LAWN MOWER DESIGN

Thesis by Lee M. Griswold

In Partial Fulfillment of the Requirements for the Degree of Industrial Designer. California Institute of Technology, Pasadena, California.
1947

TABLE OF CONTENTS

INTRODUCTION

If you were to explore the lawn mower market today, you would find that lawn mowers are essentially the same now as when your grandfather or even great-grandfather used them. Hundreds of patents have been issued on ideas which supposedly were to improve lawn mowers. However, the basic lawn mower design as we have known it for years still stands as practically the only type of lawn mower sold today. The survival of this design through so many generations and the subsequent failure of so many other suggested designs certainly tends to humble anyone who endeavours to improve the lawn mower.

The faults of the existing lawn mowers are very evident, objectionable and taunting to anyone interested in improving upon them. To be more specific, some of the faults are that lawn mowers are hard to push, unable to cut close to obstacles, cannot cut very tall grass, are noisy, are jammed easily by sticks and stones, and cannot cut properly the grass along the edges of troughs or gardens which are lower than the level of the grass. The following thesis is an investigation directed toward the solution of these problems in the design of a lawn mower.

MARKET AND CONSUMER SURVEY

A market and consumer survey is necessary to assist the designer in creating a lawn mower design that would be welcomed readily on the lawn mower market. In general, the survey determines the type, price range and expected sales volume of lawn mowers receiving greatest consumer acceptance.

The scope of this survey was limited to hand lawn mowers sold in the Los Angeles County area.

It seems that mechanical improvements or value have no effect on the retail price of lawn mowers. The retail price is determined entirely by the method of marketing, appearance of the mower, and the reputation of the maker.

Hand lawn mower prices ranged from $14 to $40 in May 1947, according to an extensive survey. All present lawn mowers under $20 retail are those sold by chain stores.* Most makes of lawn mowers are priced at about $25 to $30 even though there is a large volume of sales of those few makes handled by the chain stores. These prices, of course are inflated as are all prices now.

---

* Sears, Roebuck and Co., Montgomery Ward, Western Auto Supply Stores and others.

As with other consumer goods, dealers are now finding a resistance on the part of the consumer to paying the inflated price even though the need of a mower may be great. In spite of the fact that the peak of the lawn mower selling season is in April or May, at this time the market is changing from a seller's market to a buyer's market. Some wholesalers believe that the hardware store and garden supply outlets have a demand for a lawn mower that could be sold in the $18 to $24 price range. There is no indication that they will be supplied with such a lawn mower to be sold at such a price.

The estimated volume of sales of lawn mowers per year in Los Angeles County is 70,000 lawn mowers. This figure was estimated in the following way.

A market index was used to estimate the volume of sales in the area each year. This index consisted of the sum of the replacement market of old mowers and the market created by new residential building.

The replacement market was estimated in the following manner. Of the 880,000 "residential structures" in Los Angeles County in 1946*, it was assumed that 5 per cent do not have lawns, that 10 per cent have lawns mowed by gardeners and that 25 per cent of the rest of the lawns are cut by borrowed or co-operatively shared lawn mowers.

---

* U. S. Census 1946

Thus, the replacement of 550,000 lawn mowers in use make up the replacement market. With an estimated average life of eighteen years for a lawn mower, the yearly replacements amount to 30,000 lawn mowers. Because of the lack of replacements during the war years, this figure should be increased by about 10 per cent for each of the next three or four years, making the replacement market approximately 35,000 lawn mowers per year for the next few years.

The market created by new residential building is surprisingly large. It is expected that 55,000 to 60,000 homes are to be built each year for the next three years in Los Angeles County.* On deducting the 5 per cent without lawns, the 10 per cent cared for by gardeners and the 25 per cent using a co-operative mower as mentioned under the replacement market, it is found that 35,000 lawn mowers per year make up the new building market. Therefore, the total of the replacement market and the new building market makes the estimated 70,000 lawn mowers per year for the next three or four years in Los Angeles County. This figure includes both hand and power mowers, power mowers constituting about 10 per cent of the figure.

These market volume figures have been compared with the yearly sales of some of the larger wholesalers and chain stores in the area as well as with the U . S. Census Data of September, 1946, on lawn mower production and were found to be reasonably accurate.

---

* Los Angeles Examiner Research Bureau.

In a survey to determine where most garden implements are sold, it was found that 67 per cent of the garden implements sold in Los Angeles County were bought in the local neighborhood where they were used, while 10 per cent were bought in the downtown shopping districts.* This tendency to buy garden implements near home explains why lawn mowers are sold successfully in local hardware and garden supply stores even though their prices are considerably higher than the same quality but lower priced mowers sold by chain stores. This also explains the great success experienced by the garden supply departments of chain stores which have moved into out-lying districts.

Seasonal sales are very apparent in the lawn mower market in the Los Angeles area. The "season" is from February to September. The sales peak is in the spring, usually in April, depending upon the rainfall of the particular year.

The subject of power mowers was investigated because of the recent increase in their popularity. It was necessary to determine what effect they had upon the hand lawn mower market.

The sales argument often used in selling power lawn mowers is that a power lawn mower will eventually pay for itself in that it saves time for the user.

---

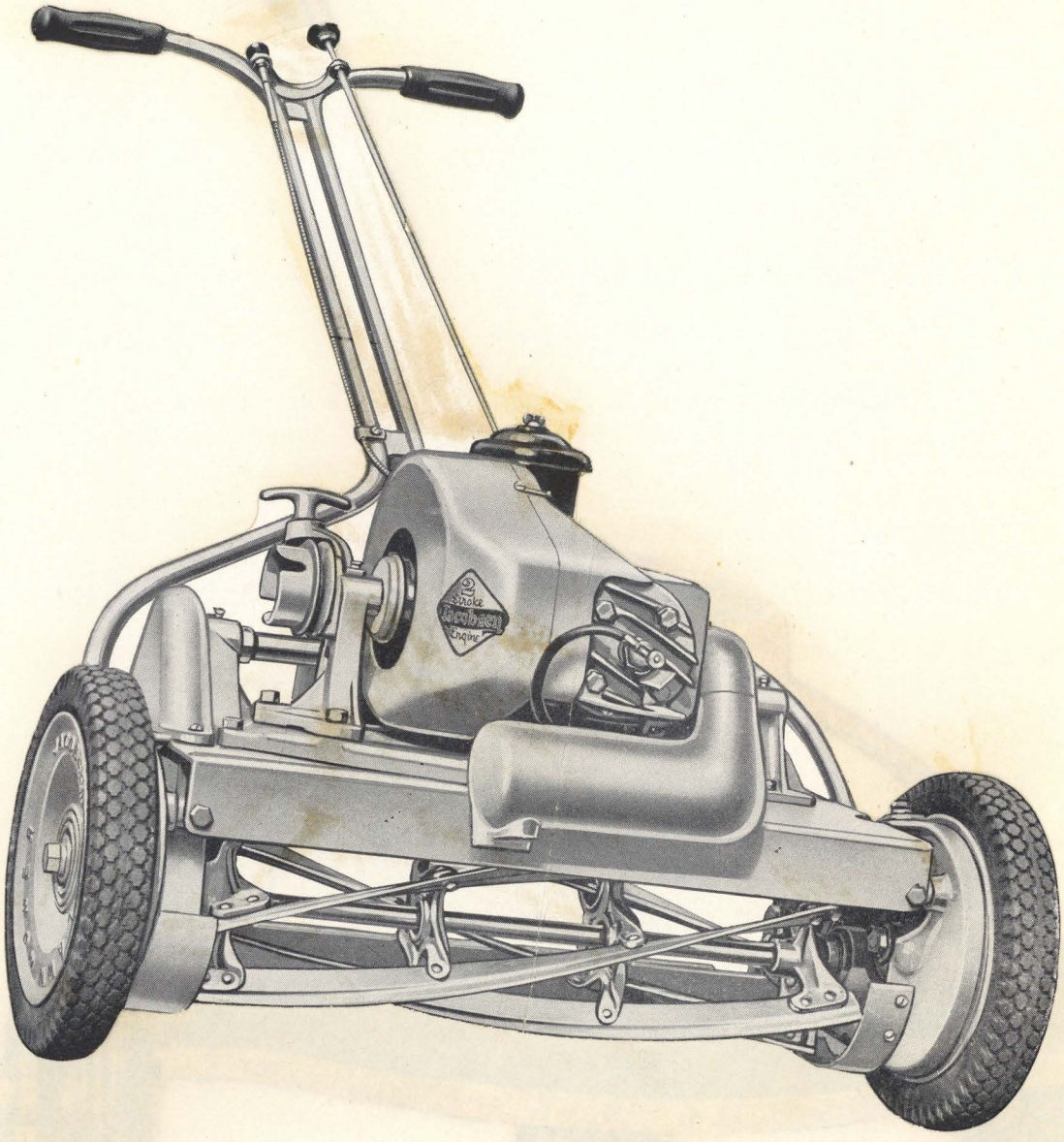
* These figures were complied in a survey made by the Los Angeles Times' Research Department in 1946.

A power mower does save time because it usually cuts a wider swath than a hand lawn mower. Of course, it depends upon the operator as to how fast the mower moves. It is evident that a power mower is worth while for cutting a large lawn. The question then arises as to how large a lawn must be to warrant the use of a power mower. It has been argued in favor of power mower sales that a lawn of a quarter of an acre or more in area will warrant a power mower. Upon calculating the savings in time through the use of a power mower on this size of lawn, it was found that a power mower might pay for itself in seven to eight years. Considering that the average size lawn in Los Angeles County is about 3000 square feet in area* or 1/15 of an acre, it would not seem probable that power mowers at their present day prices will be bought for average size lawns.

There are a number of types of power mowers. The most satisfactory type is the gasoline power mower of the reel type (fig. 1). It will probably remain expensive (about $150.00) and because of this will be comparatively small in unit sales. Power lawn mowers of the rotating blade type (fig. 2), both gasoline and electric, although being much simpler, are also in the $150.00 class. All the rotating blade type mowers on the market cut by means of rotating a dull blade at a very high speed, They have been placed on the market in large numbers since the war.

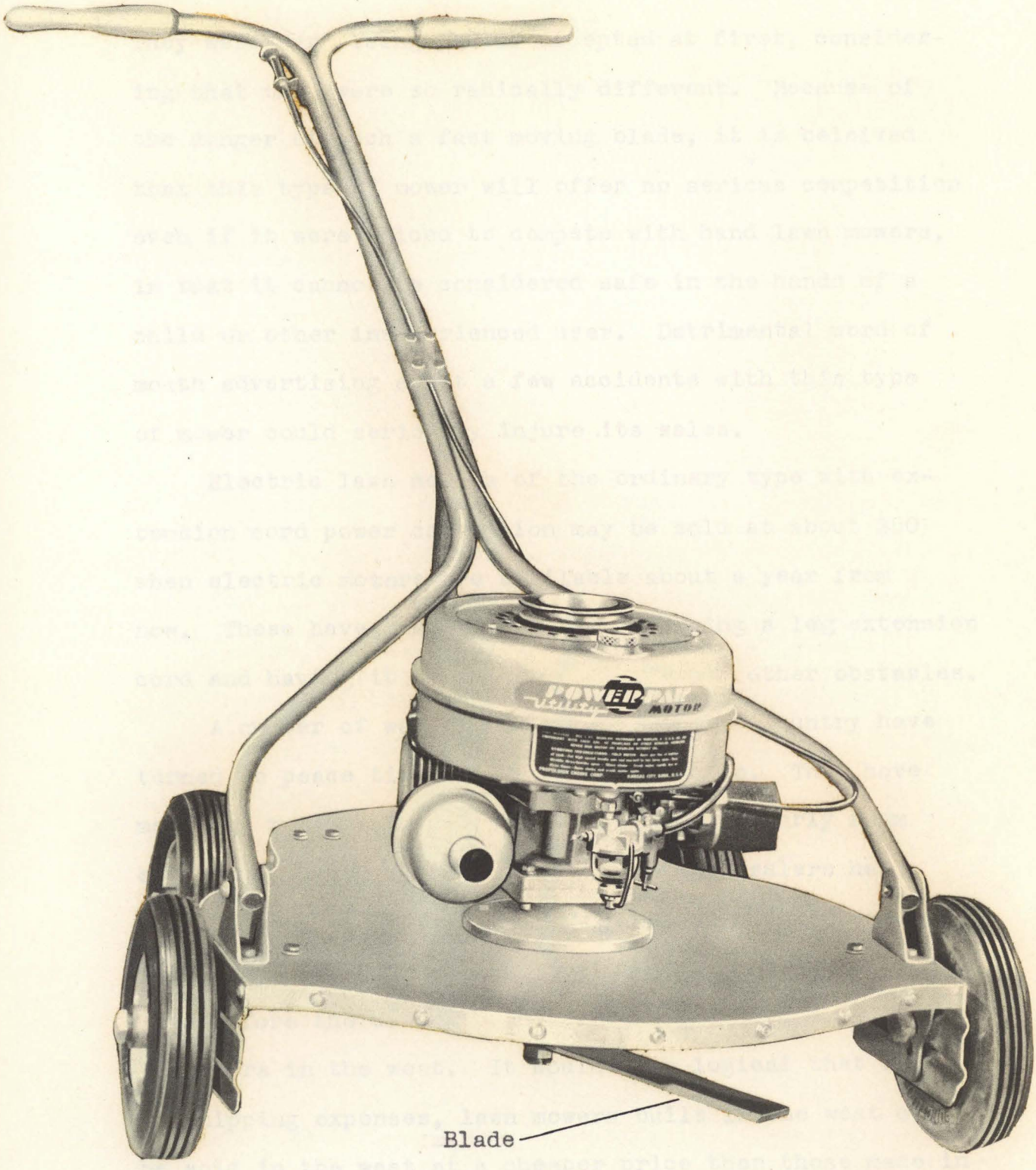
---

* The average size lot in Los Angeles County was estimated to be 5000 square feet, 3000 square feet of which was estimated to be lawn.



TYPICAL GASOLINE POWER MOWER OF THE REEL TYPE

Fig. 1



GASOLINE POWER ROTATING BLADE TYPE MOWER

Fig. 2

They were surprisingly well accepted at first, considering that they were so radically different. Because of the danger of such a fast moving blade, it is beleived that this type of mower will offer no serious competition even if it were priced to compete with hand lawn mowers, in that it cannot be considered safe in the hands of a child or other inexperienced user. Detrimental word of mouth advertising about a few accidents with this type of mower could seriously injure its sales.

Electric lawn mowers of the ordinary type with extension cord power connection may be sold at about $50 when electric motors are available about a year from now. These have the objection of dragging a long extension cord and having it catch around trees and other obstacles.

A number of war plants throughout the country have turned to peace time lawn mower production. They have met with resistance in their sales, particularly from established wholesalers, since these wholesalers have standardized on well-established makes because of need for catalog and pricing standardization.

Before the war there were no large lawn mower manufacturers in the west. It would seem logical that because of shipping expenses, lawn mowers built in the west could be sold in the west at a cheaper price than those made in the east and shipped here. The shipping cost is approximately one dollar per lawn mower in carload lots from east of the Mississippi.

The eastern manufacturers, because of their large volume, experience and long standing reputation, find it easy to compete with new local manufacturers even with the shipping cost handicap.

Conclusions.

Concealed mechanical improvements contribute little to sales promotion.

A less expensive and more attractive hand lawn mower is in demand.

Approximately 70,000 lawn mowers will be sold in each year for the next few years in Los Angeles County.

Most lawn mowers are bought in local neighborhoods.

The peak of the selling season is usually in April.

It is seen that despite the recent increase in popularity of power mowers, hand lawn mowers will continue to hold a very large percentage of the lawn mower market.

PRESENT LAWN MOWER DESIGNS AND DESIGN TRENDS

A study of the design, mechanics and trends of the present day lawn mowers was deemed requisite before one could make an intelligent approach towards designing a more attractive and more functional lawn mower. For this reason the following study was made.

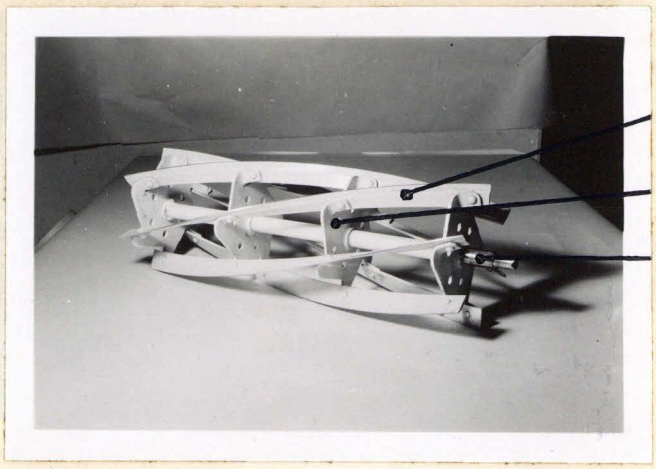
As mentioned in the market survey, lawn mowers are priced more according to their appearance, sales outlet and manufacturer's reputation than their mechanical advantages. The importance of appearance has forced most manufacturers into using some things which improve the looks but not the utility of the mower. An excellent example is the current use of a tubular handle which is more expensive, but actually not much better, than wood (fig.3). A considerable number of chromium plated parts have appeared on many mowers. All kinds of color combinations are on the market--anywhere from pink and light blue to black and yellow. Which colors are correct is only determined by the volume of sales of the various mowers. These sales figures were not available. Information was available that some mowers, because of poor appearance design, did not sell well even when lawn mowers were scarce.

SALES APPEAL ADVANTAGE OF TUBULAR HANDLE OVER WOODEN

Fig. 3

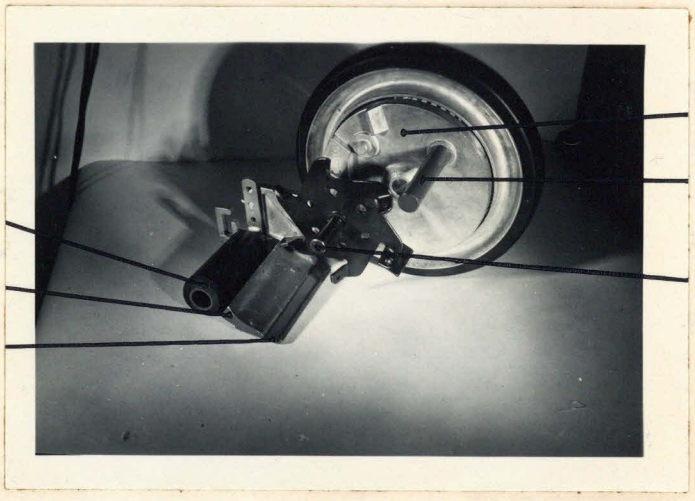
One lawn mower in particular made of cast magnesium parts and well constructed is available at considerably below the established retail price simply because it is "old fashioned" in appearance. It can be noticed that the trend in the appearances of lawn mowers follows very closely that of automobiles of a few years ago. Solid disc wheels are replacing spoke wheels and large chromium plated hub caps are becoming quite apparent (fig.3). A smoother outward appearance, like the automobile, is definitely the trend.

The standard type lawn mower that has stood the test of time for so many years is a rotary shear. It consists of helical rotating blades that shear the grass against a cutter blade placed near the bottom of the cylinder of rotating blades (figs.4 and 5). The rotating blades are driven by pinion gears meshed with ring gears in the wheels at the ends of the reel (fig.6). In conjunction with the pinion gears there is a one-way clutch or ratchet at each end of the reel shaft, the clutches or ratchets being arranged so as to be free-wheeling devices for the reel (figs. 7 and 8). The frame of the lawn mower consists of two side frames or inner wheels which are connected by cross-frame members and the cutter bar, and which hold bearings for the reel, wheels and roller (fig.9).



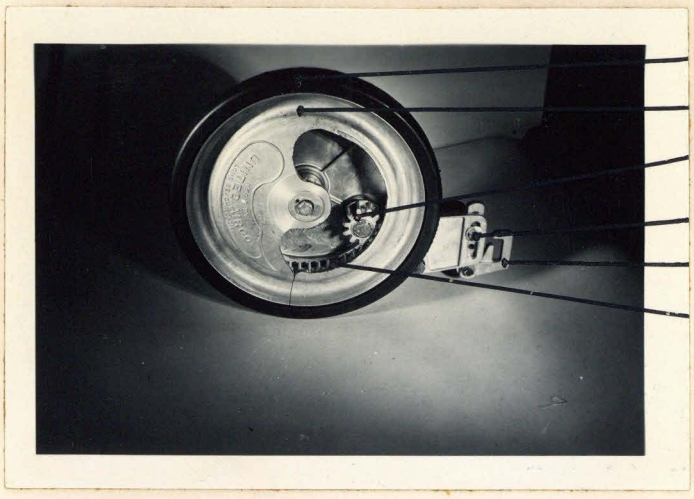
SIX-BLADED REEL

Fig. 4



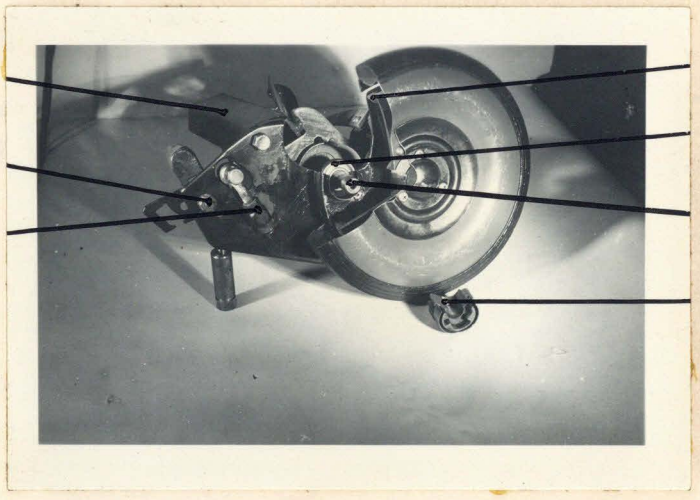
CUT-AWAY VIEW OF ROLLER, CUTTER BAR,
REEL AND BRUSH BAR

Fig. 5



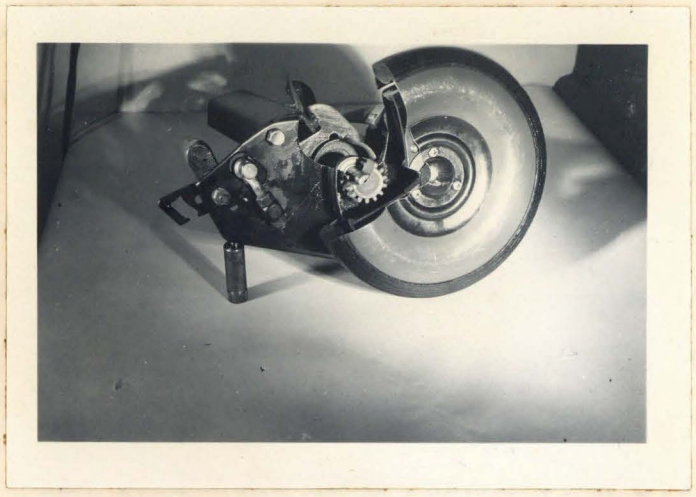
CUT-AWAY SHOWING RING AND PINION GEARS INSIDE WHEEL

Fig. 6



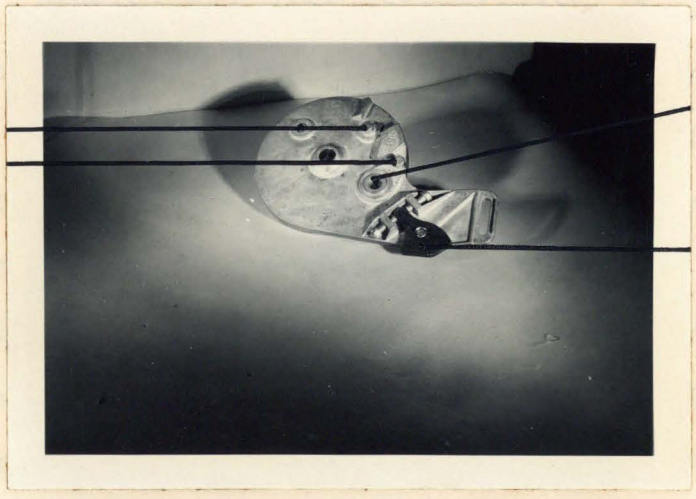
CUT-AWAY VIEW OF LAWN MOWER OF DRAWN STEEL PARTS

Fig. 7



VIEW SHOWING PINION GEAR AND RATCHET TEETH IN PLACE

Fig. 8



DIE-CAST INNER WHEEL OR SIDE FRAME
SHOWING CUTTER BAR ADJUSTMENT

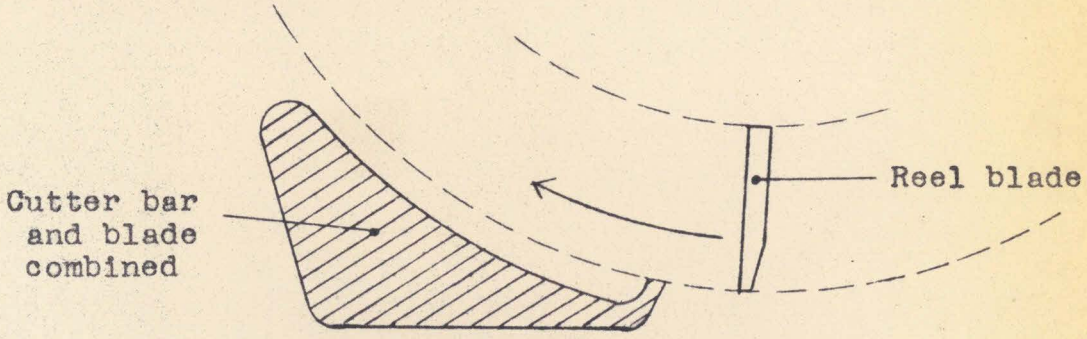
Fig. 9

The cutting height is adjusted by rotating the mower about the axis of the wheels. The cutter bar and reel are behind the axis of the wheels and therefore their height from the ground is changed by this rotation (fig. 5). The cutting height is maintained by adjusting the roller in back so as to support the rear of the frame in the desired position. The position of the cutter bar is adjustable so that allowance can be made for wear of the reel blades and cutter blade (fig.9).

The following is a resume of a study of the shortcomings apparent to the user of present lawn mowers. Such an analysis of the faults and the success of attempted remedies is pertinent in that it is necessary in order that improvement can be made in the basic function of lawn mowers.

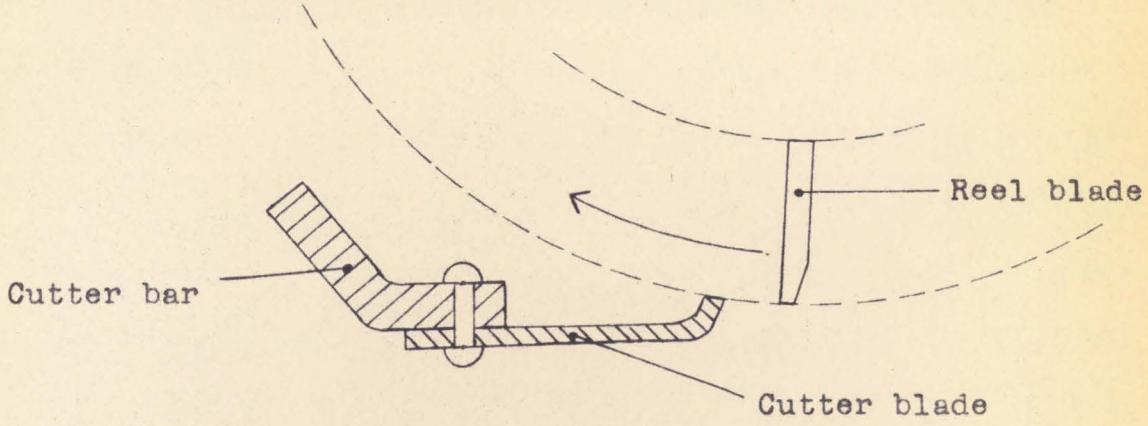
Perhaps the most objectionable fault of the lawn mower is that it is hard to push. The energy needed to shear the average amount of grass on a lawn is not great. The greater part of the energy of pushing is usually consumed in friction between the fast moving cutting blades of the reel and the cutting blade on the cutter bar. Because of the proportionately high speed and gear ratio of the reel, the slightest friction between the reel blades and cutter blade is magnified to the person pushing on the handle.

The ideal solution to this problem is to have the reel blades pass as close as possible to the cutter blade without touching it, but since fine grass can be bent about a radius of a few thousandths of an inch without being cut or broken, this clearance between the two cutting edges must be very small. The only practical method used so far for obtaining accurate close clearance between the cutting edges is that of "lapping in" the reel and cutter blade and then adjusting the reel so that it does not quite touch the cutter blade. To maintain this close "lapped in" clearance, it is necessary to have a very rigid cutter bar and reel as well as the frame that holds them. This has proved difficult to accomplish without excessively increasing the weight and cost (fig.10). The next best solution to the problem is to have a cutter blade that has a slight spring tension against the reel blade (fig. 11). The scraping of the cutting edges produced by the spring tension is objectionable in that it is noisy, creates excessive wear and, even worse, does not solve the problem of friction between the cutting edges. The "lapped in" edges solve the problem but bring about new problems by requiring extreme rigidity. When a small stone or other object is jammed between the rigid blades serious nicking or distortion of the cutting blades may result.



SECTION OF SOLID CUTTER BAR NEEDED FOR
STABILITY FOR "LAPPED IN" MOWER

Fig. 10



CROSS SECTION OF TYPICAL CUTTER BAR AND BLADE EMPLOYING SPRING TENSION OF THE CUTTER BLADE AGAINST THE REEL BLADES

Fig. 11

The older less rigid type of spring tension cutter blade was not so seriously affected by jamming.

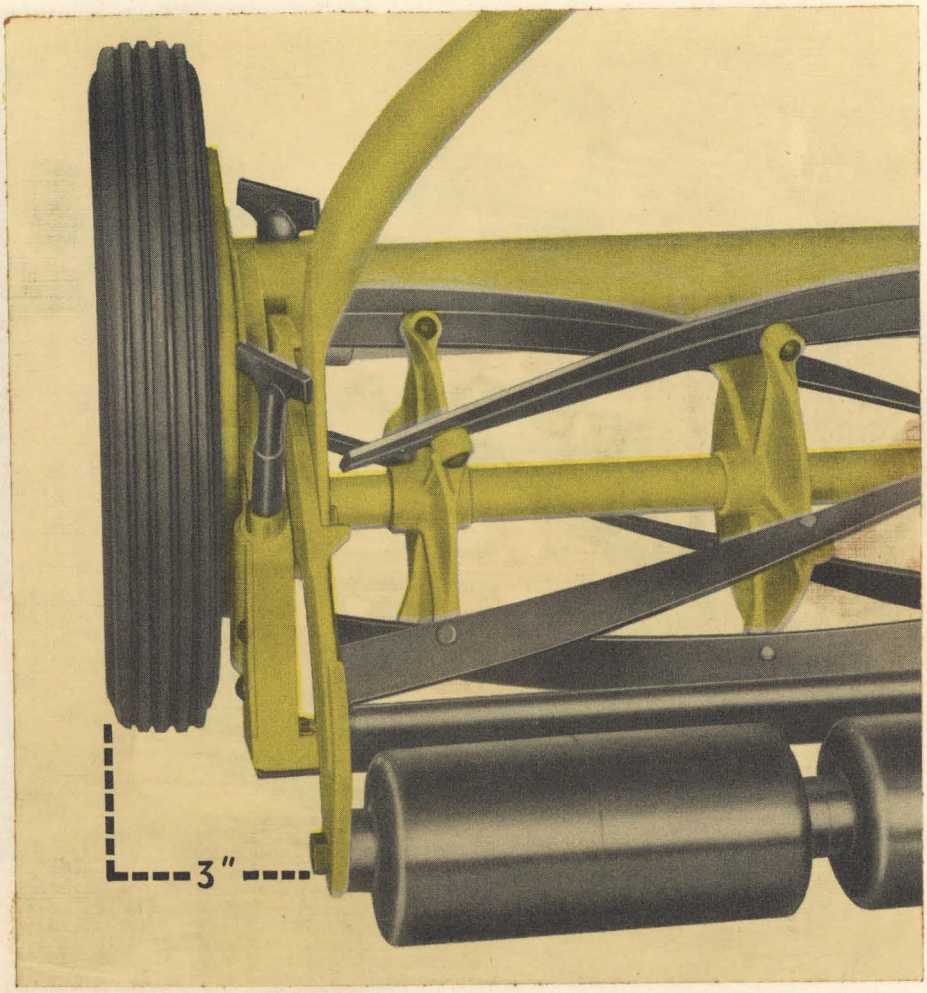
The inertia of a lawn mower contributes to the resistance in handling in small spaces where the lawn mower is started and stopped frequently.

The weight of the lawn mower is determined through a compromise between having enough weight for sufficient traction to power the reel and having sturdy construction, and yet being light enough for easy handling. Recently some mowers have saved weight and cost by being constructed of drawn parts instead of the usual cast frame members. Efforts have been made to lighten lawn mowers by using cast aluminum and magnesium parts. This has increased the cost and not appreciably decreased the weight in comparison with those fabricated of drawn steel parts. The average weight of 41 different lawn mowers was found to be 43 pounds. Except for the "Montamower" which weighs 8½ pounds, the lightest mowers all weighed slightly over 30 pounds. These were constructed of cast magnesium, aluminum or zinc parts. Lawn mowers of drawn steel parts usually weighed between 35 and 40 pounds. Recently the light weight of lawn mowers has become a prominent selling point. Apparently the lighter weight mowers have encountered no difficulty in loss of traction.

Another major fault of today's lawn mowers is their inability to cut or trim close to obstructions or along edges of gardens. The inability to cut close to obstructions such as trees and fences is, of course, because of the width of the wheel and gearing mechanism between the end of the reel and the side of the lawn mower (fig.12).

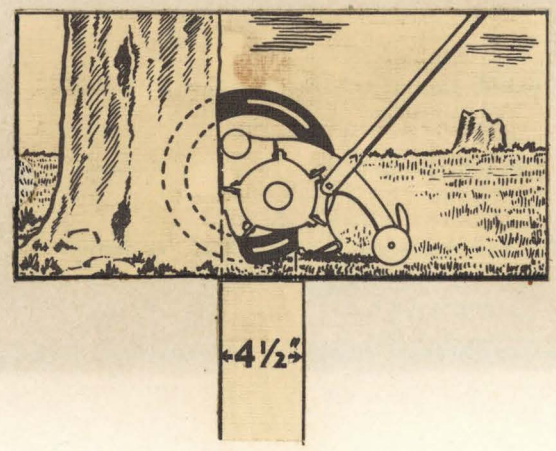
The diameter of the reel and the wheels that protrude beyond the reel prevent the mower from trimming close to an obstruction when the obstruction is met head on with the mower (fig.13). An effort has been made in some power mower designs to put the reel in front of the driving mechanisms so that the cutting width is wider in comparison to the over-all width of the machine (fig.14). However, no hand mower of the reel type has this wide cutting width in comparison to the over-all width. The better hand lawn mowers on the market are six inches wider than their cutting width. There is one mower (the "Montamower") which has a cutting width approximately as wide as the mower itself. However, it was found to be unsatisfactory for cutting larger areas of grass as it does not cut all of the grass blades in its path (fig.15).

Cutting the grass along the edges of gardens is usually difficult in that when the mower is pushed parallel to the edge of the garden one wheel must be well into the garden in order to cut the grass on the edge.



3" MINIMUM DISTANCE FROM OUTSIDE
OF MOWER TO REEL

Fig. 12



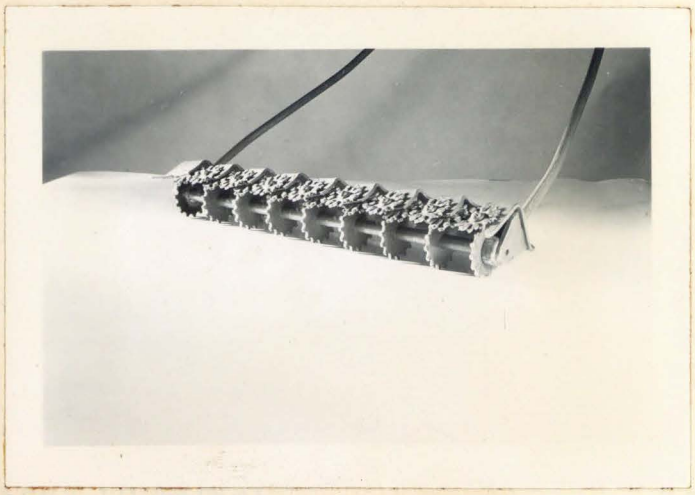
TYPE OF HEAD ON OBSTRUCTION

Fig. 13

▲ Cuts to within 1¼ inches of tombstones, reduces hand trimming.

LEFT. POWER MOWER DESIGNED TO CUT CLOSE TO OBSTACLES

Fig. 14



"MONTAMOWER" TYPE WITH FULL CUTTING WIDTH

Fig. 15

ADVERTISEMENT OF AN ATTACHMENT THAT POINTS OUT THE PROBLEM OF MOWING GARDEN EDGES

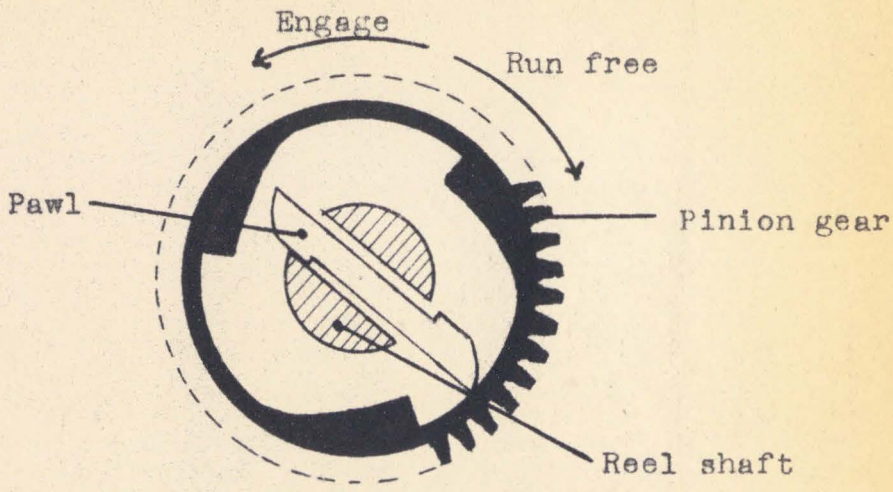
Fig. 16

This is extremely difficult without a special attachment when the garden is at a lower level than the lawn or there is a trough at the edge (fig.16).

The "Montamower" type of mower is better than the reel type for cutting tall grass. The reel type is not able to cut tall grass because the reel blades "roll over" the tall grass instead of guiding it into the cutting blade as it does with short grass.

Many patents have been issued on lawn mowers that will cut any height of grass and on attachments to allow the reel type mower to cut tall grass. None of these have proven too practical to market.

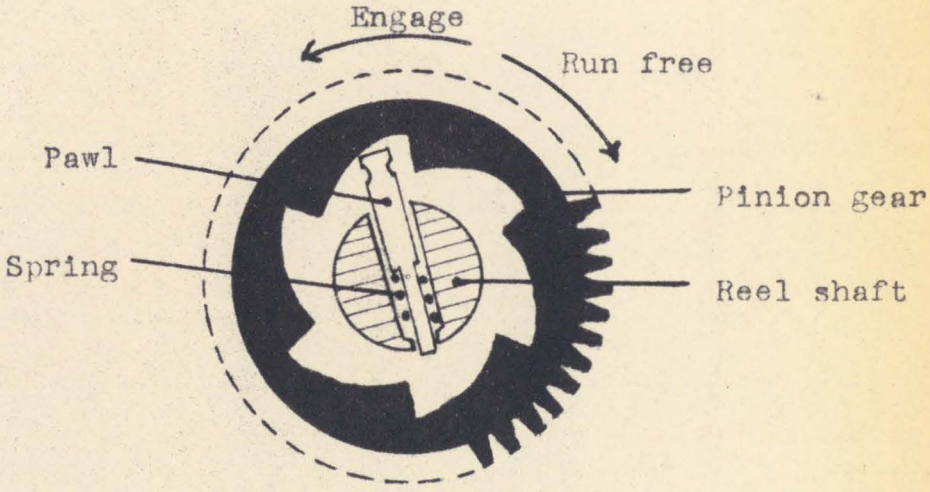
A quiet lawn mower does much to sell itself, but a noisy lawn mower cannot be considered as being too objectionable functionally. The principle cause of noise as well as the principle cause of friction is the scraping of the cutting edges. This noise is entirely eliminated when the cutting edges are "lapped in" and then "backed off" so that they do not quite touch. Ratchet type one-way clutches are also a source of noise (figs. 17 and 18). In an effort to avoid this objection, a few manufacturers have used the roller and cam type of clutch (fig.19). This has not been too successful, however, as they have been known to either jam or run free in both directions when filled with dirt and grease.



LOOSE PAWL TYPE OF ONE-WAY RATCHET CLUTCH WITHIN PINION GEAR

This type is quieter than the spring pawl type but is not as positive and therefore wears faster.

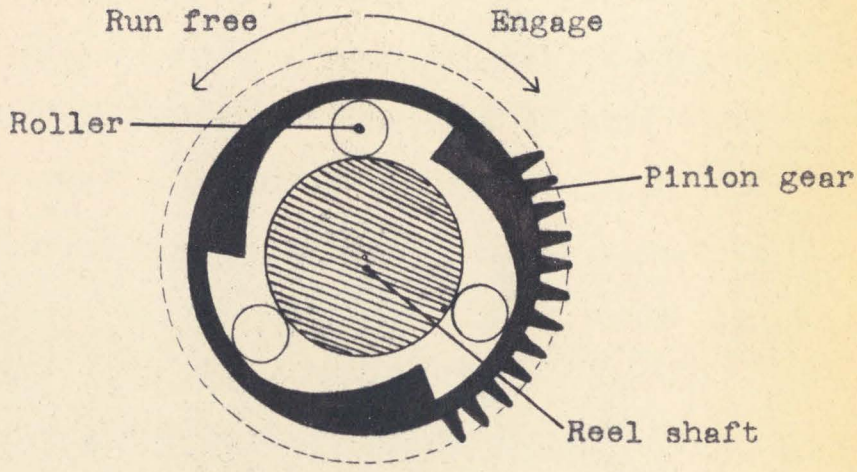
Fig. 17



SPRING PAWL TYPE OF ONE-WAY RATCHET CLUTCH WITHIN PINION GEAR

This type is quite noisy when running free as when the lawn mower is backed.

Fig. 18



SILENT ROLLER AND CAM TYPE CLUTCH

This type is sometimes used, but it is not too dependable.

Fig. 19

Somewhat before the war, and particularly since, most all manufacturers have placed rubber tires on the wheels and a rubber sleeve on the roller both for sake of appearance and to prevent noise when the mower is rolled on the sidewalk or similar hard surface (fig.3). Rubber covered rolling surfaces seem to be very definitely "here to stay".

All lawn mowers, particularly those of the reel type, are easily jammed by sticks, stones or twigs lying in the grass. All attempts to correct this jamming apparently have been unsuccessful. The most effective preventives have succeeded somewhat in keeping articles from jamming the cutting blades, but at the same time have lessened the chance for the grass to freely enter the cutting blades.

What should be done with the grass cuttings when the lawn is mowed is a question about which many people who cut lawns have a definite opinion, but few of whom have plausible reasons for their opinions. Authorities on plant physiology seem to agree that the grass cuttings should be left on the lawn or else some other type of organic fertilizer should be used. When the grass cuttings are long they are apt to lie on top of the lawn and soon turn brown, thus becoming objectionable in appearance. Short cuttings, resulting from frequent cutting or from a power mower that chops up long cuttings, fall down through the grass and turn brown unnoticed.

The ability to chop up the cuttings is necessarily limited to power mowers for the extra effort required to do this with a hand mower is too great. There are always those who insist upon removing the cuttings from the lawn and also since dealers appreciate the chance to sell an extra attachment, all lawn mowers on the market have provision for the attachment of a grass catcher.

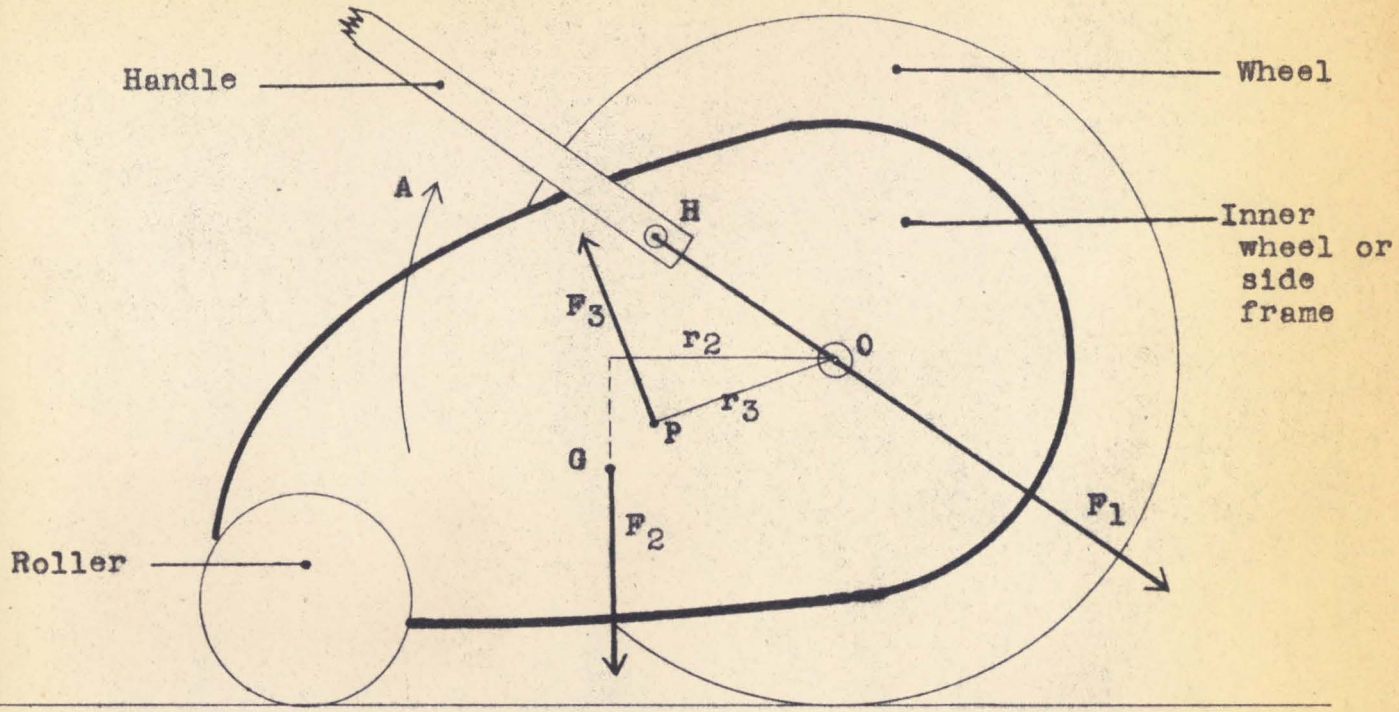
The "inches per clip" is the distance traveled by the mower while the reel rotates from one blade to the next. When the "inches per clip" is large (one-and-a-half inches or more), ripples in the lawn are quite apparent. People who object to these ripples sometimes "cross mow" their lawn, that is, they mow the lawn twice, the second time mowing in a direction at right angles to that of the first time. The "inches per clip" of a mower can be decreased so as to eliminate this by adding more blades or increasing the speed of the reel, both of which increase the resistance in pushing the mower. Most mowers on the market compromise these two objections by having from 1.1 inch to 1.3 inch "inches per clip".

Another compromise that is necessary is the placement of the connection of the handle. It is desirable for the force vector, caused by pushing on the handle, to pass through the axis of the wheels so that the vertical component of this force increases as much as possible the pressure of the wheels on the ground in order to increase the traction.

This cannot be done, however, as then the lawn mower will tend to "rear", particularly in rough grass. This "rearing" is brought about by the upward force of the ring gear on the pinion gear, which raises the rear section of the frame when the cutting is heavy (fig.20). The "rearing" is corrected by placing the handle connection so that part of the vertical force component is distributed to the rear roller as well as the wheels, thereby holding down the frame (fig.21).

The sharpening of lawn mowers is required when the cutter blade or reel blades become bent or excessively nicked. If the lawn mower cut only clean grass it would probably never need sharpening in its lifetime. Lawn mower repair men usually have some form of grinding machine made especially for sharpening mowers. These machines usually require the cutter bar and blade to be removed from the mower in order to be sharpened. The reel blades are sharpened with the reel in the frame. One type of sharpening machine depends upon a rod or tube type of brush bar for the support and alignment of the reel in the machine. Lately lawn mowers have appeared on the market with some type of formed brush bar (fig.22) which cannot be mounted in this machine and, because of this, these particular mowers have met some sales resistance by repair men who have this particular type of sharpening machine.

ANALYSIS OF TORQUES ON INNER WHEEL ABOUT THE WHEEL AXIS CAUSING "REARING"



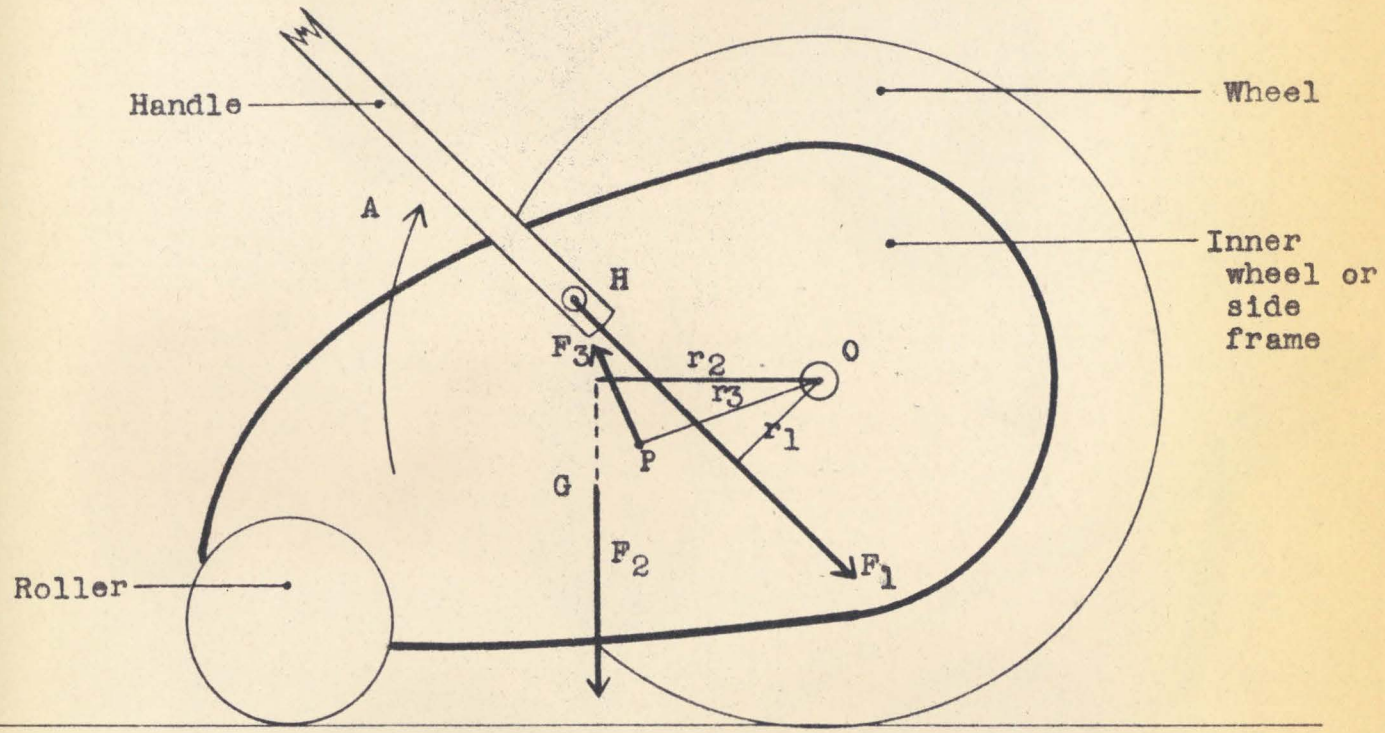
Point H -- Handle connection
Point O -- Axis of wheel
Point P -- Point of contact of pinion gear and ring gear
Point G -- Center of gravity of frame, reel and roller
F_1 -- Force of handle on inner wheel
F_2 -- Force of center of gravity (G)
F_3 -- Force of ring gear on pinion gear

When the handle is improperly connected so that the force of pushing F_1 has no moment arm about point O, the force of F_3 caused by the cutting resistance or jamming need only be sufficient so that the moment F_3r_3 is greater than the constant moment F_2r_2 to cause "rearing" or rotation of the frame in direction A. As soon as the mower begins to "rear" force F_1 shifts so that it becomes a moment increasing the tendency to "rear."

This is a much too often repeated mistake in the design of current lawn mowers.

Fig. 20

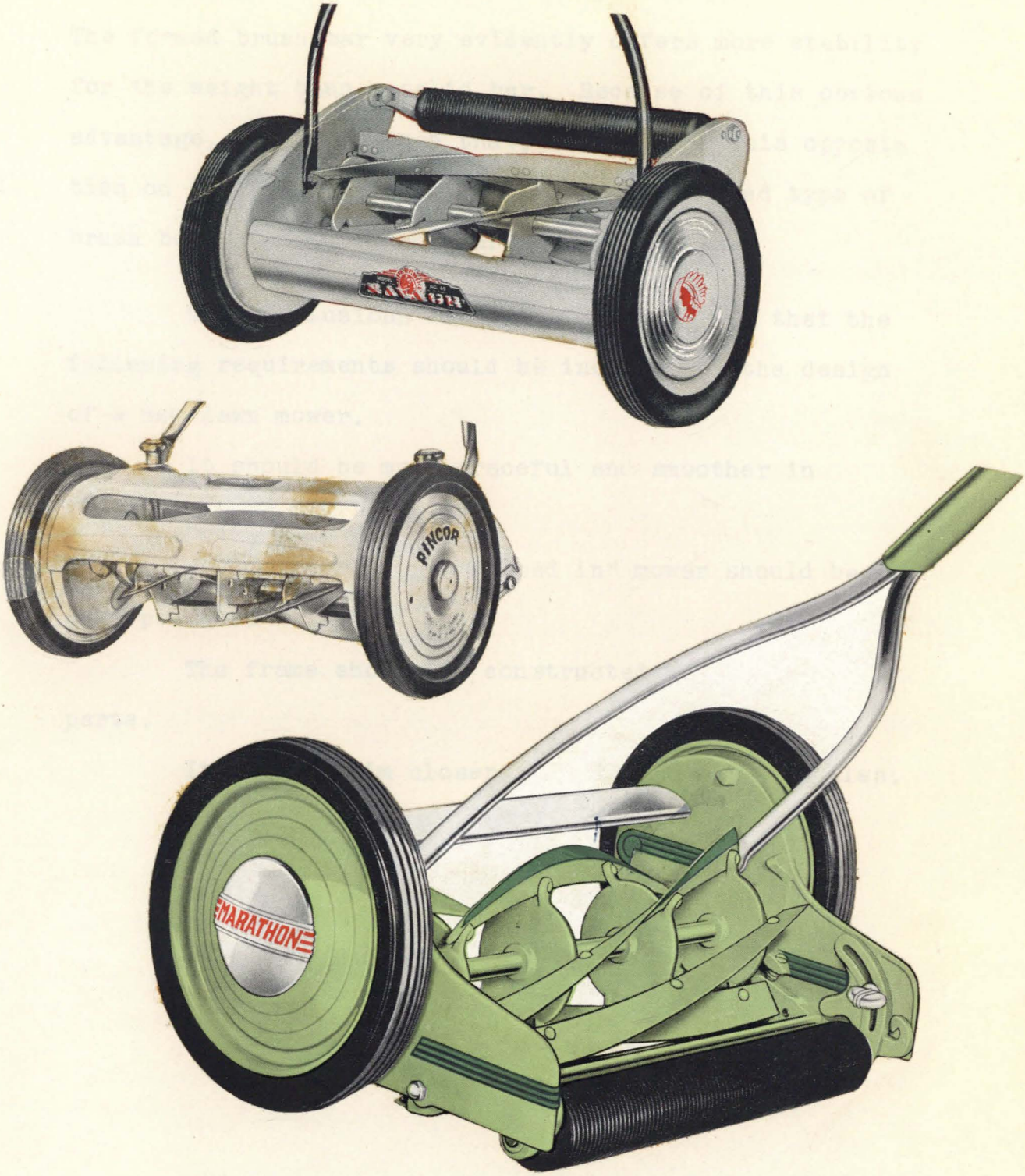
ANALYSIS OF TORQUES ON INNER WHEEL ABOUT WHEEL AXIS PREVENTING "REARING"



Point H -- Handle connection
Point O -- Axis of wheel
Point P -- Point of contact of pinion gear and ring gear
Point G -- Center of gravity of frame, reel and roller
F_1 -- Force of handle on inner wheel
F_2 -- Force of center of gravity (G)
F_3 -- Force of ring gear on pinion gear

When the handle is connected so that it creates the moment $F_1 r_1$ "rearing" is prevented in that an increase of F_3 is caused by an increase in F_1. Moment arm r_1 should be kept at a minimum as long "rearing" is prevented, thus maintaining maximum pressure on the traction wheel.

Fig. 21



EXAMPLES OF FORMED BRUSH BARS

Fig. 22

The formed brush bar very evidently offers more stability for the weight than a solid bar. Because of this obvious advantage, it is believed that, in spite of this opposition on the part of some repair men, the formed type of brush bar will become popular.

The conclusions of this study indicate that the following requirements should be included in the design of a new lawn mower.

It should be more graceful and smoother in appearance.

Advantages of the "lapped in" mower should be incorporated.

The frame should be constructed of formed sheet parts.

It should trim closer to all types of obstacles.

It should operate quietly.

DESIGN RESEARCH

The approach to this design problem was intentionally as basic as possible. Many of the methods of cutting grass which were considered and were experimented with might seem ridiculous. However, the methods were studied so that it could be determined if the principle underlying these methods of cutting possessed any potential possibilities of development into a functionally better lawn mower.

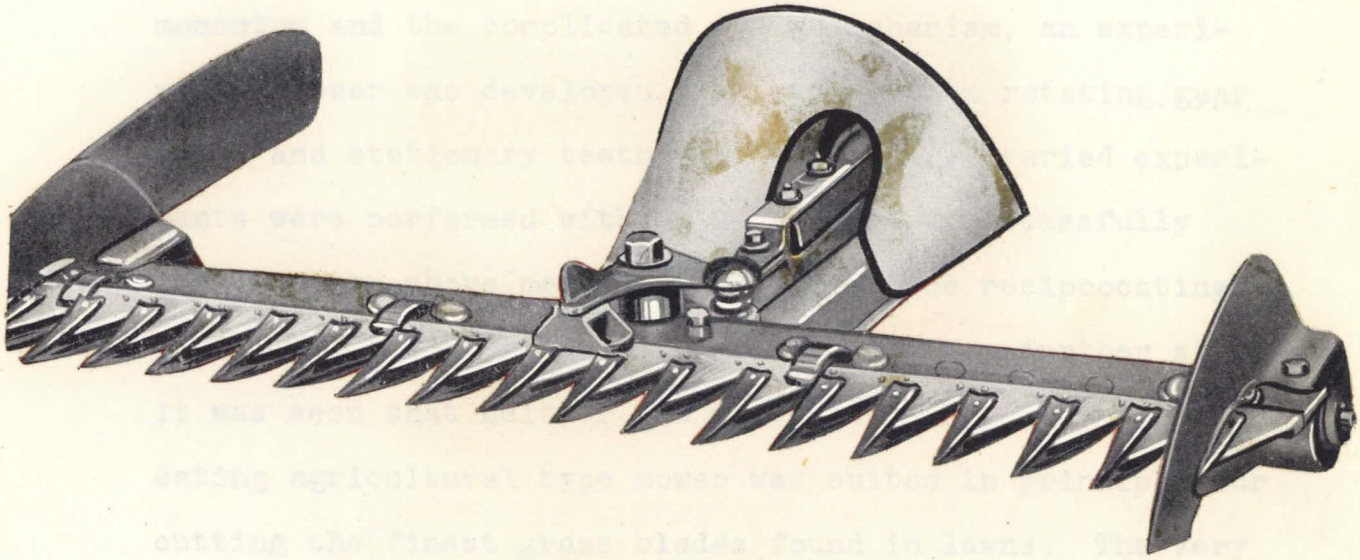
One such method studied was that of cutting grass by means of a horizontal flame held at the desired cutting height and moved in various directions through the grass. This was very successful in cutting grass but, of course, has disadvantages, fire hazard being the greatest. In the experiment, the flame scorched about a half an inch of the length of the grass blade below where it was burned off. Possibly this could be improved by using a thinner flame. The major disadvantage to this method, however, was that the flame would cut the grass only when it was moved very slowly through it.

Experience with a hand sickle indicated that either an extremely sharp edge must be maintained or the edge must be moved at an exceedingly high speed in order to cut the grass. As mentioned previously, power mowers of

the rotating blade or sickle type employ a somewhat dull blade and do the cutting by means of a very high speed rotation (fig. 2). Since even a carefully handled hand type sickle needs frequent sharpening, it is only reasonable that no attempt be made to maintain a sharp edge on the power operated rotary sickle type mower. Hand powered sickle type mowers have been invented and developed. These, of course, require very sharp blades in order to operate satisfactorily when pushed at slow speeds. No doubt this type has not been seen on the market because of their need for frequent sharpening.

The "Montamower" type of mower consists of sets of gears which cut the grass between the ends of the gear teeth on adjacent gears (fig. 15). This is done by having the ends of the teeth overlap each other as they mesh. A slightly worn "Montamower" was tested and it was found that some blades of grass passed through the cutting edges without being cut. It was also found that the driving and traction wheels tended to roll over grass blades growing on a slant and prevent them from being cut by the gears. There is no practical way of readjusting this type of mower so as to allow for wear. Because of this inability to do a complete job of cutting in one pass over the lawn, particularly when the gears are slightly worn, this type was not considered a satisfactory basis upon which to design.

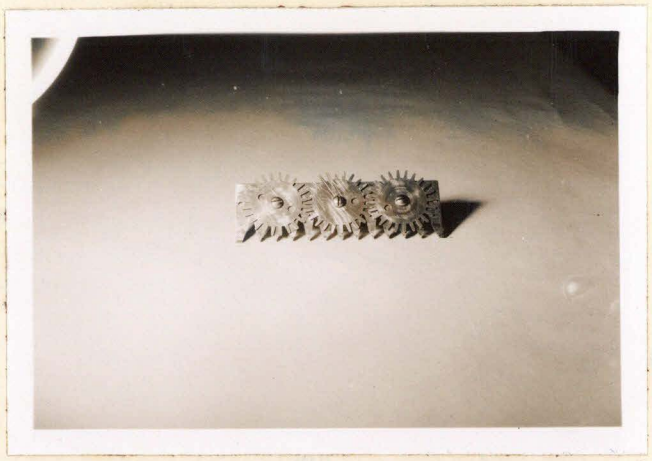
The agricultural type mowing machine was studied (fig. 23).

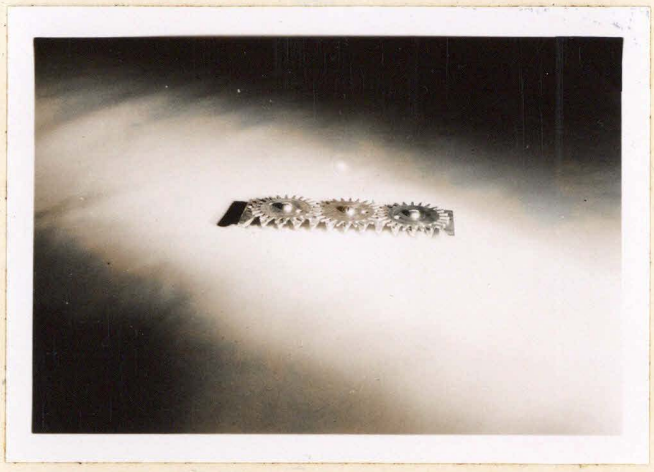


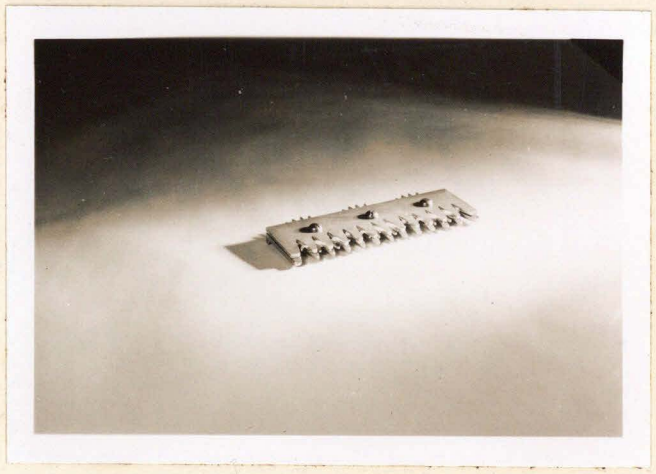
RECIPROCATING AGRICULTURAL TYPE MOWER

Fig. 23

The obvious objection to this type of mechanism on a hand mower is the increased friction of the numerous reciprocating teeth on the stationary teeth and the lack of conservation of momentum of the reciprocating motion. Additional friction is encountered also in the comparatively complicated mechanism needed to convert the rotary traction power to a reciprocating cutting action. In an effort to overcome the objections of this lack of conservation of momentum and the complicated power mechanism, an experimental mower was developed that cut between rotating gear teeth and stationary teeth (fig. 24). Many varied experiments were performed with this mower. It successfully overcame the above mentioned faults of the reciprocating teeth mower and cut grass quite well. After further study it was seen that neither the above mower nor the reciprocating agricultural type mower was suited in principle for cutting the finest grass blades found in lawns. The very fine grass blades sometimes were bent over the stationary tooth cutting edge by the moving edge without being cut regardless of the sharpness or accuracy of the cutting edges (fig. 25). It is difficult to maintain any appreciable clearance angle behind the cutting edges on this type mower and so the bent over grass blades jam between the bearing surfaces of the stationary and moving teeth.

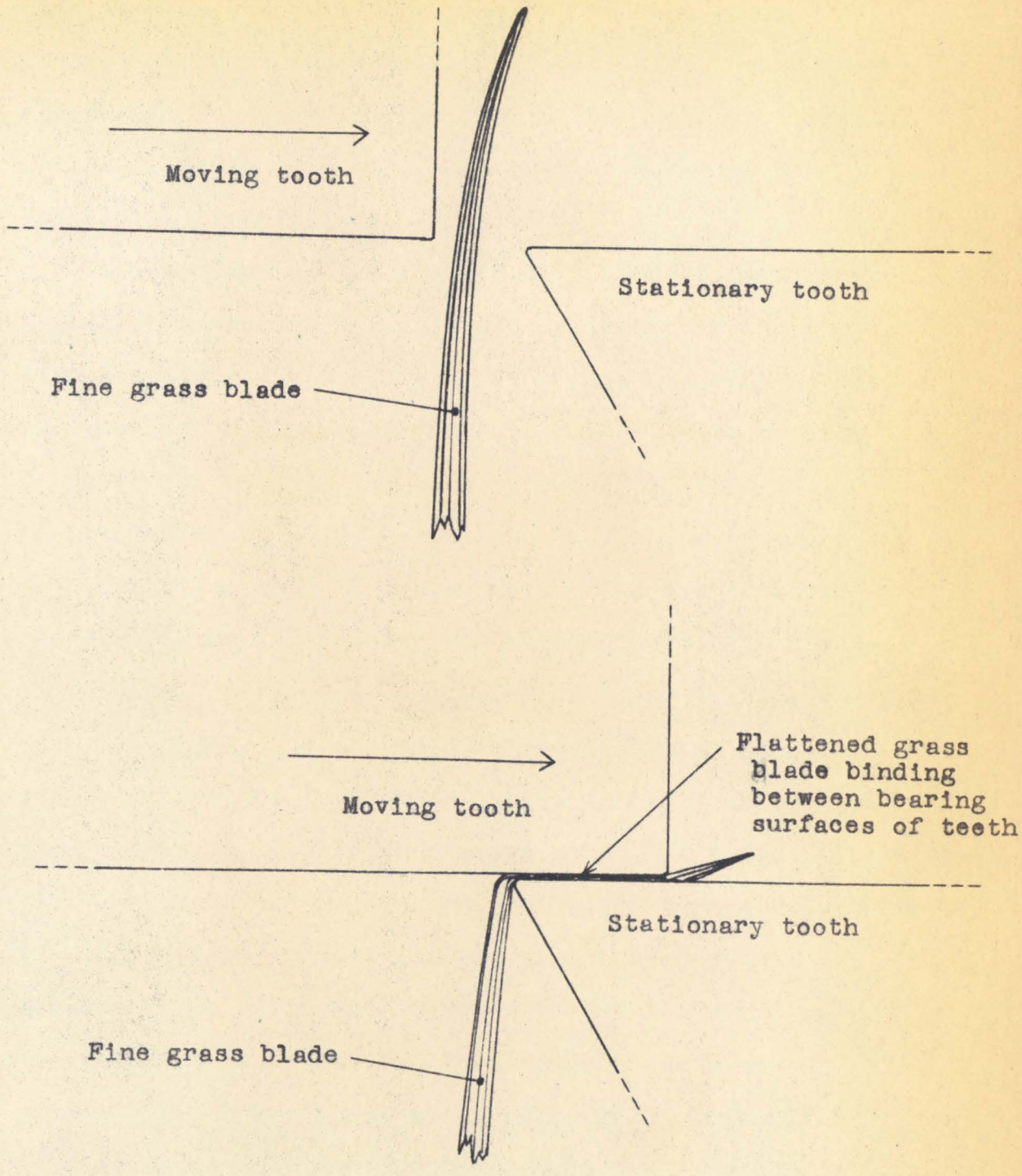






ROTARY MOTION EXPERIMENTAL MOWER

Fig. 24



ENLARGED DIAGRAM OF BINDING ACTION OF FINE GRASS BLADE BETWEEN BEARING SURFACES OF TEETH

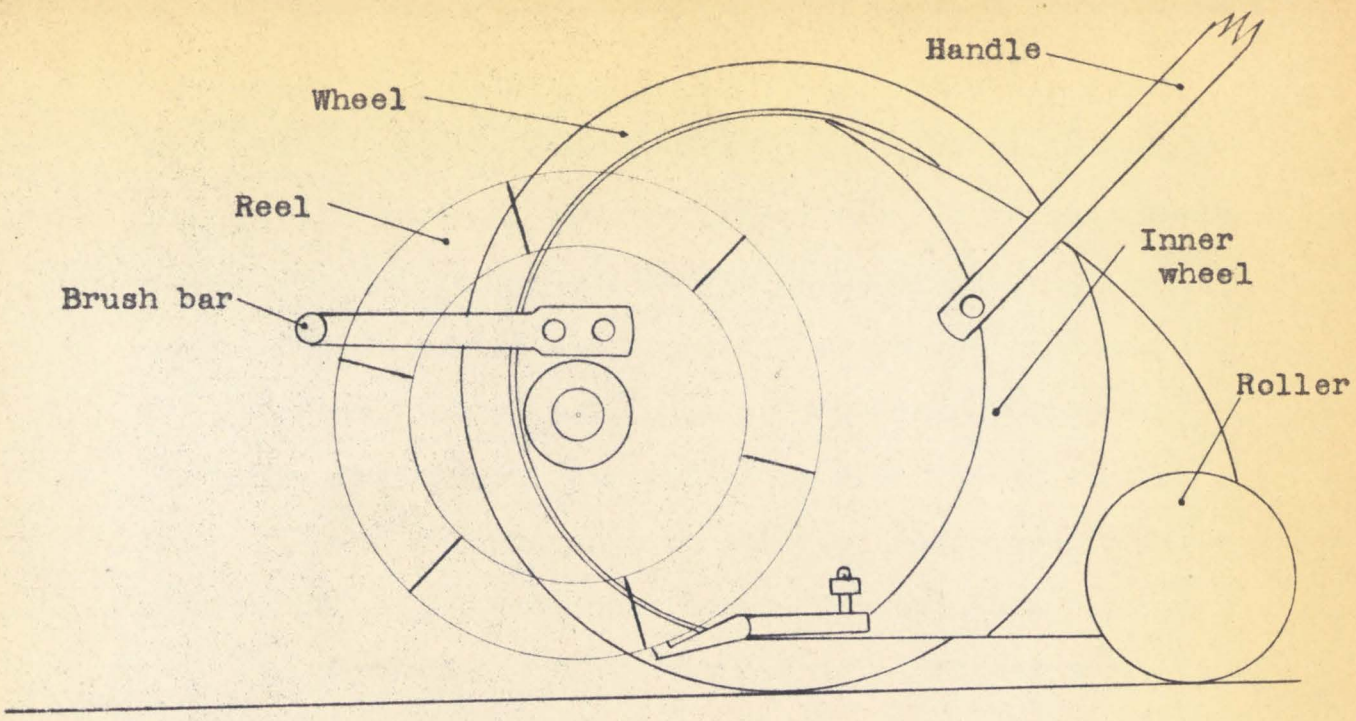
Fig. 25

This jamming increases the pressure and therefore the friction between the bearing surfaces. In a power driven mower this increase in friction is not too objectionable, but it is sufficient in a hand powered mower to make this design impractical.

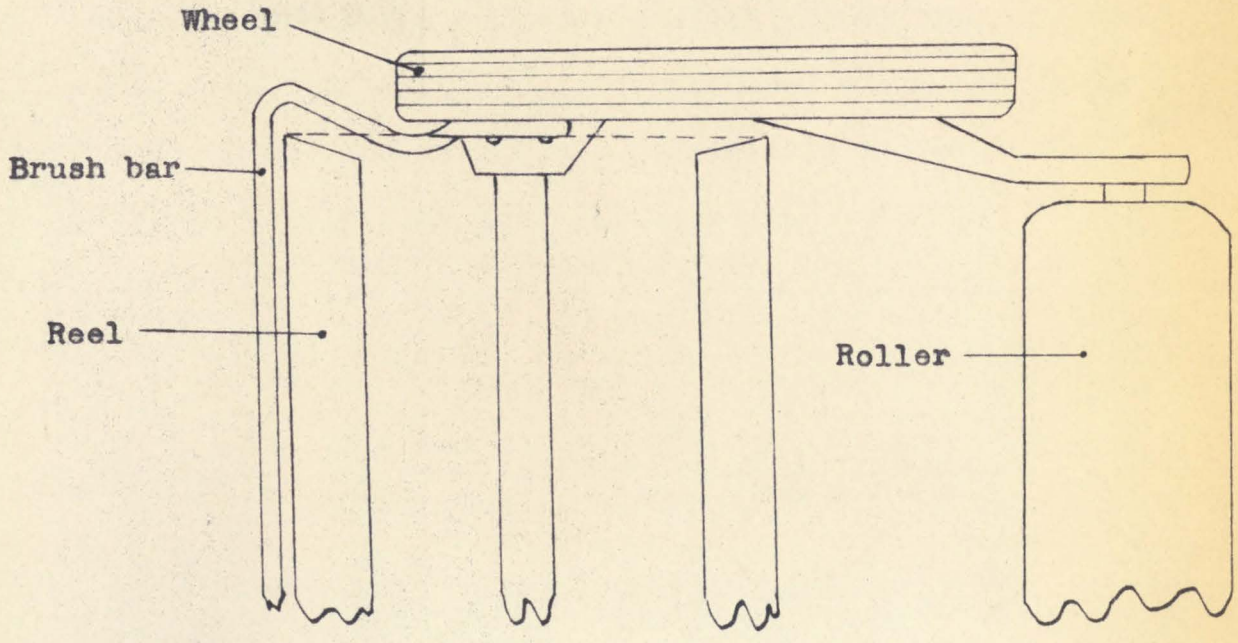
On considering the results of the above mentioned experiments and analyses, it was decided that the conventional reel type mower, in spite of its apparent faults, was the most satisfactory type to design. The ability of this type to clip the grass between two accurately positioned sharp edges while maintaining its bearings and mechanisms above and free from the grass cuttings and dirt, makes it superior for cutting lawn type grass.

Three different arrangements of the reel type mower were developed, one of which was decided upon as being worthy of further development and submission as the final thesis design. The other two are described here.

The first of the designs that was not chosen used the conventional wheels and ring and pinion gears. The essential difference between it and the usual mower was that the reel shaft was placed well ahead of and somewhat below the wheel shaft (fig. 26). This offered advantages in that the cutting position of the blades was ahead of the most forward support of the mower and, because of this, grass along the edges of gardens and obstructions could be mowed more easily.



SIDE ELEVATION SECTION OF MOWER WITH REEL IN FRONT

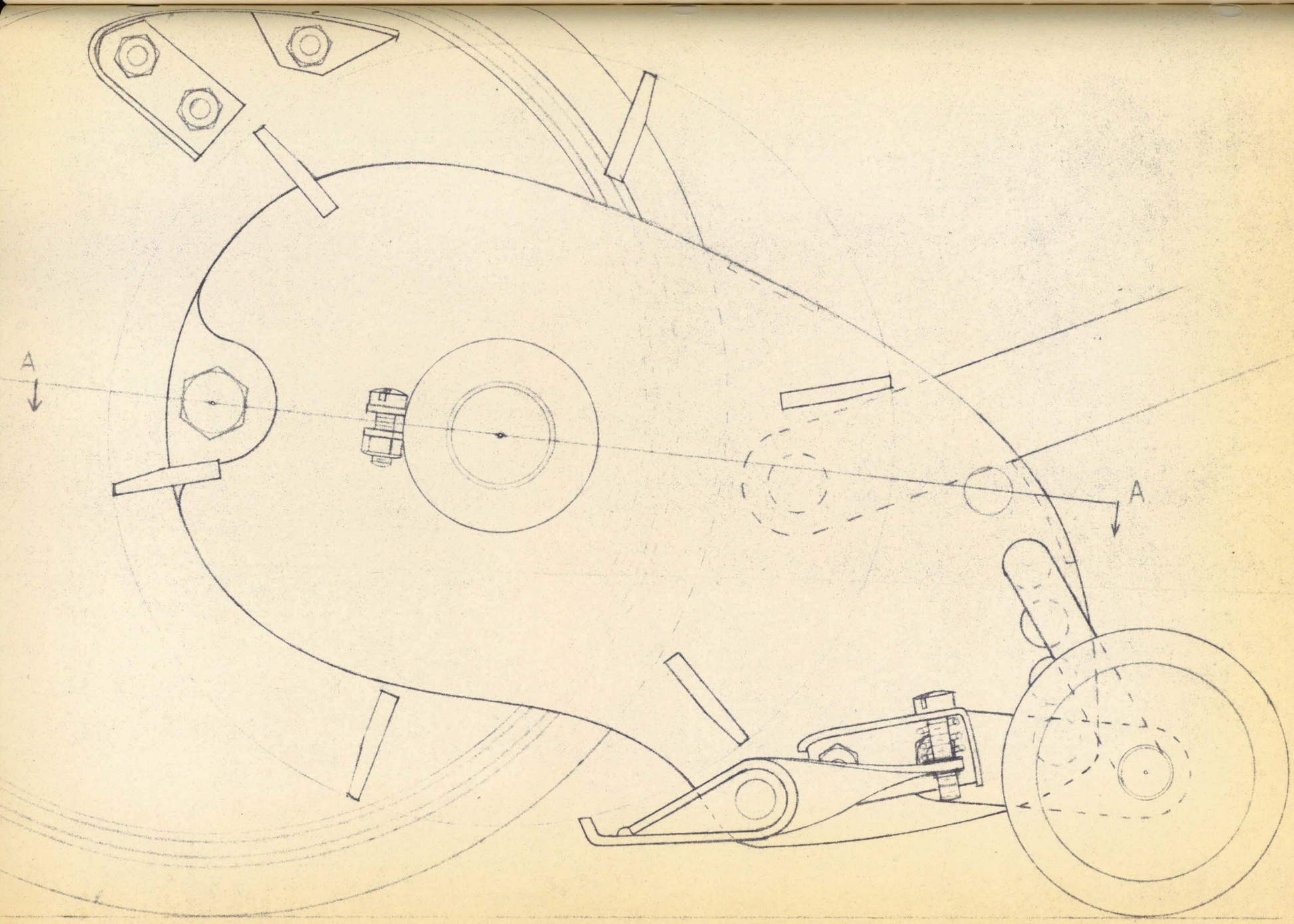


TOP VIEW OF MOWER WITH REEL IN FRONT

Fig. 26

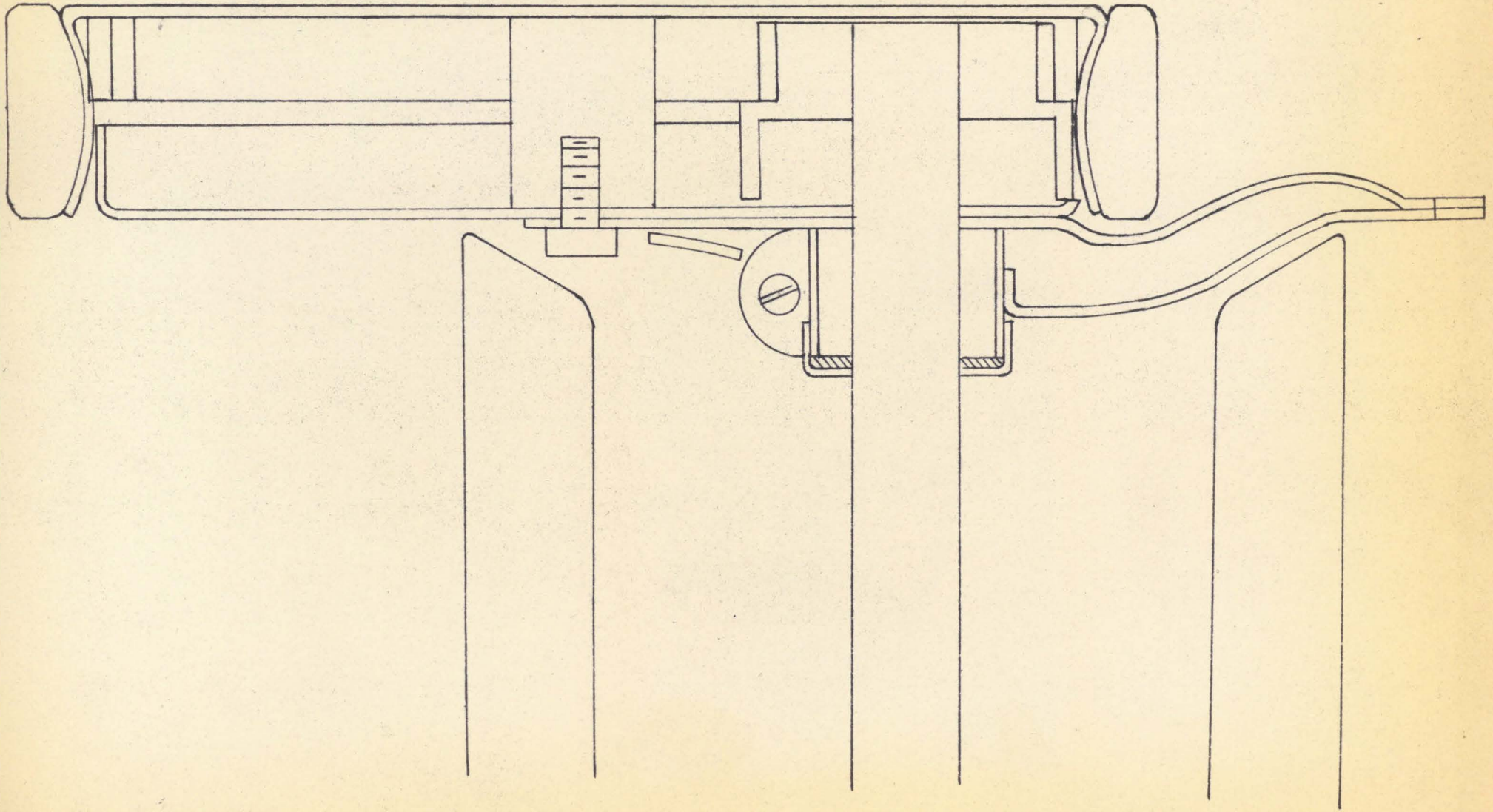
This design also allowed a wider cutting width in comparison to the over-all width of the mower since frame members supporting the roller and handle connections could be extended from behind the area of the reel. The design was rejected because difficulties were encountered in providing the proper gear ratios between the wheel and reel. It was not possible to achieve this proper ratio without enlarging the wheel beyond a reasonable extent.

The other design that was not selected was very similar to the conventional mower, the only essential difference being that the frame was arranged in such a way as to allow a wider reel in the usual position providing again a wider cutting width in comparison to the over-all width of the mower (figs. 27 and 28). This design necessitated somewhat smaller wheels than are commonly used, but this was not considered to be the least bit disadvantageous. It was rejected in favor of the proposed design that has many more improvements.



SIDE ELEVATION SECTION OF MOWER WITH EXTRA WIDE REEL

Fig. 27



SECTION A-A OF FIGURE 32, TOP VIEW

Fig. 28

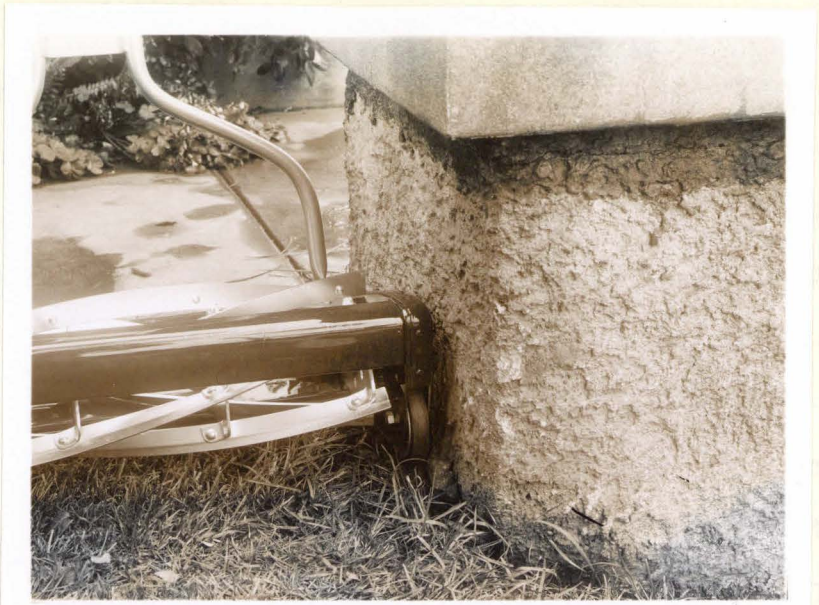
PROPOSED DESIGN

PROPOSED DESIGN

As stated in the introduction, the purpose of this design is to eliminate or improve upon one or more of the more objectionable shortcomings of present lawn mowers. The proposed design includes a number of such improvements that do much to facilitate and widen its uses.

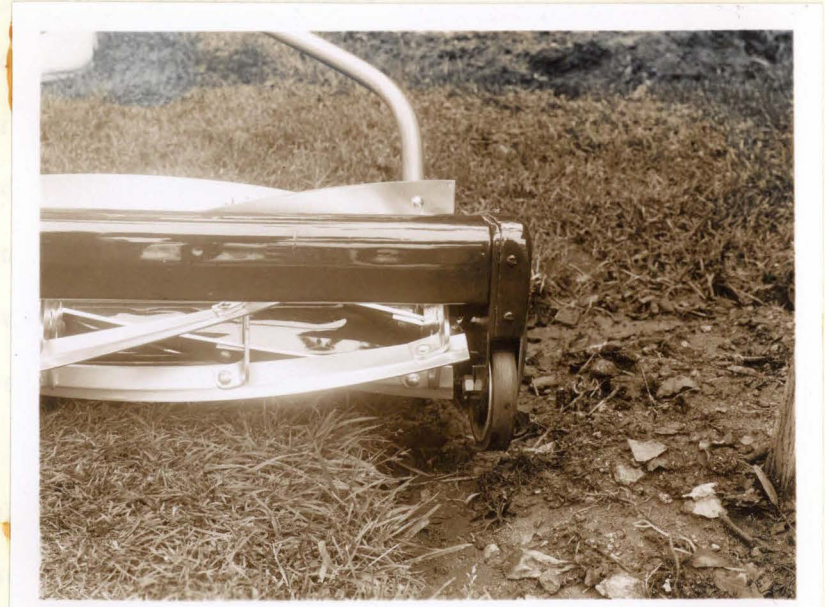
The most important and most apparent advantage of this mower is its ability to cut close to obstacles such as trees, fences and walls (fig. 29). The distance from the outside of the mower to the ends of the reel and cutter blade has been reduced from the usual three or three-and-one-half inches to one-and-a-quarter inch thereby enabling this mower to cut very much closer to obstacles than any other hand lawn mower of the reel type.

The proposed design offers another outstanding improvement in that the user can easily mow out over edges of troughs or gardens. By simply depressing the handle slightly the weight is lifted off of the front dolly wheels and the mower is supported by the roller in back which supplies the power to the reel. With the handle in this position the mower can be operated easily with one end suspended out over an edge of the lawn thereby allowing it to cut the grass all the way out to the edge (fig. 30).



CUTTING CLOSE TO OBSTACLE

Fig..29



CUTTING EDGE OF LAWN

Fig. 30

In the same manner the edges can be cut easily when they are met head on with the mower since the cutting is done well ahead of the line of support of the roller. As previously mentioned, no other mower of the reel type is capable of mowing such edges easily without special attachments.

The noise of this mower has been reduced to a minimum. All surfaces that roll on the ground are covered with rubber tread. The power is transmitted by a silent "V" belt drive and a quiet non-ratchet clutch.

The designer has taken advantage of the merits of the "lapped in" type mower and incorporated them in this mower so that it cuts grass with a minimum of effort on the part of the user.

Many minor improvements have also been incorporated in this design.

When this new mower is in the "wheeling" position as when used in going to or from a garage or storage place, it will move very easily in both directions, unlike the usual mower that can be pushed but not pulled easily in the "wheeling" position (fig. 31). This ease of handling results from its resting only on the free-running dolly wheels when in the "wheeling" position. When the handle is raised past the vertical position it will stand by itself nearly upright and leaning forward slightly (fig. 32).

"WHEELING" POSITION

Fig. 31

STORAGE POSITION

Fig. 32

Space is saved in storage and more ease of handling when storing is achieved by the handle resting in this vertical position.

By utilizing a simpler and more compact design, light weight is accomplished without sacrificing the necessary strength or rigidity.

The most outstanding difference between this design and ordinary mowers is that it is powered by a large roller behind the reel instead of by two wheels at the ends of the reel (fig. 33). This arrangement was chosen to achieve the advantage of narrowing the uncut width at the end of the reel.

The following is a description of the various parts and mechanisms of the mower.

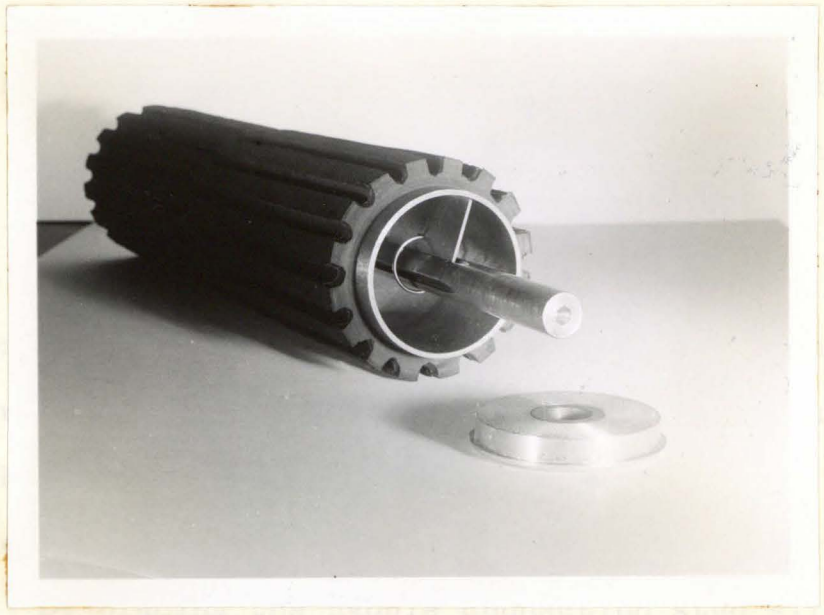
The reel used in the model is the same as that used by a local manufacturer. This has six chromium-molybdenum steel blades, formed steel spiders, and a cold rolled steel shaft (fig. 33). Formed steel spiders are less expensive to produce and at the same time offer a maximum of strength and stability in comparison to various types of cast spiders. The type of reel used in the model is highly recommended for use in a production model. The "inches per clip" produced by the six blades and gear ratio of the model is 1.3 inch. The roller that powers the mower is divided into two equal and independent sections mounted on the same shaft. Each section has a free-wheeling clutch within it.

REAR VIEW WITH HANDLE DISCONNECTED

Fig. 33

The clutches are housed within the two sections of the roller so that they do not occupy precious space at the ends of the reel. Greater ease of turning is provided by two sections and the mower may be turned sharply, such as around a tree, and like the ordinary lawn mower with two wheels and two clutches, the reel will cut at a corresponding speed to that speed of the outside wheel or section of roller as in this case. In the model, as shown here, the roller sections are made of tubing with caps and bearings at each end (fig. 34). It is suggested that in the production model these sections be made of wood with a formed cup-shaped clutch housing at one end of the wood section. The wood would be covered with rubber tread as the tube is covered in the model.

The question has been presented as to whether the roller would have sufficient traction to power the mower. On inspecting the forces involved it is seen that the tangential traction force on the roller is the same as that tangential force on the wheel of an ordinary lawn mower providing the reel speeds and blade friction are the same. The tangential force on the roller or wheel is equal and opposite to the horizontal force on the handle which is the force F in the formula Work=Fs. Considering that the work required to cut the grass is constant over a unit distance s it is apparent that F is constant and independent of the diameter of the wheel or roller.



ROLLER PARTIALLY DISASSEMBLED WITH
ONE PAWL OF CLUTCH IN PLACE.

Fig. 34

There must be a sufficient load on the roller to prevent it from slipping on the lawn since the static friction between the roller surface and the lawn is directly proportional to the load. Because the static friction must be sufficient to transmit the traction power to the mower it is important that the load be great enough to prevent the roller from slipping. On the other hand it is desirable to have the load light enough so that when the mower is jammed in any way the roller will slip on the lawn enough to absorb the shock.

It is apparent that the center of gravity of this mower is well ahead of the roller, and because of this the load on the roller possibly may not be great enough to supply the proper static friction between the roller and the lawn. By placing the handle connection stud slightly behind and below the roller shaft (fig. 33) the force on the handle increases the load of the roller sufficiently to prevent the roller from slipping except when it is desirable as when the mower is jammed.

Rolling friction is the factor that limits the minimum diameter of the roller. Since the rolling friction is inversely proportional to the radius, a very small roller would meet considerable rolling friction in rolling over thick grass, soft ground or other yielding surface. The coefficient of rolling friction of lawns is extremely variable because it depends upon so many widely varying

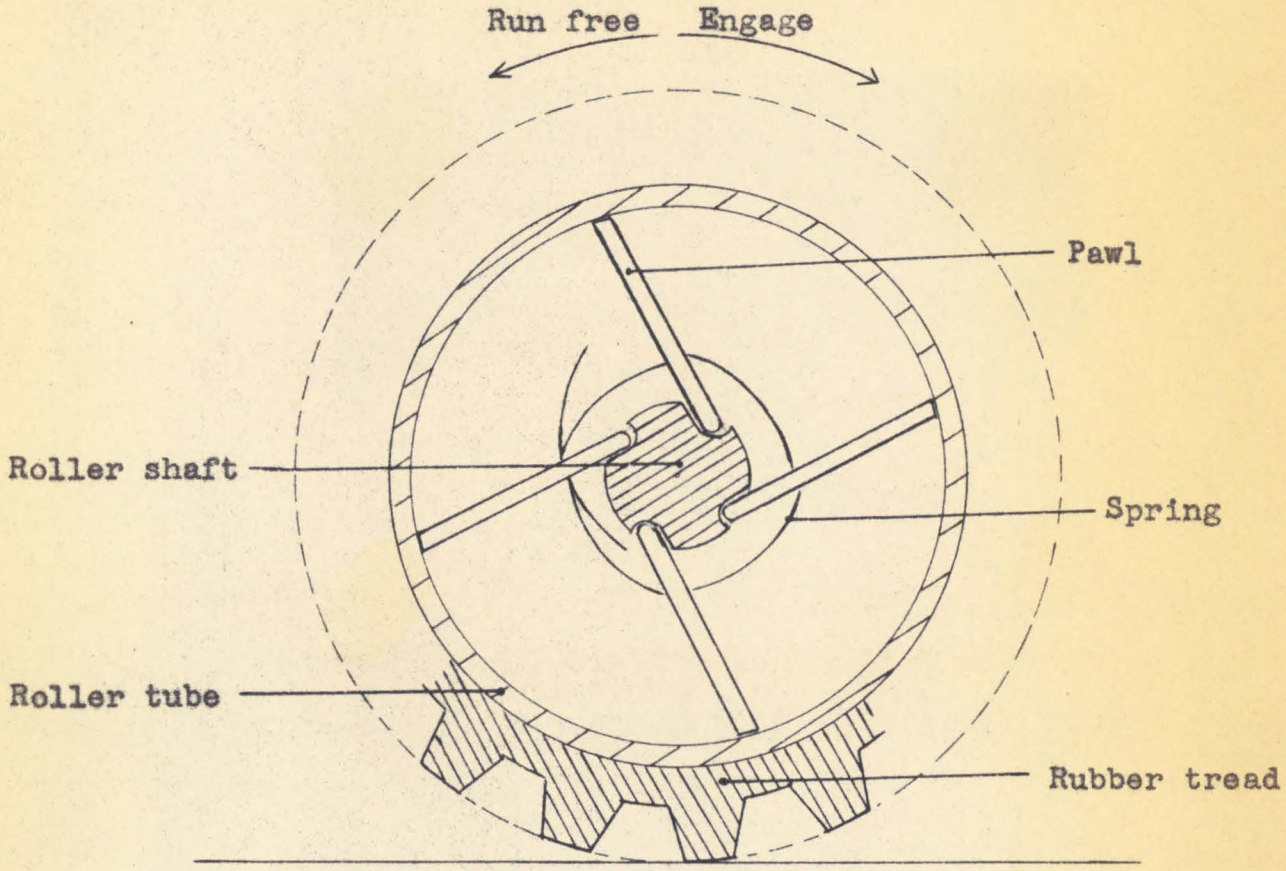
factors, such as, the type of soil, the kind of grass, the height of the grass, the moisture content of the soil and the density of the grass. Direct tests of different diameter rollers on lawns in various conditions were found to be the most satisfactory method of determining the proper diameter of the roller. These tests indicated that a roller four inches in diameter would be satisfactory.

An innovation in this mower is the type of free-wheeling clutch used. This clutch has all the advantages of the roller and cam type and at the same time tends to clean itself of dirt by a slight scraping action of the pawl when the mower is backed (fig. 34). Silent action and inability to jam are not the only advantages of this clutch. All forms of ratchets, widely used at present, possess the disadvantage that they usually do not engage immediately at the beginning of forward travel and also the clutches in each wheel seldom engage simultaneously. Thus, when the mower is backed up and started forward, after a small amount of forward travel the clutch in one of the wheels engages and starts the reel in motion with a jerk, which is hard on the mower and unpleasant for the operator. Since one clutch usually engages before the other, the mower tends to turn in direction until the unengaged wheel becomes engaged and then the mower pushes in the direction which it is headed which is usually not the direction

intended. The new type clutch used in the proposed mower engages silently and immediately upon forward motion of the mower. Since both clutches act simultaneously there is no tendency for the mower to turn as they engage. In adapting this type of clutch to use in a lawn mower it was simplified so that one circular spring holds all four of the pawls in the proper position with a slight pressure against the inside of the roller tube (fig. 35). Because the pawls do not engage in teeth but on a smooth surface the clutch is very quiet when "running free."

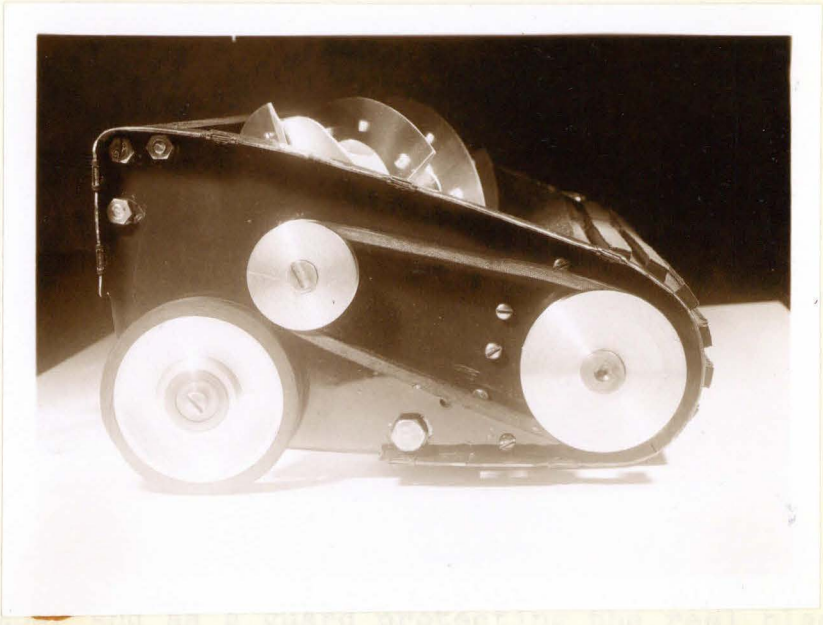
A "V" belt drive was chosen in preference to a chain or gear drive because it is quiet, light in weight, and supplies a needed safety device (fig. 36). It is a safety device because when a rock or stick jams the reel when the mower is moving at high speeds, the belt will tend to slip sufficiently to prevent the momentum of the rest of the mower from adding strain to the jammed reel and cutter bar.

The frame of the lawn mower is constructed of formed sheet steel parts. Experience with ordinary mowers of formed steel construction indicates that this type of construction is superior in many ways to that of cast parts. The economy of forming sheet steel in comparison to the cost of casting aluminum or magnesium is of primary importance. Iron or zinc castings cannot, of course, compare with the strength to weight ratio of formed steel parts.



SECTION OF ROLLER ILLUSTRATING ACTION OF ONE-WAY CLUTCH

Fig. 35



OUTSIDE PANEL REMOVED SHOWING "V" BELT DRIVE

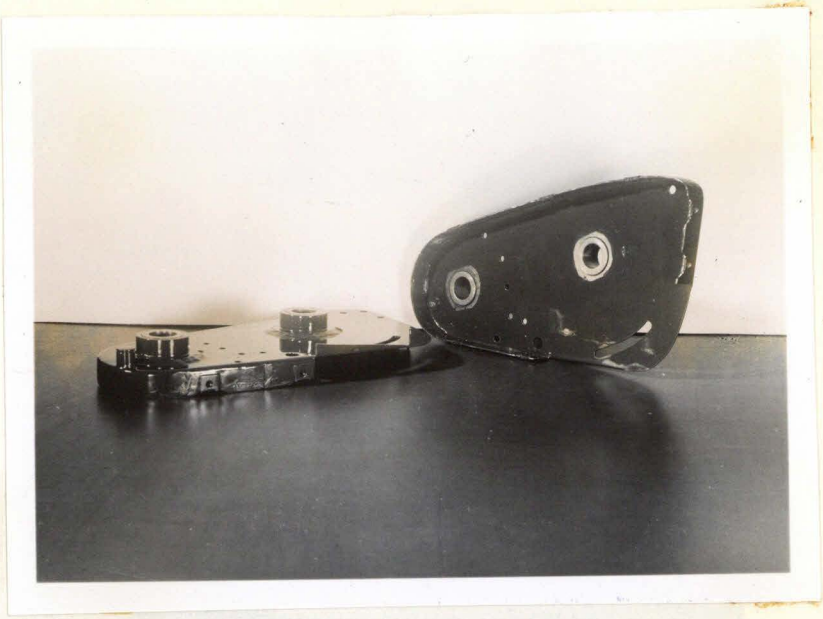
Fig. 36

The use of formed aluminum or magnesium parts is not considered practical since the steel blades are so heavy that the difference in weight of steel or light metal frame members would not be too noticable.

The side frame members (or inner wheels) are formed of 16 gauge cold rolled steel (fig. 37). Tests show that 16 gauge is too thin for these parts and that probably 11 gauge would be thick enough to provide the proper rigidity. Holes and slots are blanked in the side frame for the connection of cross-frame members, the cutter bar and the dolly wheels. Supports for the bearings for the reel and roller are welded in place on the inner side of the side frames.

The formed steel brush bar in front acts as a cross-frame member and as a guard protecting the reel blades (fig. 38).

For the sake of additional rigidity and less strain of the cutter bar, two cross-frame members are used instead of one cross-frame member and the cutter bar as the second cross-frame member as is usually the case with an ordinary mower. The rear cross-frame member is situated between the cutter bar and the roller (fig. 38). Two alternative shapes have been worked out for this rear cross-frame member, both of 16 gauge cold rolled steel (fig. 39). The smaller of the two is L-shaped in cross section and, being smaller, provides less rigidity than the larger.



SIDE FRAMES (OR INNER WHEELS)

Fig. 37

SIDE FRAME REMOVED SHOWING CROSS-FRAME MEMBERS AND CUTTER BAR ADJUSTMENT

Fig. 38

SMALL AND LARGE INTERCHANGABLE REAR CROSS-FRAME MEMBERS

Fig. 39

This smaller one fits directly behind the cutter bar and allows the grass cuttings to travel back and impinge on the forward surface of the roller and in turn be rolled over by the roller, thus helping to get the cuttings down in the grass so that they will not be objectionable in appearance when they turn brown. This is, of course, advantageous, but for those persons who prefer to remove the grass cuttings from the lawn, a somewhat different type of grass catcher than commonly used would be needed to guide the cuttings up over the roller. The larger rear cross-frame member provides a guide for the reel to direct the cuttings up over the roller and enables the use of a rather ordinary grass catcher. The problem here is that when the mower is not used with a grass catcher the advantage of rolling over the cuttings cannot be utilized. Both alternative rear cross-frame members were made and used in the model. With 16 gauge steel it seemed somewhat doubtful if the smaller alternative provided sufficient rigidity, although if it is found that the use of a heavier gauge steel throughout, with this smaller cross-frame member, provides sufficient rigidity, it is recommended that this be used in the production model. A grass catcher can be designed to function with this smaller member to satisfy those who insist upon using one and for those who do not it offers an improved appearance of their lawn after cutting.

Many years ago ball bearings were introduced into use as reel bearings. This provided a very good sales feature in that the average consumer considered all ball bearings as being of very high precision and causing no friction. The success of this sales feature forced all manufacturers to adopt ball-bearing reel bearings. Since at the present time all known mowers on the market use ball bearings, it ceases to be a sales feature and has become an assumed incorporation. It is considered doubtful that ball bearings actually improve the operation of a lawn mower over extended periods of time because, although the ball bearings undoubtedly allow the reel to turn more easily, ball bearings as used in lawn mowers wear much faster than bushing type bearings. It was found that it is practically impossible to completely shield a ball bearing from dirt and water when used on a lawn mower. With either dirt or rust in a ball bearing, the ball bearing is apt to wear fast and lose what accuracy it had. On the other hand, a properly fit bushing type bearing, even without shielding, quite effectively prevents dirt or water from entering between the bearing surfaces. On comparing the resistance to pushing of a new ball-bearing equipped lawn mower to the resistance of an old bushing-bearing equipped lawn mower, that incidently still had its original bushings, there was no detectable difference in the effort required to push the two. What little difference there may have been was completely over-

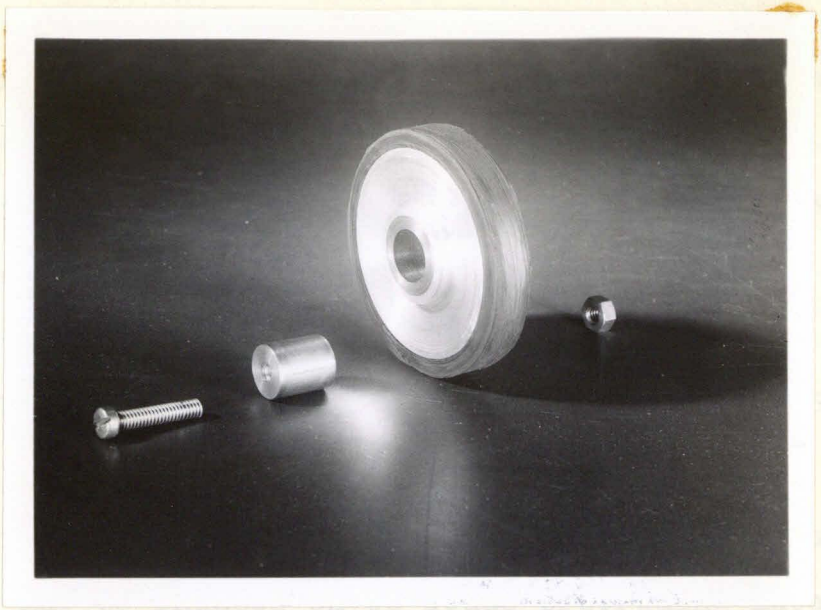
shadowed by slight differences in the resistance caused by the friction between the cutting blades. This friction, as has been pointed out, depends greatly on the accuracy of the reel bearing. Since the development of powdered metallurgy, bushing type bearings are available with an oil-impregnated porous structure. By using "Oilite" bearings, the mower does not need to be oiled. Those mowers that require oiling do present a problem in that, depending upon the particular user, they are often either never oiled or oiled excessively to the extent that the oil accumulates dust and dirt within the mechanism and on the outside surfaces of the mower creating wear and a dirty appearance. For these reasons, "Oilite" bearings have been used throughout this proposed design.

The cutter blade and bar are combined in a hollow formed section of 3/32 inch medium carbon steel (SAE 1040). The hollow section provides a maximum strength to weight ratio.

A safety device like that of the use of the "V" belt is incorporated in the mounting of the cutter bar (fig. 38). It is mounted so that it is quite free to rotate about the axis of its supports. This rotation is limited in one direction by a bolt through a tab on the rear of the cutter bar which provides a definite stop preventing the cutter blade from coming closer than the allowed distance to the reel. Rotation in the other direction, that is,

of the cutter blade away from the reel, is limited by a spring on this same tab which allows the cutter bar to give way against the spring when the reel and cutter blade are jammed. Adjustment of the cutter blade is made simply by the turning of one screw at each end of the bar. By incorporating these safety features in the design there is less need for the massive rigidity required in the average lawn mower to withstand the shock of being jammed when moving at a high speed. This is, of course, a saving in material and weight.

The dolly wheels support the front of the mower so that the cutting height remains at whatever height the dolly wheels are set (figs. 40 and 41). They are easily adjusted to provide a cutting height of from one-half inch to an inch-and-a-half. These cutting heights of the cutter bar are plainly indicated on the dolly wheel adjustment. This cutting height indication is rarely found, and sorely needed on all lawn mowers, particularly since it enables the person adjusting to set both ends of the roller, or both dolly wheels as in this case, at the same height. This adjustment is made on the proposed mower with a screw driver. A method of adjusting the cutting height by hand was considered by not adopted since it was slightly more complicated and particularly since the cutting height was only infrequently changed during the entire life of the mower.



DOLLY WHEEL, SHAFT AND MOUNTING SCREW

Fig. 40

CUTTING HEIGHT ADJUSTMENT AND INDICATIONS

Fig. 41

The proper cutting height for various grasses is something about which the average lawn mower user is entirely ignorant. It is proposed that proper cutting height information be provided the consumer by being included with the directions on the care of the lawn mower.

The handle is of tubular steel construction (16 gauge) and is attached to the mower by the somewhat common method of flattening the tube ends and blanking a hole in them so that they may be snapped on to studs protruding internally from the rear of the side frames. These studs are screw-machine parts riveted or welded to the frame and having grooves near their ends for snap rings which hold the handle on. The studs are mounted in such a position that the extreme ends of the flattened tubes bear against the bottom of the base of the roller shaft bearing holders and prevent the handle from dropping below about a thirty degree angle with the ground.

In order to determine the proper and most comfortable length of the handle, tests were made with handles of different lengths. A handle forty-five inches long was decided upon as being the most comfortable. Handle grips of green transparent plastic are placed on the ends of a piece of chromium plated tubing across the top of the handle (fig. 42). The handle grips are wide enough apart to allow a comfortable grip.

TOP OF HANDLE

Fig. 42

A patent search was conducted to ascertain if and what features in this design were infringements on other patents. The formed reel spider is the only apparent part that infringes on a patent. The owners of this particular patent are quite liberal in their licensing to other manufacturers at a reasonable royalty.

A cost estimate was attempted for this design, but because of the fact that no specific plant or set of conditions were available on which to base the estimate it was not considered to be even roughly correct. The experience of the designer indicates that a cost estimate made with the utmost care, but not under set conditions of a specific actual plant can be in error by as much as two hundred to three hundred per cent and therefore be very misleading. As previously mentioned, the general cost has been considered and kept at a minimum in choosing materials as well as methods of manufacturing. On comparing this mower with mowers on the market which were manufactured by similar methods and of like materials, it was estimated that this mower could be manufactured and retailed successfully at about twenty to twenty-five dollars.

As pointed out in the market survey the appearance of a lawn mower has a great effect on its sales. The interesting and attractive appearance of this design more or less speaks for itself in the photographs. The colors, not shown, are zircon green on the frame, aluminum on the

reel and metalic mercury grey on the handle. For expense reasons the amount of chromium plated material was kept at a minimum. What little there is is placed at the top of the handle near the operator or prospective customer so as to achieve maximum effect with such a small amount of chromium plating (fig. 42). The ribs on the outside panels on the ends of the mower are polished but not plated. This could be accomplished best in a production model by using aluminum for the outside panels. In general this design is smooth and attractive in appearance and its compactness gives it the effect of being very functional.

SUMMARY

The solution of this problem provides a design for a mass-produced lawn mower that is new and very much improved in efficiency, appearance and mechanical arrangement.

Working improvements that are important and very evident to the lawn mower buyer and user have been incorporated in the design. They are the following:

This design will cut more than twice as close to obstacles in the lawn as will ordinary type mowers.

By having roller traction power instead of two wheels, it is able to cut along edges of gardens and troughs where hand trimming was previously necessary.

Many concealed but important mechanical improvements result in the mower cutting very quietly and with much greater ease of pushing.

By rolling the grass cuttings into the lawn as it cuts, a more attractive surface is obtained.

The mechanical arrangement of this design allows a more compact lawn mower, in use and in storage, with sturdy, rigid construction.

Although mechanical improvements do little towards selling a lawn mower, when these improvements result in

such outstanding working advantages, they help the mower to sell itself.

This lawn mower with its improved workability and exceptionally attractive appearance can probably be produced at equal or less cost than ordinary mowers and thereby fulfills a great demand in the lawn mower market.

APPENDIX

ACKNOWLEDGEMENTS

Thanks are due the following for their assistance in the accumulation of data for this design thesis:

Mr. C. C. Straub	Curmar Mfg. Co., Long Beach
Mr. J. M. Powell	Curmar Mfg. Co., Long Beach
Mr. W. L. McKay	Curmar Mfg. Co., Long Beach
Mr. H. B. Lee	Curmar Mfg. Co., Long Beach
Mr. D. G. Winge	Curmar Mfg. Co., Long Beach
Mr. M. W. Mecoveck	Modern Mfg. Co., Pasadena
Mr. J. W. Snyder	Bishop and Mathews, Los Angeles
Mr. C. C. Dover	Los Angeles Examiner Research Dept.
Dr. F. W. Went	Professor of Plant Physiology, California Institute of Technology
Mr. H. B. Grant	Union Hardware, Los Angeles
Mr. J. F. Cass	Sears, Roebuck and Co., Los Angeles

The Los Angeles Times' Research Department.

CORRESPONDENTS

Yard Man Inc., Jackson, Michigan
The J. P. Engineering Co., Limited, Leicester, England
Toro Mfg. Corp., Minneapolis, Minnesota
Pioneer Gen-E-Motor Corp., Chicago, Illinois
United Machine Tool Co., Grand Rapids, Michigan
The E. T. Rugg Co., Newark, Ohio
Remonte Mfg. Co., Corsicana, Texas
The Eclispse Lawn Mower Co., Prophetstown, Illinois
Clemson Bros., Inc., Middletown, New York
R. Herschel Mfg. Co., Peoria, Illinois
Heineke and Co., Springfield, Illinois
Flex Blade Works, New York, New York
Reo Motors, Ind., Lansing, Michigan
Jacobsen Mfg. Co., Racine, Wisconsin
Blair Mfg. Co., Springfield, Massachusetts
The F. and N. Lawn Mower Co., Richmond, Indiana
Pennsylvania Lawn Mower, Division of American Chain and Cable Co., Inc., Camden, New Jersey

BIBLIOGRAPHY

U. S. Patent Office Patents and Patent Gazettes 1930 to 1947

U. S. Census 1940 and 1946

Better Lawns, Sprague

"House Beautiful" January 1947

Consumer's Research Bulletin July 1944
"How to Keep Your Lawn Mower Sharp"

"Facts for Industry," Bureau of Census September 1946

First 10 Years After the War, U. S. Department of Commerce

"Popular Science" July 1946