DESIGN OF A MULTIPURPOSE POLISHING MACHINE FOR DOMESTIC APPLICATIONS

Thesis by

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ABSTRACT

The design of a multipurpose polishing machine for domestic use was selected as the subject of this thesis in answer to an existing demand for such a device.

A study was made of the potential market, the consumer requirements and the competitive machines. A functional analysis of the proposed machine in conjunction with consideration of the possible methods of manufacture established the general form of the unit. Further refinement of the design from the standpoint of engineering and appearance defined the final form.

The proposed machine is composed of a universal series motor with geared drive to the disc or polishing head. Integral handles make the device suitable for portable applications and a detachable extension handle adapts it to floor polishing. Two speeds are available and power-driven accessories may be attached for various tool and buffing operations.

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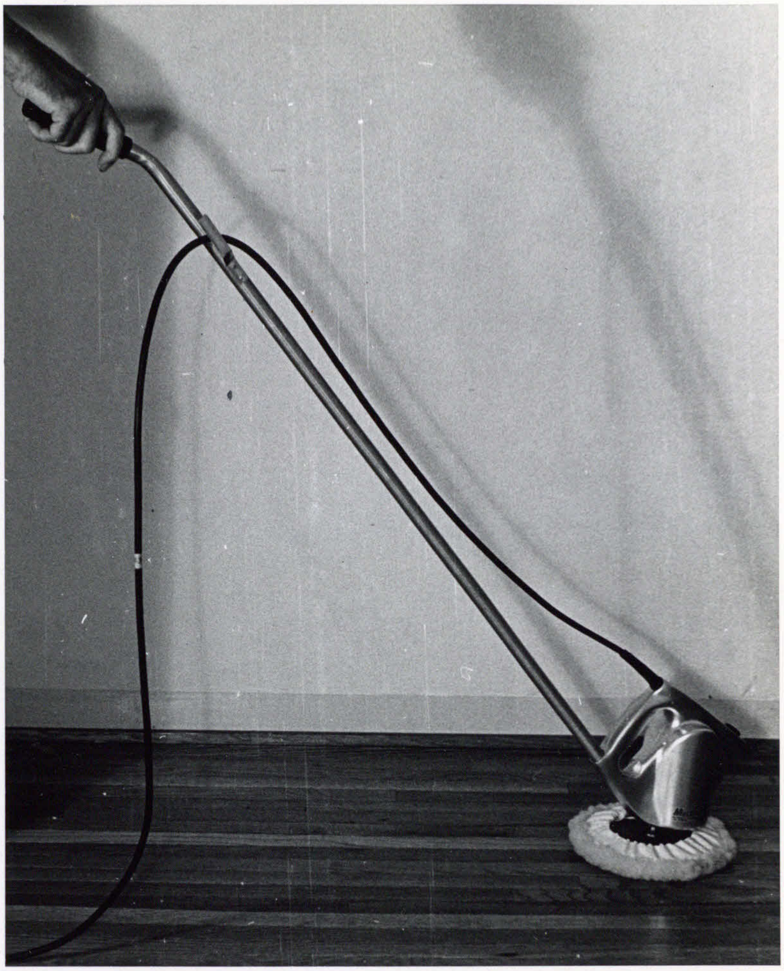

FIG. 1 PHOTOGRAPH OF COMPLETED POLISHER

DESCRIPTION OF FINAL DESIGN

MULTIBUFF, the polishing machine resulting from this study, is well adapted to use in the average household. It is extremely versatile in its applications and may be used for polishing floors, automobiles, furniture, shoes, for buffing silver and copper, and for home shop work such as sanding, wire brushing, light grinding, and other rotary tool operations. Two speeds are available rather than the single speed usually found in light polisher-sander units, and consequently this machine is better suited to the wide variety of tasks suggested for it.

The polisher is light in weight, being composed principally of aluminum, and thus is suitable for operation by the housewife. By removing the extension handle the unit can be stored in a very small space. The methods of production and the simplicity of the parts make it possible to manufacture and sell the polisher at a moderate price.

Essentially the polisher consists of a universal series motor in a die-cast aluminum housing which also contains the gearing and the control switch. This housing has two handles for use in portable operation and a socket for the extension handle. The two secondary gear shafts are hollow to receive the shank of the buffer head, making it possible to select either of the two speeds. Accessory arbors can also be inserted into either of the drive sockets.

With the basic motor unit would be included a buffer head and the extension handle. Other accessories, such as a bracket designed to be mounted permanently on a bench or wall and onto which the motor unit can be placed for buffing operations, would be optional.

INTRODUCTION

In selecting the subject of the thesis it was considered that the item to be designed should have certain characteristics in order to afford valuable design experience and to permit a complete and satisfactory solution within the time allowed and with the facilities available. The device should be suitable for volume production, should have a wide appeal and market, should be used by persons who could be contacted locally for research purposes, should permit new developmental work somewhat limited in scope so as to not involve lengthy testing and research, and should be a reasonably small unit so that development could be carried to the stage of a working model.

Small household appliances seemed to meet most of these requirements but an examination of these appliances indicated that the majority of them have been quite completely covered by producers now in the field.

The study did show a need for a polishing machine fairly low in cost and flexible enough in its applications to permit sufficient use to make it economically feasible for the average home. The polishers now on the market are limited in use to either portable or floor applications but not both (except for one model which proved to be too heavy and expensive to consider), although both needs occur in the home. A single unit combining both uses is a logical development.

There are some other polishing tasks in the home which might also be lightened by such a unit.

The machine would probably be made by a producer of electric hand tools and the materials and processes usually employed by such manufacturers were considered in the design. Since no commitment had been made to any particular manufacturer, however, the choice was not unduly limited in this respect.

MARKET ANALYSIS

The importance of adequate research into all phases of the marketing problem has yet to be realized by many manufacturers. Production costs may be known to a fraction of a cent but marketing costs and prospects are the subject of guesses (1)*.

Market research can provide management with valuable information, but certain limitations have to be recognized. The factors studied are dynamic in nature, there is always an appreciable time lag between inception and completion of the study, and personnel may be inadequate. Cognizance of these limitations prevents the reading of too much into the results of such research while assisting management in the formulation of adequate policy decisions (2).

Market research is properly initiated prior to the design of a product and continues on through the selling of the finished item. Its first objective is to discover what the facts are about the potential customers. Then these facts can be interpreted to determine their effects on peoples desires and needs so that the product can be designed and engineered to appeal to the greatest number of people (3).

The appeal of the polisher proposed in this thesis is not particularly subject to geographical limits, but it is influenced by other factors

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*Numerals in parentheses refer to references in appendix.

such as the number of family units, automobile and home ownership, the cost of living, and the like.

Market Potential

The number of family units has grown 12 per cent since 1940, a net increase of 6 million units, while population increased 9 per cent (1,4)(See Fig. 2). This is particularly significant for markets of items, such as the proposed polisher, which are purchased primarily for and by the family (1).

While national income has increased about 40 per cent since 1940, by 1947 money available for "discretionary spending" had increased by about 160 per cent (1). Estimates for 1948 show an even further increase in this surplus over and above the basic cost of living (5). The recent cut in the Federal income taxes will add to this reservoir of buying power to the extent of some 4 to 6 billions of dollars for the year.

Great changes in the distribution of incomes have occurred in the past decade. The number of family units in the ranges below $2000 per year has dropped from 64.5 per cent of the total in 1941 to only 40 per cent in 1947. The number of units with incomes over $3000 has more than doubled in the same period (1,5)(See Fig. 3), an expansion of the potential market since the polisher is a luxury item with the bulk of sales to higher income groups.

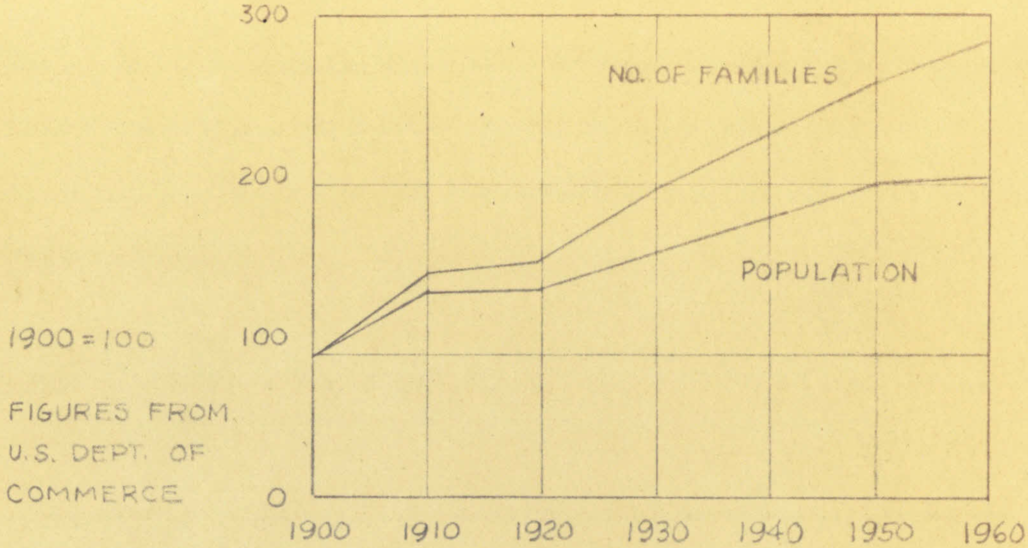

FIG. 2 POPULATION AND FAMILY TRENDS
(FROM REFERENCE 3)

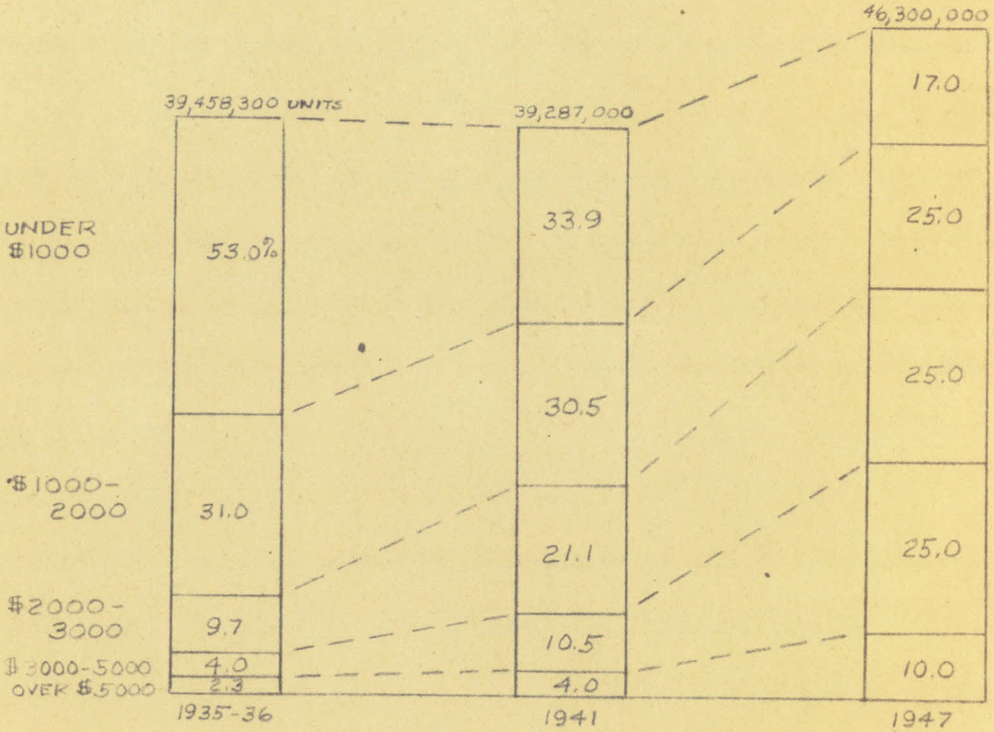

FIG. 3 DISTRIBUTION OF INCOMES
(FROM REFERENCE 5)

FIGS. 2-3
POPULATION AND INCOMES
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Women are especially influential in the purchase of electrical appliances in general (6), but the appeal of the proposed polisher would possibly be greater for the husband since he is likely to be a frequent user.

Distribution Channel Considerations

Certain characteristics of the existing market channels influence the design of the unit (1). Approximately 60 per cent of the appliance trade is through wholesalers and jobbers (7,8). Electrical household appliances are usually distributed through wholesale channels separate and distinct from those for tools and hardware.

The proposed machine is designed primarily for home use and thus would fall into the general line of household appliances. However, in view of the general purpose nature of the device, it is likely that distribution should be carried out through electrical tool channels also.

Some of the waxers now on the market are distributed directly to the retailers by wax manufacturers as one of the regular items of their line. In such cases the machines are usually manufactured by an outside vendor and the wax company in effect is the wholesale agent.

Since average wholesale and retail markups in the appliance field total to at least 50 per cent of the retail price (8) and are more probably in the nature of 60 per cent, the design must be produced at a cost low enough to allow the manufacturer a profit on this basis.

Market Conclusions

The prospects in 1948 and the near future for sales of items of a household nature appear to be good. As housing becomes available, many recently formed families will be in the market for appliances. The percentage of families in high income brackets has increased, and money available for discretionary spending is high in spite of increased living costs.

The estimate of first year sales of the polisher, 12,500 units, is based on the following analysis. Of the 46,000,000 family units in the U. S., about 25 per cent are in income groups below \$1000 and are not in the market. Home owners (the most likely prospects) make up about another 25 per cent of the total, and few, if any, of this group fall in the under \$1000 income classification. Of the automobiles now registered (37,000,000) an estimated 5 per cent are owned by persons outside of family units. The consumer survey (89 answers) indicated that over 1/3 of the persons interviewed had considered buying a polisher but had not done so because of cost and/or limited use. Including 1/3 of the family units with incomes over $1000 and 5 per cent of the automobile owners as interested in purchasing, the total potential market for polishers is about 13,000,000 units. About 2 per cent of the persons interviewed in the survey owned polishers, indicating an annual replacement market of some 23,000 units (assuming a 10 year unit life and that the persons interviewed were typical of the over $1000 group).

Using this information as a basis, it is estimated that in competition with present devices the proposed polisher could be sold to 1/10 of 1 per cent of the prospective purchasers in the first year (presupposing national distribution by an established manufacturer, but not necessarily one in the polisher field at present). The low cost and increased utility of the polisher will appeal to the large group of interested family units not now owning polishers.

The proposed polisher must be produced profitably for about 40 per cent of the retail price (which should be approximately $40 to compete with existing devices), and it should be distributed through both household appliance and hardware wholesalers and jobbers.

PRODUCT STUDY

An investigation of the waxers and polishers now on the market revaled that there is nothing comparable to the multipurpose unit proposed herein. There are portable polishers in a wide range of sizes and there are floor machines of a variety of types and sizes but no true combination of the two*.

One floor machine, the Holt model HST 12, could be equipped with special handles at extra cost, and when so equipped was claimed to be suitable for portable applications. Since the floor version weighs 16 pounds, it is likely that the machine would weigh at least 12 pounds with the hand grips and would be much too heavy for the housewife to handle. The cost of the unit is $97 and the special handles amount to $15 more, a total investment much in excess of that required for the average machine and of the amount indicated as a reasonable price by the consumer study.

Of the portable polishers currently available only two are in the domestic class, the Clarke-Duo and Sears Craftsman. The first is a very light (4 pounds) single speed machine claimed to be suitable for both buffing and sanding. The 5'' disc is somewhat small to accomplish work at a reasonable rate and makes it difficult to achieve good results on a large flat surface. Compared to the speeds used

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*See Product Study chart, page 53, appendix

in commercial machines the 3000 rpm loaded speed is slow for sanding and fast for polishing. The Sears machine is about the right size (6") and weight (6 pounds) for home use, although the shape of the handle is such that it results in an uncomfortable twisted wrist position. Again the claim is made that the machine is suitable for both sanding and polishing. The single speed is about right for buffing, hence compared to usual practice is too slow for good sanding. The price on this machine is $41.95, comparable with the Clarke-Duo at $36.50. Both of these machines sell well and under present market conditions supply is about keeping up with demand.

The other portable machines examined were all of the commercial type, considerably too expensive and heavy for home use, but of value in determining desirable characteristics to be included in the proposed design.

Three of the floor polishers investigated were designed primarily for domestic applications. Of these the Clarke and the Johnson are quite similar. An apparent discrepancy in speeds is the result of a difference in motors. The loaded speeds are nearly the same, 1750 rpm for the Clarke and 1450 rpm for the Johnson. In use the drum brush rotates away from the operator and tends to pull the machine across the floor. Although the price is not much greater than that of the light portable polishers, the floor machines are inclined to be slow moving on the market. The general opinion of consumers seems to be that floor machines are too limited in use. In contrast, the portable machines suggest a number of uses, even though the likelihood of their being used in many of the advertised ways is slim.

The third machine examined in the home use classification was the Regina. It is considerably heavier and more expensive than the other two. The use of counterrotating disc brushes overcomes the objectionable riding characteristic of the Clarke and the Johnson but at a cost which seems to place it out of their class.

Other floor machines investigated were the Holt drum polisher model HDT 8 and the Holt twin disc model HST 12. The former is comparable to the Clarke and Johnson in size and weight but more expensive, about $70 retail price. The HST 12 is very much like the Regina although heavier, and it is aimed at the double market of homes and small businesses. Both of the Holt machines are considered to be too costly for home use in view of the availability of satisfactory machines at lower cost.

CONSUMER SURVEY

A consumer study was undertaken to determine the desires and needs of the users of polishing machines. Information was desired concerning attitudes of various income groups toward polishers, the usual intervals of time between waxings of cars and floors, influence of home ownership on upkeep of floors, extent of home waxing of autos, ownership of waxers, consumer experiences with rented machines, and consumer suggestions as to household polishing tasks other than floors, autos, and furniture.

A questionnaire* was prepared and given to a number of individuals for answering. An attempt was made to assure a fair sampling, although primary emphasis was placed on higher income groups (the polisher being an appliance of interest primarily to those groups). So as to achieve a wide coverage, a number of the questionnaires were sent by mail to persons selected at random from the telephone directories of several widely scattered cities. While mail returns (22 answers) were evaluated and used as a checking device, more significance has been placed upon 67 answers obtained through personal interviews. The question of validity of mail questionnaires has been investigated by Brooks (9) and it was determined that people who reply tend to be an upper income, better educated sample of the population than a true cross section. For the present study this was no handicap.

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*Copy on page 54 in appendix.

The total number of interviews made and questionnaires returned was not sufficient to obtain truly significant answers to the questions posed, but a few trends were indicated.

Of the 89 persons answering, some 5 per cent had incomes under $2000, 30 per cent were in the range of $2000 to $4000, 55 per cent had incomes of $4000 to $6000, and 10 per cent were over $6000. As indicated by Johnson (5) a true cross section of the U. S. income picture would show a distribution of about 40, 43, 10, and 7 per cent in the four groups. The results are definitely weighted toward the higher income groups but not to the detriment of the report. Those answers by persons with under $2000 income showed a complete lack of interest in polishing machines.

No significant average was found for the interval between floor waxings, since the answers varied from once a month to once a year. However, the results indicated that home owners do tend to wax the floors oftener than do non-owners and would be likelier prospects for the purchase of a floor polishing machine.

The houses of higher income groups (nearly all occupant owned) usually have a larger area of hardwood floor and this probably influences the number of waxings per year. The larger expanse of floor area may direct attention to the need for upkeep, whereas the owner of a house with a small hardwood floor area may feel the bother is more than the worth.

The car owners contacted wax their cars on the average once or twice a year and usually do the job themselves by hand. They have had little experience with rented machines, have not considered buying one, but think about \$10 to \$15 would be a fair price.

Very few of the persons questioned owned floor waxers. 40 per cent of them had considered buying machines, but they had usually decided that the relatively large investment required as compared to the limited use to which the machines could be put made the waxers too expensive. They thought a household floor machine should sell for about \$20.

Experience with rental floor machines was indicated by about 50 per cent of the answerers, rentals varying from \$1 to \$7 a day. Since most of the rentals were in the \$1 to \$3 range, the higher rates have been interpreted to mean floor sanders and commercial heavy-duty machines. Assuming an average rental of \$2 per day and a use interval of 3 months, a polisher selling for about \$40 would pay for itself in a life of 6 to 7 years.

The most commonly suggested uses for the machine other than for polishing autos, floors, and furniture were shining shoes, buffing silver and copper, and sanding.

In summary, the conclusions reached as a result of this survey are:

1. Income groups below $2000 are not in the market.
2. Autos are usually waxed once or twice a year and floors at intervals varying from monthly to yearly.
3. Home owners are apt to wax oftener than renters and thus are more likely prospects for sales.
4. 90 per cent of the waxing of cars is done by the owners.
5. Only about 2 per cent of the householders own floor waxers and less than 1 per cent of the auto owners have polishers.
6. About 50 per cent of the householders have used rental floor machines and less than 5 per cent of the car owners have rented portable polishers.

PRELIMINARY DESIGN CONSIDERATIONS

Ideal Solution

The ideal solution to the polishing probelm might be to use "self-polishing" waxes. Actually there is no such thing at present, the so-called self-polishing floor waxes consisting merely of a very light coat of soft wax which is buffed by the movements of individuals and objects over the floor after the wax has dried. Harder, more durable waxes can be polished only by the application of pressure and friction.

Assuming that some sort of machine is desirable for buffing household waxes, advantageous characteristics for the device can be set up. Since the unit will be used as a portable polisher it should be light in weight. However, its effectiveness as a polisher is a function of the pressure, and too light a weight would mean that the operator would have to apply pressure in using the device.

The cost of the unit must be kept low, the principle objection to the present waxers being that they are too expensive. The proposed combination of portable and floor uses into one unit increases the value of the machine over the present waxers and is in effect a decrease in cost. The consumer study indicated that a price of about \$30 to \$35 would be approximately right, but such a price is about 30 per cent lower than the lowest priced floor machines now on the market and would be difficult to attain.

The polisher must require a minimum of maintenance. Household appliances take a beating from neglect and from operator ignorance of machine care. Operating parts must be self-lubricated as completely as possible. It should be finished so as to retain a satisfactory appearance throughout its expected life.

An ever present problem in most modern houses is the shortage of storage space. The unit needs to be compact and convenient for storage.

The ideal unit would not creep over the floor. Many of the present machines of the drum type tend to pull out of the operator's hand, and the single disc type have a tendency to turn in a large circle. The twin disc machines solve this problem satisfactorily.

Finally, the ideal machine would be versatile in use. It could be adapted to do all of the household tasks that can be accomplished by rotary tools, such as polishing all types of waxed surfaces (autos, floors, furniture, and shoes), buffing silverware and copper, sanding jobs of all sorts, wire brushing, light grinding operations, and even home shop work such as drilling holes.

From a practical standpoint it is possible to attain a suitable weight, to eliminate creeping, to minimize storage space required, and to make a large variety of attachments capable of doing a multitude of tasks. To reduce the price to $30 or $35 is something else again under present costs. A 1/5 Hp motor alone retails for about $20. To achieve the other four goals it would be necessary to ignore costs and the result would be a unit priced right out of the market, and therefore certain compromises are indicated.

Modified Solutions

As regards the weight requirement, no compromise is necessary. Costs of using any of the common materials are nearly enough the same to give primary importance to other aspects of the materials problem. Choice of materials is fully covered under the engineering discussion of the various parts of the unit.

To eliminate creeping it would be necessary to use some form of counterrotating buffers. This has been done with twin side-by-side discs on several machines now on the market. Invariably it results in higher costs due to the more complicated power transmission involved. Using twin drums driven by a double ended motor would accomplish the desired effect (fig. 4). This arrangement introduces a necessity for gears or crossed belts to achieve the counterrotation of the second drum, the former expensive and the

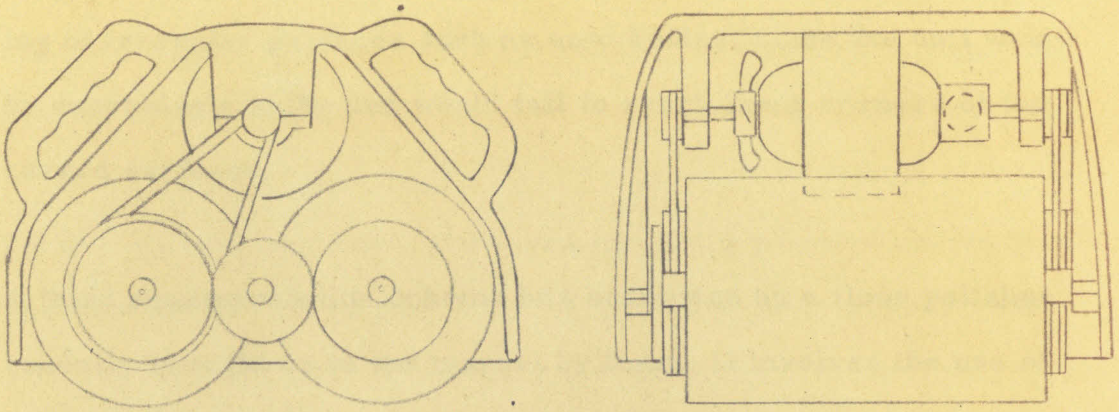

FIG. 4 DOUBLE DRUM POLISHER

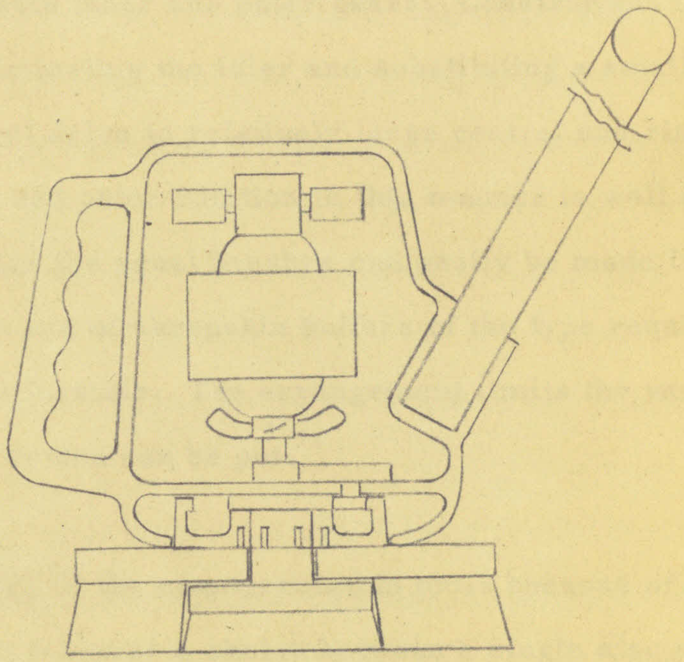

FIG. 5 COUNTERROTATING CONCENTRIC DISC UNIT

FIGS. 4-5
DRUM AND DISC UNITS

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latter conducive to excessive wear. While most satisfactory for floor use, such a machine would not be suitable for portable polishing of irregular surfaces such as auto bodies, since the unit would be excessively bulky and would fail to reach inner corners of the curved surfaces.

A third counterrotation scheme has been used on a floor polisher recently brought on to the market by Kent. It involves the use of a ring brush moving in one direction with a center brush rotating oppositely. This could be adapted to a portable by an arrangement such as is indicated in Fig. 5, using an idler gear as a fixed planet driving movable inner and outer gears. Construction could be simplified by eliminating the idler and substituting a small motor pinion with direct drive to relatively large central and ring gears. Use of inner and outer rotation in this manner is well suited to floor use since the usual brushes can easily be made in this form. However, the use of sheepskin buffers of the type required for fine buffing is not feasible. The arrangement limits the variety of uses to which the device can be put.

Eliminating all of the counterrotation units because of bulk, cost, and limited use leaves a choice between a single disc and a single drum. Of the two, the single disc is the more desirable. It has a less objectionable form of creep, one more easily correctable by design of the handle and by proper operation. The disc is also more suitable for portable use. Some speed reduction would be necessary, and the most economical and compact arrangement would be to mount the motor vertically over the disc and connect the two by gearing such as is indicated in Fig. 6.

From a storage angle this arrangement would be quite satisfactory. Removal of the long handle would permit storage on a shelf. The machine might be kept on a bracket in the home shop or utility room ready for miscellaneous buffing operations and removed only when needed for floors or portable use.

A single disc could be operated by a long flexible shaft rather than by a directly connected motor. This might have some definite advantages in general portable use, but it is not suitable for polishing applications. Extra pressure would have to be applied by the operator and the flexible shaft would have to be excessively long to allow coverage of an adequate area. Since the arrangement would be especially unsuited to floor use it has not been considered further.

Inclusion of a large number of attachments to the device for accomplishing various jobs would be objectionable from a cost standpoint. It is proposed that the basic unit cost be kept as low as possible and that purchase of attachments be made optional. By providing a drive socket in each of the reduction steps of the gear train it is possible to obtain two speeds for operation of attachments. Polishing and

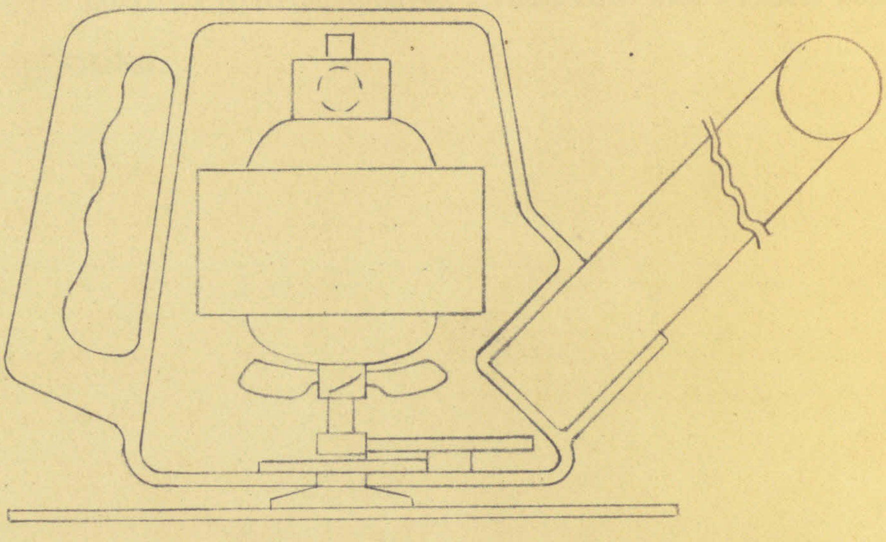

FIG. 6
SINGLE DISC UNIT

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and buffing would be at thelower speed and sanding at the high speed. With the basic motor unit would be included the disc and the extension handle. Optional attachments could include an arbor for grinding wheels and wire brushes, a chuck for other jobs such as drilling, and a simple bracket suitable for attaching to a wall or table and on which the motor could be mounted for buffing. (Fig. 7)

Essentially the unit will be as shown in Fig. 6. Details of construction and design are considered element by element in the sections of this report entitled ENGINEERING ANALYSIS and FINAL DESIGN CONSIDERATIONS.

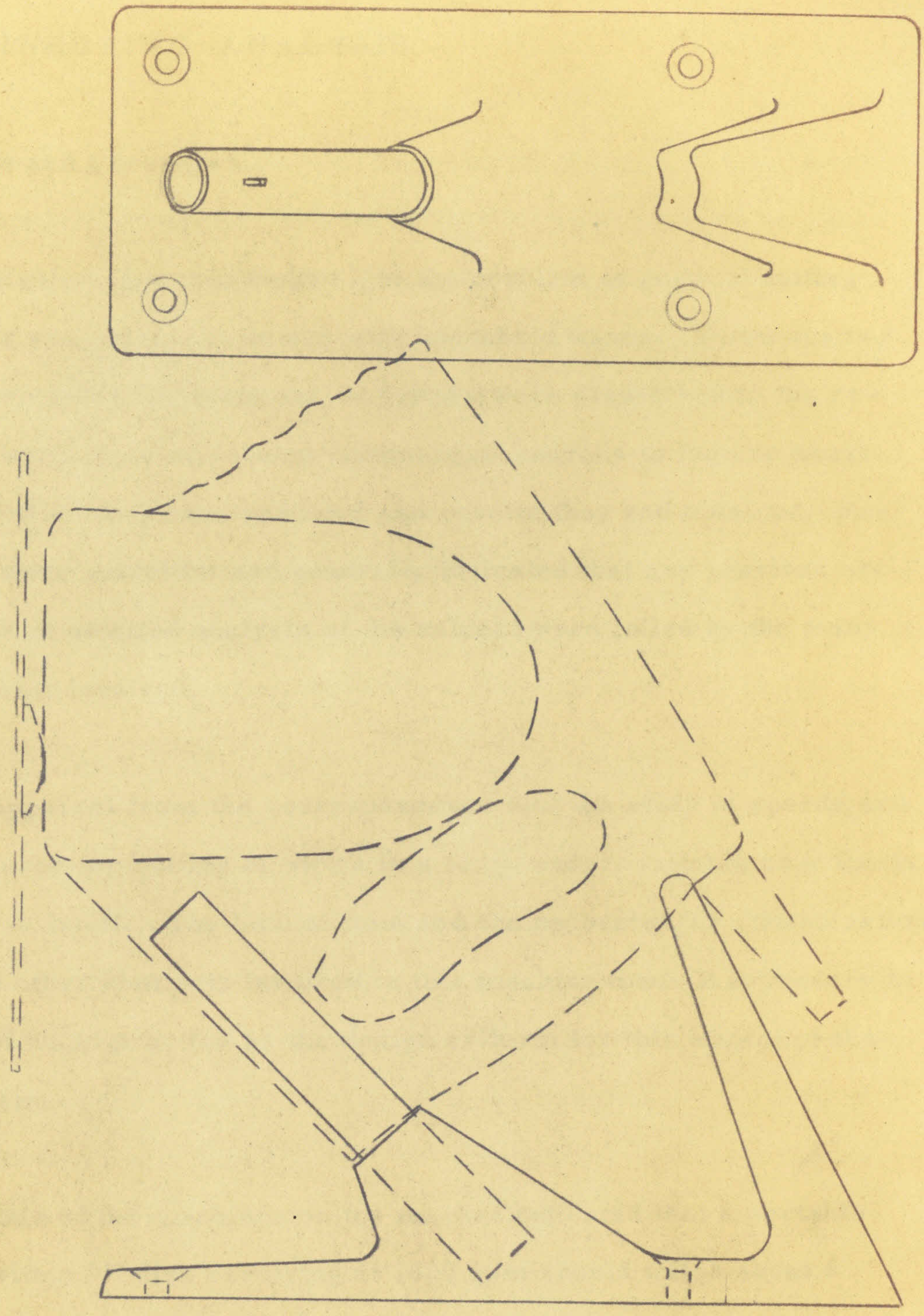

FIG. 7
BRACKET

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ENGINEERING ANALYSIS

Speeds and Pressures

Investigation was undertaken into the problem of correct buffing speeds and pressures to use with household waxes. There seemed to be no published material, so letters were dispatched to the research divisions of several commercial sources to inquire about any studies they had conducted and results they had obtained. Replies were unfruitful and generally indicated that any previous attempts at detailed analysis of the subject were foiled by the many variables involved.

It is apparent from the correspondence that the study of speeds and pressures for buffing of waxes is a large order, suitable as a thesis study in itself. The lack of time and the necessity for consideration of the other elements involved in this machine made it necessary to accept usual practice as the design criteria for this aspect of the problem.

Analysis of the machines on the market indicated that a portable unit with a 7'' disc revolving at 1800 rpm should weigh about 6 pounds if most of the weight were centered over the disc.

Motor

The motor for use in this polisher must meet certain requirements due to the operating conditions. It has to be light weight, small, cool in operation, and operable under conditions of varying load. It need not have a constant speed, high starting torque, nor be suitable for continuous duty.

The universal series motor most nearly meets these requirements and is used in most portable tool applications. For a given size and weight it develops more torque than any other type, has a high starting torque, hence reaches speed in a short time, and is fairly low in cost (10)*.

Series universal motors are built in two general types, salient pole non-compensated, and distributed wound compensated. Large series motors have a high armature reactance and compensating or distributed windings are necessary to improve the power factor and commutation characteristics. In small motors, however, the number of armature turns is small enough so that satisfactory operation may be secured without resorting to compensation (10).

Assuming proper design then, the non-compensated motor has been selected for this application in view of its simplicity of construction

*Performance chart of typical series motor, page 56, appendix and ease of ventilation. Since series motors are seldom used for continuous operation and the duty cycle is determined by the allowable temperature rise in the unit, ventilation improves the duty cycle for a given motor. For the usual series motor the duty cycle should not exceed one hour, although special heavy duty motors are available. For polisher duty it is unlikely that the unit will be used for periods as long as one hour continuously, and a normal duty motor has been specified with adequate provision made for ventilation.

An examination of 7'' disc polishers now on the market indicated that a 1/5 HP motor is adequate for this size unit.

Bearings

An analysis of the radial and thrust loads on the bearings by the sliding action of the gear teeth and the pressure on the disc reveals that the loads are variable under polishing conditions. Assuming a pressure of 10 pounds at the edge of the disc and a bearing length of 5/8'', the maximum load per square inch of projected bearing area was calculated to be 71 pounds*. This is below the range usually allowed for ordinary sleeve bearings with fluid lubrication. In view of the necessity for keeping costs low and for reasons of self-lubrication, bearings of the oilite type have been selected. Bearing lengths conform to usual practice of a length-diameter ratio of between one and two.

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*See appendix, page 62

Gears

The requirements of limited size and weight make it necessary to use a high speed motor in the polisher. Since polishing is accomplished at rather low speeds (about 1800 rpm for a 7'' disc) some means of speed reduction must be employed. For reasons of limited size and weight many of the possible reduction devices are eliminated and some form of gearing is indicated. The total reduction required is about 6 to 1, and to obtain an intermediate speed of about 4500 rpm for sanding applications, a double reduction with equal steps of $2\frac{1}{2}$ to 1 in each step was provided.

With parallel shafts it would be possible to use either spur gears or helical gears. The latter have certain definite advantages of silence, smoothness in operation, long life, and high operating efficiency, but they introduce end thrust and are more expensive than spur gears (11). In this application helical gears are ruled out by cost. Spur gears are inclined to be noisy, but the cost advantage outweighs the noise nuisance.

Noise in the spur gearing could be minimized by using non-metallic intermediate gears. The lower strength of the material would necessitate a wider gear face. In the proposed polisher the principal disadvantage of using non-metallic gears is that to do so precludes the use of die-cast drive spindles with the gears cast integrally, hence increased cost and difficulty of manufacture results. The consumer is accustomed to noise associated with high speed motors such as in vacuum cleaners and portable electric drills and would be inclined to accept the noise of the polisher as normal. The gearing can be completely enclosed so as to reduce the noise to a minimum.

The standard $14\frac{1}{2}$ degree involute gear system is based on a 12-tooth pinion as the smallest that will give satisfactory tooth action (12). The available space in the polisher limits the motor pinion to $\frac{1}{2}$'' pitch diameter, so a diametral pitch of 24 is required. The first reduction gear is two step, the motor pinion engaging a 30-tooth wheel while the smaller 24-tooth step drives the final 60-tooth gear. The total reduction is thus 6-1/4 to 1. An analysis of the stresses on the teeth of the motor pinion revealed that a standard face of 1/4'' is adequate*.

The spur gears could be produced by cutting or die casting. The cutting processes are costly, especially in the case of the two step gear, which would have to be made in two parts, and the teeth of most forms of gears can be die cast within close limits and require little or no machining (13). For economy and ease of manufacture, die casting of the gears integral with the drive spindles is specified. It is proposed to use aluminum bronze for the die castings. S.A.E. 68 is suggested because of its favorable strength and good wearing qualities in addition to its comparative ease of fabrication (14).

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*See appendix, page 58

Motor Housing

Of primary importance in the selection of the material to be used for the housing is the finish required. The machine will be used where scratching of the surface is likely to result, and the use of paint or any other applied surface coating is not desirable. Hard plating might be suitable except for cost. Of the materials adaptable to shaping into a motor housing by stamping or casting, only aluminum meets the two requirements of moderate cost and suitable natural finish. Steel and magnesium suffer from continued corrosion of the unprotected surface. Zinc die-castings in the natural finish corrode to an undesirable appearance, and the brasses are too costly.

Parts for the motor housing could be made from assembled stampings. The necessity for the use of several inner pieces to support the elements of the mechanism and the limited shapes possible (without resorting to an excessive number of parts) work to the disadvantage of the stamped case. Die cost for stampings is likely to be greater than for a die casting due to the greater number of dies required (15). Basic material costs may also be greater than for casting because of scrap waste. Stamped parts may generally be made lighter, however, than cast parts of the same strength.

Cast housings could be made in sand molds, permanent molds, or in pressure dies. Sand castings require thicker sections, are limited as to coring possibilities, need more machining and finishing, are low in rate of production, and are not suitable for use with inserts. They usually have an advantage over the other types of castings in cost, especially in small runs (although excessive machining can offset the savings).

Permanent molds are usually cast of alloy iron and cost less than equivalent dies, perhaps 1/2 to 1/3 as much (15). In large runs the labor involved in permanent molding may offset the initial die savings, and production rate is much lower than for die castings. Thicker sections are required and more machining and finishing are likely to be necessary than for die castings.

On the basis of a die amortization run of 25,000 units, die casting has been specified for forming the motor housing. The use of pressure die casting makes it possible to reduce machining to a minimum and the length of run is well within the usual range of die life for aluminum casting. Aluminum alloy S.A.E. 309 is used since it is well suited to polishing (14).

Finishing can be accomplished by brushing or polishing. Simple polishing is recommended, buffing and coloring operations being usually sufficient for die castings (16). The form of the motor housing has been kept clean to minimize polishing time and effort.

Motor Control

Since no necessity exists for variable speeds in the polisher, the motor control is simply an on-off switch. Portable polishers generally are controlled by a trigger-type switch which may operate only as long as the trigger is held closed, or which may be a sequence switch, one press for on and a second for off. Floor machines are equipped with a handle-mounted toggle on-off switch in most cases.

In the proposed design, the requirements for use as a floor machine make the use of a trigger switch inconvenient. So as to provide ease of switching while in portable use, a toggle switch located on the housing would have to be near enough to the grips to allow the operator to work it without removing his hand from the grip. A push button sequence switch of the type used on some tank-type vacuum cleaners could be located on top of the hand grip so as to be convenient to be operated by the thumb, and in this position it could also be easily operated while the unit is in use as a floor machine.

It would be possible to use a switch mounted on the cord some distance from the housing. The cord could be clipped to the extension handle when the unit is used for floors, and the switch would then be in a convenient position. Such an arrangement would be poor for portable operations since the switch would then be difficult to reach and would be likely to strike the surface being polished.

By using separate switches on the handle and on the housing and wiring the two in parallel through a pair of contacts at the base of the handle, the advantages of the trigger switch for portable use could be obtained while having a convenient handle-mounted toggle switch for floor use. This method has a big disadvantage of cost, since it involves two switches, a special pair of contracts for the handle, and considerable wiring.

In view of the convenience of the push button switch located on the top of the grip, and its relatively low cost (not the lowest since the switch itself is more expensive than the toggle), this type of switch has been selected for the unit. Fig. 8 shows the details of the switch installation.

Extension Handle

In designing the handle to be used with the machine while polishing floors, the most important requirement is that the handle be of such a shape as to provide the operator with leverage to resist the torque of the machine. This can be accomplished with a horizontal grip but requires a long grip to allow good spacing of the hands.

The use of a "T" shaped grip (Fig. 9) introduces some serious problems of manufacture, strength, and cost. A molded plastic grip would require rather expensive inserts of brass to reinforce the

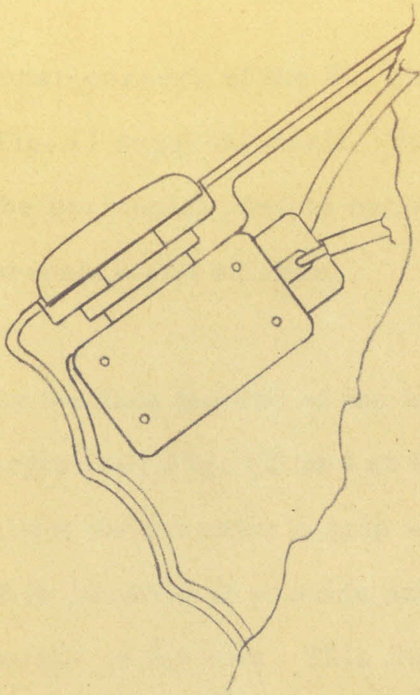

FIG. 8 MOTOR SWITCH

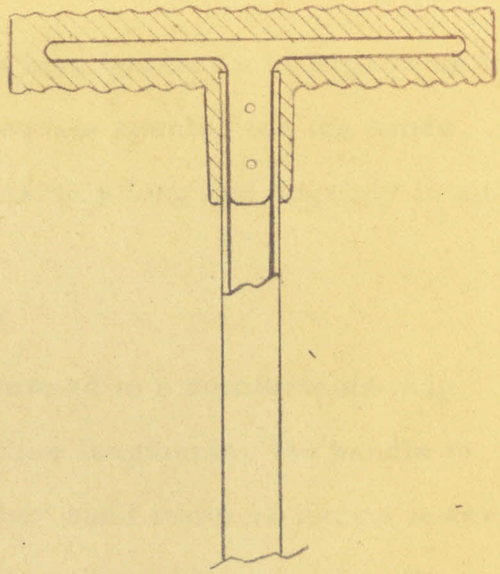

FIG. 9 "T" GRIP

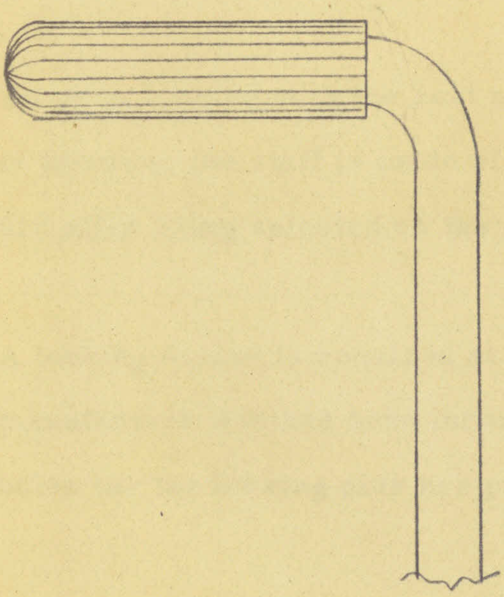

FIG. 10 BENT HANDLE

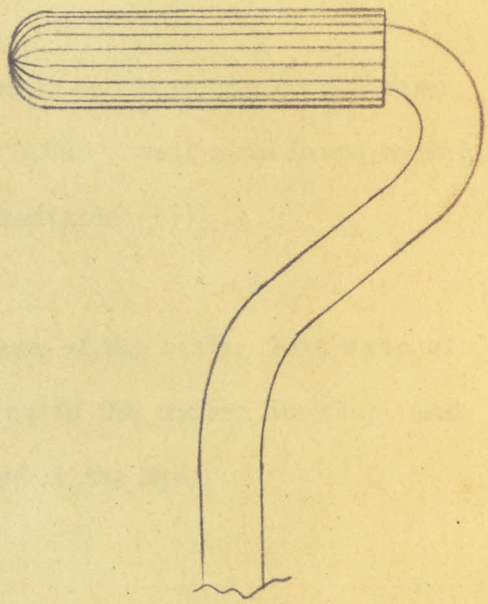

FIG. 11 IMPROVED HANDLE

FIGS. 8-11
SWITCH AND HANDLE

R. BRINKMAN APR. 27, 1948

inner corners of the T. The use of a bent handle as in Fig. 10 or in Fig. 11 suggests itself. To allow adequate spacing for the hands, the horizontal portion becomes excessively long and ungainly in appearance and balance.

By bending the end of the handle downward to a comfortable grip angle (see Fig. 12) and at the same time lengthening the handle to allow the operator a grip with the other hand some 12 inches lower, it is possible to provide adequate and comfortable control of the torque of the unit. This form of handle can be equipped with a simple molded grip and will be low in cost and easy to assemble. It is standard practice on floor type vacuum cleaners.

To be in keeping with the rest of the unit and because of the ease of forming, the staff is made of 3/4'' 0.035'' wall aluminum tubing, 61S alloy being selected as the most suitable (17).

A locking device is required at the base of the staff. For ease of manufacture this has been incorporated in the motor housing, and holes for the locking pins are provided in the staff.

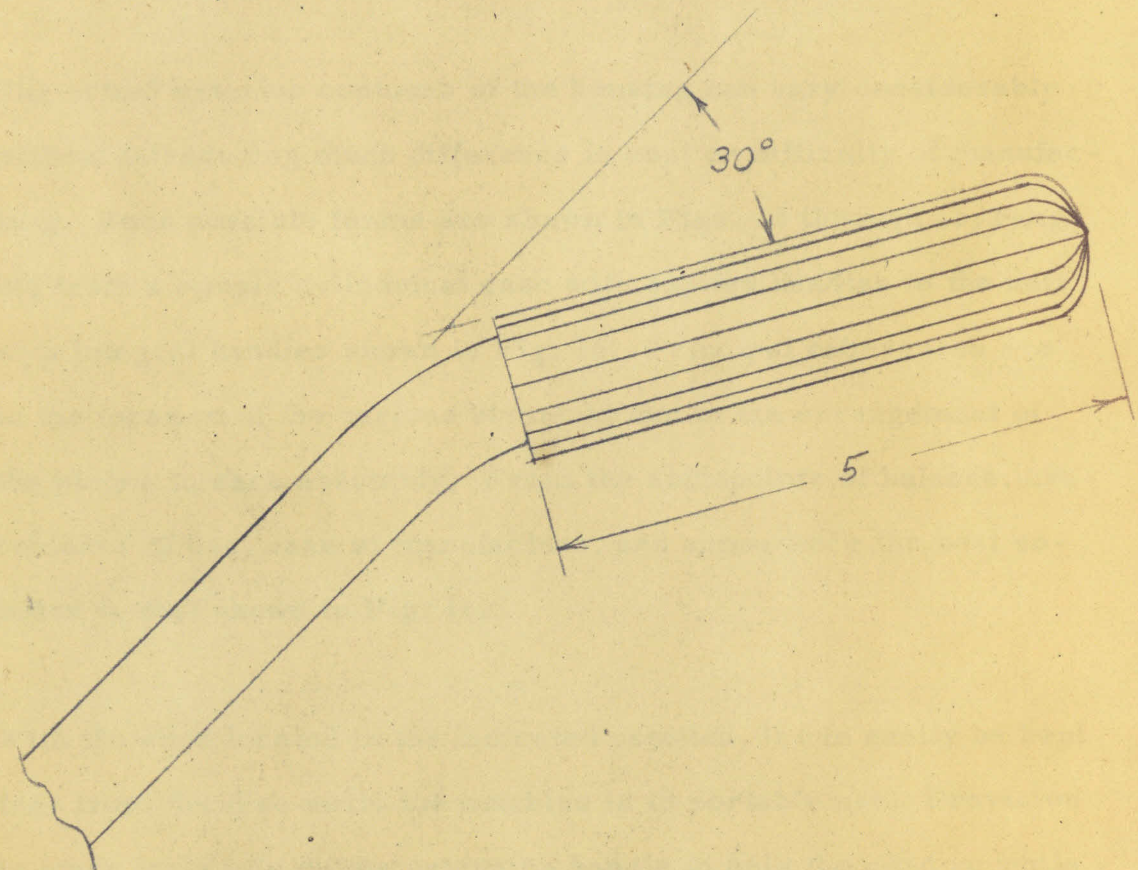

FIG. 12
SELECTED HANDLE DESIGN
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FINAL DESIGN CONSIDERATIONS

An analysis of the motor housing reveals that it must be made in more than one part. To provide a hollow handle and for ease of casting, it is advisable to form the body in two halves split vertically front and back. For assembly reasons it is desirable to have all interior parts fasten to one half while the other serves only as a cover.

The actual exterior contours of the housing can vary considerably without introducing much difference in cost or difficulty of manufacture. Four possible forms are shown in Figs. 13 through 16, ranging from a simple cylindrical case with applied handles to the unit with integral handles shown in Fig. 16. Principal differences are in the location of the various elements and in the arrangement of the pieces in each assembly. From the standpoints of balance, convenience of use, ease of manufacture, and appearance the best solution is that shown in Fig. 16.

With the cord located in the indicated position, it can easily be kept free from the disc while the machine is in portable use. Provision is made for a clip on the extension handle to hold the cord up while polishing floors. At the housing, the cord is provided with a reinforcing sleeve to serve the dual purpose of strengthening the cord at that point and to hold the cord free from the housing.

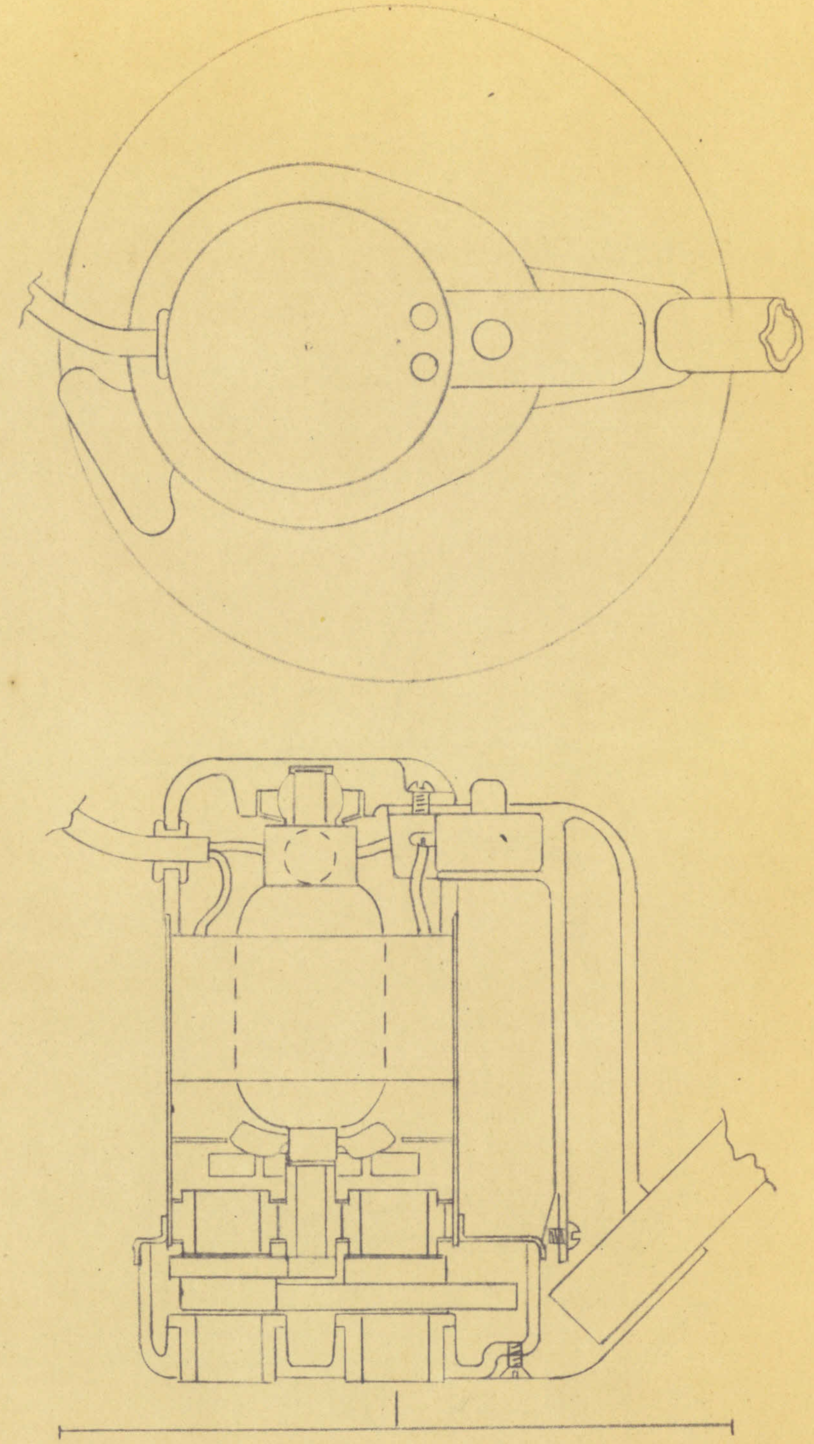

FIG. 13
POSSIBLE DESIGN
FOR POLISHER

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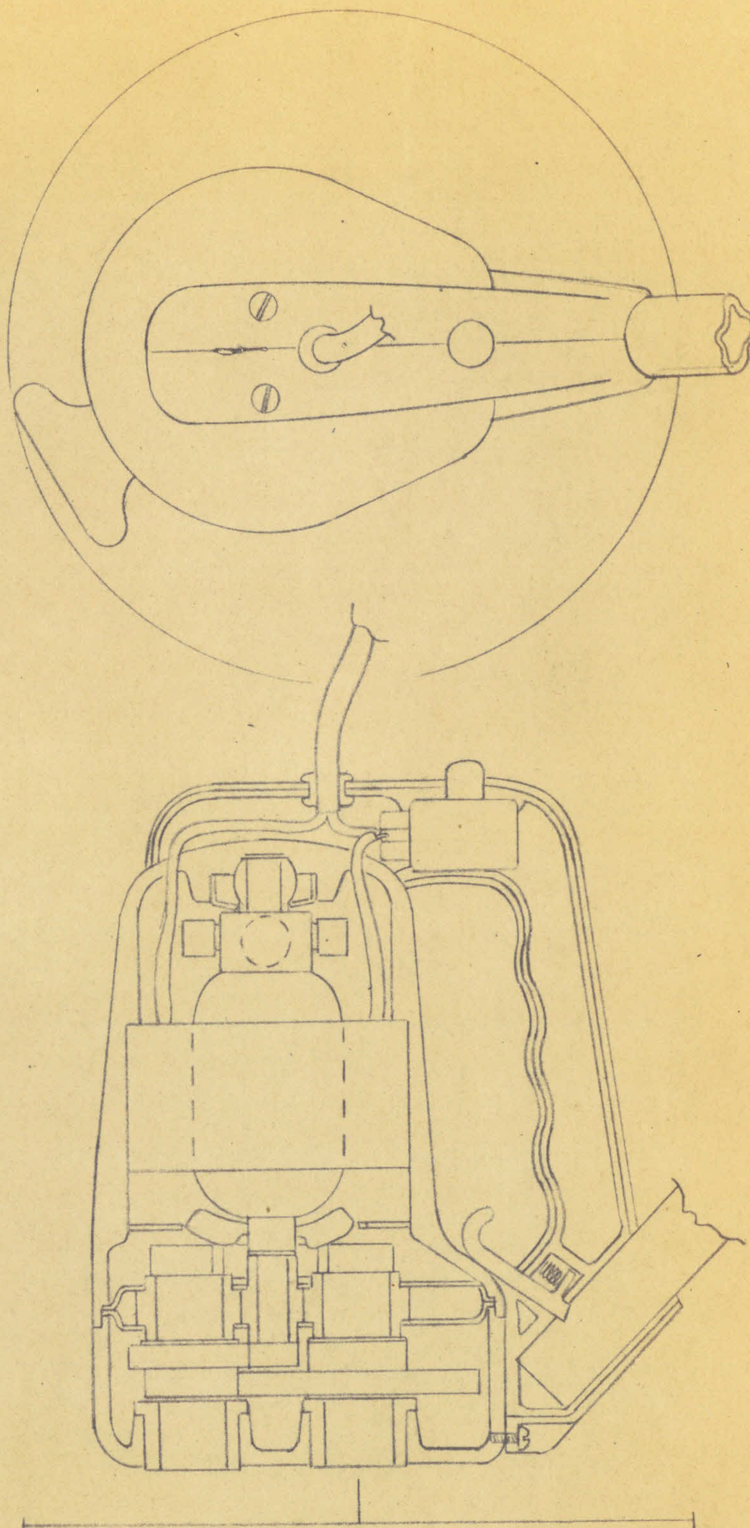

FIG. 14
POSSIBLE DESIGN
FOR POLISHER

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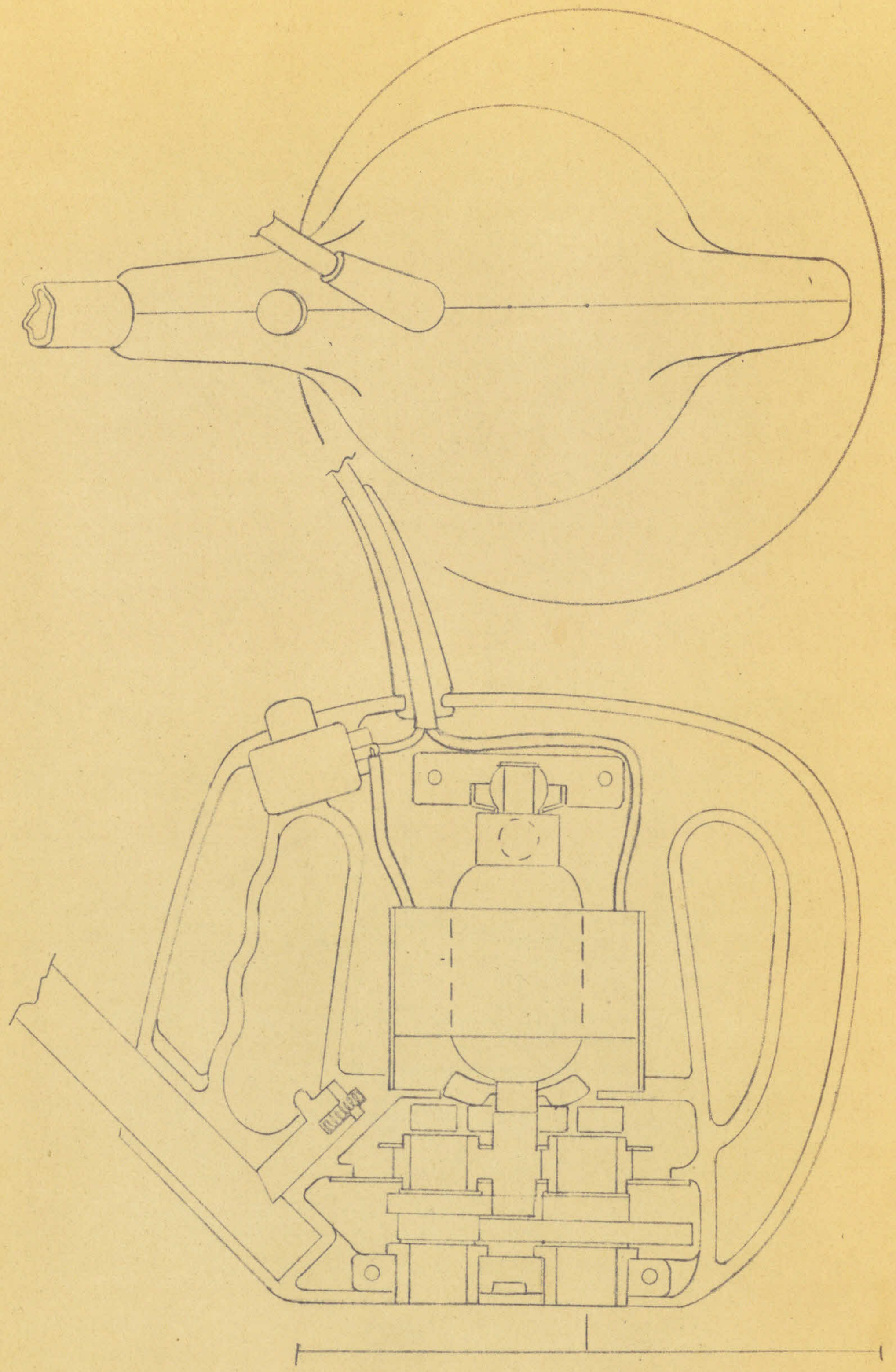

FIG. 15
POSSIBLE DESIGN
FOR POLISHER

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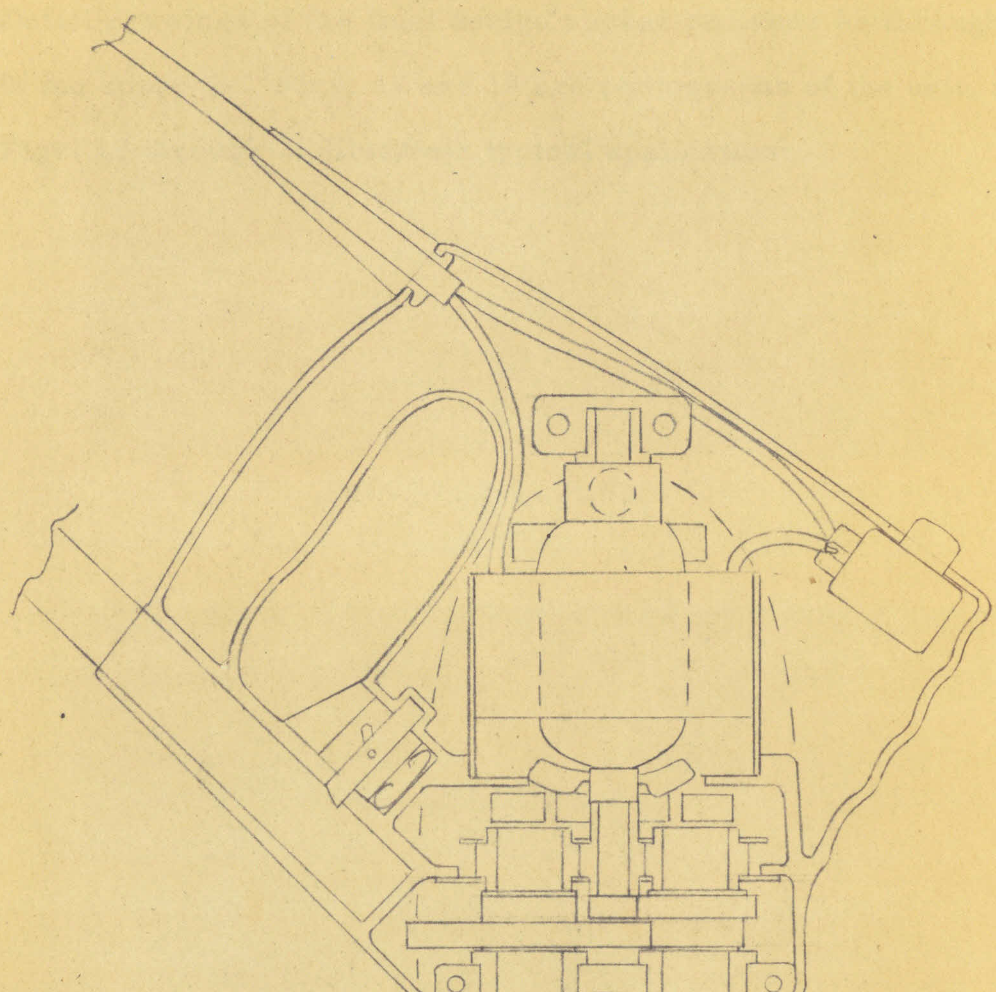

FIG. 16
FINAL HOUSING DESIGN

R. BRINKMAN APR 29, 1948

Air intake is through the upper vents and exhaust at the lower to minimize the inhalation of dust into the motor while sanding.

Detail drawings of the final design appear on pages 65 through 71 in the appendix. Figs. 17 and 18 are photographs of the unit, and Figs. 19 through 22 illustrate typical applications.

FIG. 17 THE POLISHER AS A PORTABLE UNIT

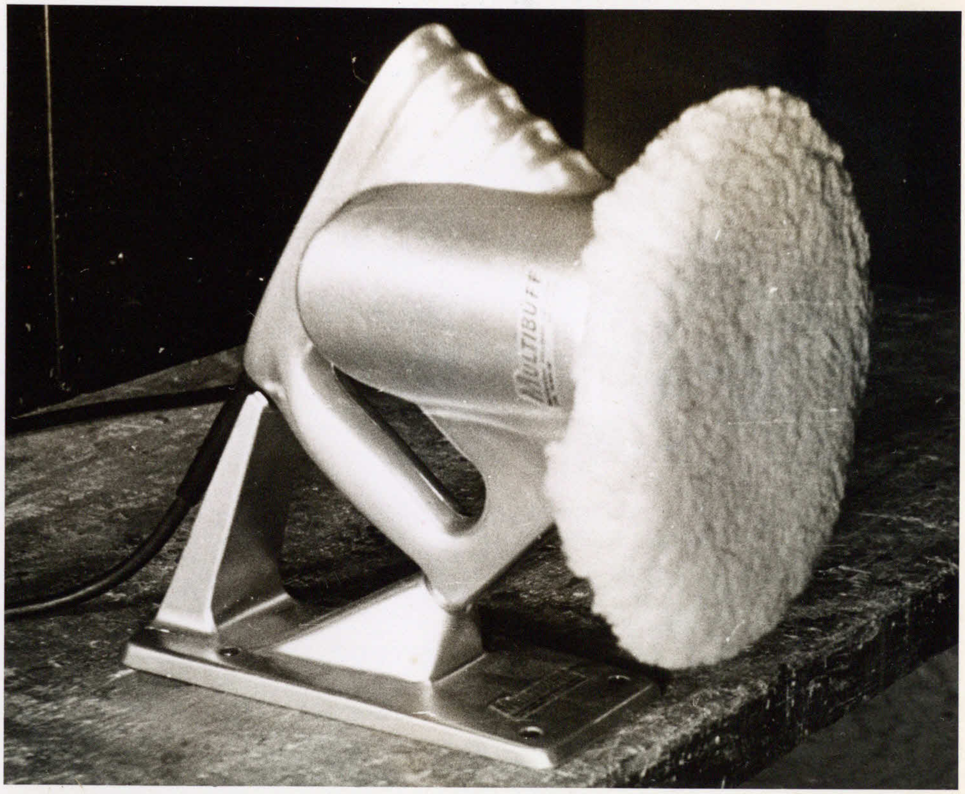

FIG. 18 THE POLISHER ON THE BRACKET

FIG. 19 FLOOR POLISHING

FIG. 20 AUTO POLISHING

FIG. 21 SANDING

FIG. 22 BUFFING

CONCLUSIONS

The polisher design resulting from this study is simple to manufacture, moderate in cost, and fulfills the need in the home for a multi-purpose machine for floor duty and portable applications. Among the possible sales points are the following:

Multiplicity of uses

Low cost

Small storage space required

Light weight

Two speed operation

The name MULTIBUFF has been suggested as short, descriptive, and of value as a sales aid.

The methods of manufacture have been selected on the basis of volume production. However, with minor modifications the design is suitable for low volume manufacture (as for preliminary sales studies) using sand-cast housings and cut gears.

One subject encountered in the research is worthy of further examination, speeds and pressures for the buffing of waxes. Nothing seems to be published in this field, and the producers of waxes, polishers, and floor materials apparently have not conducted any controlled studies into the problem.

APPENDIX

POLISHING MACHINES NOW ON THE MARKET

Item	Unit Weight lbs	Free Speed rpm	Motor Current amp	Buffer Size inches	Price
Portable Machines					
Thor Polisher	10	2100	5.5	7 (disc)	
Thor Sander	10	4200	5.5	7 (disc)	
Clarke-Duo	4	5000	3.0	5 (disc)	$36.50
Skilsander Disc	15	4200	5.5	7 (disc)	57.50
Sears Craftsman	6	1600	3.0	6 (disc)	41.95
Mall Polisher	14	2000		7 (disc)	86.00
Mall Sander	14	4600		7 (disc)	83.00
Floor Machines					
Clarke	11.5	6000	2.75	$4\frac{1}{2}$ (drum)	44.00
Holt Twin Disc	16			6 (disc)	97.00
Johnson Floor Polisher	11.5	1600	2.5	$4\frac{1}{2}$ (drum)	44.50
Regina Twin Disc	15 (est.)		3.6	6 (disc)	59.95

CONSUMER SURVEY QUESTIONNAIRE

A. Consumer Group Information

1. Family Income
   - Under $2000 ______
   - $2000-4000 ______
   - $4000-6000 ______
   - Over $6000 ______

2. Do you own _____ or rent _____ your home?

3. Do you own a car? _____ If more than one, how many? _____

   Where is it kept? Closed garage____ Car port____ Outside____

   Approximately how often is it waxed? ________________________

   Who waxes it? Member of family____ Service Station____ Garage____

4. Approximately how many square feet of floor area in your house require waxing? Hardwood ______________ Other ______________

   How often is it waxed? ______________________________________

B. Experience with Waxing and Polishing Machines

	Floor Waxer	Auto Polisher	Other (Specify)
Check which you own, if any	________	________	________
What make is it?	________	________	________
Have you considered buying any?	________	________	________
Why didn't you buy?	________	________	________
	________	________	________
Estimate what you think each should cost.	________	________	________
Have you rented any?	________	________	________
What was the rental per day?	________	________	________

C. General Comments

Have you any suggestions as to household polishing tasks (other than floors, autos, and furniture) which you would like to have performed by machine? ______________________________

____

____

Other comments ______________________________

____

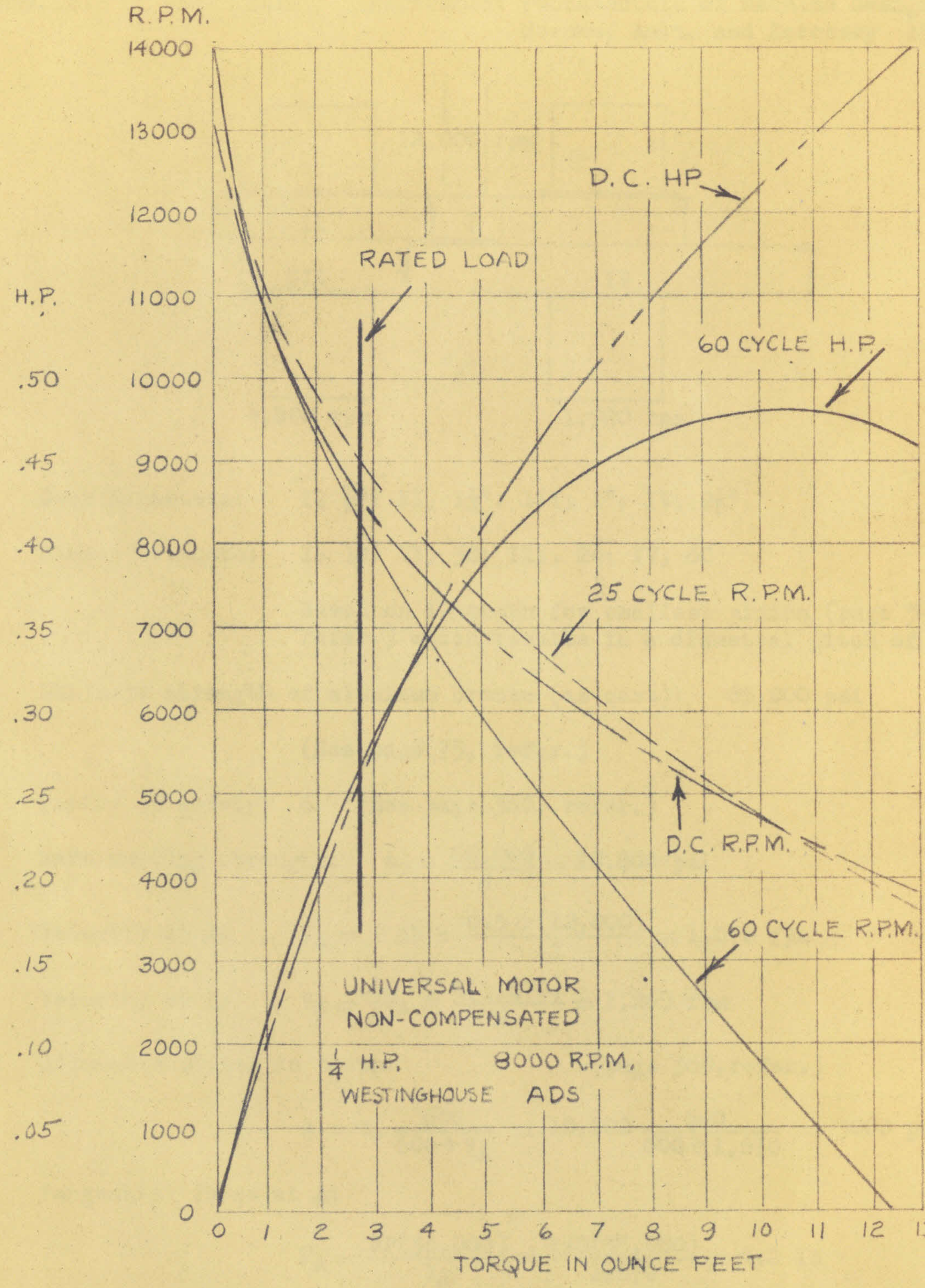

FIG. 23

TYPICAL PERFORMANCE CURVES
FOR UNIVERSAL SERIES MOTOR

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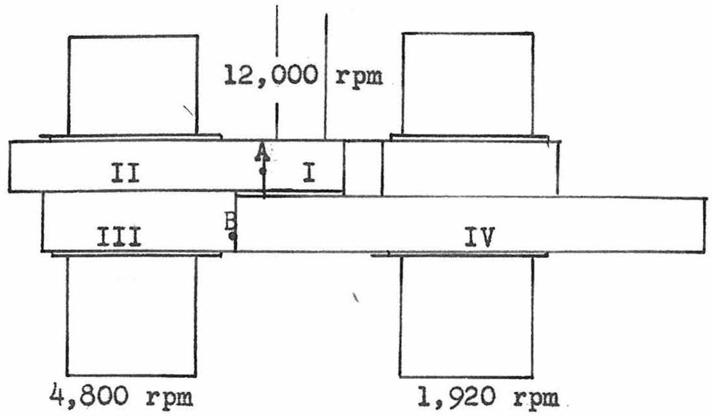
ANALYSIS OF GEAR TRAIN   Reference: Fundamentals of Machine Design
Norman, Ault, and Zarobsky 1938



Gear Diameters: I, $\frac{1}{2}$"; II, $1\frac{1}{4}$"; III, 1"; IV, $2\frac{1}{2}$"

Number of teeth: I, 12; II, 30; III, 24; IV, 60

Based on 12 teeth for smallest pinion (page 347, refer.) which results in a diametral pitch of 24.

Ultimate strength of aluminum bronze (as cast): 65,000 psi

(See page 73, refer.)

Factor of safety: 6 (See page 360, refer.)

Safe working strength: $s_o = \frac{65,000}{6} = 10,800$ psi

Velocity at A: $V_A = \pi dN = \frac{0.5\pi(12,000)}{12} = 1,570$ fpm

Velocity at B: $V_B = \frac{4}{5}V_A = \frac{4(1,570)}{5} = 1,260$ fpm

Allowable stress in tooth: (page 360, refer.)

$$s = s_o \frac{600}{600+V_A} = 10,800 \frac{600}{600+1,570} = 3000 \text{ psi}$$

Tangential force at A:

$$F_A = \frac{HP(33,000)}{V_A} = \frac{1/5(33,000)}{1,570} = 4.2 \text{ lb}$$

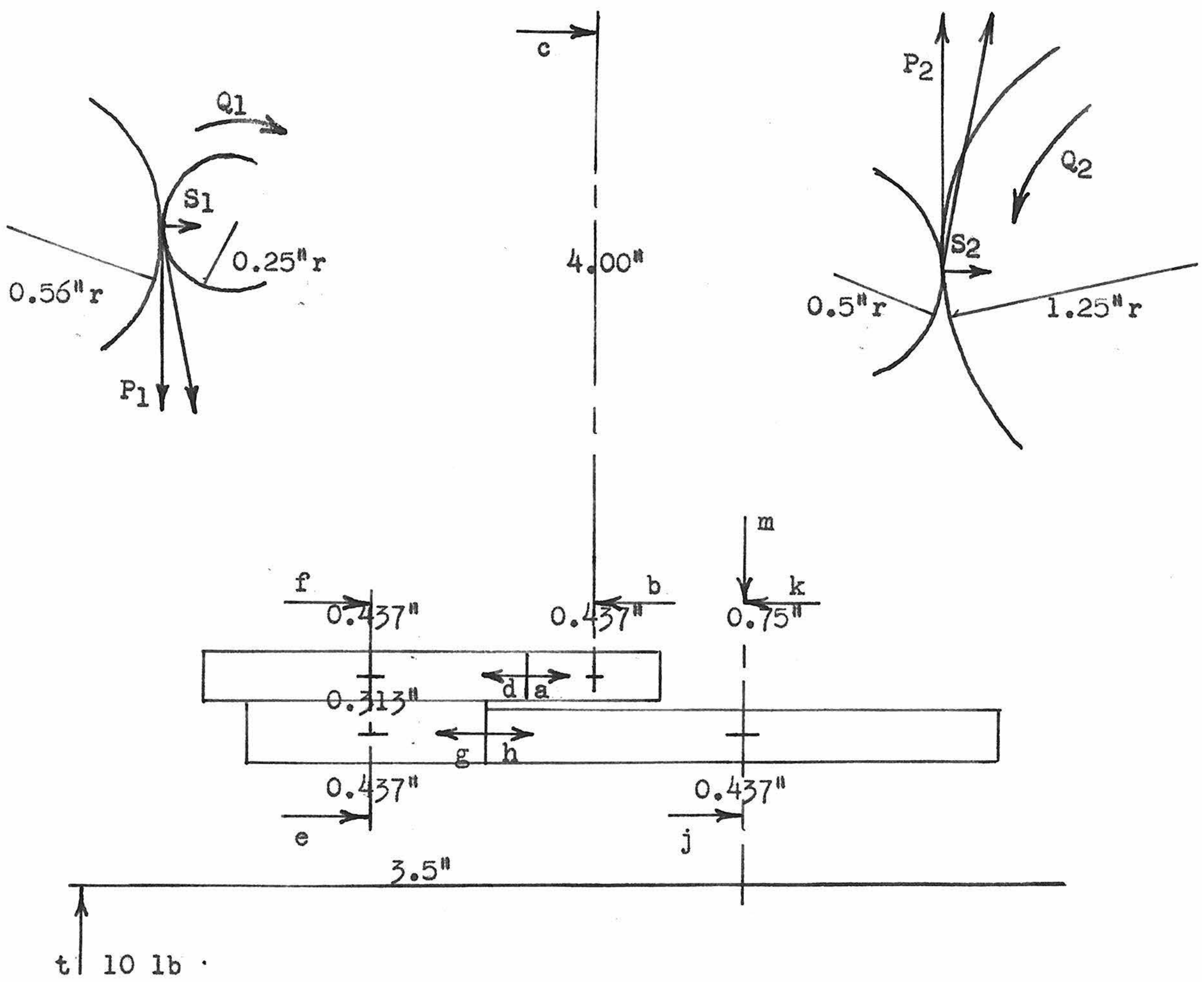
Required width of face:

$$F = \frac{\pi s b y}{P_d} \qquad y = 0.067 \quad \text{(pages 358-9, refer.)}$$

$$b = \frac{P_d F}{\pi s y} = \frac{24(4.2)}{\pi(3{,}000)(0.067)} = 0.160 \text{ in.}$$

Use $\frac{1}{4}$" face, standard for 24 pitch gears.

BEARING LOADS   Reference: New Departure Handbook Vol. II 6th Edition, 1945



For the purpose of the following analysis, the loads on the bearings are assumed to act at the centers of the bearings 5/16" from the respective gear faces. Friction loses would tend to reduce the forces involved and hence are neglected.

Forces on the motor pinion:

$$\text{Torque } Q_1 = \frac{HP(63,024)}{N} = \frac{1/5(63,024)}{12,000} = 1.05 \text{ lb-in.}$$

$$\text{Tangential Force } P_1 = \frac{Q_1}{r_1} = \frac{1.05}{0.25} = 4.2 \text{ lb}$$

$$\text{Separating Force } S_1 = P_1 \text{ Tan } 14\tfrac{1}{2}^\circ = 4.2(0.258) = 1.09 \text{ lb}$$

Forces on largest gear:

$$Q_2 = \frac{1/5(63,024)}{1,920} = 6.6 \text{ lb-in.}$$

$$P_2 = \frac{Q_2}{r_2} = \frac{6.6}{1.25} = 5.25 \text{ lb}$$

$$S_2 = P_2 \text{ Tan } 14\tfrac{1}{2}^\circ = 5.25(0.258) = 1.35 \text{ lb}$$

Motor bearings:

$$F_a = S_1 = 1.09 \text{ lb}$$

$$F_b = \frac{F_a(4.437)}{4.0} = \frac{1.09(4.437)}{4.0} = 1.21 \text{ lb} \qquad (\Sigma M_c = 0)$$

$$F_c = F_b - F_a = 1.21 - 1.09 = 0.12 \text{ lb} \qquad (\Sigma F_{horz.} = 0)$$

Intermediate shaft bearings:

$$F_d = F_a = 1.09 \text{ lb}$$

$$F_g = S_2 = 1.35 \text{ lb}$$

$$F_e = \frac{F_d(0.437) + F_g(0.75)}{1.19} = \frac{1.09(0.437) + 1.35(0.75)}{1.19}$$

$$= 1.49 \text{ lb} \qquad (\Sigma M_f = 0)$$

$$F_f = F_d + F_g - F_e = 1.09 + 1.35 - 1.49 = 0.95 \text{ lb} \qquad (\Sigma F_{horz.} = 0)$$

Final drive shaft with buffer, 10 lb load applied to rim:

$$F_h = F_g = 1.35 \text{ lb}$$

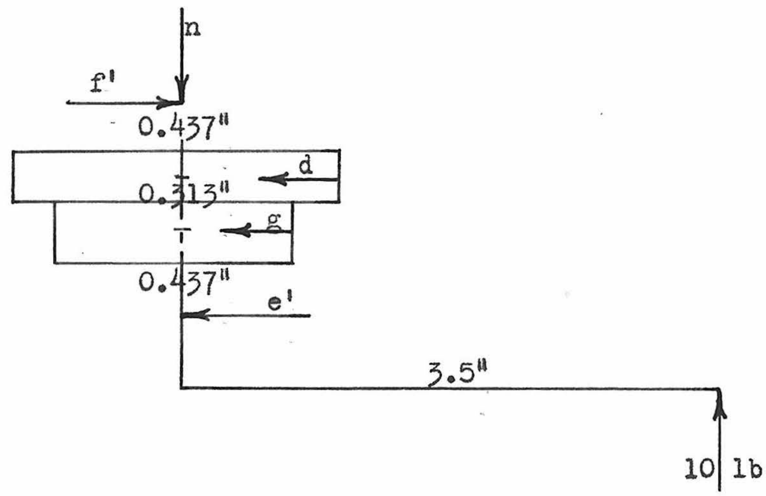
$$F_j = \frac{F_t(3.5) - F_h(0.75)}{1.19} = \frac{10(3.5) - 1.35(0.75)}{1.19} = 28.6 \text{ lb}$$

$$(\Sigma M_{k1} = 0)$$

$F_k = F_j + F_h = 28.6 + 1.35 = 30.0$ lb $\quad (\Sigma F_{horz.} = 0)$

$F_m = F_t = 10$ lb $\quad (\Sigma F_{vert.} = 0)$

Intermediate drive shaft with buffer, alternate position:



$F_n = 10$ lb $\quad (\Sigma F_{vert.} = 0)$

$F_d = 1.09$ lb $\quad$ (no change)

$F_g = 1.35$ lb $\quad$ (no change)

$$F_{e'} = \frac{10(3.5) - 1.09(0.437) - 1.35(0.75)}{1.19} = 28.2 \text{ lb}$$

$(\Sigma M_{fn} = 0)$

$F_{f'} = 1.09 + 1.35 + 28.2 = 30.7$ lb $\quad (\Sigma F_{horz.} = 0)$

SHAFT ANALYSIS $\qquad$ Reference: Fundamentals of Machine Design
Norman, Ault, and Zarobsky 1938

Motor drive shaft -- Torsion and bending:

Torque $M_t = Q_1 = 1.05$ lb-in.

Bending moment $M_b = F_a(0.437) = 1.09(0.437) = 0.48$ lb-in.

$K_b = 2.0$; $\quad K_t = 1.5$ $\qquad$ (page 192, refer.)

Required diameter $D_m = \sqrt[3]{\frac{16}{\pi s_{s\ max}}\sqrt{[K_bM_b]^2+[K_tM_t]^2}}$

$$= \sqrt[3]{\frac{16}{\pi\, 8{,}000}\sqrt{[(2)(0.48)]^2+[(1.5)(1.05)]^2}}$$

$$= 0.098 \text{ in.}$$

Buffer disc shaft:

Torque $M_t' = Q_2 = 6.6$ lb-in.

Bending moment $M_b' = T(3.5) = 10(3.5) = 35$ lb-in.

Required diameter $D_d = \sqrt[3]{\frac{16}{\pi\, 8{,}000}\sqrt{[(2)(35)]^2+[(1.5)(6.6)]^2}}$

$$= 0.165 \text{ in. minimum}$$

Use 7/16" shaft to allow for forged keys. Deflection not considered since shaft is supported laterally by hollow drive shaft.

Final drive shaft (7/16" inside diameter):

Required outside diameter D_o (page 198, refer.)

$$\frac{D_o^4 - D_i^4}{D_o} = \frac{16\sqrt{(K_bM_b)^2+(K_tM_t)^2}}{\pi\, s_{s\ max}}$$

$$\frac{D_o^4-(0.437)^4}{D_o} = \frac{16\sqrt{[(2)(35)]^2\ \ [(1.5)(7.2)]^2}}{\pi\ 8{,}000}$$

$$\frac{D_o^4 - 0.036}{D_o} = 0.045$$

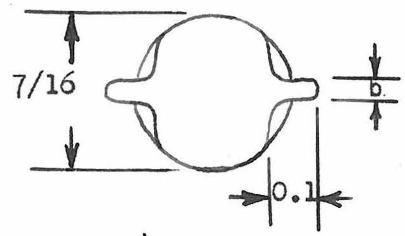
$$D_o^4 - 0.045D_o = 0.036$$

by trial $D = 0.49$ in.

Use 11/16" outside diameter to allow for internal keyways.

KEYS

Reference: Fundamentals of Machine Design
Norman, Ault, and Zarobsky 1938



Because of stress concentrations and cantilever loading use added factor of safety of 5.

Design load

$$F = \frac{Mt'}{r} = \frac{7.2}{0.22} = 32.5 \text{ lb}$$

$$F' = 5F = 162.5 \text{ lb}$$

Resistance to compression

$$F' = s_c \frac{t}{2} L \qquad \text{(page 296, refer.)}$$

$$L = \frac{2F'}{s_c t} = \frac{2(162.5)}{16000(0.1)} = 0.203 \text{ in. minimum}$$

Use 0.5 in.

Resistance to shear

$$F' = s_s bL \qquad \text{(page 206, refer.)}$$

$$b = \frac{F'}{s_s L} = \frac{162.5}{8000(0.5)} = 0.040 \text{ in. minimum}$$

Use 1/16 in.

BEARING AREAS AND PRESSURES

Maximum bearing load (radial) = 30.7 lb

Projected area of bearing = (0.69)(0.63) = 0.43 sq.in.

Maximum radial pressure $= \frac{30.7}{0.43} = 71$ psi

This is below the allowable pressure range for ordinary sleeve bearings with fluid lubrication. (Marks Handbook, Lionel S. Marks, 4th Edition, 1941)

Thrust area required $= \frac{30}{50} = 0.6$ sq.in.

Outside diameter of bearing face $= 2\sqrt{\frac{A}{\pi} + r_i^2} = 1.1$ in.

Use 1 1/8 in. outside diameter bearing face.

MOTOR HOUSING

Because of limitations of the die casting process the minimum section thickness possible is about 1/16". It is readily seen that the torques and bending moments imposed on the housing are insignificant in view of the 20,000 psi yield strength of the aluminum alloy used.

EXTENSION HANDLE Reference: ANC-5, 1942

Material: 61 S 3/4" O.D., 0.035" wall

$$\frac{L'}{\rho} = \frac{L}{\rho\sqrt{c}} = \frac{40}{0.25(0.61)} = 263$$

$E = 10.3 \times 10^6$ psi

$$F_c = \frac{\pi^2 E}{(L'/\ )^2} = \frac{\pi^2(10,300,000)}{64,000} = 1,600 \text{ psi} \qquad \text{(Euler)}$$

$A = 0.079$ sq.in.

$F_{max.\ allowable} = A(F_c) = 127$ lb

This exceeds any load likely to be placed axially on the handle in use.

$M_t = 7.2$ lb.in.

$$S_s = \frac{M_t}{2(A)(t)} = \frac{7.2}{2(0.079)(0.035)} = 1,300 \text{ psi}$$

Ultimate strength in shear ($s_{s\ max.}$) = 27,000 psi

ESTIMATE OF COSTS

Prime cost (material, labor, and dies)	Tooling Cost	Unit Charge	Wt. lb.	Unit Cost
Die Castings				
Housing (2 pieces)	$3,000	$ .12	1.50	$ .87
Upper frame	500	.02	.45	.11
Gear case	500	.02	.60	.14
Gear spindles (2)	1,000	.04	.60	.40
Sand Casting				
Bracket base			2.20	1.00
Stampings				
Bearing supports (2)	500	.02	.30	.05
Handle lock	250	.01	.05	.04
Buffer disc	250	.01	.70	.15
Pressings				
Bearings (6)			.30	.60
Forging				
Buffer shank	250	.01	.30	.07
Turning				
Buffer head			.20	.04
Seamless tubing				
Motor shield			.10	.06
Handle shank			.40	.25
Bracket			.05	.03
Miscellaneous Parts	250	.01		.01
Motor			2.00	4.25
Switch			.10	.32
Cord set			.10	.28
Grip for handle			.04	.04
Springs			.01	.01
Buffer pad			.25	.50
Carton			.10	.20
Total Tooling	$6,500			
Total Weight (basic unit only)			6.60 lb.	
Total Prime Cost				$9.42

Total Manufacturing Cost (with burden of 70% of prime cost) $16.00

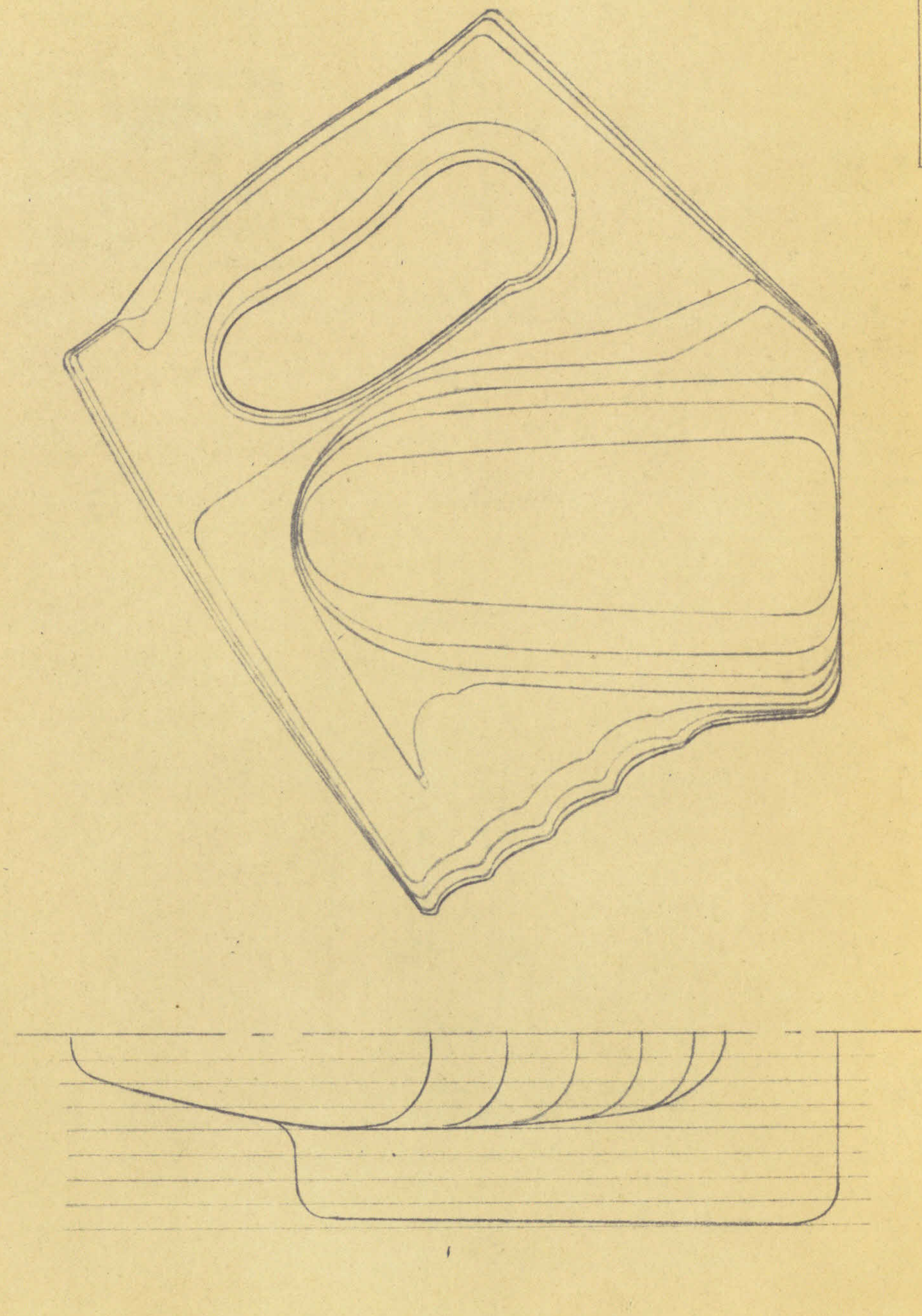


FIG. 24
HOUSING CONTOURS
R BRINKMAN APR. 22, 1948

SCALE: HALF SIZE
CONTOUR INTERVAL: $\frac{1}{4}$"

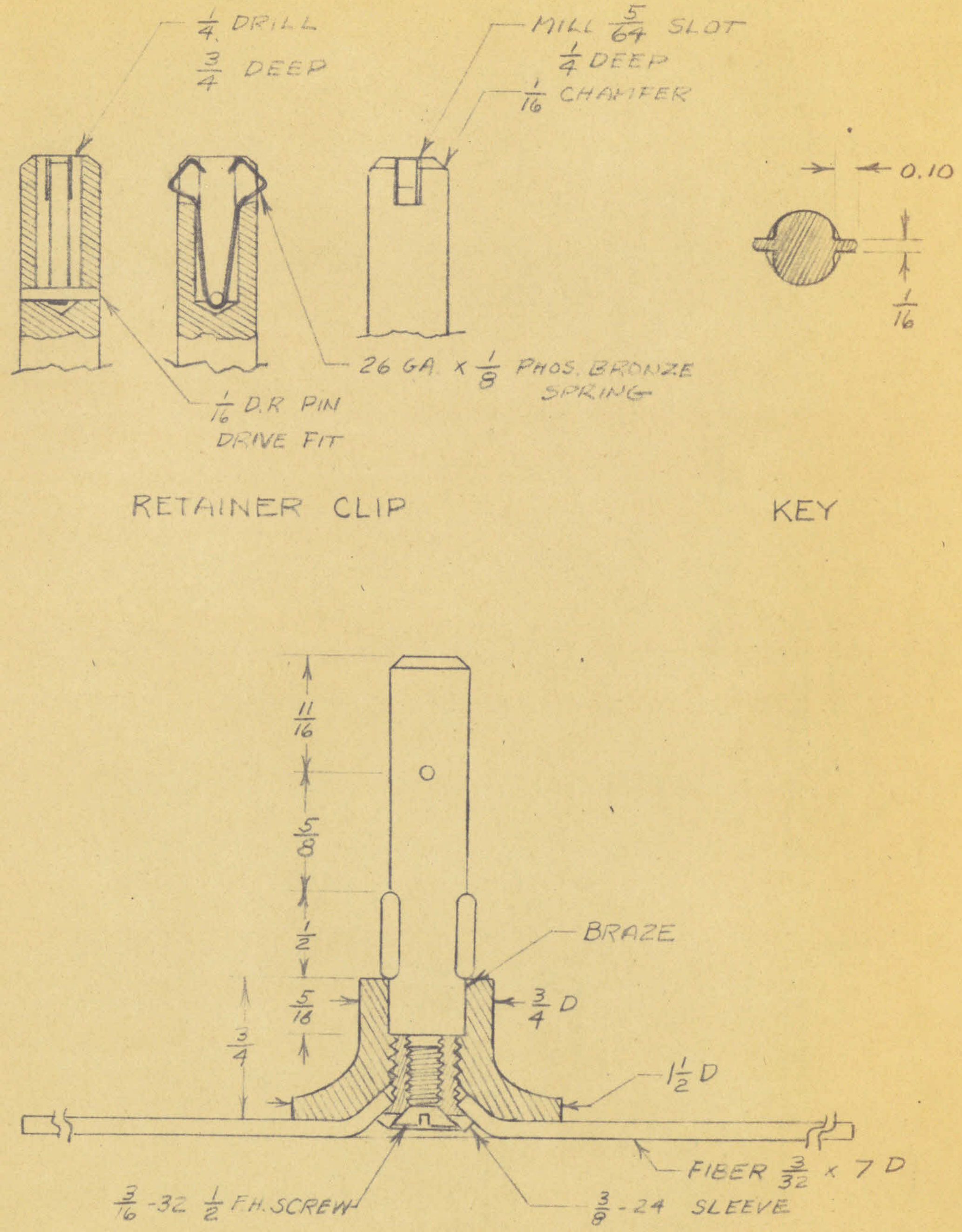
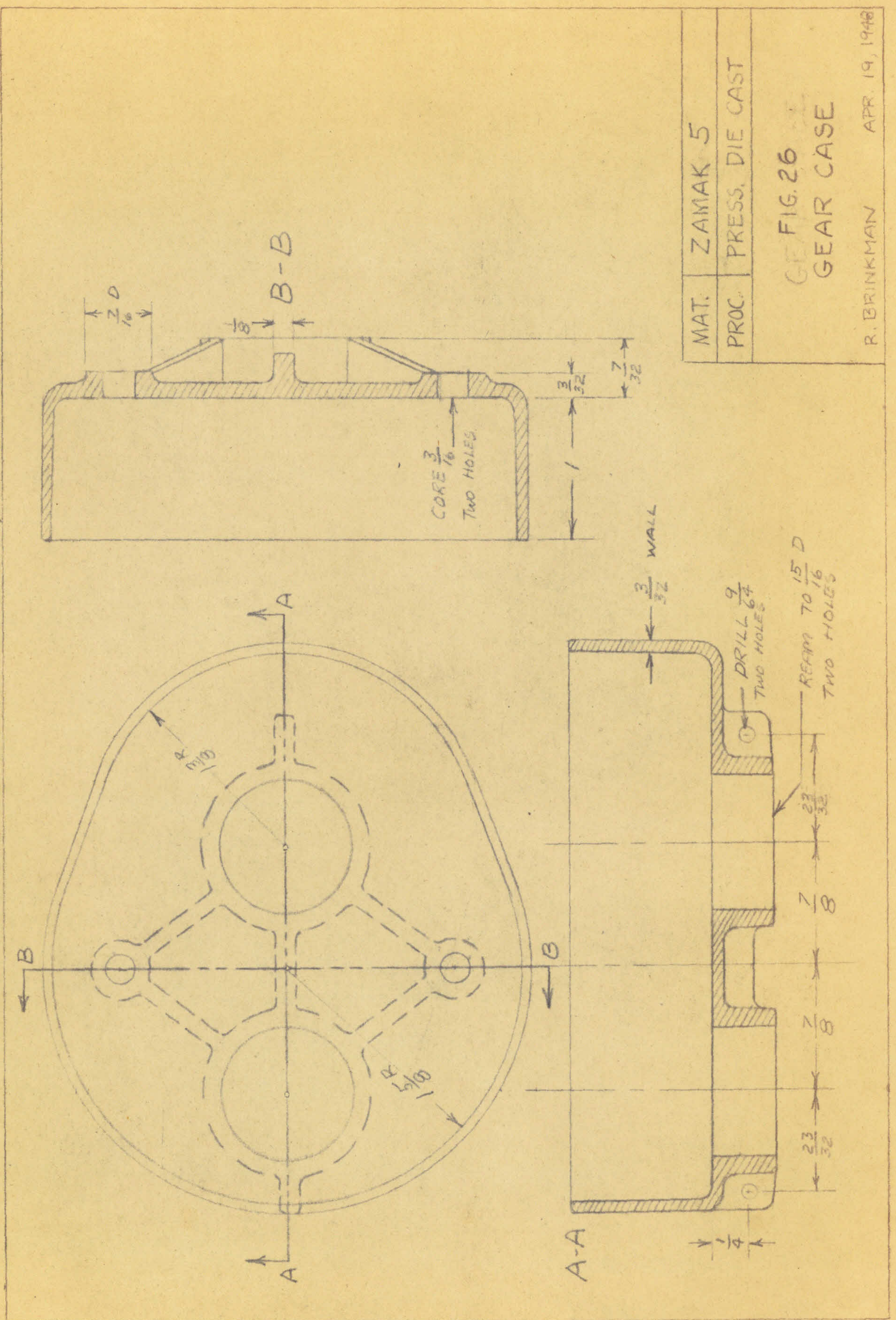
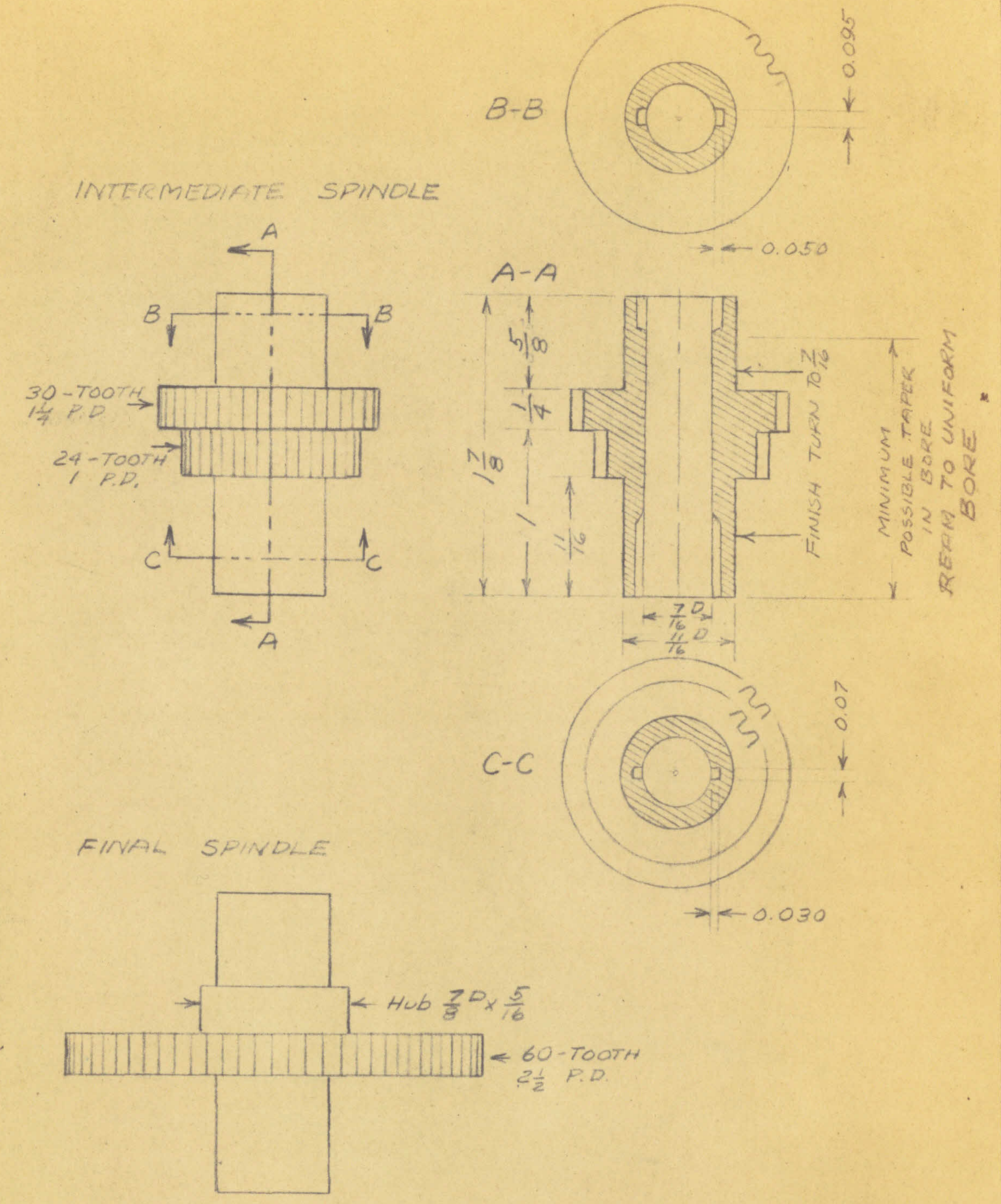


FIG. 25
BUFFER HEAD DETAIL

R. BRINKMAN APR. 23, 1948


MAT. ZAMAK 5
PROC. PRESS. DIE CAST
FIG. 26
GEAR CASE
R. BRINKMAN APR. 19, 1948
B-B
A-A
CORE 3/16 TWO HOLES
DRILL 9/64 TWO HOLES
REAM TO 15/16 D TWO HOLES
3/32 WALL



Note: Detail similar to intermediate spindle

MAT.	ALUM. BRONZE S.AE 68
PROC.	PRESS. DIE CAST

FIG. 27
GEAR SPINDLE DETAIL

R. BRINKMAN APR. 18, '48

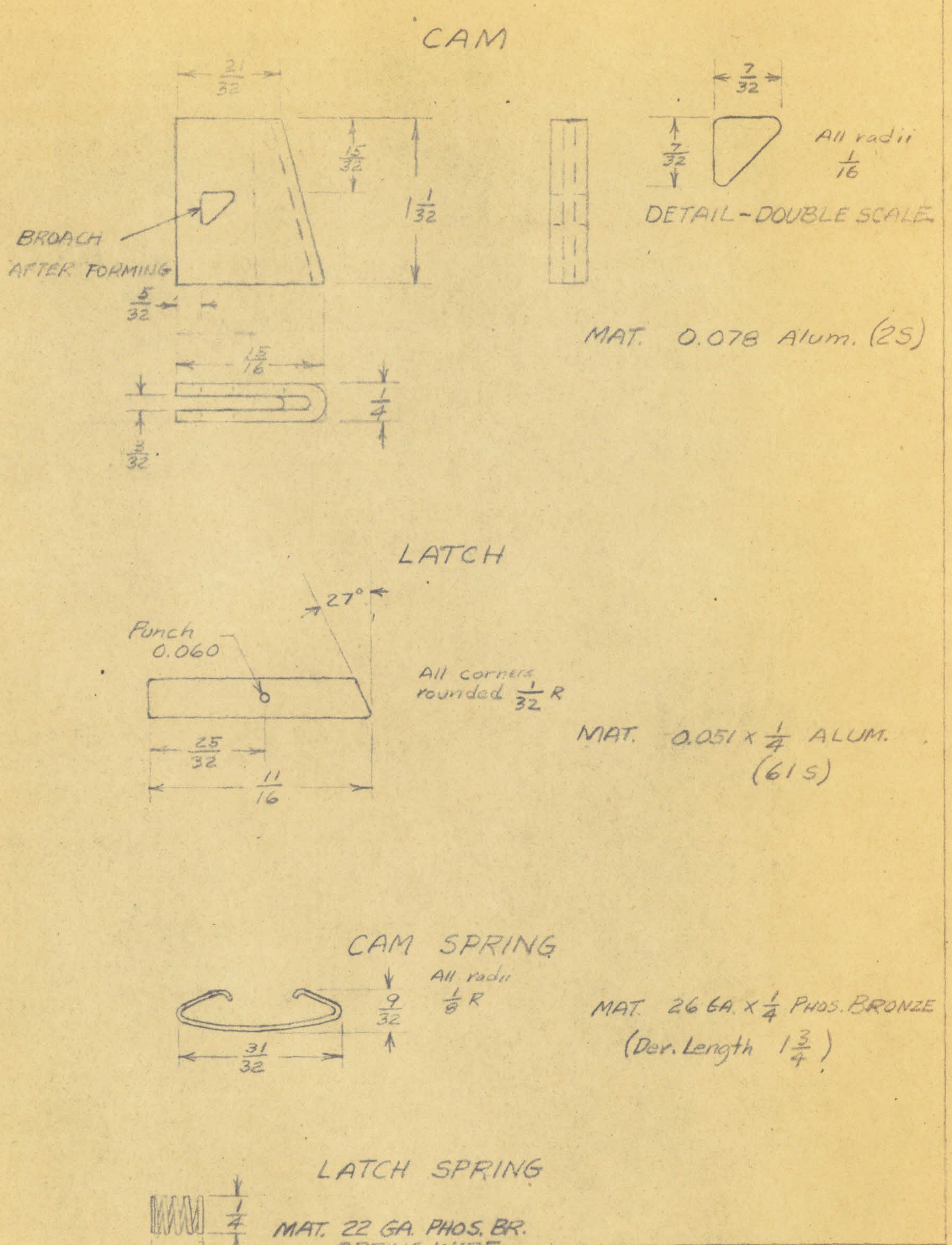
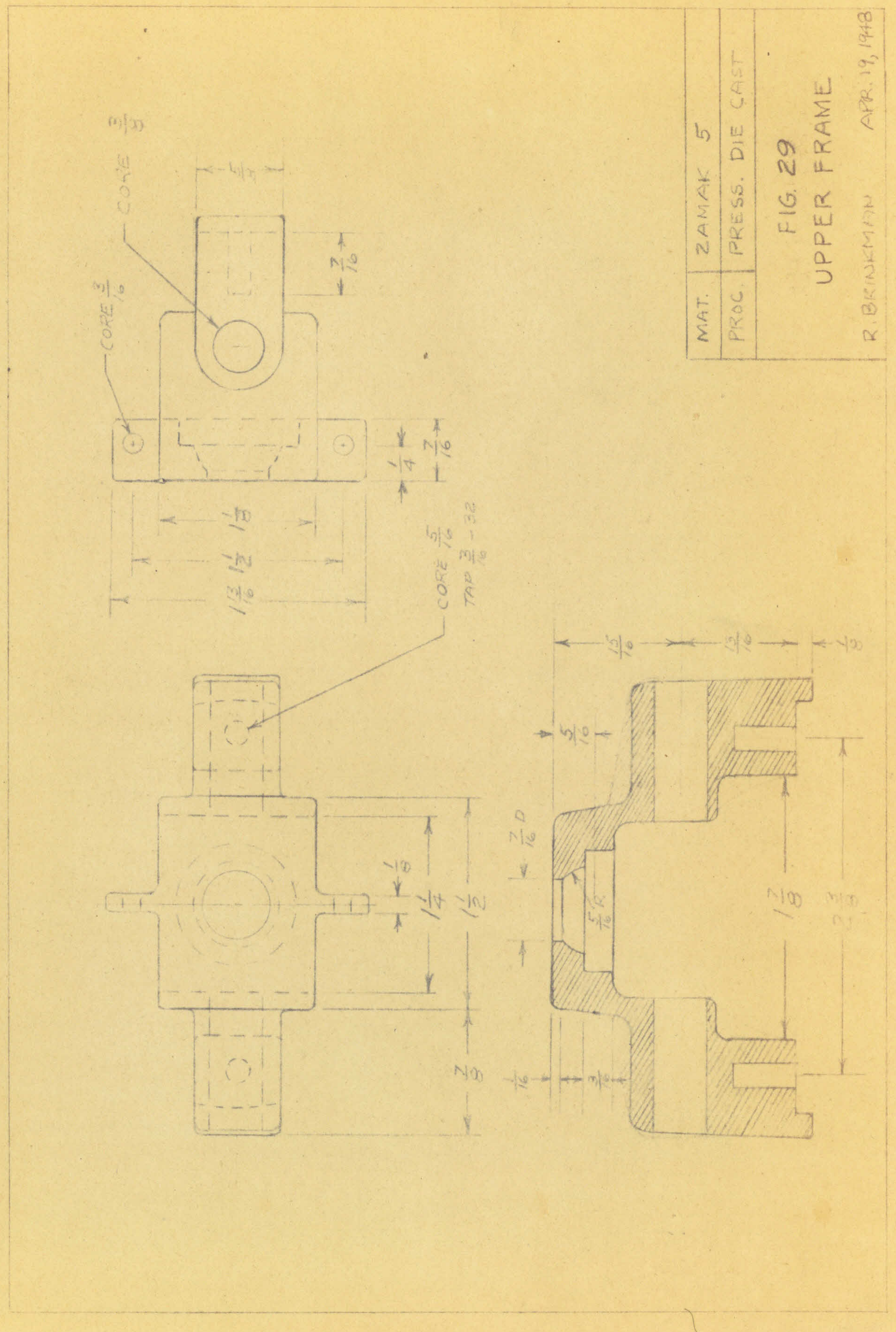


FIG. 28
HANDLE LATCH DETAIL

R. BRINKMAN APR. 19, 1948


MAT. ZAMAK 5
PROC. PRESS. DIE CAST
FIG. 29
UPPER FRAME
R. BRINKMAN APR. 19, 1948
CORE 3/16
CORE 3/8
CORE 5/16
TAP 3/16 - 32

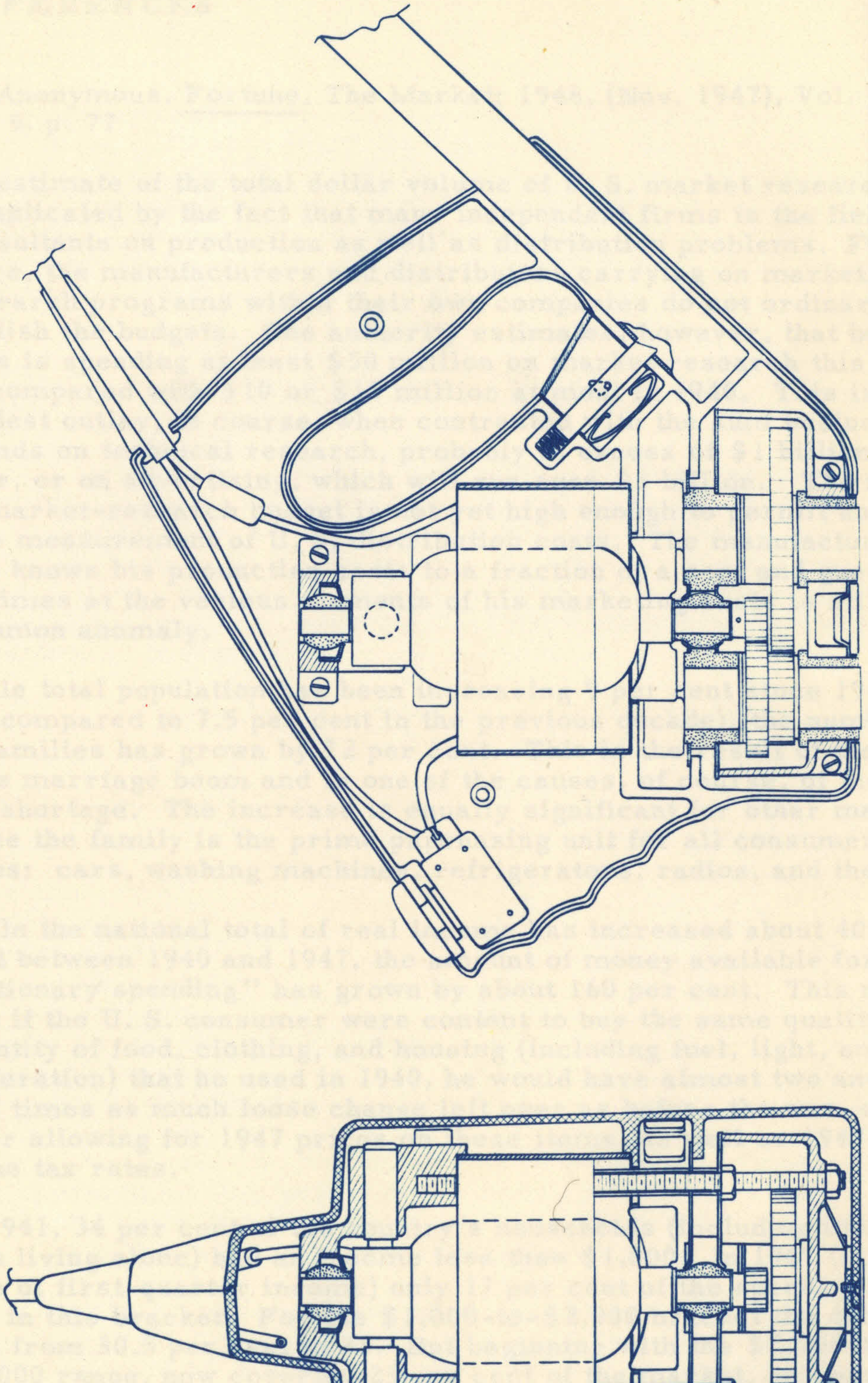


FIG. 30
UNIT ASSEMBLY
HALF SIZE
R. BRINKMAN
APR. 21, 1948

REFERENCES

1. Anonymous, Fortune, The Market: 1948, (Nov. 1947), Vol. 36, No. 5, p. 77

An estimate of the total dollar volume of U. S. market research is complicated by the fact that many independent firms in the field are consultants on production as well as distribution problems. Furthermore, the manufacturers and distributors carrying on market-research programs within their own companies do not ordinarily publish the budgets. One authority estimates, however, that business is spending at least $50 million on market research this year, as compared with $10 or $15 million at most in 1940. This is a modest outlay, of course, when contrasted with the sum business spends on technical research, probably in excess of $1 billion this year, or on advertising, which will run over $3 billion. The national market-research budget is not yet high enough to permit any precise measurement of U. S. distribution costs. The manufacturer who knows his production costs to a fraction of a cent and guesses in dimes at the various elements of his marketing costs is still a common anomaly.

While total population has been increasing 9 per cent since 1940 (as compared to 7.5 per cent in the previous decade), the number of families has grown by 12 per cent. This is the result of the wartime marriage boom and is one of the causes, of course, of the housing shortage. The increase is equally significant for other markets, since the family is the prime purchasing unit for all consumer durables: cars, washing machines, refrigerators, radios, and the rest.

While the national total of real income has increased about 40 per cent between 1940 and 1947, the amount of money available for "discretionary spending" has grown by about 160 per cent. This means that if the U. S. consumer were content to buy the same quality and quantity of food, clothing, and housing (including fuel, light, and refrigeration) that he used in 1940, he would have almost two and a half times as much loose change left over as before the war, even after allowing for 1947 prices on these items, as well as 1947 income tax rates.

In 1941, 34 per cent of the country's households (including individuals living alone) had an income less than $1,000. In 1947 (at the rate of first-quarter income) only 17 per cent of the spending units fell in this bracket. For the $1,000-to-$2,000 bracket the decline was from 30.5 per cent to 23. But beginning with the $2,000-to-$3,000 range, now covering 25 per cent of the market, as compared to 21 per cent before the war, all the brackets have become more heavily populated. In the $3,000-to-$5,000 bracket the increase is from 10.5 per cent to 25, and in the $5,000-plus bracket from 4 per cent to 10.

The best marketing, of course, reaches even behind the production lines to the field of product development and design. This is an area where market research, the analysis of what people want and what they can pay, merges with technical research and engineering decision. The functions of market research do not end here, however; they also cover selection of the most logical channels of distribution.

2. Charles F. Philips, Marketing by Manufacturers, (1946), pp. 72, 16, 85

It is the function of marketing research to aid top management in reaching adequate policy decisions by providing the necessary facts and to analyze them so that they can be used as a basis for policy decisions in the field of marketing. As a matter of fact, marketing research usually goes so far as to suggest to top management what the decision should be, although the final decision is, of course, not a function of research.

Percentage Distribution of Marketing Costs
for Various Products*

Electrical Household Appliances

	Through Wholesalers	Direct To Retailers
Consumer pays	100.0	100.0
Retailer's margin	31.6	31.6
Retailer pays	68.4	68.4
Wholesaler's margin	13.8	.....
Wholesaler pays	54.6	.....
Manufacturer's distribution cost	10.2	9.5
Manufacturer gets	44.4	58.9
Total cost of distribution	55.6	41.1

These figures do not include all of the transportation costs belonging to certain of these products. As a result, the cost percentages may be somewhat inaccurate; but they are probably substantially correct.

Source: Computed from material presented by the Twentieth Century Fund in "Does Distribution Cost Too Much?" and by the Federal Trade Commission in a report on "Distribution Methods and Costs" (1944).

* Excerpt from Table 9, reference.

While marketing research can provide management with valuable facts and analysis concerning both general business conditions and specific marketing problems, management should always be aware of certain limitations of its marketing research program (dynamic nature of the factors, time lag between inception and completion of study, and personnel inadequacies). Unless these limitations are recognized, too much may be expected of research, or too much may be read into the results of such research.

3. Anonymous, Modern Plastics, Markets--Present and Future, (May 1947), Vol. 24, No. 9, pp. 94-97

The first step in preparing to market a product is logically taken even before the product is designed. That step is market analysis, to determine not only where the people are, but roughly how much money they have, what kind of people they are, how they are grouped by ages and sexes, what their living and cultural habits may be. From these factors may be determined the effects of standards of living, climate, habits and even heredity on people's desires so that a product may be designed and engineered in the size, shape, style, color, and weight to appeal to the greatest number of people living in that area.

4. Katherine Phelps, Printers' Ink, The Demand for Household Goods, (Mar. 14, 1947), Vol. 218, No. 11, pp. 50-51

Manufacturers who produce goods to be sold to families know that during the past five or six years there has been the greatest number of marriages and the highest employment in our history. In the same period there was a decided increase in the minimum level of income. This adds up to a tremendous potential demand for the kind of goods produced and sold to the family as a unit, everything from paint and pots and pans to houses themselves.

According to recent releases by the Census Bureau, between July 1940 and July 1950, nearly 15,000,000 new families will have been formed. (During this same period almost 9,000,000 homes will have been broken up by death or divorce, leaving a net growth for the decade of 6,000,000 families.)

5. Arno H. Johnson, Harvard Business Review, Market Potentials, 1948, (jan. 1948), Vol. 26, No. 1, pp. 11-31

It is estimated that in 1948 the surplus income of individuals available for discretionary spending or saving will be about three-and-a-half times the highest prewar levels. This is after full account has been taken of the higher tax level and allowance has been made for a 60 per cent increase since 1940 in consumer prices applicable to basic living costs.

The average United States family had an income of $2,240 (arithmetic average, not median average) in 1940, of which $74 went for personal taxes and $1,408 for food, clothing, housing, and household operation, leaving $758 of surplus income for discretionary spending for items other than food, clothing, and shelter, or for saving.

At present trends the average United States family income for 1948 is estimated at $5,174, of which $543 must be set aside for personal taxes. To maintain the same standard of living as in 1940 for food, clothing, and shelter would now require $2,253, or 60 per cent more than the $1,408 in 1940. After deducting the increased taxes and the increased costs of food, clothing, and shelter to maintain a 1940 level of living, the average family would now have $2,378 of surplus income, or three times as much as it had in 1940.

The great increase in national income payments and the addition of about 10,000,000 persons to the employment rolls have resulted in shifts in the income grouping of families and single individuals. The total of 27,780,000 consumer spending units (families and single individuals) in the United States early in 1947 with annual incomes over $2,000, for example, is 4½ times the 6,285,700 in 1935-36 and nearly double the 14,009,000 there were in 1941. Even this does not show the whole shift since the Federal Reserve Board Study accounts for about $135 billion of income received by consumers, whereas by July 1947 personal income payments had reached the rate of $197 billion. This additional $62 billion of income would indicate even more extensive upward shifts than shown in the chart in Exhibit XVI.*

This market analysis has shown that even with increased living costs most of those in the $3,000-to-$5,000 income group, for example, have as much to spend for discretionary items like automobiles as had families in the similar income group in 1941; and that there are lots more families in that group now, which provides an enlarged potential market.

6. Anonymous, Printers' Ink, The Influence of Women in Buying, (Oct. 17, 1947), Vol. 221, No. 3, p.84

Women's Influence Ratings**

The percentage of total sales finally influenced by women; not necessarily purchases by women.

Electrical Appliances (general). 80%

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* See Fig. 3

** From a table in reference

7. Anonymous, Modern Plastics, Reaching the Market You Want, Vol. 24, No. 9, May 1947, pp. 100-101

The hardware field, including housewares, operates through the big merchandising outlets either direct with quantity discounts or through wholesalers. The 30,000 independent hardware stores are all serviced through 510 wholesalers and jobbers.

8. R. Everly, The Review of Economic Studies, Distribution Methods and Costs in the U.S.A., (1946-47), Vol. 16 (1), No. 35, pp. 16-22

The high profit margins (to canvassers and demonstrators) attracted many types of wholesalers and retailers, and their intervention was so successful that by 1939 nearly 60 per cent of all electrical household appliances produced in the U. S. A. were sold to independent wholesalers and jobbers, while numerous manufacturers practiced direct sales to retailers.

9. Vernon Brooks, Printers' Ink, Can you Trust Mail Questionnaires?, (Sept. 19, 1947) Vol. 220, No. 12, p. 86

The people who reply to a mail survey are much the same as those who don't providing you are investigating a homogeneous group, for example, those in the upper income. But that does not apply when you seek true representativeness from a cross section of a diversified population.

Findings from our survey checked very closely with the findings made by another organization with respect to one thing: namely those people who reply to a mail questionnaire are apt to be the upper-income, better educated groups.

10. E. A. Loew, Direct and Alternating Currents, (1946) p. 636

To develop a good torque in a weak field in large series motors requires a large number of armature turns. This results in an armature winding with a comparatively large inductive reactance. It is possible to reduce the armature reactance by means of a compensating winding or a distributed field winding, and in large machines either one or the other of these methods is employed. In small motors (under 3/8 HP), however, the number of armature turns is small enough so that satisfactory operation may be secured without resorting to compensation. The commutator has a large number of segments and the number of armature turns per segment is small. In this way good commutation is secured. High-resistance brushes are also used to limit the current in the short-circuited coil and thus to aid in securing sparkless commutation.

It will be observed that the speed varies inversely with the load. In these motors the torque is proportional, approximately, to the square of the current and is inversely proportional to the speed. The starting torque is high - approximately three times the torque at rated load. The power factor is good and the efficiency at rated load is about 50 per cent.

Because of their very high armature speeds (about 7000 rpm), universal motors develop very high outputs per unit of weight. This is a great advantage on portable equipment and in applications where space is limited.

11. Reginald Trautschold, Standard Gear Book, (1935) p. 85

Silence and smoothness in operation, long gear life, and high operating efficiency demanded of modern, quality gearing assemblages are well served by the expediency of having the gear teeth extend helically across the face of the gears, instead of axially, as in ordinary spur gearing.

In ordinary commercial practice, the helix angle of helical gears is advisably kept within values that will hold the developed end thrust to a maximum of 10 to 13 per cent of the transmitted load.

12. Norman, Ault, and Zarobsky, Fundamentals of Machine Design, (1938) p. 347

All gears in this system (Standard $14\frac{1}{2}$ Degree Involute System) are interchangeable: that is, they will run with one another if they are of the same pitch and of standard proportions. The system is based on a 12-tooth pinion as the smallest that will give satisfactory tooth action.

13. Anonymous, Die Casting for Engineers, The New Jersey Zinc Co., (1942), p. 136

The teeth in most forms of gears can be cast within moderately close limits and require little or no machining. Often stepped gears, or combinations of two types of gears, are produced in a single die casting. Shafts and driving members, such as sheaves or pulleys, can often be cast integrally with the gear or gears, or steel shafts can be employed as inserts.

14. Charles O. Herb, Die Castings, (1936), pp. 54, 258

Aluminum-bronze S.A.E.-68 has the same tensile strength as medium carbon steel and possesses the further advantage of not being acted upon by water, brine, and other liquids. Among its applications may be mentioned conveyor-chain links, swivel brackets for outboard motors, washing machine parts, bearing hubs, and ratchet wheels.

These castings are generally made from an alloy composed of 89 per cent copper, 10 per cent aluminum, and 1 per cent iron. The composition can, however, be varied slightly to adapt the castings to special requirements. In addition to the advantages of high strength and unusual hardness, these aluminum-bronze die-castings offer effective resistance to abrasion and high resistance to corrosion under many adverse conditions.

The aluminum-bronze die-castings have a tensile strength of 85,000 pounds per square inch, as cast, and a hardness of 140 Brinell. By reheating the castings to 1700 degrees F. and quenching them in water, their tensile strength can be increased to as much as 100,000 pounds per square inch and their hardness to 260 Brinell.

Aluminum alloy S.A.E.-309 (A.S.T.M. spec. B85-31 T alloy IX) is particularly suited to the manufacture of die-castings to be polished, since the reduced amount of silicon and the increased nickel give it a whiter appearance than the other aluminum alloys possess.

15. Herbert Chase, <u>Handbook on Designing for Quantity Production</u> (1944), p. 432

Although opinion to the contrary is sometimes erroneously held, tooling for the die casting is often lower in cost than for the stamped or formed part. Here tooling refers to true production tools including dies and other supplementary items that may be required; it does <u>not</u> refer to temporary dies, which are made, especially for stamping, for trial purposes for short runs only, or to dies cast in soft metal or those made from fiber or from other nonmetallic materials, such as are used for forms to shape parts, chiefly from aluminum or other soft metal, especially by the rubber-pad method, the pad taking the place of a female die.

Permanent molds cost less than equivalent die-casting dies in the average case, perhaps one-third to one-half as much. Upkeep cost as between dies and molds is reported to be about on a par, and die and mold life is said to be about equal when both die and mold are used for casting the same type of metal.

16. Anonymous, <u>Finishes for Alcoa Aluminum</u>, Aluminum Company of America, (1947), p. 16

Typical Polishing Procedures*

Article	Operation	Wheel	Composition
Die Castings	1. Greasing**	Glued rag wheel	No. 100 emery
	2. Greasing**	Felt wheel	No. 150 emery
	3. Buffing	Sewed muslin buff	Tripoli
	4. Coloring	Open muslin buff	Soft Silica

17. Anonymous, Alcoa Aluminum and its Alloys, Aluminum Company of America, (1947), p. 43

For most structural applications, 61S is becoming more and more the generally used alloy. It is, therefore, regularly manufactured in all the commercial forms, except forgings, for which other alloys are equally well, or better, suited. This alloy combines the qualities of excellent resistance to corrosion, substantially equal to that of 2S, 3S and 52S; greatest ease of fabrication of any of the heat-treatable alloys, which quality also results in lower manufacturing cost and consequently lower selling price; and good mechanical properties.

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* Excerpt from Table on page 16 of reference
** May omit one or both