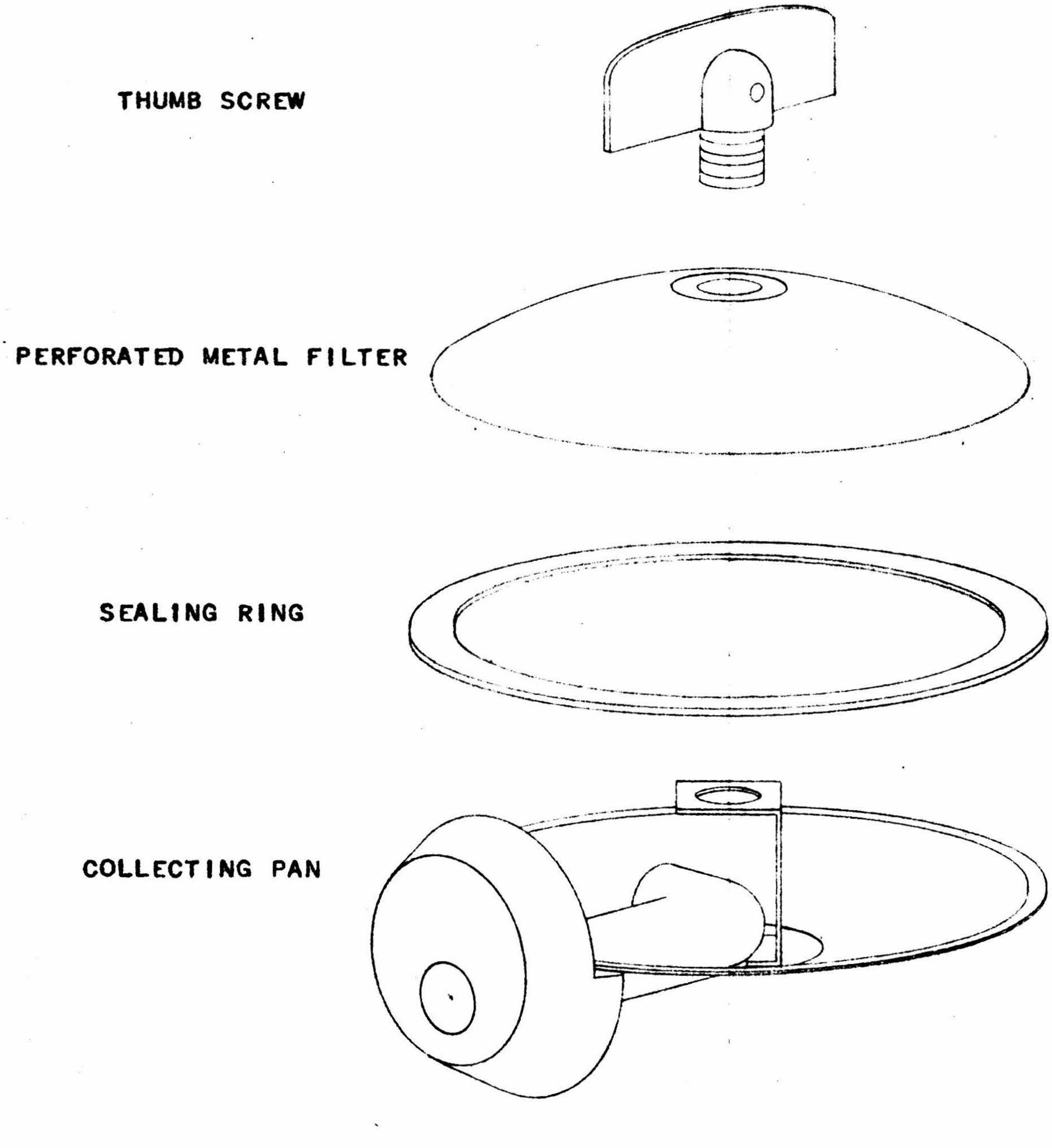


FILTER IN THE HORIZONTAL OR BREWING POSITION



FILTER IN THE VERTICAL OR WASH-OUT POSITION

FIGURE 16 DIAGRAMS ILLUSTRATING THE FLOW OF COFFEE AND WATER THROUGH THE FILTERING MECHANISM



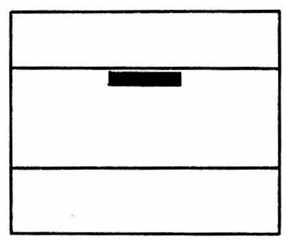
ASSEMBLY OF ROTATING ELEMENT OF THE FILTERING MECHANISM

FIGURE 17

chamber to help maintain the proper temperature of the water during the infusion process. It is held in place by metal straps.

The location of the chamber at the top of the coffee maker was necessary in order to take advantage of a gravity feed from it to the reservoirs below. At this location, the distance of the upper edge from the floor is just below eye level, and the shallow depth of seven inches is convenient to reach to clean the interior of the chamber.

The Filtering Mechanism



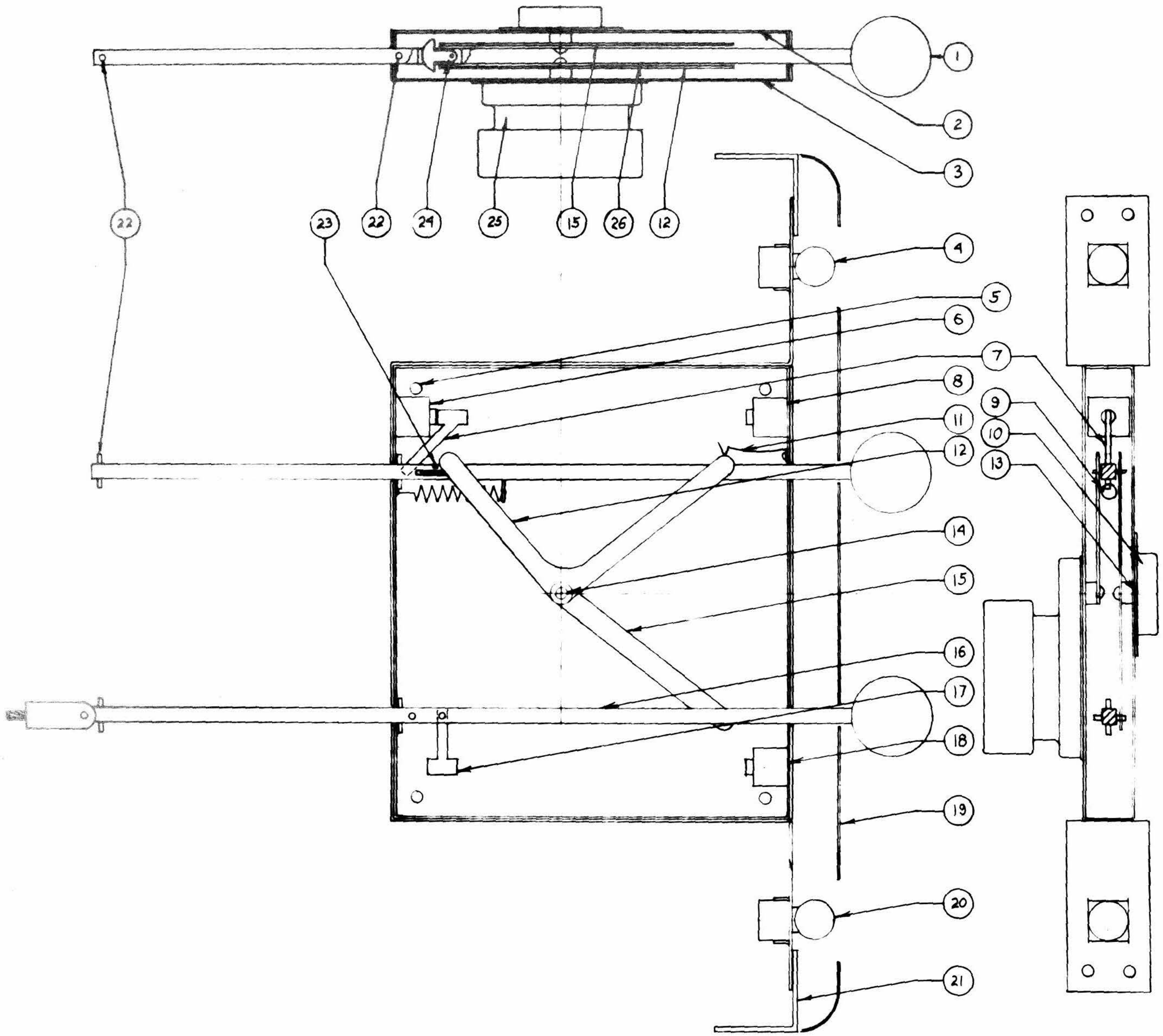
The filtering mechanism is designed to serve two functions; to filter the grounds from the coffee brew and to provide a means of disposing of the used coffee ground (Fig. 15).

This dual function is solved by the use of a rotating unit made up of a filter and a collecting pan (Fig. 16). When this element is in a horizontal position, the coffee passes through the filter and into the collecting pan. It then drains to the center of the pan where it enters a tube that directs it to one of the reservoirs. When the rotating element is in the vertical position, the used coffee grounds are washed down past it to a drain. The tube in the collecting pan that directs the coffee to the reservoirs is bent at a right angle to the axis of rotation, and, when the element is in the vertical position, the tube entrance faces downward, preventing the wash-out water and the coffee ground sediment from entering.

The rotating element is assembled from stamped and machined stainless steel parts (Fig. 17). These parts are the collecting pan, a conical-shaped bearing, a small tube and a bent metal support. The bearing, tube, and support are silver soldered to the collecting pan. The perforated metal filter is attached to this assembly with a thumb screw so that it may be removed for cleaning. A synthetic rubber sealing ring is held between the filter and the collecting pan to provide a watertight seal between the rotating element and the housing.

The other part of the mechanism is a split ring that surrounds the housing. It holds the bearing surfaces for the rotating element, a fitting for the two-way valve to the reservoirs and the drive shaft that actuates the rotating element. One end of the shaft is a conical shape. This acts as both a bearing surface and a seal. Both ends are keyed, the conical end to the rotating element and the other end to a drive link. A torsion spring around the shaft maintains the filter in a horizontal position. The shaft is placed in position from the inside of the housing, and may be removed for cleaning. A rubber ring between the split ring and the housing eliminates possible leakage at the bearing points.

Should it prove difficult to draw the housing from the bottom of the mixing chamber, an alternate means of fabrication might



26	RECTANGULAR ROD
25	MECHANICAL TIMER
24	SWIVEL CATCH
23	NOTCH
22	STOP PIN
21	CHANNELON CABINET BODY
20	RED INDICATOR LAMP
19	CONTROL PANEL
18	2-WAY SWITCH
17	SWITCH ACTUATING ARM
16	RECTANGULAR ROD
15	BELL CRANK ACTUATING ROTARY SWITCH
14	SHAFT OF MECHANICAL TIMER
13	℄ OF ROTATING PARTS
12	BELL CRANK ACTUATING TIMER
11	SPRING CLIP
10	ROTARY SWITCH
9	TENSION SPRING
8	2-WAY SWITCH
7	SWITCH ACTUATING ARM
6	2-WAY SWITCH
5	SCREW HOLE
4	GREEN INDICATOR LAMP
3	FIXED PART OF HOUSING
2	REMOVABLE PART OF HOUSING
1	CONTROL KNOB

FIG. 18

TOP VIEW AND SIDE AND FRONT ELEVATIONS OF THE CONTROL ASSEMBLY

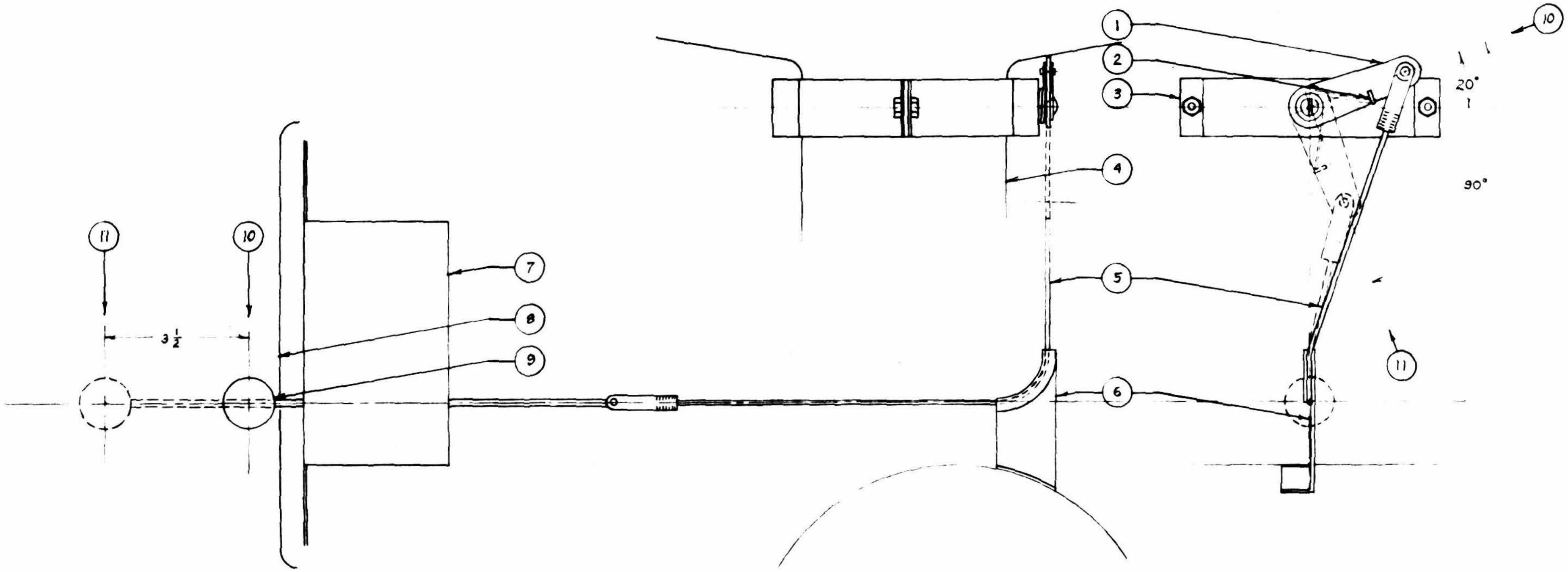
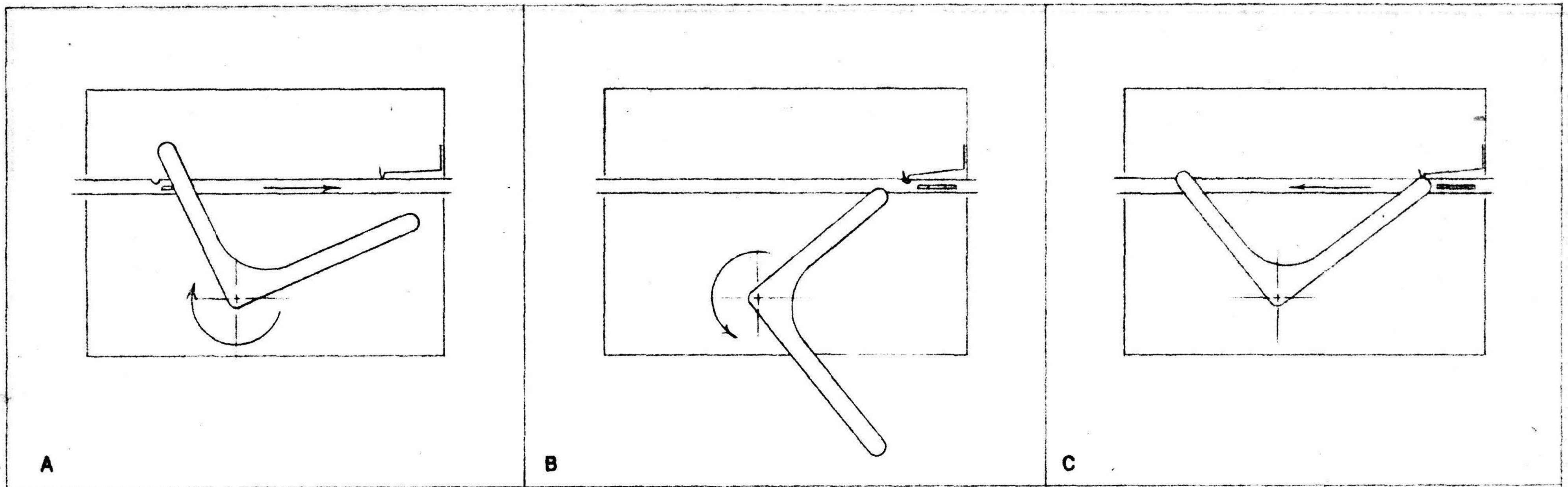


FIG. 19 RIGHT SIDE AND REAR ELEVATIONS OF LINKAGE TO ROTATING FILTER

11	LEVER POSITION - FILTER VERTICAL
10	LEVER POSITION - FILTER HORIZONTAL
9	CONTROL KNOB
8	CONTROL PANEL
7	CONTROL LEVER ASSEMBLY HOUSING
6	GUIDE FOR WIRE CABLE
5	WIRE CABLE
4	DRAIN PIPE
3	FILTER MECHANISM HOUSING
2	TORSION SPRING
1	LEVER ARM



MOVEMENT OF THE BELL CRANK CONTROLLING THE BOILER INLET AND OUTLET VALVES

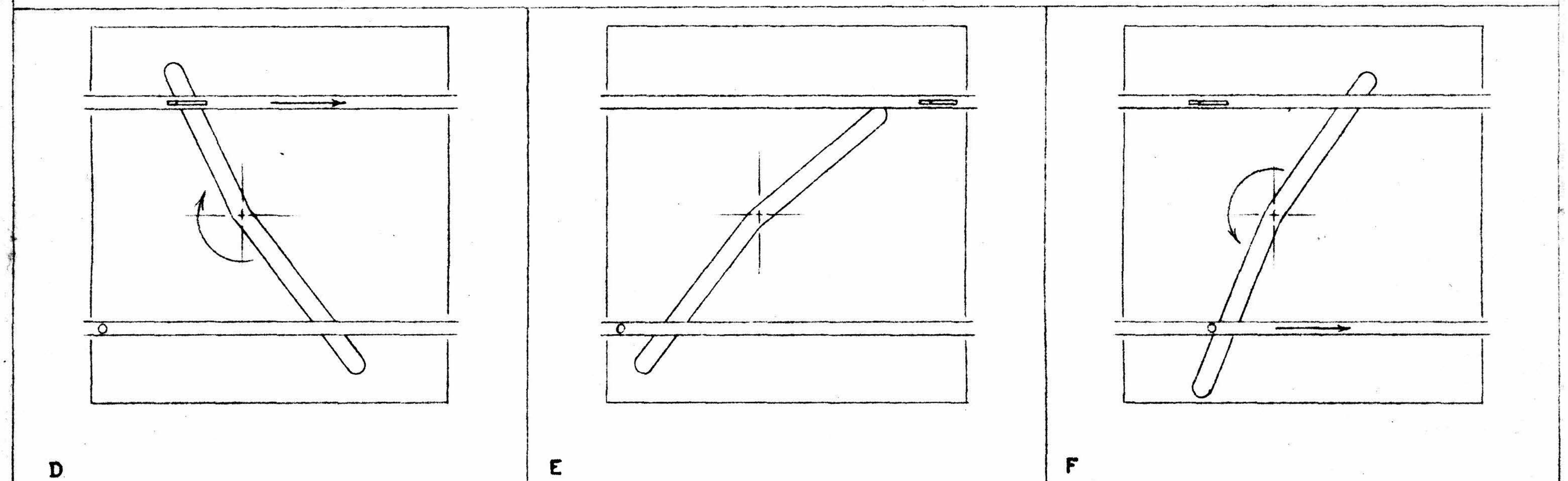
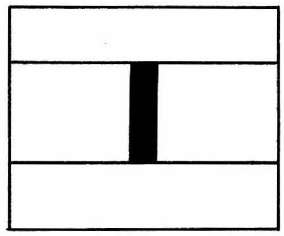


FIGURE 20 MOVEMENT OF THE BELL CRANK CONTROLLING THE RED INDICATOR LIGHT

be used. The housing would be formed separately from sheet stock and the bearing points and tube fittings attached directly to it. This complete assembly would then be welded to the open bottom of the mixing chamber.

The Control Knob Assembly



The control knob assembly is located directly behind the central section of the control panel.

The assembly is housed in a stamped metal box of two parts (Fig. 18). One of these sections is mounted on the upper front and the lower front transverse channels of the cabinet, and the other is removable for access to the interior. This assembly includes both of the control knobs and the red and green indicator lights. It also houses the switches for the three solenoid valves and the switch for the red indicator light.

The upper knob controls the brewing cycle. Attached to the knob is a rectangular rod that penetrates the assembly housing. A small arm that projects up from the rod is positioned to contact a switch at the extreme of travel of the rod. When the rod is in its normal position, the arm closes the switch at the rear of the housing that energizes the boiler inlet valve. When the rod is pulled forward to the end of its three and one-half inches of travel, the arm closes the switch at the front of the housing that energizes the boiler outlet valve. A swivel catch attached to the rod engages the arm of a bell crank as the rod is pulled forward. This bell crank is mounted on the shaft of a mechanical timer, and, as the bell crank is rotated, the timer is wound. The positions of the rod and the bell crank after the crank has rotated through fifteen degrees are shown in Figure 20-a. Near the end of the travel of the rod, and when the crank has passed through forty-five degrees, the crank arm slips from the swivel catch and starts to return to its original position. The rod is held in the "out" position by a spring clip that engages a notch in the rod (Fig. 20-b). After forty degrees of rotation, the second arm of the bell crank lifts the spring clip and the rod is returned to its normal position by the coil spring affixed to it (Fig. 20-c). Since the boiler outlet valve is open when the control rod is in the "out" position, and this position exists while the bell crank rotates through forty degrees, the mechanical timer is set to travel through this angle during a five minute period. The twenty second time differential between the calculated time of four minutes and forty seconds and the timer speed allows for a possible variation in the speed of transfer of the hot water from the boiler to the mixing chamber.

The lower knob controls the wash-out operation in the mixing chamber (Fig. 19). A rectangular rod fixed to the knob is moved through the housing when the knob is pulled forward. On the other end of the rod is attached a cable that is connected to the lever arm of the rotating filter. As the rod travels through three and one-half inches, the filter is rotated through ninety degrees to the vertical or wash-out position. At the end of travel, a small arm that projects down from the rod contacts and closes a switch at the front of the housing that energizes the hot water inlet valve to the mixing chamber. When the control lever is released, the torsion spring on the filter shaft returns the filter to its normal horizontal position. Stop pins are inserted in the rod to limit its movement.

A second bell crank in the control assembly is actuated by both control knobs. This bell crank is mounted on the shaft of a rotary on-off switch that operates the red indicator light. In its normal position, the switch is off; when rotated through forty-five degrees, the switch is on. The swivel catch on the upper control rod also engages this bell crank when it is pulled forward (Fig. 20-d). After the arm has travelled through forty-five degrees, it slips off the swivel catch and the red light is illuminated (Fig. 20-e). The bell crank remains in this position until the lower control knob is pulled forward. When this knob is operated, a pin projecting from the side of the rod engages the other arm of the bell crank and returns it to its normal positon (Fig. 20-f)

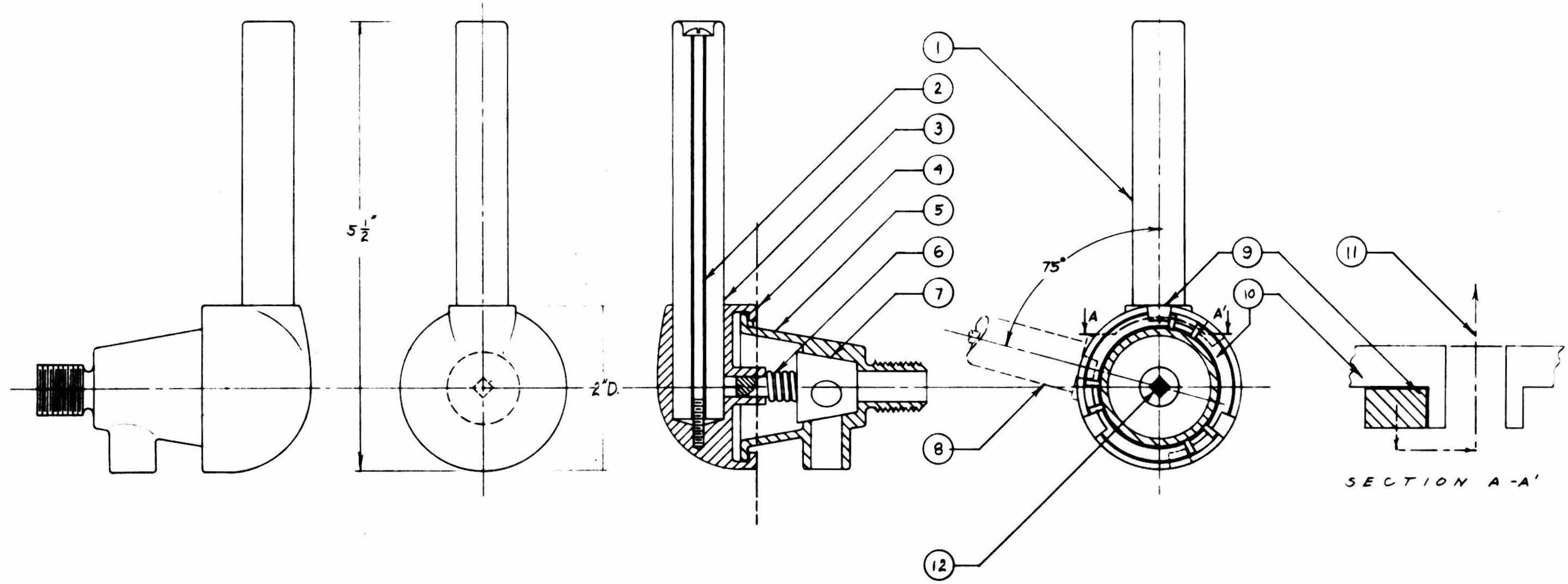
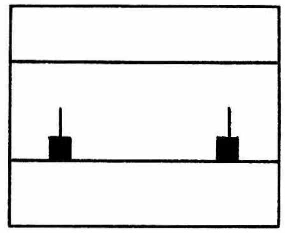


FIG. 21

FRONT AND SIDE ELEVATIONS, CROSS-SECTION AND DIAGRAM OF OPERATION OF THE SPIGOTS

12	RECTANGULAR SHAFT OF VALVE PLUG
11	PATH OF HANLE FLANGE WHEN REMOVING
10	FLANGE ON VALVE BODY
9	FLANGE ON HANDLE HUB
8	HANDLE POSTION-VALVE OPEN
7	VALVE PLUG
6	COMPRESSION SPRING
5	HUB OF HANDLE
4	BODY OF VALVE
3	HANDLE OF PLASTIC BAR STOCK
2	CARRIAGE BOLT
1	HANDLE POSITION-VALVE CLOSED

The Spigots



Two spigots are located on the front control panel, one for serving from each reservoir.

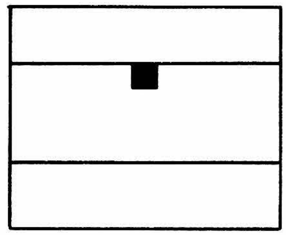
The spigot is made up of four parts; the valve body, the valve plug, the handle and a compression spring (Fig. 21). All parts are of machined cast brass except the handle lever which is cut from melamine plastic bar stock and attached to the hub with a carriage bolt. The handle hub is buffed and chromium plated.

The valve surfaces are held in contact by the compression spring. This spring also provides a frictional force on the locking surfaces of the handle hub and the valve body.

The handle is normally in a vertical position and is rotated clockwise for pouring. The valve is fully open when the handle has passed through seventy-five degrees. To remove the handle and the valve plug from the valve body for cleaning, the handle is pressed in so that it may be rotated beyond the limit of the stops which project from both ends of the flanges on the valve body. It is then pulled free from the valve body. The motion of the handle is transmitted to the valve plug through a square shaft that slides freely in a hole broached in the handle hub.

The entrance side of the valve is threaded with standard one-half inch pipe thread to fit the stainless steel tube connection from the reservoirs. The exit end of the valve is extended to direct the flow of coffee downward.

The Two-Way Coffee Valve



This valve is attached directly to the fitting provided for it on the filtering mechanism. The two outlets are connected by pipe unions to threaded flanges on the reservoirs which are located on either side of the valve.

Since this valve has coffee running through it, it is designed so that the plug may be lifted from the body for cleaning. The plug is lapped to the body and held in contact by spring pressure. No other sealing means is required.

The valve is operated by a knob which is located between the two reservoirs on the support sheet. An arrow on the knob points to the reservoir that the flow is directed to. A shaft connects the knob with the valve plug. The assembly is removed for cleaning by grasping the knob and pulling the plug up through the support sheet.

Tube Connections

Stainless steel tubing of one-half inch outside diameter is used throughout the system. All clearances are based on the dimensions of standard AN fittings and valves.

INDEX TO THE APPENDIX

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RESULTS OF STUDIES CONDUCTED BY DR. S. C. PRESCOTT

(1). Very hard or very alkaline waters exert an unfavorable influence on the character of beverage coffee. Ordinary soft waters or waters of low hardness may be used without noticeable difference in the quality of the beverage.

(2). The temperature of the water plays an important part in coffee making. Actual boiling increases the bitter taste. The most favorable temperatures seem to range from 85 degrees C. to 95 degrees C. (185 degrees F. to 203 degrees F.), as at these temperatures the caffeine is nearly all dissolved, the flavor giving oils or ethers are not so largely boiled off and certain changes resulting in bitterness and woody taste are absent and negligible.

(3). The time of infusion should be brief. In general, it should not exceed two minutes at the temperatures stated above. One minute is even better. Long infusion, even at the lower temperatures, increases the bitter taste and decreases the flavor and aroma.

(4). About 80% of the caffeine is dissolved in two minutes at the boiling point and nearly as much at 95 degrees C.

(5). The action of the coffee on metals is pronounced, and bitter, astringent or metallic tastes may be produced.

(6). Coffee boiled for one minute is markedly more bitter than that prepared at 95 degrees C.

(7). Tin-plate, aluminum, copper, and nickel all affect the taste of coffee, and in general in the order named, tin-plate has the greatest effect.

(8). Glass, porcelain, stoneware, agate, and other vitrified wares exert no influence on the taste of coffee.

(9). Some metals form compounds with caffeine and probably also with other constituents of coffee.

(10). Freshly roasted and freshly ground coffee are necessary for the best flavor.

(11). Coffee in the bean retains its flavor longer than in the ground form.

(12). The fineness of the grind exerts an influence on the flavor. In general, a fine grind yields a richer flavor than a course grind because of the more rapid and complete solution of the flavor-giving substances. The grind should, however, be adapted to the method of brewing.

(13). It is desirable to grind the coffee beans immediately before infusion if one wishes to secure and conserve all the available flavor and aroma.

(14). Different types of coffee have their characteristic flavors which may be detected by the expert. Even coffee of low commercial grade, if freshly roasted, freshly ground and properly brewed will be superior to coffees of higher grade which have not been suitably stored to prevent oxidation changes, or which are badly prepared.

(15). We believe the best results will be obtained with freshly roasted coffee, infused at temperatures 185 degrees F. to 195 degrees F. for not over two minutes in a glass, porcelain, or vitrified container, and immediately filtered from the grounds.

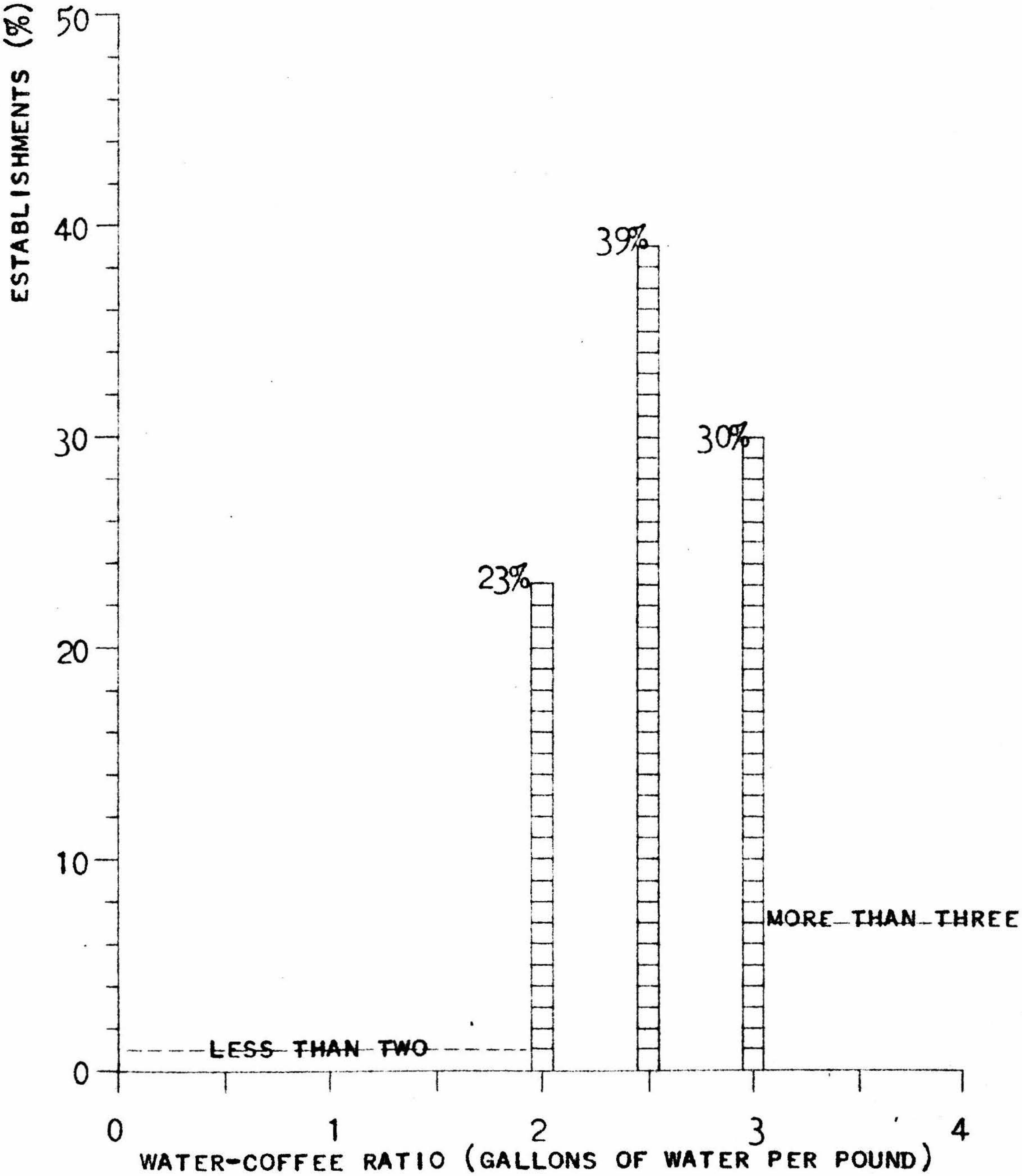


FIGURE 22 PERCENTAGE UTILIZATION OF WATER-COFFEE RATIOS IN THE UNITED STATES

LIST OF MANUFACTURERS OF COMPETITIVE COFFEE MAKING EQUIPMENT STUDIED

All-Lite Manufacturing Company
510 West 26th Street
Chicago 16, Illinois

Amcoin Corporation
1148 Main Street
Buffalo 9, New York

Cory Corporation
221 North LaSalle
Chicago, Illinois

Enterprise Aluminum Company
Massilon, Ohio

Ershler and Krukin, Incorporated
Bayonne, New Jersey

Franklin Products Corporation
2155 Pershing Road
Chicago 9, Illinois

Hill-Shaw Company
311 North Desplaines Street
Chicago, Illinois

J. H. McKie, Manufacturer
649 Wall Street
Los Angeles, California

Silex Company
Hartford, Connecticut

West Bend Aluminum Company
West Bend, Wisconsin

Zees Coffee Urn Company
Chicago, Illinois

PROCEDURE FOR OPERATING AND CLEANING AN URN-TYPE COFFEE MAKER

(1). After the operator is satisfied that the urn is in a proper state of cleanliness, the boiler is filled with hot water up to a level indicated on a gauge glass. When filled, the heating unit beneath the boiler is turned on.

(2). When the water has come to a vigorous boil, the jacket surrounding the urn is filled by opening a valve on the line connecting the boiler with jacket. The jacket is only 3/4 filled as space must be allowed in which the steam can expand. This amount is determined by a line on the gauge glass.

(3). The urn bag is rinsed in clean cold water before being placed in the urn. (The bag is kept in cold water overnight to prevent its turning rancid.)

(4). After the bag is fitted on the urn, the amount of coffee it is a practice to use is placed in the filter.

(5). When the boiler water is at the boiling point it is drawn off and poured over the coffee slowly and with a circular motion to keep the grounds from backing up and overflowing into the jacket.

(5a). Another means provided on some units to perform this operation is by syphoning the water through an automatic spray, thereby eliminating the danger of spilling the boiling water and possible scalding. However, the manual method is preferred by operators as they feel that they can obtain a more accurate measurement that way.

(6). In some cases it is a practice to repour the coffee through the grounds once again after the first infusion. If this is done (the practice is carried out by the majority of operators), the coffee brew is drawn from the urn into a gallon measuring can and poured over the grounds in the same manner as was the freshly boiled water.

(7). When the infusion period is completed, and all the coffee has dripped through the urn bag, the bag is removed from the urn. This must be done immediately as eventually the bitter oils of the coffee would seep into the urn.

(8). A gallon of the coffee is drawn off and mixed again with the rest of the brew to insure uniform strength throughout.

(9). The heat under the urn is checked to be certain that it maintains the water jacket at an even temperature of 190 degrees F. while the coffee is being served.

To insure proper care and cleaning of the coffee maker, one of the essential requirements of good coffee, the following steps are necessary:

(1). The used coffee grounds are removed from the filter bag, and the bag thoroughly rinsed and placed in a pan of cold water.

(2). When the coffee in the urn has been used, a gallon of hot water is poured into the urn and drawn off.

(3). A second gallon of hot water is poured into the urn and its interior scrubbed with an urn brush.

(4). Finally, a third gallon of hot water is used to rinse the urn.

At the end of the business day, the coffee maker is given an even more thorough cleaning.

(1). The inside of the urn liner is scrubbed as prescribed on the preceding page.

(2). The interior of the gauge glass is cleaned by scrubbing with hot water and a gauge brush.

(3). The exterior of the boiler and the urn are given an overall polishing.

(4). Finally, the urn cover is left partially off and a small quantity of clean fresh water left in the liner over night.

Once each week the coffee maker should be cleaned with a special urn cleaning compound.

(1). The water jacket is 3/4 filled and the heating unit beneath the jacket turned on.

(2). One gallon of boiling water is poured into the urn and a package of the cleaning compound added.

(3). When the compound has dissolved, a small portion of the water is drawn off through the spigot and the pet cock on the coffee gauge glass, and the solution allowed to stand for about fifteen minutes.

(4). The inside of the liner and the plug at the bottom of the liner are scrubbed with the coffee urn brush.

(5). The coffee gauge glass is cleaned.

(6). The cap nut air vent holes on top of both the coffee and water gauges are checked.

(7). The clean-out caps on the coffee spigots are removed and the inside scrubbed thoroughly with the coffee pipe brush.

(8). The removable parts of the spigots are soaked in a pan of hot water to which has been added half a package of urn cleaning compound. They are scrubbed, rinsed, and replaced.

(9). Finally, the urn liner is again scrubbed, and the liner and gauge glasses rinsed two or three times with hot water.

PROCEDURE FOR OPERATING AND CLEANING A VACUUM GLASS TYPE COFFEE MAKER

(1). After all the elements have been cleaned, the lower bowl is filled with clear fresh water to an indicator mark on the side of the bowl.

(2). The lower bowl is placed on the heating unit.

(3). A filter cloth and drainer are obtained from a pan where they have been soaking in fresh cold water.

(4). The complete filter is inserted into the upper bowl. The tension spring is pulled down through the stem and the small clamp at the end of the spring hooked to the end of the stem.

(5). The amount of coffee it has been a practice to use is placed in the upper bowl and spread evenly over the filter cloth.

(6). When the water in the lower bowl has come to a boil, the upper bowl is placed in the lower with a slight twisting motion in order to provide a seal between the bowls.

(7). After the water has entered the upper bowl, the ground coffee and water are stirred with a spoon so that they are well mixed.

(8). The coffee is held in the upper bowl for a period of 90 seconds. Then the heating unit is turned off and the coffee returns to the lower bowl.

(9). As soon as all the coffee has returned to the lower bowl, the upper bowl is removed and the coffee kept over a low heat.

The following steps are recommended for cleaning vacuum-glass coffee equipment:

(1). After removal of the upper bowl, the grounds are immediately disposed of and the bowl rinsed thoroughly.

(2). The filter is removed and rinsed and placed in fresh cold water to prevent souring.

(3). When the coffee in the lower bowl has been used, all the equipment is rinsed and cleaned.

(4). The upper bowl is rinsed with hot water and the coffee stains on the inside of the stem cleaned off with a stiff funnel brush.

(5). The lower bowl is rinsed in hot water and scrubbed. At the end of the business day, the apparatus is given an even more thorough cleaning. The procedure followed is the same as just prescribed with the addition of a good dish washing powder. The metal spring on the filter should also be cleaned with scouring powder once a day.

MARKET ESTIMATE

The data used in this market estimate was derived from the Report on Coffee in Public Eating Places and the Statistical Abstract of the United States, 1947. The total market was broken down into two groups and each analyzed separately.

THE REPLACEMENT MARKET

The number of establishments included in the survey		326
The number of customers served each week in these establishments		2,980,809
The seating capacity of these establishments		60,296
During the winter months, the number of customers that order coffee with their meals		75% - 90%
	average	82.5%
Number of customers who order a second cup		5% - 10%
	average	7.5%
The number of first cups served in a week:	(.825) (2,980,809) =	2,460,000
The number of second cups served in a week:	(2,460,00) =	184,000
Total number of cups served per week:		2,644,300
The peak loads occur during breakfast, lunch and dinner hours. Assume that the duration of the peak load for a weekly period equals (in hours)		42
The number of cups served per hour, assuming all service occurs during the peak loads:	(2,644,300)/(42) =	63,000
On the basis that the designed unit will provide 350 cups per hour, the number of units of this capacity required by the 326 establishments in the survey	(63,000)/(350) =	180

Total number of establishments as estimated in this survey	525,000
The total number of units of this capacity that are required	(180) (525,000)/(326)= 290,000
The period of time generally allowed for depreciation of the units (in years)	5 to 10
average	7.5
Number of replacements per year of units of this capacity	(290,000)/(7.5)=38,700
With ten other manufacturers in the field and assuming all receive an equal share of the market, the replacement market would be:	(38,700)/(11)=3,520

THE NEW MARKET

The estimate of the new market is based on the assumption that the increase in the number of restaurants each year is proportional to the commercial building (in square feet of floor space) that was contracted for during the previous year.

Thousands of square feet increase per year between 1930 and 1941:	(3650 - 1250)/(11) = 218
Thousands of square feet increase per year between 1945 and 1948:	(6100 - 4900)/(3) = 400
Number of restaurants increase per year between 1929 and 1941:	(177,500 - 137,500)/(11) =3,635
Number of restaurants increase per year between 1945 and 1948:	(3,635) (400)/(218) = 6,670
From the survey, the percentage of establishments that are restaurants is:	(190)/(326) = 58.3%
Total increase per year of all establishments at the present time:	(6670)/(.583) = 11,440
Total number of units of the design capacity	(180) (11,440)/(326)= 6,320

With ten other manufacturers in the field and assuming all receive an equal share of the market, the new market would be:	(6,320)/(11) = 575
Replacement Market:	3,520
New Market:	575
Total Market:	4,095

PERSONAL INTERVIEWS HELD FOR CONSUMER RESEARCH

Mr. R. E. Ballerino	Farmer Bros. Restaurant Service 3828 South Main Street Los Angeles 37, California
Mr. A. Charles Draper Supervisor, Soda Department Planning	The Rexall Drug Company Rexall Square Los Angeles, California
Mr. Ted Ehler, General Manager	McDonnels Restaurants 1138 South Main Street Los Angeles, California
Mr. Franklin, General Manager	Dixie Waffle Shop 542 South Broadway Los Angeles, California
Mr. Glenn J. Greene Manager Cafeteria Facilities	California Institute of Technology 1201 East California Street Pasadena, California
Miss Leita Harmon, Manager	The Athenaeum 551 South Hill Avenue Pasadena, California
Mr. H. S. Lokey Regional Soda Director	The Rexall Drug Company Rexall Square Los Angeles, California
Miss Rose Masser, Dietician	Commissary Department The Prudential Life Insurance Co. 5757 Wilshire Boulevard Los Angeles, California
Mr. Dearle R. McCulley Representative	Standard Brands Inc. 41 South De Lacey Street Pasadena, California
Mr. Victor Nenow	Dohrmann Hotel Supply Company 444 South Broadway Los Angeles, California
Mr. Paul J. Norcross District Manager	Manning's Incorporated 319 West 5th Street Los Angeles, California

SURVEY GROUPS AND TRADE ASSOCIATIONS CONTACTED

Bureau of Foreign & Domestic Commerce	Dept. of Commerce Washington 25, D. C.
The Copley Press Incorporated	State Journal Bldg. Springfield, Illinois
Curtis Publishing Company Research Department	Independence Square Philadelphia 5, Penn.
Illinois State Journal & Register	Springfield, Illinois
Institutions Magazine Readers' Service Department	1900 Prairie Avenue Chicago 16, Illinois
The Milwaukee Journal Promotion & Research Department	Milwaukee, Wisconsin
Patterson Publishing Company Research Department	5 South Wabash Avenue Chicago, Illinois
Scripps-Howard Newspapers Research Department	230 Park Avenue New York 17, New York
Southern California Edison Company	Edison Building Los Angeles 53, Calif.
The Times-Mirror Company Research Department	Los Angeles, Calif.
National Coffee Association	120 Wall Street New York 5, New York
National Electrical Manufacturers Association	155 East 44th Street New York 17, New York
National Restaurant Association	8 South Michigan Avenue Chicago 3, Illinois

LIST OF CALCULATIONS

1. CALCULATION OF THE BOILER SIZE

Quantity of water to be heated:
= 3 gal.

Quantity of excess water:
= 1 gal.

Total quantity of water:
= 4 gal.
= 925 cubic inches

Volume of steam:
= 231 cubic inches

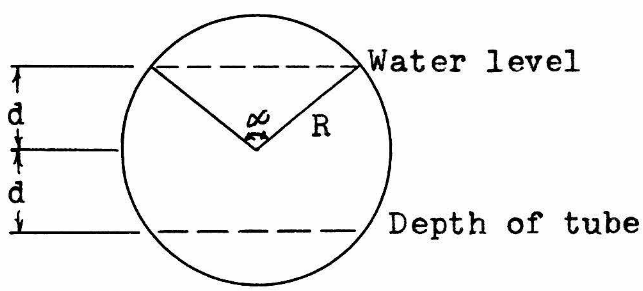
Total volume required:
= 1156 cubic inches

Space limitations dictated that the boiler length be:
= 10 inches

Length of boiler:
$= (4)(V)/(\pi)(D)^2$
$= (4)(1156)/(\pi)(10)^2$
= 14.7 inches

Because of the concave ends, the boiler length was made:
= 15 inches

2. CALCULATION OF THE LENGTH OF THE OUTLET TUBE IN THE BOILER



Area of boiler end:
$= (\pi)(D)^2/(4)$
$= (\pi)(10)^2/(4)$
= 78.5 square inches

The location of the chord is determined by the water level when the boiler is filled. Therefore, the area of the segment is proportional to the volume of steam space:
$= (78.5)/(5)$
= 15.7 square inches
$= (R)^2(\alpha - \sin\alpha)/(2)$

Various values were assumed for α and it was found to be:
= 121 degrees

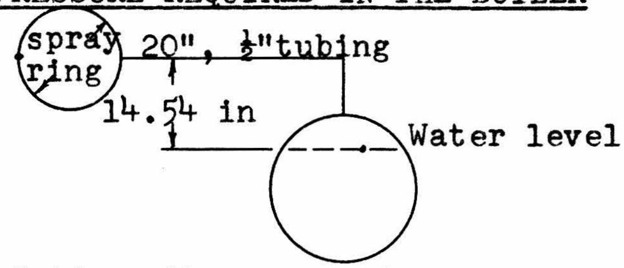
The distance from the center of the boiler end to the water level (d):

$= (R)(\cos \alpha/2)$
$= (5)(\cos 60.5^{o})$
$= 2.46$ inches

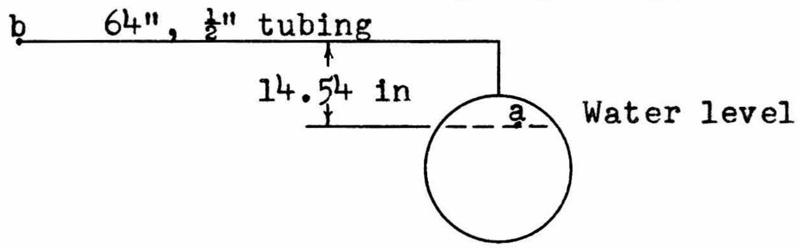
Depth of the tube in the boiler:

$= R + d$
$= 5 + 2.46$
$= 7.46$ inches

3. CALCULATION OF THE PRESSURE REQUIRED IN THE BOILER



To simplify calculation, the spray ring was opened and considered as a continuation of the tube. The outlets were assumed to be combined at the tube exit:



Energy equation:

$$p_a/w + V_a^2/2g + Z_a = p_b/w + V_b^2/2g + Z_b + \text{losses}$$

Calculation of V_a:

Area of the water surface when the boiler contains four gallons:

$= .91$ square feet

Maximum volume of water to transfer:

$= 3$ gal.
$= .4$ cubic feet

Assume the transfer time is:

$= 60$ seconds

Flow: $= (V)/(t)$
$= (.4)/(60)$
$= .0067\ ft^3/sec.$

Velocity (V_a):

$= (F)/(A_a)$
$= (.0067)(.91)$
$= .00732$ feet/second

Calculation of V_b:

Area of the tube cross-section:
$= (\pi)(D)^2/(4)$
$= (\pi)(.5)^2/(4)$
$= .1962$ square inches

Velocity (V_b):
$= (F)/(A_b)$
$= (.0067)/(.1962)(.0069)$
$= 4.88$ feet/second

Calculation of h_f:

Kinematic viscosity of water at 212 degrees Fahrenheit:
$= (3)(10^{-6})$ ft^2/sec.

The Reynolds number:
$= (D_b)(V_b)/\nu$
$= (.4165)(4.88)/(3)(10^{-6})$
$= 67,800$

From fig. 119, p. 179, Fluid Mechanics by Cox and Germano: f is:
$= .021$

Loss due to friction (h_f):
$= (f)(L)(V^2)/(D)(2g)$
$= (.021)(64)(4.88)^2/(.5)(64.4)$
$= .995$ ft.

Calculation of h_o:

Number of exit holes in the spray ring:
$= 80$

Assuming that an equal amount of water passes through each hole, then the flow:
$= (F)/(\#\text{ of holes})$
$= (.0067)/(80)$
$= .0000833$ ft^3/sec.

Area of a hole:
$= (\pi)(.0625)^2/(4)(144)$
$= .0000213$ ft^2

Velocity through the hole:
$= (.0000833)/(.0000213)$
$= 3.91$ ft/sec.

Loss at one exit hole:
$= (C_v^{-2} - 1)(V)^2/(2g)$
$= (.98^{-2} - 1)(3.91)^2/(64.4)$
$= .00949$ ft.

Total exit loss (h_o):
$= (80)(.00949)$

$= .759$ ft.

<u>Calculation of h_e:</u>

Entrance loss (h_e):

$= (.05)(V_b)^2/(2g)$

$= (.05)(4.88)^2/(64.4)$

$= .0185$ ft.

<u>Calculation of h_b:</u>

From fig. 126(a), p. 193, <u>Fluid Mechanics</u> by Cox and Germano, when the radius of the bend is one inch and the diameter is one-half, k is:

$= .19$

Bend loss (h_b) for three bends:

$= (3)(k)(V_b)^2/(2g)$

$= (3)(.19)(4.88)^2/(64.4)$

$= .210$ ft.

The pressure required in the boiler:

$= (p_b/w + V_b^2/2g - V_a^2/2g + Z_b - Z_a + \text{losses})(w)$

$= (0) + (4.88)^2(w)/(64.4) - (.00732)^2(w)/(64.4)$
$+ (1.211)(w) - (0) + (.995)(w) + (.759)(w)$
$+ (.0185)(w) + (.210)(w)$

$= 1.48$ #/in^2 gage

$= 16.18$ #/in^2 absolute

At the end of the transfer, the only change is in the value of Z_b:

$= 19.46$ inches

$= 1.62$ feet

The pressure required in the boiler at the end of the transfer:

$= (3.973)(59.83)/(144)$

$= 1.65$ #/in^2 gage

$= 16.35$ #/in^2 absolute

4. CALCULATION OF THE TRANSFER TIME

The transfer time was determined by test.

Apparatus:

a. Two and one half quart pressure vessel
b. Sixty-four inches of one-half inch pipe
c. Pressure gage
d. Valve
e. Timer

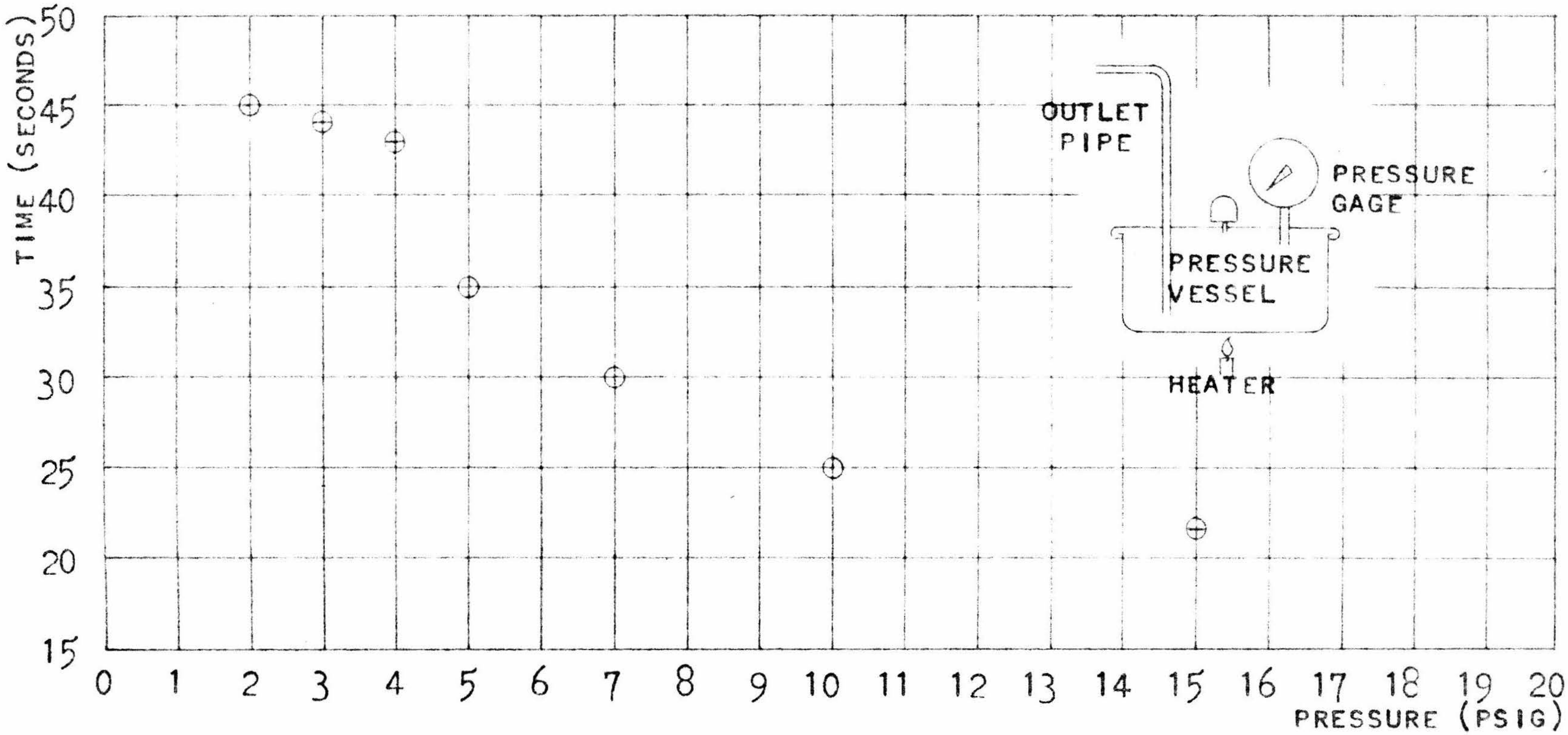


FIGURE 23 GRAPH OF PRESSURE VERSUS TIME

AND

DIAGRAM OF THE TESTING APPARATUS

Procedure:

Two quarts of water were placed in the vessel and the vessel sealed. Heat was applied to the vessel and removed at various pressures indicated on the pressure gage. At the same time, the valve was opened and the water in the vessel allowed to escape through the pipe. The amount of water that left the vessel was determined by the distance that the outlet pipe entrance was from the bottom of the vessel; this amount was one and one-half quarts. The time for removal was recorded and a graph of pressure versus time plotted. (Fig. 23)

Results:

The time required to remove the water when the valve was opened at five pounds per square inch gage was thirty five seconds. As the volume of the pressure vessel and the quantity of water used were proportional to the volume of the boiler and the quantity of water used in the coffee maker, the time of transfer for the test and the actual design were proportional:

$$T_a/Q_a = T_t/Q_t$$

$$T_a = (35)(12)/(1.5)$$

$$= 280 \text{ seconds}$$

$$= 4 \text{ minutes and } 40 \text{ seconds}$$

5. CALCULATION OF THE HEAT LOSS FROM THE BOILER

The overall heat transfer coefficient was calculated for both the area of the boiler wall in contact with steam and the area in contact with water. As the two coefficients were very close to the same value, less than one ten thousandth, a single value was used for the entire boiler area:

$$= .243 \text{ BTU/ft}^2\text{/hr/}^{\circ}\text{F}$$

The area of the boiler wall:

$$= (\pi)(D)(L)/(144) + (\pi)(D)^2(2)/(4)(144)$$

$$= (\pi)(10)(15)/(144) + (\pi)(10)^2(2)/(4)(144)$$

$$= 4.36 \text{ ft.}$$

The temperature outside of the boiler:

$$= 70\ ^{\circ}\text{F}$$

The temperature inside of the boiler:

$$= 212\ ^{\circ}\text{F}$$

The heat flow (Q):

$= (A)(U)(T_i - T_o)$
$= (4.36)(.243)(212 - 70)$
$= 150.5$ BTU/hr.

The watts required:

$= (Q)(1000)/(3413)$
$= (150.5)(1000)/(3413)$
$= 44.1$ watts

6. CALCULATION OF THE SIZE OF THE HEATING UNIT FOR THE BOILER

Weight of water to be heated:

$= (3)(8.33)$
$= 25$ #

Initial temperature of the water:

$= 60$ degrees F.

Final temperature of the water:

$= 212$ degrees F.

Enthalpy of the water at 60 degrees F:

$= 28.06$ BTU/#

Enthalpy of the water at 212 degrees F:

$= 180.7$ BTU/#

Enthalpy differential:

$= h_2 - h_1$
$= 180.7 - 28.06$
$= 152.64$ BTU/#

Heat required:

$= (\#)(h_2 - h_1)$
$= (25)(152.64)$
$= 3815$ BTU

Time allowed to heat the water:

$= 10$ minutes

Watts required:

$= (3815)(6)(1000)/(3413)$
$= 6710$ watts

Watts required to make up for heat loss:

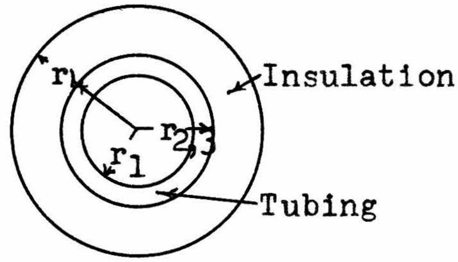
$= 44$ watts

Total watts required:

$= 6710 + 44$
$= 6754$ watts

Use a 7000 watt unit

7. CALCULATION OF HEAT LOSSES OCCURRING DURING THE TRANSFER



Tubing specifications:

Inside radius (r_1) = .25 inches
Outside radius (r_2) = .402 inches
Wall thickness = .152 inches
Length of tube = 20 inches
k_s = 300 BTU/hr/ft^2/^{o}F

Insulation specifications:

Inside radius (r_3) = .402 inches
Outside radius (r_4) = .902 inches
Wall thickness = .5 inches
k_i = .29 BTU/hr/ft^2/^{o}F

Temperature of the water at tube entrance:
= 212 degrees F

Velocity of the water in the tube:
= 4.88 ft/sec.

The Reynolds number:
= 67,800

The Prandtl number:
$= (c)(\mu)/(k)$
$= (1)(5)(10^{-9})(32.2)(3600)^2/(0.349)$
$= 5.98$

The Nusselt number:
$= (0.023)(N_{RE})^{.8}(N_{PR})^{.4}$
$= (0.023)(67800)^{.8}(5.98)^{.4}$
$= 178$

The film coefficient (h):
$= (N_{NU})(k)/(D)$
$= (178)(.349)(12)/(.5)$
$= 1490$ BTU/hr/ft^2/^{o}F

The overall heat transfer coefficient: (U):

$$= \frac{1}{1/h + (r_1/k_s)(\ln r_2/r_1) + (r_3/k_i)(\ln r_4/r_3)}$$

$= 2.06$ BTU/hr/ft^2/^{o}F

Rate of flow of the water:
= 1436 #/hr.

Area of the tube:

$= .218 \text{ ft}^2$

Since the heat transferred from the water is equal to that passing through the tube wall, the heat balance is:

$(W)(c)(\Delta t) = (U)(A)(\Delta T)_m$

The decrease in water temperature (Δt):

$= t_1 - t_2$

$= 212 - t_2$

The log mean temperature difference $(\Delta T)_m$:

$$= \frac{(\Delta t)_{max} - (\Delta t)_{min}}{\ln (\Delta t)_{max}/(\Delta t)_{min}}$$

$$= \frac{212 - t_2}{\ln (142)/(t_2 - 70)}$$

Substituting in the heat balance equation:

$$(212 - t_2)/(.000313) = \frac{212 - t_2}{\ln (142)/(t_2 - 70)}$$

Or: $\ln(142)/(t_2 - 70) = .000313$

The temperature at the end of transfer is:

$= 211\ {}^{o}F$

This temperature is satisfactory for brewing coffee

8. CALCULATION OF THE THICKNESS OF THE BOILER WALL

For a thin-walled cylinder: the stress is :

$= (p)(D)/(4)(t)$

The thickness is:

$= (p)(D)/(4)(S_L)$

Design stress for stainless steel:

$$= \frac{\text{Ultimate Strength}}{\text{Factor of Safety}}$$

$$= \frac{(70700)}{(4)}$$

$= 17670\ \#/\text{in}^2$

Pressure in the boiler:

$= 5\ \#/\text{in}^2$ gage

Diameter of the boiler:

$= 10$ inches

Thickness of boiler wall:

$= (5)(10)/(4)(17670)$

$= .000709$ inches

Therefore, 18 gage stainless steel will be sufficient.

19. CALCULATION OF THE SIZE HEATING ELEMENT FOR THE RESERVOIRS

Reservoir specifications:

Wall thickness (t_s) = .05 inches
k_s = 300 BTU/hr/ft^2/^{o}F
Area (A) = 2.715 ft^2

Insulation specifications:

Thickness (t_i) = 1 inch
k_i = .29 BTU/hr/ft^2/^{o}F

The heat transferred:

$$= \frac{(A)(T_1 - T_2)}{(t_s)/(k_s) + (t_i)/(k_i)}$$

$$\frac{(2.715)(165 - 70)}{(.05)/(12)(300) + (1)/(12)(.29)}$$

= 74.6 BTU/hr.

The watts required:

= (74.6)(1000)/(3413)
= 21.85 watts

Use a 50 watt unit

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