336-490D INDIVIDUAL PROJECT

DESIGN OF AN AUTOMATIC DOOR TO FURTHER ENHANCE AN EXISTING AUTOMATIC FEEDER

SUBMITTED BY

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ABSTRACT

An automatic door was designed to upgrade an automated feeding system for dairy cattle. The design was custom made to fit the present manual doors at the existing dairy farm of Gerald and Lise Routhier, located in Stanstead, Quebec. The design used standard materials and on farm devices wherever it was possible. Micro switches placed in the path of the feeder in conjunction with a reversing switch for the motor made this system fully automatic. A delaying switch on the door rail allowed for variable times for open door time-limit. The payback period of the automatic door was calculated to be 1.1 year and is recommended as a viable addition to the feeding automation system.

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INTRODUCTION

To be able to feed the young cattle in the perpendicular barn (refer to figure 6) at any time without the aid of a human, it is necessary to install an automatic door in the path of the automatic feeder. There are several different types of door openers presently on the market. Some of these systems include: infrared detection, load cells activated by walking pressure and push button signal (standard garage door).

Right now on the farm, the young cattle are fed manual ly once the cold weather starts to minimize the amount of time when the door stays open (which creates cold draft on the young cattle and increase sickness). In the warm season, the doors are left open during chores and the robot is programmed to feed during chores. This restricts the time and number of feedings that the young cattle can receive as well as reduces the efficiency of the summer ventilation systems.

For this project, an automatic door was designed to enable the automatic feeder ~~to allow~~ to feed the young cattle regularly throughout the year at any time of the day without any assistance of man.

An automatic machine is one that performs a repeating sequence of operations on a continuous flow of workpieces without operator inputs (except START, STOP,EMERGENCY STOP, etc.), Lentz (1985). Literature throughout animal science research has also proven that frequent feedings is far more beneficial to the animals than concentrated ones.

The time saving by eliminating the manual feeding can prove to be a great asset. This labour can then be transferred over to an other task or may eve~~t~~n reduce the necessity of another hired hand.

The OBJECTIVES of this design are:

(1) To be able to feed at any time

(2) To minimize the amount of time that the door remains open

(3) To be completely automated

(4) To use as much standardized material as possible

(5) To be very reliable

(6) To be affordable to every farmer

RESULTS AND DISCUSSION

Choice of an opener

Two existing door-opening packages were looked at, but they both had their faults for this design and environmental conditions. In general, it is a good practice to use a packaged, off-the-shelf, standard product capable of performing the desired operation (Lentz 1985).

? scratch?

SELECTING OFF-THE-SHELF MACHINE VS DESIGN FROM THE SCRAP

Advantages of selecting existing packages

-Packaged components have been fully engineered and de-bugged.

-Packaged components have been field tested and have properly undergone design revisions.

-Component reliability has been demonstrated through actual operating experience.

-Manufacturer warranties the component or system.

-Large scale production results in lower costs compared to the fabrication of one item of your own design.

-Manufacturer sales or engineering personnel can be extremely helpful in solving your specific problem.

Disadvantages of selecting existing packages

-Possibility exists of comprising machine performance down to level of existing packages.

-Existing packages are not always aesthetically complementary to your machine.
-It may be necessary to incorporate additional stations on operations in order to use the existing packages in conjunction with your machine.
-The existing package may be unsuitable for the existing environmental conditions.
-It may be impossible to fit the existing package in the design layout.

(Lentz 1985)

For this design, an automatic door using an electric eye was looked at, but was not selected. Firstly, their would be no detection difference between any movement (ie. humans, animals, and other feed carts) and the automatic feeder. Therefore, this would cause additional unnecessary openings in the cold winter months. Also, the allowable space was not sufficient for such a design. Another possible problem which might evolve could be the accumulation of dust on the eye due to neglected maintenance which might cause periodically faulty opening.

An automatic "car-door-garage" opener was considered but was also considered to be unsuitable. The actual chain movement fits the allowable space but proved to be limiting in other areas. For example, presently a rotational force will causes the door to bind and drastically increase the demanded force. This could possibly occur with a chain and sprocket design, but the selected design totally eliminates this possibility due to the rigidity of the overhead threaded rods. Also, the door opener would have to be rewired to allow for the linear motion of the robot feeder to be transferred into the switch mechanism of the opener by a series of external switches.

The chosen design is one of total originality and the use of as many standardized parts as possible in order to keep the construction costs as low as possible.

<u>A material listing includes:</u>

-Motor (¼ hp)

-2-V belts

-3-pulleys (diameter 2x3", 1x2")

-3-bearings (½" centre)

-14 x ½" nuts

-4 modified door hinges

-1 x ½" x 44" clockwise UNC threaded rod

-1 x ½" x 44" counterclockwise UNC threaded rod

-4 line-switches

-1 double-pole, double-throw switch

-1 delay switch

-1 current safety trip-switch

There are two critical components of this design which make it very specific. The first is the allowable space under the existing ventilation inlets (see figure 1).

The threaded rod is to be placed out from the door slightly as to not interfere with the full line of travel of the inlet vent. A look at the side view gives a better picture of what it looks like (see figure 2).

The second critical component is the clearance required by the travelling robot (see figure 3). The allowable space between the top of the running wheel and the bottom of the ventilation duct is 1.94". Because of the size of the chosen design and the placement, it minimizes the required space and satisfies the required parameters.

To trace the design from start to finish, one can start at the pulley assembly (see figure 4). The motor used will be a ¼ hp totally enclosed which will operate at 3450 rpm. The threaded rods used are ½" Unified National Coarse (UNC) rods. If one wants the door to open in less than half a minute, a 2:1 ratio in the pulley system will reduce the speed of the rod to 27.3 revolutions per second (rpm). Giving that a UNC rod has 13 threads per inch and there are 42" of travel, this design will open the door in 20 sec.

A concern of interest is to determine whether or not the bolts and threads will take the implied forces. The maximum torque for a grade 8 threaded rod is 80.0 ft-lbs. Knowing the weight of the doors to be 61.45lbs per door and that the coefficient of friction for steel is 0.6, the horizontal force is equivalent to 36.87 lbs. Transferring this into a required torque, the calculated amount is 0.48 lb-ft.

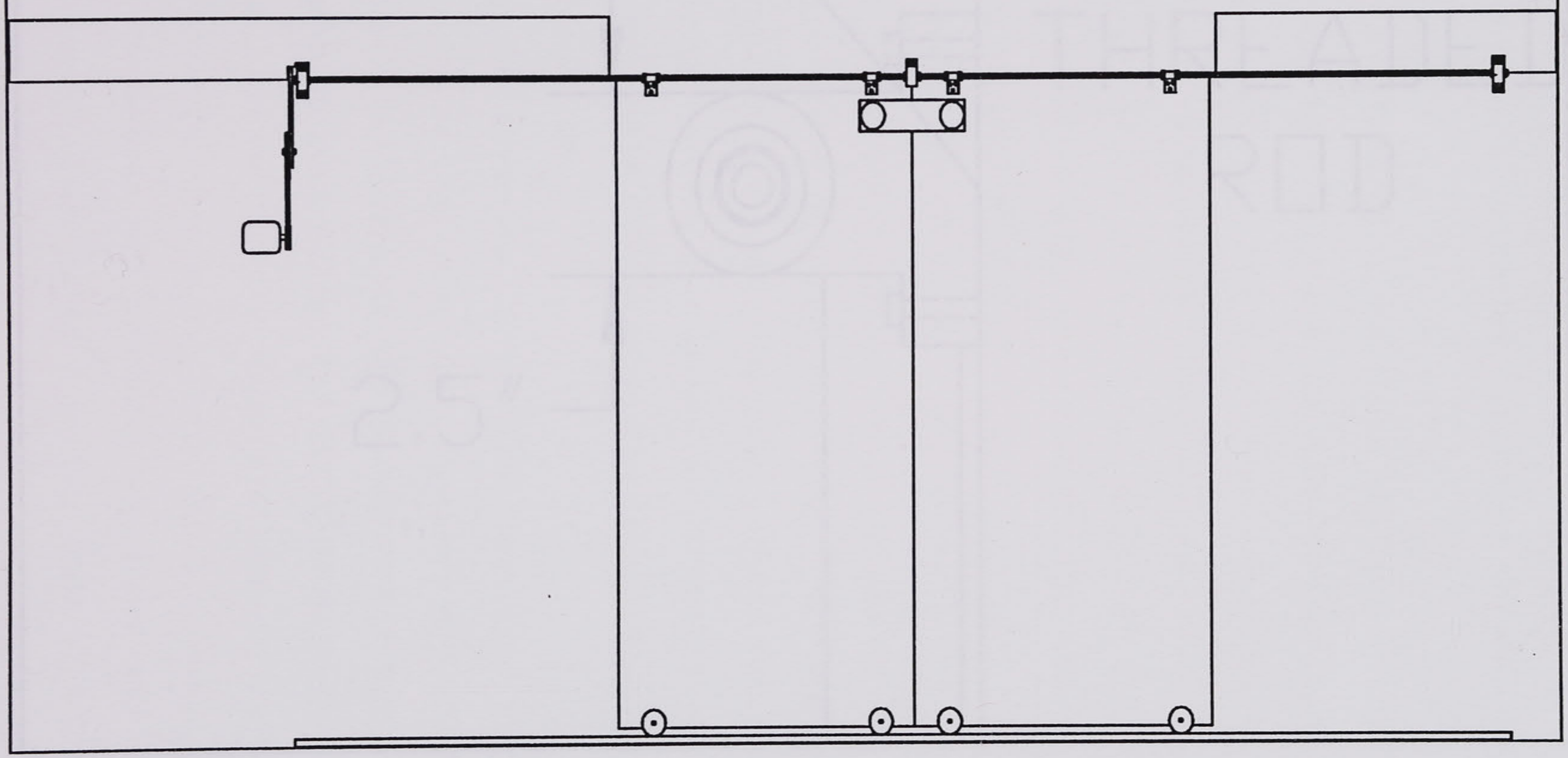
This starting torque is by far less than the allowable maximum

Figure 1

COMPLETE DESIGN OF AUTOMATIC DOOR ASSEMBLY

NOTE:

1. THE OVERHEAD VENTILATION INLETS
2. THE TWO CIRCLES INDICATING THE RAIL
3. THE PLACEMENT OF THE PULLEY SYSTEM
4. THE BOTTOM RUNNING RAIL



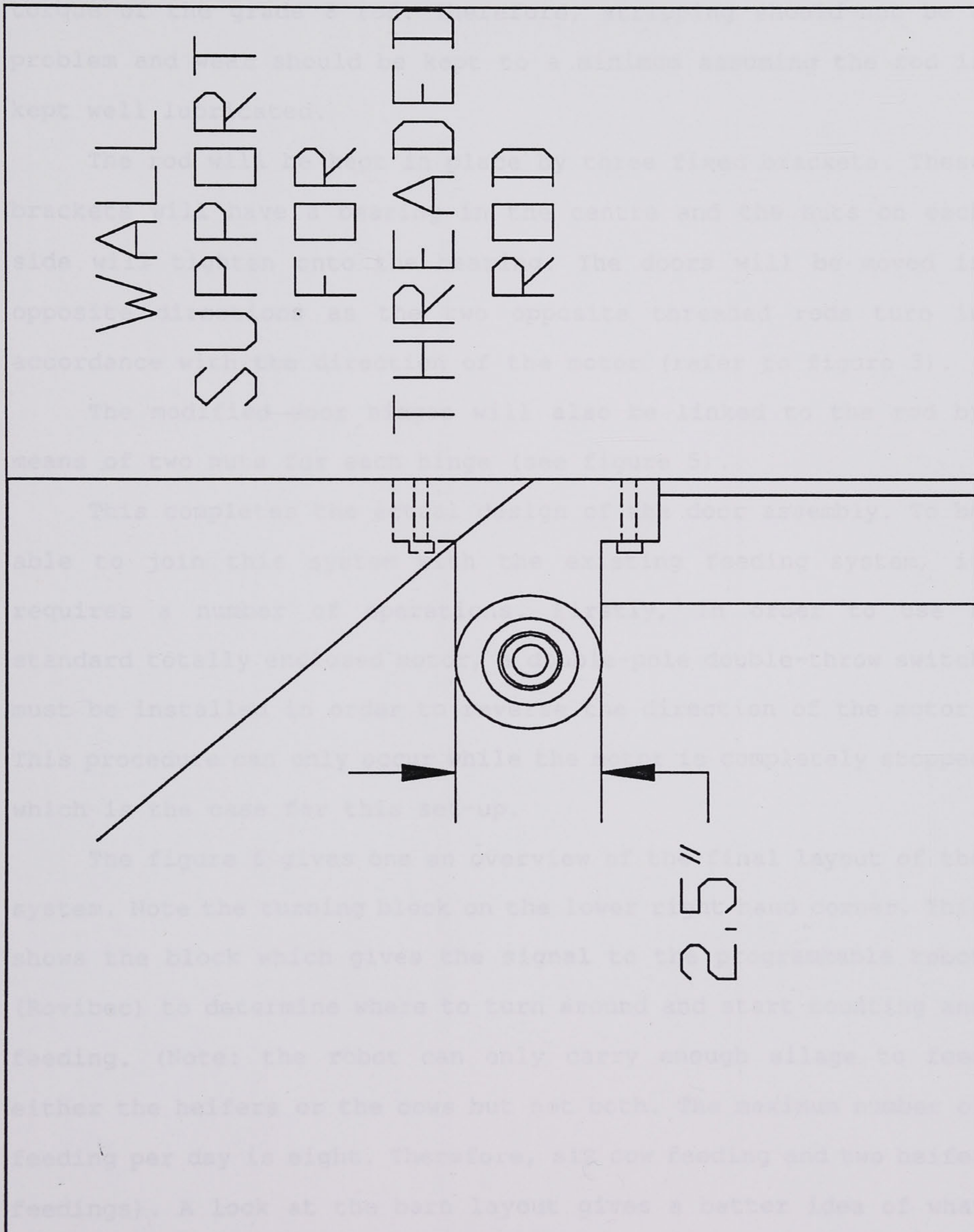


Figure 2

torque of the grade 8 rod. Therefore, stripping should not be a problem and wear should be kept to a minimum assuming the rod is kept well lubricated.

The rod will be kept in place by three fixed brackets. These brackets will have a bearing in the centre and the nuts on each side will tighten onto the bearing. The doors will be moved in opposite directions as the two opposite threaded rods turn in accordance with the direction of the motor (refer to figure 3).

The modified door hinges will also be linked to the rod by means of two nuts for each hinge (see figure 5).

This completes the actual design of the door assembly. To be able to join this system with the existing feeding system, it requires a number of operations. Firstly, in order to use a standard totally enclosed motor, a double-pole double-throw switch must be installed in order to reverse the direction of the motor. This procedure can only occur while the motor is completely stopped which is the case for this set-up.

The figure 6 gives one an overview of the final layout of the system. Note the turning block on the lower right hand corner. This shows the block which gives the signal to the programmable robot (Rovibec) to determine where to turn around and start counting and feeding. (Note: the robot can only carry enough silage to feed either the heifers or the cows but not both. The maximum number of feeding per day is eight. Therefore, six cow feeding and two heifer feedings). A look at the barn layout gives a better idea of what the set-up looks like (refer to figure 7).

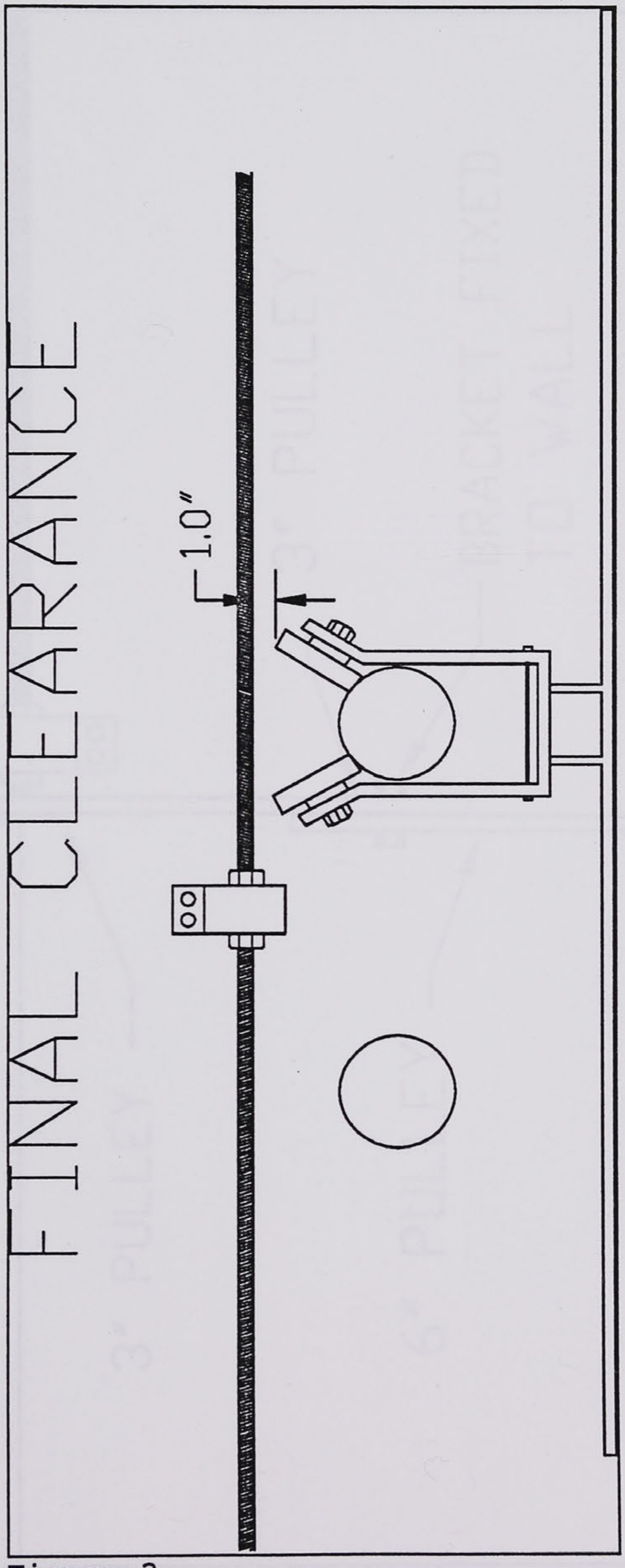
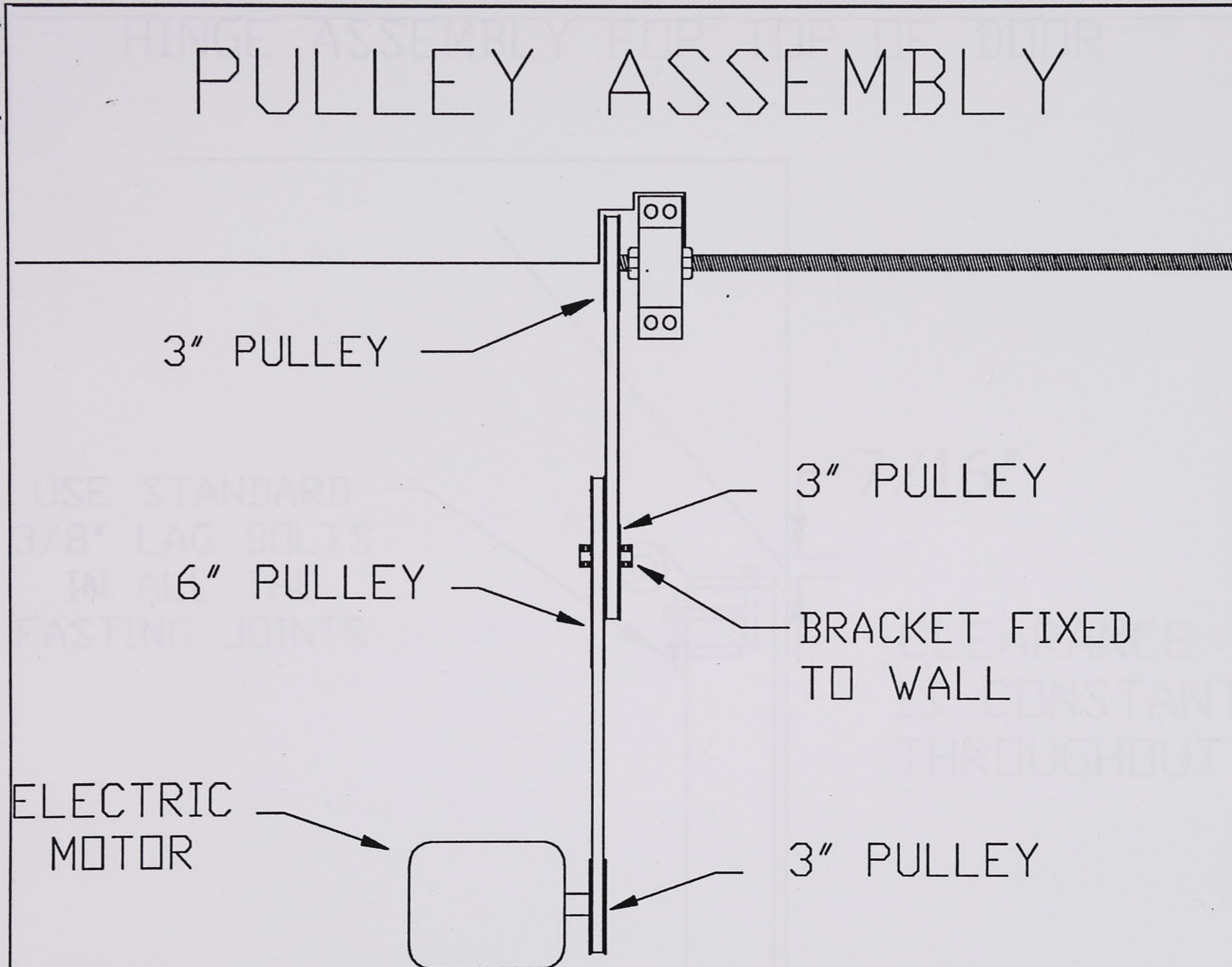


Figure 3

Figure 4


PULLEY ASSEMBLY
3" PULLEY
3" PULLEY
6" PULLEY
BRACKET FIXED TO WALL
ELECTRIC MOTOR
3" PULLEY

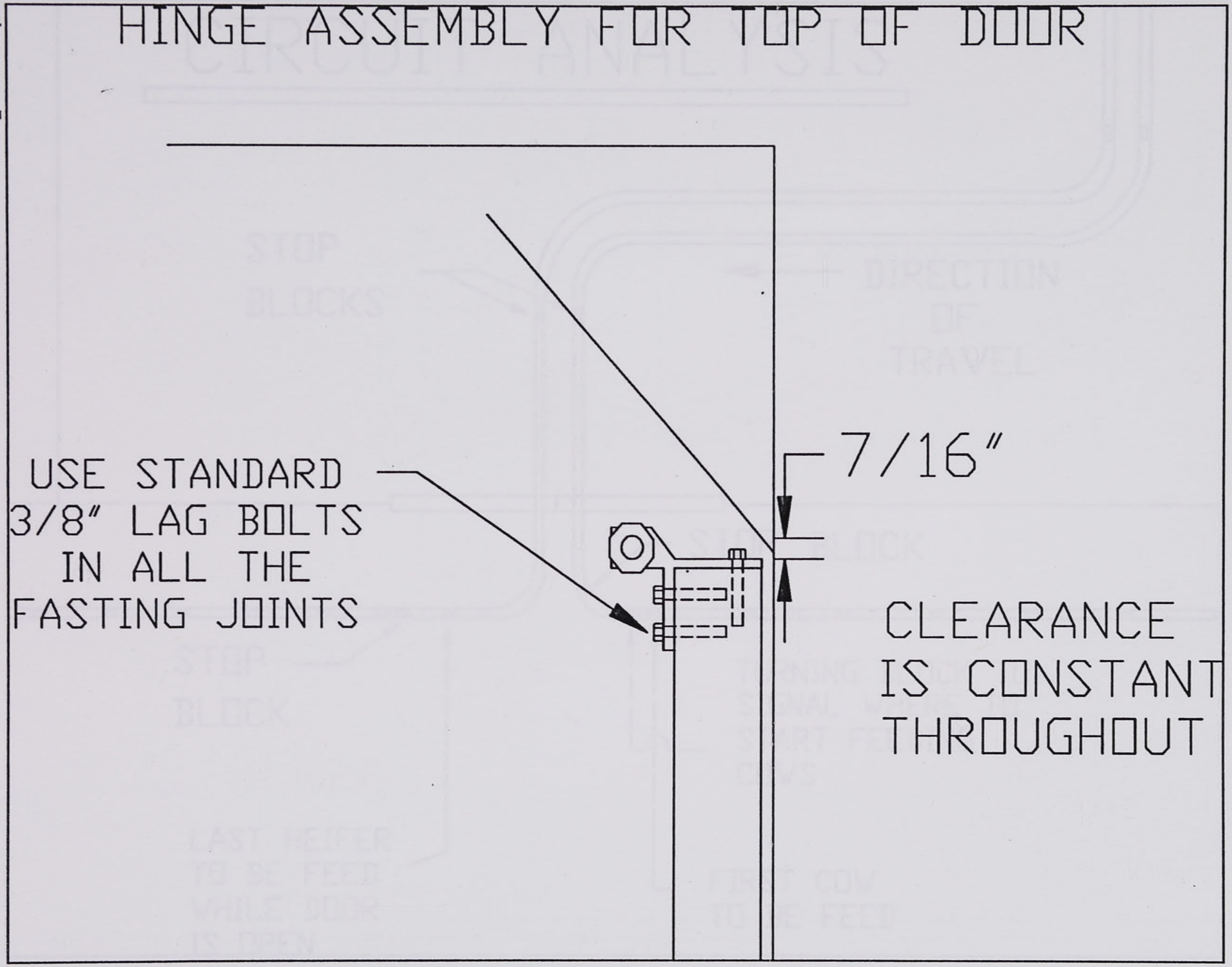
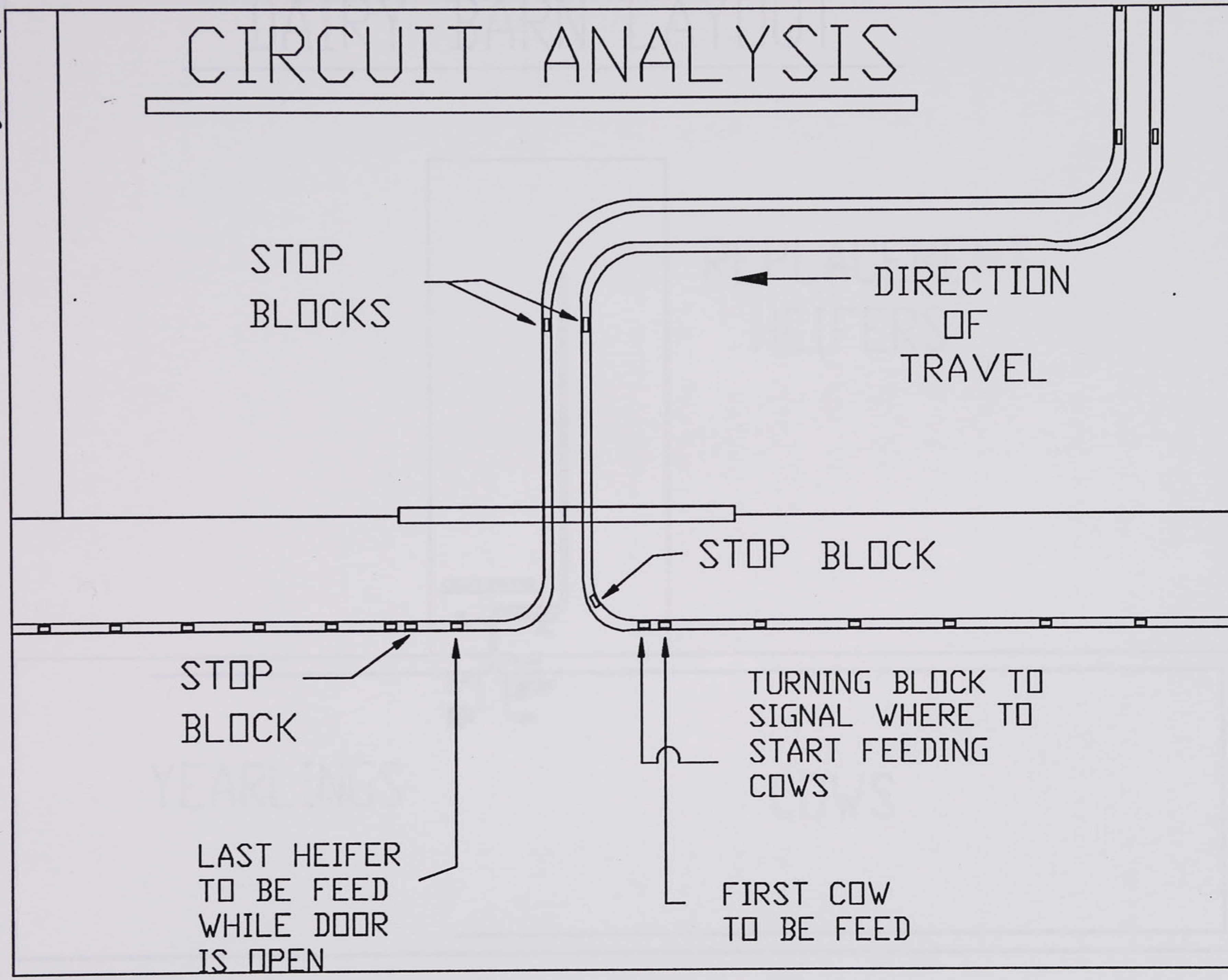

HINGE ASSEMBLY FOR TOP OF DOOR
7/16"
USE STANDARD
3/8" LAG BOLTS
IN ALL THE
FASTING JOINTS
CLEARANCE
IS CONSTANT
THROUGHOUT

Figure 5

Figure 6


CIRCUIT ANALYSIS
STOP BLOCKS
DIRECTION OF TRAVEL
STOP BLOCK
STOP BLOCK
TURNING BLOCK TO SIGNAL WHERE TO START FEEDING COWS
LAST HEIFER TO BE FEED WHILE DOOR IS OPEN
FIRST COW TO BE FEED

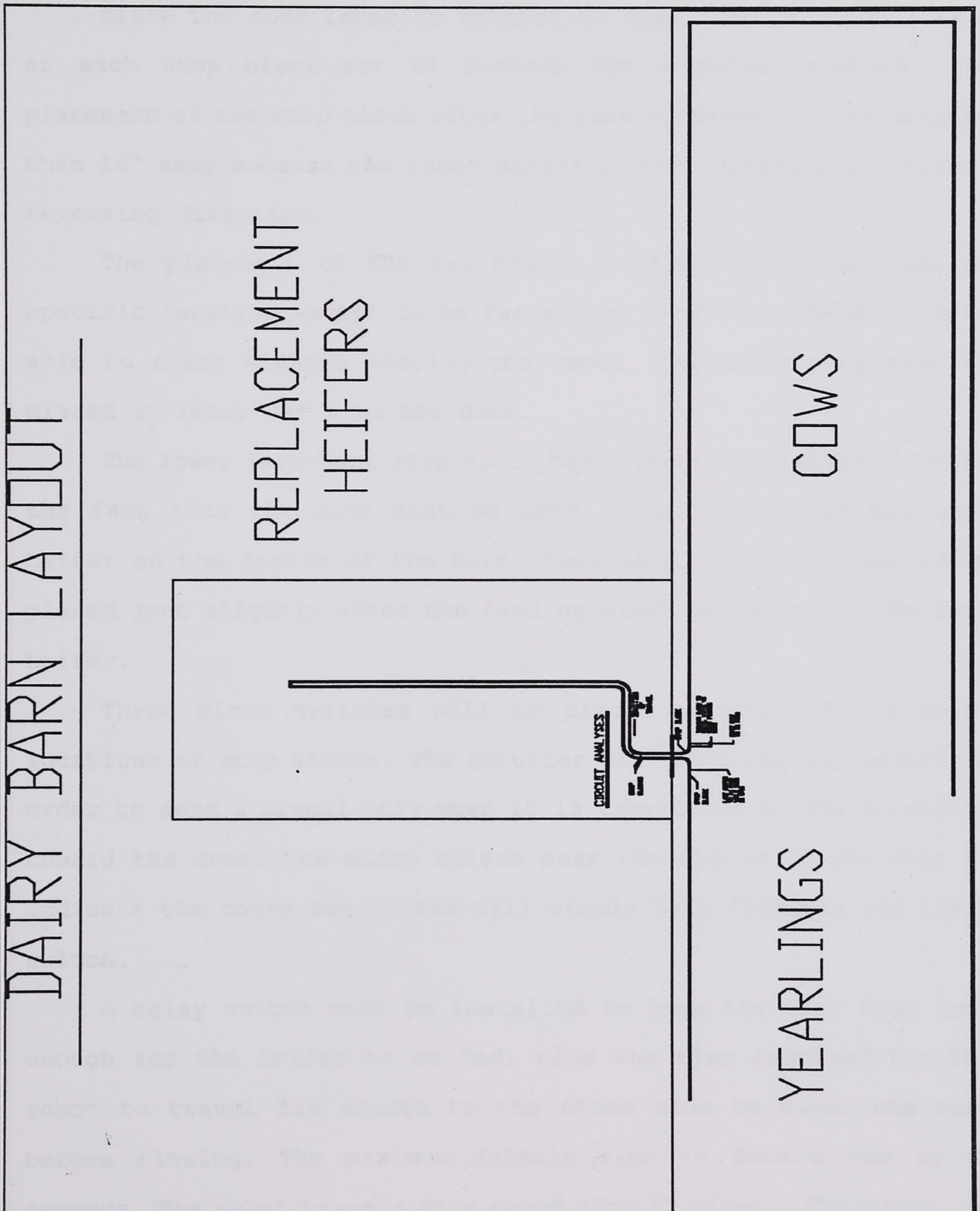

DAIRY BARN LAYOUT
REPLACEMENT HEIFERS
COWS
YEARLINGS
CIRCUIT ANALYSES

Figure 7

Since the door takes 20 seconds to open, the robot will wait at each stop block for 25 seconds for a safety measure. The placement of the stop block after the turning block must be greater than 16" away because the robot passes by the turning block before reversing direction.

The placement of the two blocks in the heifer barn has no specific location except it be far enough away from the door to be able to close without hitting the robot. Therefore they must be placed at least 85" from the door.

The lower left-hand stop block has a specific placement due to the fact that the door must be open in order to feed the last heifer on the inside of the barn. Therefore, the block should be placed just slightly after the feeding block of second to the last heifer.

Three micro switches will be placed at each of the three locations of stop blocks. The actuator will be a one-way switch in order to send a signal only when it is travelling in the direction toward the door. The micro switch near the middle of the door to indicate the doors are closed will simply be a flexible rod limit switch.

A delay switch must be installed to keep the door open long enough for the heifer to be fed, plus the time required for the robot to travel far enough to the other side to clear the door before closing. The maximum default time to feed a cow is 60 seconds. The robot travels at a speed of 0.33 m/sec.. Therefore, it takes 16 seconds for the robot to travel out of the way of the door closing. These two times added together give a 76 seconds requirement. Therefore, set the delay switch for 80 seconds for safety requirements.

To complete the design, a current drawn safety switch will be placed in line to the power supply for the motor. If the current drawn to the motor goes above the required current for starting, the breaker will trip and the system will shut down.

This feature will provide additional safety in the event that an obstruction might get in the pathway of the door.

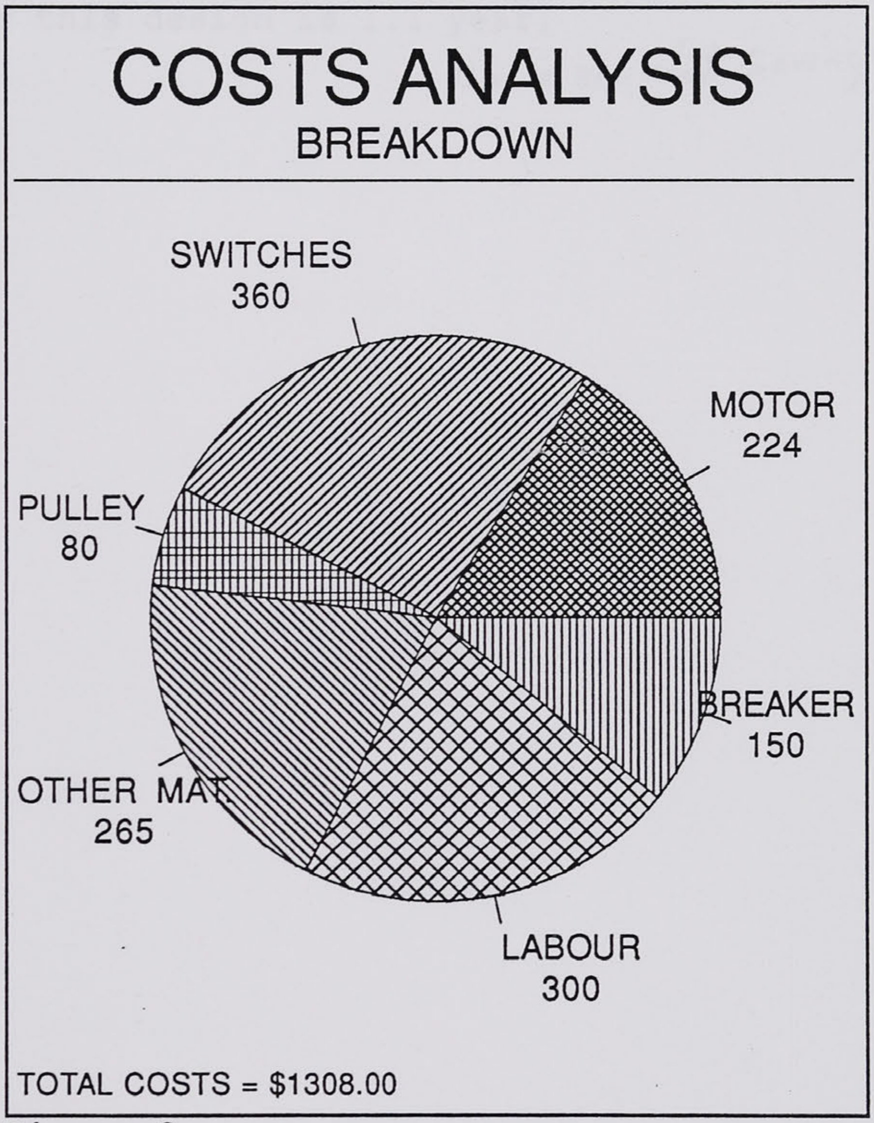


Figure 8

A breakdown of the costs can be seen in the following figure. This shows the high cost of ~~heavily weight cost impact~~ due to the motors and switches.

A total cost of this system as compared to an existing system is very high, however, one must not overlook the fact that this is a specific design for a limited space and does not have the advantage of mass production. A total cost of $ 1,380 is comparable when looking at the costs of the complete existing feeding system of $40,000.

reasonable?

The payback period of this design is 1.1 year.

Based on what savings?

CONCLUSION

This design enables the automatic feeder to be fully automatic throughout its entire route. It minimizes the amount of time the door is open, therefore reducing the amount of draft and improving the ventilation system both summer and winter. The design uses a wide range of standardized materials and is reliable due to the simplicity of the design.

The design provides the required clearances and runs at a high level of accuracy. The system gives rigidity to the top of the door and thus cuts down on drafts.

The overall design is relatively cost effective and is competitive. Therefore the farmer must decide if the saving in labour and the increased quality of feeding and ventilation is worth the extra costs.

APPENDIX 1

PULLEY DESIGN

Motor Speed = 3450 rpm

Actual speed = 3450 * 96% = 3278 rpm

Pulley ratio 1:2

Actual speed of rod = 27.3 rev/s

½" Bolt (NUC) = 13 thread/inch * 1 rev/thread = 13 rev/inch

42" of travel * 13 rev/inch = 546 rev

If rod is turning at 27.3 rev/s ; speed of door opening =

546 rev / 27.3 rev/s = 20 seconds

TORQUE - Determine the torque in the rod as a result of moving the door.

Maximum Allowable Torque for a Grade 8 rod is 80 ft-lbs.

Required force per door = 36.87 lbs

diameter	= 0.5 inches	dr	= 0.4056 inches
A_t	= 0.1419 inches^2	p	= 0.0769 inches
L = 2p	= 0.1540 inches	thread d	= 0.0385 inches
d_m	= 0.4248 inches		

$\alpha_n = \tan^{-1} (\tan\alpha * \cos\lambda)$

$\alpha_n = 14.41°$

$$\lambda=\tan^{-1}*\frac{L}{\pi*d_m}$$

λ = 6.58°

Assuming one keeps the rod well lubricated, an average coefficient of friction of 0.14 can be used.

$$T=\frac{Wd_m}{2}*\frac{f\pi d_m+L\cos\alpha_n}{\pi d_m\cos\alpha_n-fL}+\frac{Wf_c d_c}{2}$$

T = 0.48 lb.ft

This torque value represents the starting torque; which is far below the maximum allowable torque.

<u>Determine the required horsepower</u>

$$POWER(W)=\frac{Tn}{5252}$$

Required Horsepower = 0.15 hp

Therefore a selected standard ¼hp motor will satisfy the job.

<u>Determine timing for delay switches</u>

Must have 60 seconds for default maximum time to feed one cow. Distance to travel is 205".

Therefore: 60 seconds + 17.08 feet / 1.089 feet per second = 76 seconds

Set delay switch for 80 seconds as a measure of safety.

APPENDIX 2

COST BREAKDOWN

MATERIALS	**PRICE($)**
DELAY SWITCH	100
3 ONE WAY (IN-LINE) MICRO SWITCHES	180
DOUBLE-POLE, DOUBLE-THROW SWITCH	40
1 FLEXIBLE ROD MICRO SWITCH	40
PULLEY BRACKET	18
2 X 3" PULLEYS	20
1 X 6" PULLEY	12
2 X 56" BELTS	30
2 THREADED RODS	60
12 X ½" NUTS	10
3 BEARINGS (½" CENTRES)	75
STEEL FOR BRACES & HINGES	60
12 GAUGE ELECTRICAL WIRE	60
CURRENT BREAKER SAFETY SWITCH	150
ELECTRICIAN (4 hrs X $30.^{00}$/hr)	120
INSTALLATION (6 hrs X $20.^{00}$/hr)	180

LABOUR SAVINGS

0.5 HRS/DAY X $7.^{00}/HR X 365 DAYS/YEAR =

$1277.50 PER YEAR IN SAVINGS

Therefore a very respectable payback is calculated as follows:

$1308.00 (total costs) / $1277.50 (savings per year)

= 1.08 years to pay back

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