ERGONOMIC STUDY OF OPERATIONS RELATED TO PVC PIPE COMPOUNDING

Paul A. Ludwig

UNIVERSITY OF SOUTHERN INDIANA

Submitted to the Graduate Faculty
in partial fulfillment of the requirements
for the degree
Master of Science in Industrial Management

July, 1989

Accepted by the Graduate Faculty, University of Southern Indiana, in partial fulfillment of the requirements for the degree of Master of Science in Industrial Management.

Larry D. Goss, Chairman
Professor of Engineering Technology

Augustine J. Fredrich
Professor of Civil Engineering Technology
Chairman of the Department of
Engineering Technology

Bruce A. Abbott
Manager of Engineering
Cresline Plastic Pipe Co., Inc.

ACKNOWLEDGMENTS

I wish to thank Cresline Plastic Pipe Company for providing the necessary funding for this project, and the personnel from the management level to the mixer attendants for their assistance. I wish also to thank Professor Larry D. Goss for his professional assistance throughout this project.

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ABSTRACT

Ludwig, Paul A. M.S., University of Southern Indiana, July, 1989. Ergonomic Study of Operations Related to PVC Pipe Compounding. Major Professor: Larry Goss.

Cresline Plastic Pipe Company has become concerned with possible human factor design problems in the Polyvinyl Chloride (PVC) pipe compounding operation. PVC compounding is the addition of minor ingredients to the PVC raw resin to prevent the PVC from degrading and to aid in process control during extrusion. Cresline is currently in the process of increasing the production rate of the PVC compounding operation. An ergonomic study was performed to evaluate current and potential human factor problems. The main focus of the ergonomic study deals with the mixer attendant who manually adds the minor ingredients to the PVC resin. The study evaluates work height levels, vision angles, wrist orientation and manual lifting requirements of the mixer attendant. A revised work area and work flow pattern are developed for the compounding operation. The revised work area is evaluated as it relates to work conditions and with respect to actual cost, also the effects of change in the work area as it relates to the mixer attendant.

CHAPTER 1

INTRODUCTION

Ergonomics

In the United States the terminology of "human factors" and "human engineering" has been replaced by the term "ergonomics". One has only to read an automobile sales brochure to see the phrase "Ergonomically Designed Dashboard". One positive note with the recent emergence of ergonomics in the U.S. vocabulary is an broader awareness of the importance of human factors in design.

Ergonomics is the scientific study of the relationship between man and his working environment. Environment relates not only to the physical location, but to the worker's tools and materials, his methods of work, and how they are organized. Work is related to the nature of man, his abilities, capacities and limitations. [1]

The main objective of ergonomics is to produce increased efficiency of human activity by providing information for use in design decisions. It should enable the activity cost to the person to be minimized by removing features in design that are likely to cause inefficiency or physical disability. [2] An end goal in the use of ergonomics is to create an awareness in industry of the importance of considering human factors when planning work areas.

When equipment is intended for interaction with people it should be designed as a man-machine system. Of course, compromises may be needed in design or layout of equipment to reflect constraints imposed by economics, physical environment, and the requirements of the machine itself.

Man-Machine Systems

In the real world, it often appears that the piece of equipment is designed first and then the operator is added. Failure to consider the needs of the operator leaves him to adjust to an often unsatisfactory arrangement of controls and displays. The situation of adding the operator to the machine last stems from either of two possible factors. It could be caused by designing equipment without regard to the operator, or it could result from a new design being simply a modification of an older design. [3] The latter approach appears to result from industry acceptance of a philosophy that because a machine has "always been that way," there is no good reason to change it. The phrase "If it's not broken why fix it" is a common answer concerning equipment modifications for ergonomic reasons.

Ideally, equipment design should start with the operator, who should have his equipment laid out around him in positions which will ensure: that his posture is adequate, that he can see what he has to do, and that he can operate his controls in the most effective manner. [4]

Cresline Plastic Pipe Company has become concerned with possible human factor design problems with the Polyvinyl Chloride (PVC), pipe compounding operation. Cresline is currently engaged in a series of actions designed to increase output rates of its compounding operation. The compounding operation currently has several internal process delays, these delays are referred to as "bottlenecking". The action taken by Cresline to remove the internal process delays in the compounding operation is referred to as "debottlenecking" the operation. Increased output of the compounding operation would only worsen the human factor concerns. The focus of this project is to study the human factor design problems of the compounding operation and to design or recommend possible corrections.

CHAPTER 2

BACKGROUND

Cresline Plastic Pipe Co.,Inc.

Cresline Plastic Pipe Company is located in Henderson, Kentucky. The plant was constructed during the spring and summer of 1966, with actual production starting on October 12th, 1966. Cresline has added three additional manufacturing sites, located in Mechanicsburg, Pennsylvania, Council Bluffs, Iowa, and Corsicana, Texas. All four Cresline plants manufacture products for the plastic pipe market. This market includes Polyvinyl Chloride (PVC), Chlorinated Polyvinyl Chloride (CPVC), Polyethylene (PE), and Acyrlonitirle-Butadiene-Styrene (ABS) plastic pipe for use in all phases of commercial and residential plumbing. Annual production for the four plants is in the plus 100-million pound range or approximately 500-million feet of plastic pipe per year. PVC pipe is close to 85% of the total production.

The Henderson, Kentucky, plant is currently the largest Cresline manufacturing site, with approximately 125 hourly employees. Hourly employees are represented by the International Association of Machinists, Local 2186. Cresline processes plastics by use of extrusion techniques by utilizing seven conical twin-screw extruders for PVC and CPVC production and two single screw extruders for PE and ABS production.

PVC Compounding

Of the four types of piping products used at Cresline, only one material (PVC) requires compounding. Compounding is the addition of minor ingredients to the basic resin material. The other three plastic materials CPVC, PE and ABS, are used as received by Cresline and require no additional ingredients before extrusion processing. At the Cresline-Henderson location, PVC production is in the 40-million pound-per-year range. When Cresline-Henderson first started production in 1966, the company did not utilize a PVC compounding operation. From 1966 to 1969, Cresline purchased preblended PVC compound in fifty pound bags. In 1969, Cresline decided to start in-house compounding of PVC. Two reasons affecting the decision for in-house compounding were increases in material cost and need for better control over actual PVC compound. To understand compounding one must first understand why additional ingredients are required. The ingredients designated as minor ingredients are added to PVC resin to prevent the PVC from degrading during the extrusion process. Also, the minor ingredients can aid in the extrusion process and act to modify the PVC material to meet certain performance parameters. A list of the most common minor ingredients and main reason for their addition to the PVC resin follows;

1) Stabilizer -- Liquid tin, the main ingredient that prevents degradation of PVC during extrusion.

2) Paraffinic Wax -- Has a melting point of 165°F and acts as a lubricant between PVC particles themselves and PVC particles to metal surfaces.

3) Calcium Stearate -- Internal lubricant that penetrates the PVC particles for molecular lubrication.

4) Polyethylene Wax -- External lubricant and reinforcement for the paraffinic wax.

5) Titanium Dioxide -- Ultra-violet absorber that prevents the pipe from losing its natural white color when exposed to direct sunlight.

6) Calcium Carbonate -- Crushed limestone, not actually required in the extrusion process, but acts as a filler for material cost savings.

CHAPTER 3

CRESLINE PVC COMPOUNDING OPERATION

In 1969, Cresline put into operation a compounding system from the Welex Corporation. The Welex compounding system model 300/800 MC is shown in Figure 1.

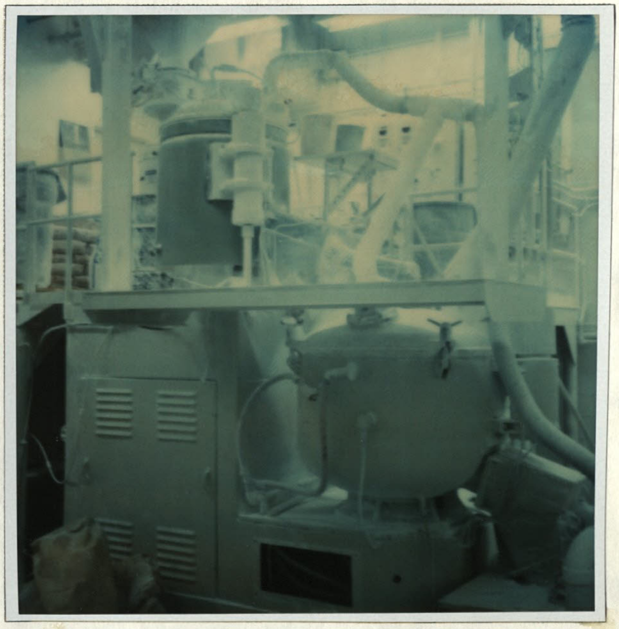


Figure 1. Welex Compounding System

In 1973, Cresline decided to replace the Welex compounder with the current Littleford compounder. The rationale for replacing the Welex compounder with a Littleford compounder follows;

1) The Littleford cooler uses a horizontal cooling chamber, at that time it was believed to be a more efficient cooling method than the bowl cooler of the Welex unit.

2) The Littleford unit offered a larger compounding capacity.

3) Cresline was in the process of building its second manufacturing site in Mechanicsburg, Pennsylvania, and the Welex unit could be utilized at that plant location.

A representative Littleford mixing system is shown in Figure 2. A breakdown of the compounding operation follows;

1) PVC resin is received by railcar and stored in a resin silo.

2) Resin is then conveyed from the silo to the compounding area.

3) At the compounding area, five powder ingredients and one liquid ingredient are added to the resin.

4) After completion of the compounding, the PVC material, now designated as PVC compound, is conveyed to a compound silo.

The six minor ingredients are added to the PVC resin in the mixing phase of the compounding operation. A

Littleford mixer independent from the compounding system is shown in Figure 3. The mixer provides controlled, rapid and homogeneous mixing of PVC resin and minor ingredients. The mixer contains a two-part mixing impeller system that achieves a high intensity mixing action. The result of this mixing action is a complete mix and uniform heat profile. The six minor ingredients are added to the PVC mixer when the resin reaches a temperature of 150° to 180°F. Frictional heat generated from the impeller system rapidly raises the compound to the desired temperature level. The 150° to 180°F temperature allows the PVC resin to rapidly absorb the minor ingredients. Heat generated during the mixing cycle must be removed to control the heat history of the dry blend and improve its flow characteristics. A Littleford cooler (Figure 4) is used to reduce the blend temperature to 125°F. The cooler has specialized mixing tools mounted on a horizontal shaft. The cooler also has a chilled water jacket. The internal mixing action constantly exposes the PVC compound to the chilled cooler surface and results in a heat exchange. In a compounding operation, the time required to heat up the PVC and add the minor ingredients should equal the time required to cool the PVC compound. Thus, the mixer and cooler can operate simultaneously. As the cooler is reducing the temperature of a PVC compound batch, the mixer should be heating up the next batch of PVC.

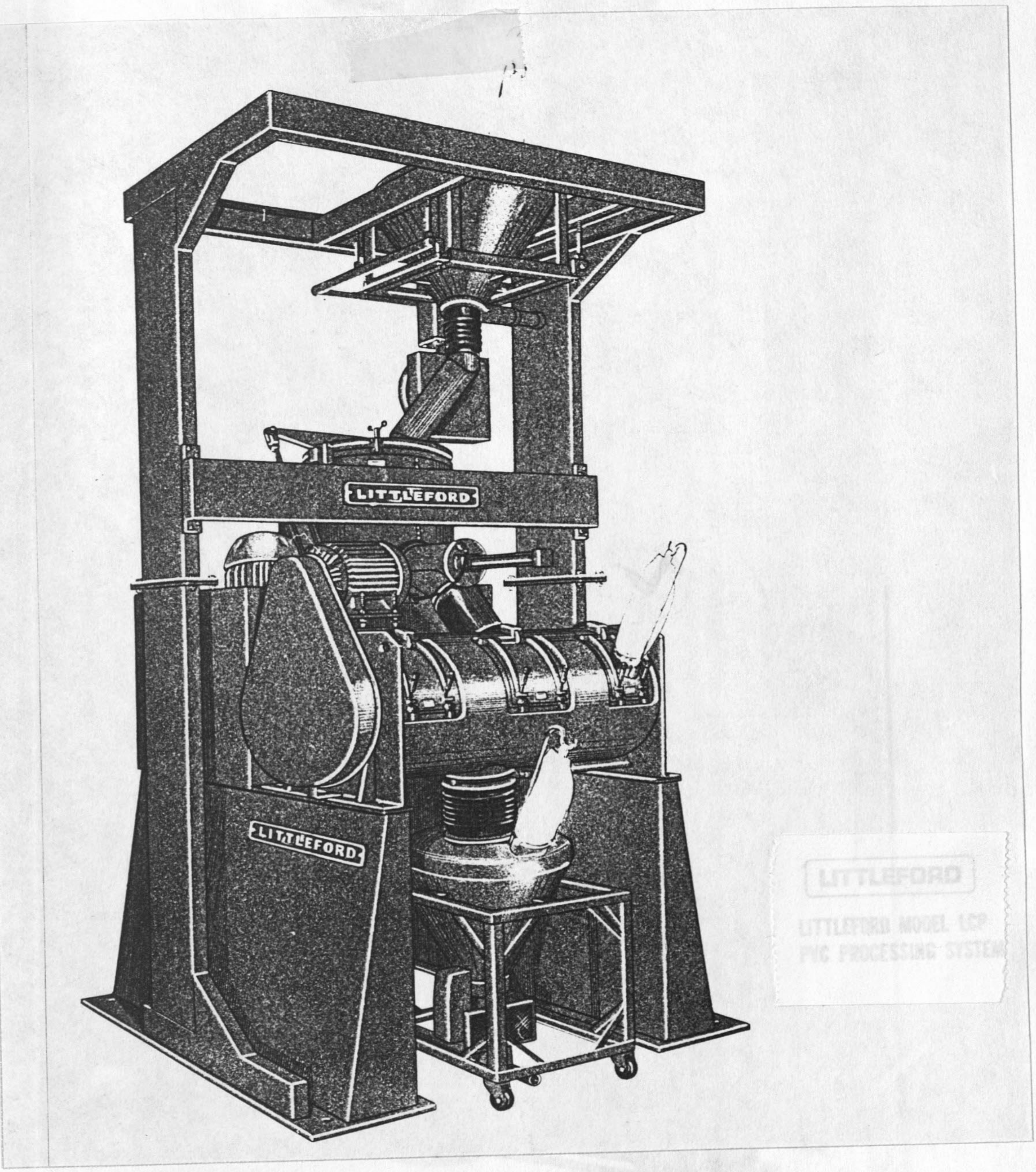


Figure 2. Littleford Mixing System

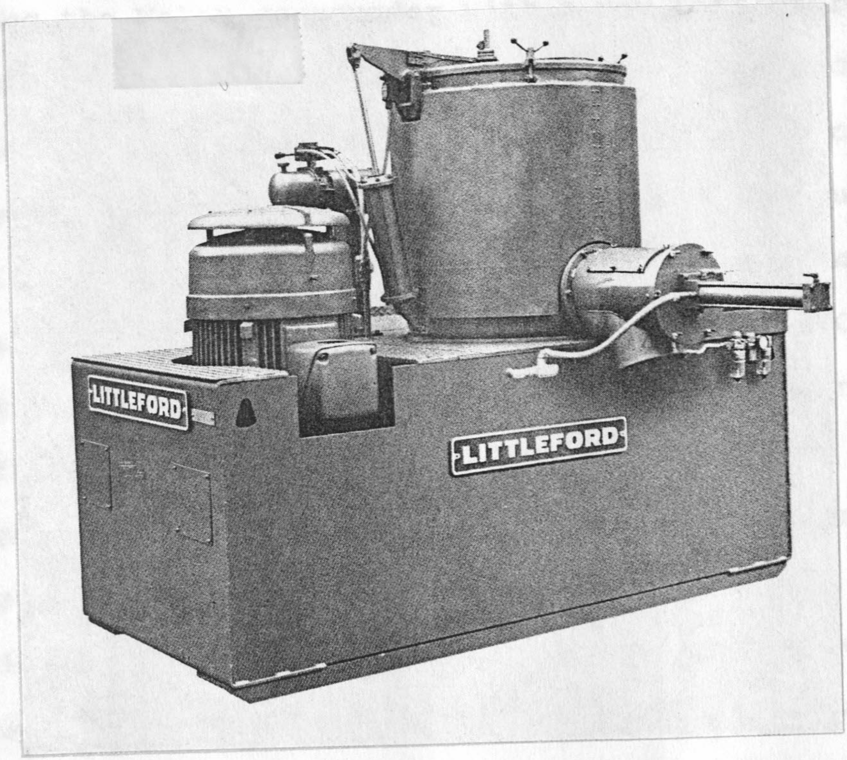


Figure 3. Littleford Mixer

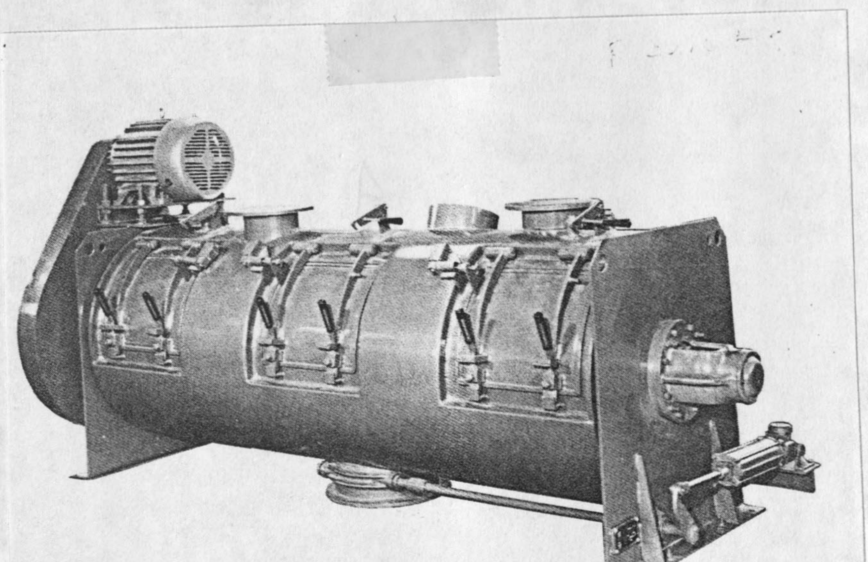


Figure 4. Littleford Cooler

Replacing the Welex compounder with a new Littleford 600/1200 compounder posed a major problem. The problem involved the fact that the two PVC compound silos could only hold a three to four day reserve of PVC compound. Thus, if the compounder was shut down for more than three to four days the plant would have to stop PVC pipe production. The decision was made to install the new Littleford compounding system around the operating Welex compounder and then switch over. This installation posed a major engineering challenge and in all probability led to some of the current ergonomic design problems. The Littleford compounder as installed at Cresline is shown in Figure 5.

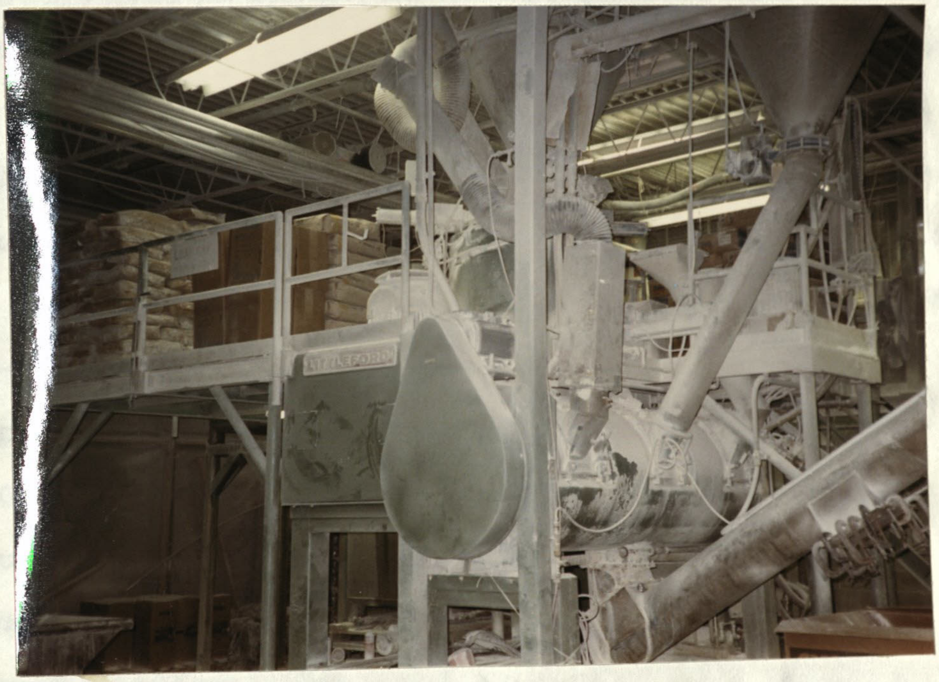


Figure 5. Installed Littleford Compounder

In 1973, PVC extruders where capable of transforming PVC material into pipe at a rate of 300 to 350 pounds-per-hour. The capacity of the Littleford compounder system in 1973 was probably around 100,000 pounds-per-day. With five to seven PVC extruders operating 24 hours-per-day the maximum required PVC compound was only 58,000 pounds-per-day. Thus the Littleford compounder was operated only one to two shifts per day and well below full capacity rates. In the past 16 years amazing strides have been made in extrusion process technology. Today the PVC extruders are capable of rates in the 1,200 to 1,300 pound-per-hour range. Now, with seven PVC extruders operating continuously the required PVC compound is 201,000 to 218,000 pounds-per-day. Obviously, PVC production has exceeded the capacity of the compounder. The Littleford compounder, in the 16 years since installation has seen little or no change in actual equipment technology. In 1988, at full capacity, the compounder was able to produce about 150,000 pounds-per-day. With the plant at full capacity and the compounder at full capacity, there exists a 60,000 to 70,000 pound-per-day shortage. Modifications were required for the compounder due to the potential lack of compound available for production. The compounder at first was operated on weekends to help meet the capacity difference. The compound produced during the weekend was used to fill two compound silos. The two compound silos, when full, gave the compounding operation a 300,000 pound PVC compound buffer. However, problems arose when production was also required to run weekends to meet sales requirements. During seasonal sales peaks, the compounding operation would run every weekend with pipe production running every other weekend at a modified level. This constant weekend operation of the compounder and the effects on actual production levels was not only costly in wages but also resulted in potential sales loss due to shortages of actual pipe production. An on-going study of the compounder rate was initiated. This study looked at the operation of the compounder itself and at dependent related equipment. The use of a "Mixer Rate Data Sheet" (Figure 6) not only gave a better understanding of the equipment but exposed several potential bottlenecking features. The mixer rate data sheet provided a process breakdown of the compounding operation. Evaluation of the cycle times for each respective process operation revealed actual process delays.

MIXER RATE DATA SHEET Date________

Plant__________ Mixer Type________ Make of Resin________ Outside Temp.____ °F

Resin into Mixer______ # Resin into Cooler________ # Ingred.____ # Total Batch______ #

Resin from Silo #___ Compound into Silo #___ Mixer Dump @_____ °F Cooler Dump @______ °F

Outside Humidity_______ Hour Meter______ This Data By____ Batch Delay Time __________

CYCLE TIMES: Beginning at "A", record elapsed times thru "F". Time "G" & "H" separately.	1	2	3	4	5
Time of Day					
A. Begin Resin Dump into Mixer					
B. Mixer Door Opens					
C. Mixer Door Closes					
D. Cooler Door Opens					
E. Cooler Door Closes					
F. Compound Hopper Empty					
G. Time to Fill Mixer Resin Hopper (From Aeropass Valve Open to Close)					
H. Time to Fill Cooler Resin Hopper (From Aeropass Valve Open to Close)					
Mixing Time = B - A					
Cooling Time = D - B					
Conveying Out Time = F - D					
Conveying In Time = G + H					
Critical Mixing Period = C - A					
Critical Cooling Period = E - B					
Critical Conveying Out Period = F - D					
Critical Conveying In Period = G + H					
Total Batch Time = C - A + Batch Delay Time					

Figure 6. Mixer Rate Data Sheet

The Littleford compounder at Henderson uses a "double batch" method of compounding. A breakdown of the actual operation follows;

1) The Littleford compounder (Figure 7) shows the mixer supplied by a hopper of PVC resin and a hopper of PVC resin directly feeding the cooler. At the cooler discharge, an auger assembly is used to transport the PVC compound to a secondary hopper for conveyance to the silo.

Figure 7. Detail of Littleford Compounder

2) The mixer (Figure 8) is on the actual working platform. The PVC resin dumped into the mixer from the hopper is half the total batch weight for the PVC resin.

3) The mixer brings the resin up to required minor ingredient discharge temperature by internal frictional heat.

4) The dry minor ingredients are loaded by hand into the two smaller hoppers on the mixer (Figure 8.) and dumped automatically into the mixer at a preset temperature. There is a completely automatic loading system for adding the one liquid minor ingredient.

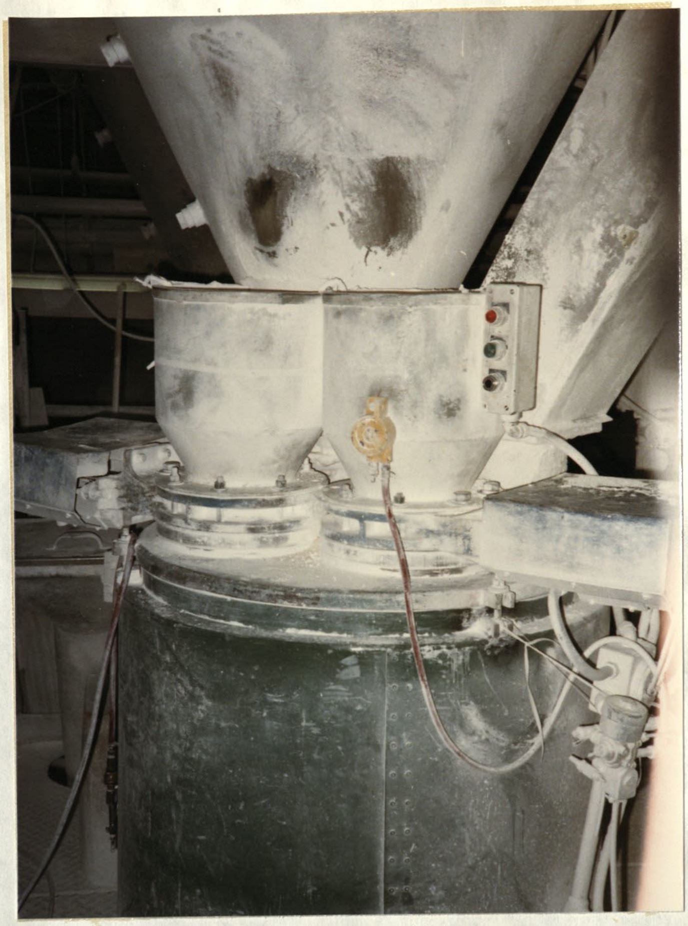


Figure 8. The Compound Mixer.

5) The PVC resin and minor ingredients are blended together in the mixer until the PVC compound reaches a preset temperature. The mixer then discharges the PVC compound into the cooler.

6) The PVC compound in the cooler is then joined by the other half of the required batch weight of PVC resin. This is accomplished by a PVC resin hopper feeding directly to the cooler (Figure 9).

7) The PVC compound remains in the cooler until it reaches a preset temperature.

8) When the cooler lowers the PVC compound to the required temperature it discharges the PVC compound into an auger assembly. The auger transports the PVC compound to a secondary hopper.

9) When the material from the cooler has been fully discharged, the mixer should be nearly ready to discharge the next load of heated PVC.

Figure 9. PVC Resin Hopper.

The compounding operation cycle is shown graphically in Figure 10. Several of the operational functions overlap, and this overlap causes the majority of bottlenecking for the total operation.

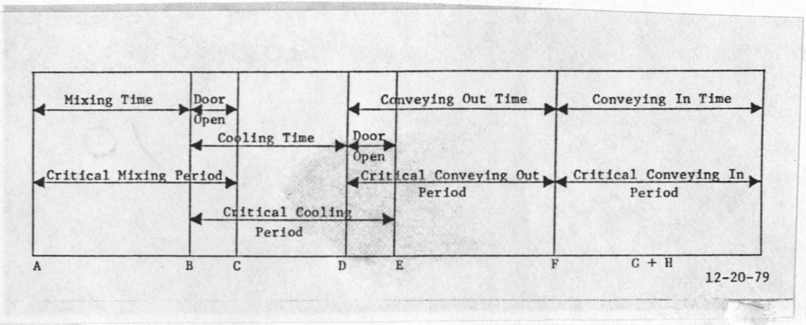


Figure 10. Compounding Operation Cycle.

<u>Bottlenecking</u>

The Littleford compounder uses timers and preset temperature controllers for its operation. This system is automatic except for the addition of minor ingredients into the two small hoppers on the mixer.

The first studies of the compounding operation revealed that the majority of bottlenecking was the result of safety-induced delays in the operation. A costly delay was the preset batch-delay timer. Since the mixer and cooler both discharge the PVC compound at a preset temperature, the possibility existed that the mixer would discharge PVC compound into the cooler at the same time the cooler was discharging into the auger assembly. This would result in hot PVC compound moving directly through the cooler into the auger assembly without undergoing cooling. The batch delay timer is used to delay the PVC resin in the hopper atop the mixer from entering the mixer. The delay increases the time between mixer batches and allows the cooler an additional cycle time period. Since the actual required batch time delay varies with seasonal ambient temperature and the compounder itself, the preset batch time delay was changed to an adjustable batch time delay controlled by the mixer attendant. A second preset timer controlled the cooler discharge door. When the cooler has lowered the temperature of the PVC compound, the cooler discharge door will open for the preset time to allow the PVC compound to enter the auger assembly. By placing sight glasses at the point of the cooler discharge door, the actual time required for complete discharge of PVC compound from the cooler to the auger assembly was determined. The actual time for cooler discharge was one-third the preset time. After re-evaluation of preset temperatures and timers the actual components of the compounder were studied. Two major component bottlenecking features were discovered;

1) The cooler in the winter months had no problem keeping up with the mixer times. This was the result of the PVC resin being supplied directly from a hopper to the cooler. This resin was at outside ambient temperature. In winter the resin acted as a cooling source. In summer the resin temperature does not aid the cooler and cooler times increase to almost twice the mixer times.

2) The time required to convey the PVC resin from the silo to the two compounding hoppers. A blower

system is used to convey the PVC resin from the silo to the two compounder hoppers. The blower produces pressurized air that conveys the PVC resin in 3-inch material lines to the hoppers. In the winter months, the time to convey material exceeded the compounding time and thus resulted in a delay. In the summer months, the convey time was well below the compounding time because of the increase cooler times and no delay was encountered. The bottlenecking of the compounding operation is the cooler in the summer and the time to convey material from the silo to the resin hoppers in the winter.

In debottlenecking these operations, Cresline had basically two options, to modify existing equipment or to replace the equipment. The process of debottlenecking resulted in the following:

1) A Littleford K1600 cooler was purchased to replace the present K1200 cooler. The K1600 cooler was installed during the two week Christmas shutdown in 1988. The K1600 cooler has a working capacity 33% larger than the K1200 model. The addition of this capacity will not be fully realized until the summer months of 1989.

2) The modification of the PVC resin conveying-in system. This involved increasing the size of the blower and the material-conveying lines from the

silo to the two resin hoppers. This modification resulted in a 40% reduction in the time required to convey the PVC resin from the silo and fill the two compounder hoppers.

With the new cooler and modified PVC resin conveying system, the projected output for the compounder is 175,000 pounds per day. This figure is still below the full capacity requirement for production. Cresline, will continue to explore options to increase the compounding operation output.

CHAPTER 4

MIXER ATTENDANT

The compounding operation is staffed by one mixer attendant per shift. The mixer attendant is responsible for the addition of minor ingredients and for monitoring the control panel of the compounder. The mixer attendant works on a 10-foot high platform adjacent to the mixer and control panel. The work platform is shown in Figure 11 and the control panel in Figure 12.

The recent debottlenecking of the compounder to increase output rate has led to potential ergonomic problems in the man-machine compounder system. The relationship between the mixer attendant and his work requirements are the main focus of this project.

The practice of letting the man adapt to the machine is a common problem in industry today. Although the potential human factors were questioned during debottlenecking of the compounder at Cresline, the main emphasis was on the machine and not the man.

Figure 11. Work Platform.

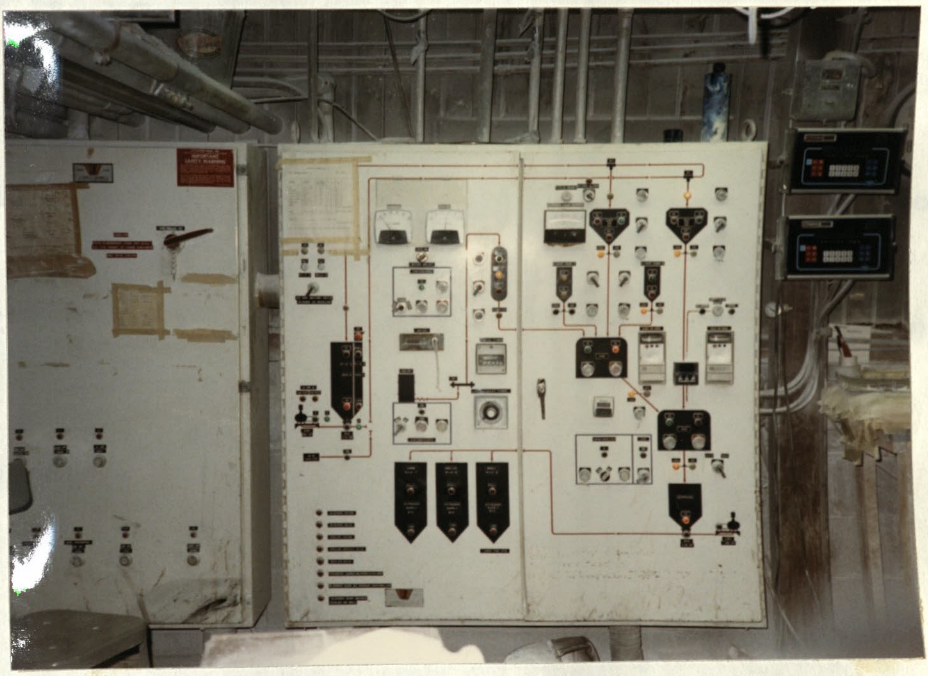


Figure 12. Control Panel.

<u>Job Routine</u>

To help understand the actual activities of the mixer attendant, a job routine breakdown follows;

1) The weighing of five dry minor ingredients for each mixer batch (Figure 13).

2) Adding the minor ingredients to the two small hoppers on the mixer (Figure 14).

3) Monitoring the compounder control panel for correct operation and adjusting the batch delay timer.

4) Restocking of minor ingredients at the end of the production shift (Figure 15a,b,c).

5) General clean-up of work area (Figure 16).

The mixer attendant usually works a nine-hour production shift -- eight hours regular and one hour of overtime. A typical nine hour production shift schedule breakdown is:

1) Seven hours of actual work on the platform.
2) Two breaks (15 minutes each).
3) Lunch break (30 minutes).
4) Restocking of minor ingredients and cleanup of work area and employee cleanup time (60 minutes).

Figure 13. Weighing Minor Ingredients.

Figure 14. Adding Minor Ingredients.

Figure 15a. Restocking Minor Ingredients.

Figure 15b. Restocking Minor Ingredients.

Figure 15c. Restocking Minor Ingredients.

Figure 16. Clean-up.

During the seven hours on the mixer platform the mixer attendant will weigh minor ingredients for 62 batches. The total weight of the five dry minor ingredients for each batch is 60.37 pounds. With 60.37 pounds-per-batch and 62 batches-per-shift, a total of 3743 pounds is weighed per production shift. At first, the total pounds the mixer attendant handles (3743 pounds) would not necessarily seem out of line. However, observation of the work-place design and the process the mixer attendant uses reveals that there are major problems. The calcium carbonate, which accounts for 38 pounds of the 60.37 pounds, is handled five times. The four other minor ingredients (22.37 pounds) are handled six times. The rehandling of the minor ingredients are caused by the current work layout arrangement of the compounding area. Because of rehandling, the 3743 pounds increases to 20,102 pounds or just over 10 tons per production shift.

Future Job Requirements

With the debottlenecking of the compounder, the number of batches will increase. The projected number of batches after the PVC resin conveying system is modified should reach 70. This increase in capacity would result in a 13% increase in lifting from 20,102 pounds to 22,695 pounds per shift. To help understand the handling and lifting requirement of the minor ingredients, a breakdown of lifts follows;

Lift 1 -- Restocking of four minor ingredients (Figure 15a & b).

Lift 2 -- Lifting the minor ingredient from the pallet (Figure 17).

Lift 3 -- Carrying the minor ingredients from the pallet and placement into the 55 gallon drums (Figure 18) and carrying the weighted minor ingredients to the small hoppers atop the mixer. The assumption is made that the carrying of the minor ingredients and placement into the 55 gallon drums is equal to a complete lift. A break-down of lift 3 would result in 25% of the total lift for material placement into the drums and 75% of the lift for carrying the material to and from the work area.

Lift 4 -- Scooping out material into buckets for correct ingredient weight (Figure 19).

Lift 5 -- Lifting the weighed material in the bucket to the work bench adjacent to the mixer (Figure 20).

Lift 6 -- Pouring ingredients in the bucket into the small hoppers on the mixer (Figure 21).

<u>Survey</u>

From observation of the work place design and the handling of materials, several obvious human factor problems were detected. The human factors problems stem from two sources. The first problem is the actual design arrangement of the work place, the second is the repeated handling and lifting of material. A survey (Appendix A) was administered to the three mixer attendants. The result of the survey revealed additional problems and reinforced known problems. All three attendants noted dust and lifting as major complaints related to their job.

The material lifting requirement is directly related to the workplace design. Changes in the workplace could have a positive or negative effect on material handling requirements.

Figure 17. Minor Ingredient Pallet.

Figure 18. Refilling Ingredient Drum.

Figure 19. Scooping Minor Ingredients.

Figure 20. Work Bench.

Figure 21. Loading Small Hoppers.

CHAPTER 5

WORK PLACE DESIGN

Current Arrangement

The arrangement of the work place can directly affect how efficiently people perform tasks. Some general considerations when designing a production workplace are as follows;[5]

1) Lines of sight for operations should be kept clear.

2) Noisy, heat-producing, odor-producing, or visually distracting operations should be modified or located so as to minimize their effects.

3) Work area arrangement with product flow principally in one direction, resulting in minimal rehandling.

4) Postural flexibility and change should be provided.

The current work place arrangement for the compounder is shown in Figure 22a. The work flow pattern is shown in Figure 22b.

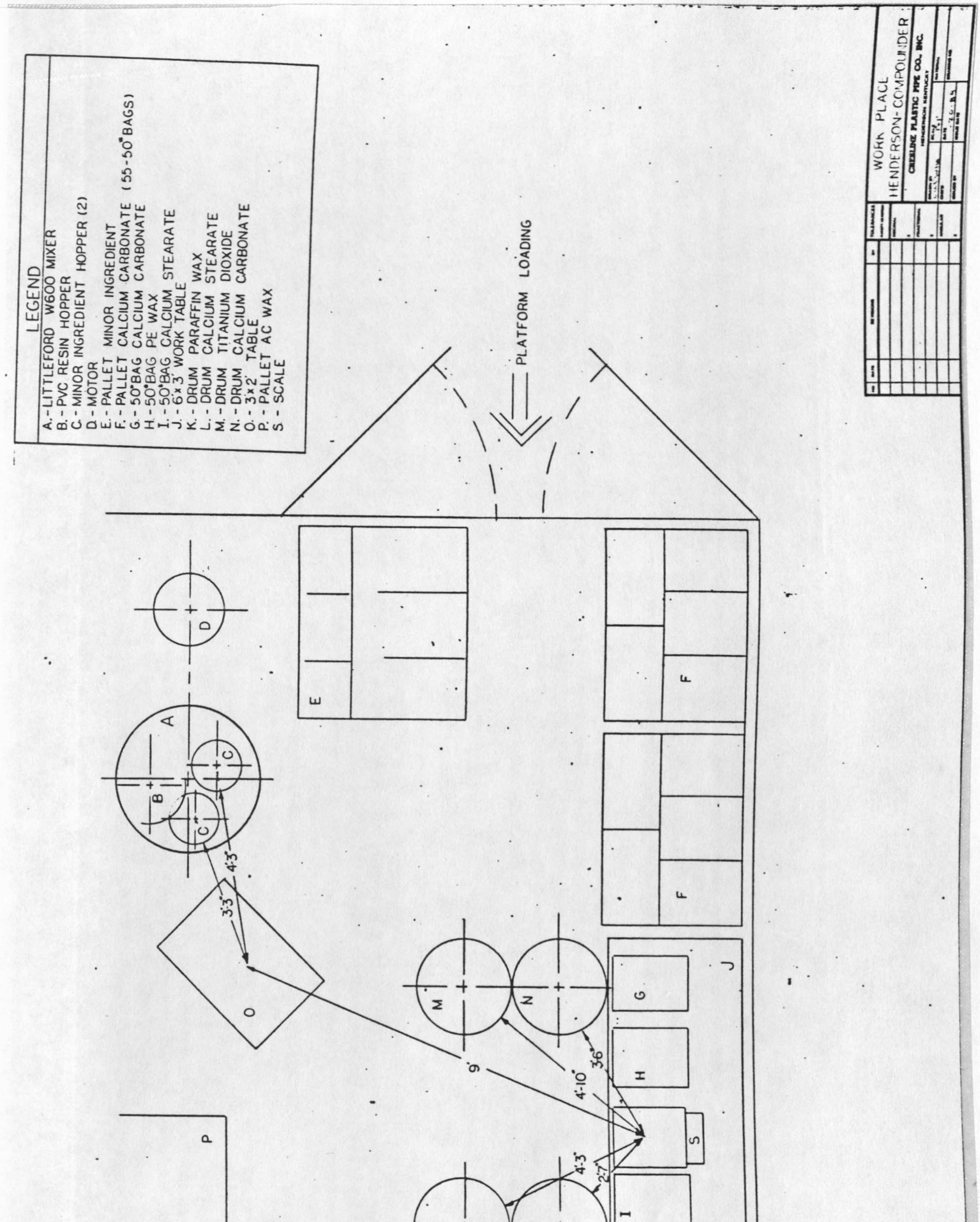


Figure 22a. Current Work Place Arrangement.

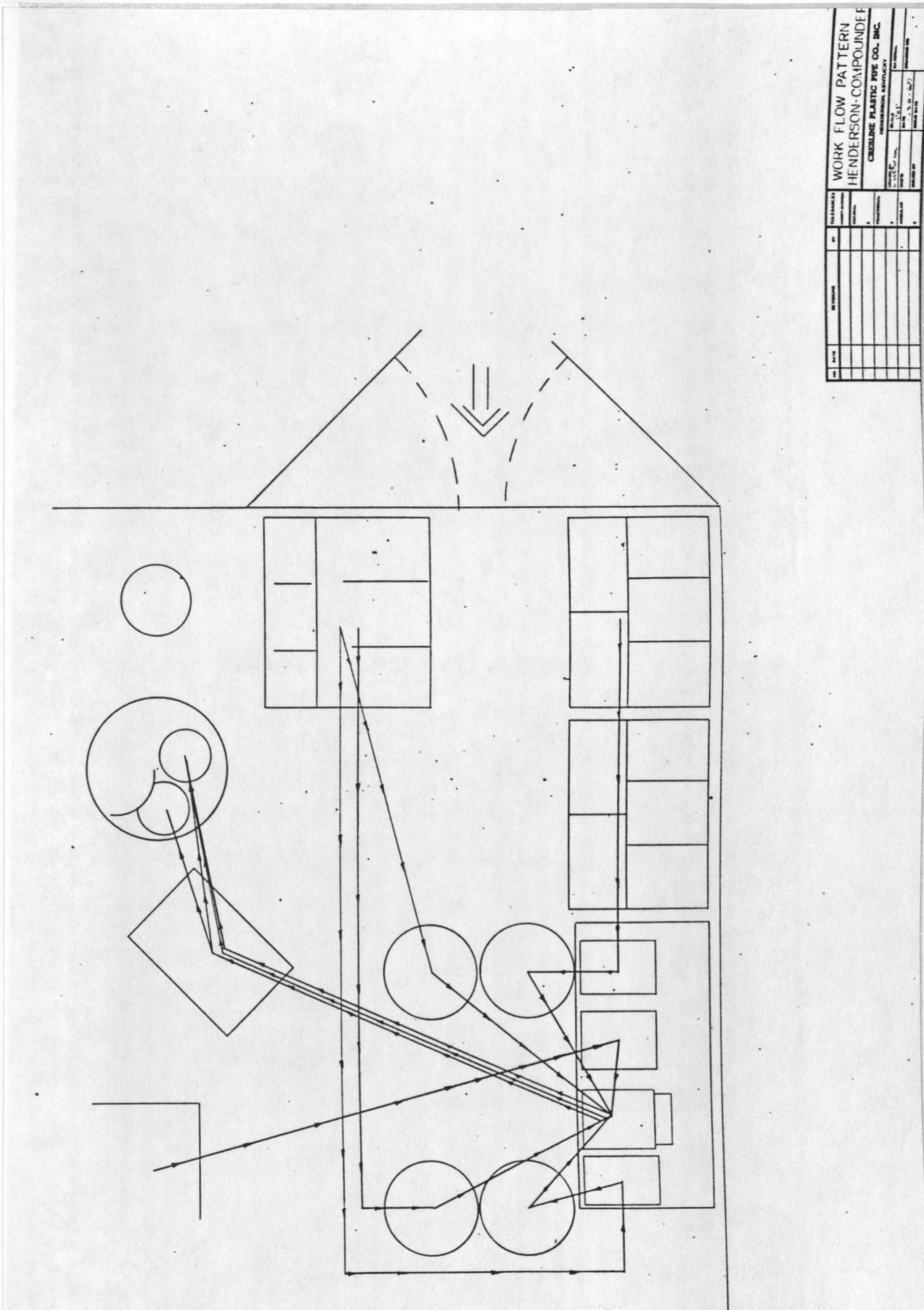


Figure 22b. Current Work Flow Pattern.

Work Height

Working height is of critical importance in the work place design. The work height has a direct effect on postural flexibility. The work height determines the angle of abduction of the arm. The most favorable working height for hard work while standing is 2 to 4 inches below elbow level. [6] The average elbow height, which is the distance from floor to underside of elbow when it is bent at a right angle with the upper arm vertical is 41.3 inches for men. [7] Therefore a working height of 37.3 to 39.3 inches would be favorable for men. When the working height is too high the angle of abduction increases. The stick figures in Figure 23 show the relationship between work height and the angle of abduction. By raising the work height 3 inches above optimum, the angle of abduction of the humerus is between 40 and 50 degrees. [8] The humerus is the bone located in the upper arm, refer to Appendix B for anatomical locations.

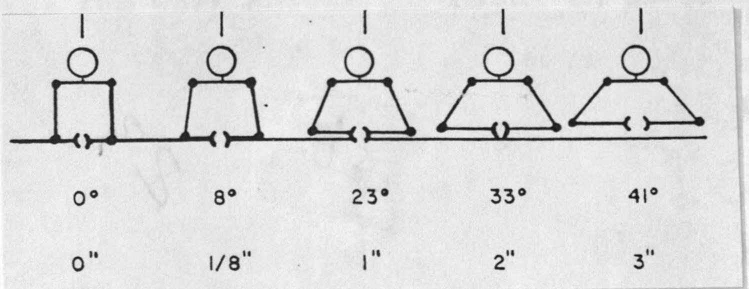


Figure 23. Angle of Abduction.

As the angle of abduction increases, the upper limb center of mass moves away from the body, and thus increases forces acting on the shoulder joint. [9] Therefore, the higher the elbow is held away from the body the farther the center of mass is moved from the body. This results in stress and strain on the upper trapezius. [10] An angle of 40 degrees results in stress on the upper fibers of the trapezius roughly eight times that of an angle of 20 degrees and approximately 64 times as much as an angle of 10 degrees. [11]

In evaluation of work height and related angle of abduction for the mixer attendant, two problems arise. The 55-gallon drums are at a height of 34 inches, but the placement of the plastic bucket (Figure 24a) adds 10 to 14 inches to the work height. Thus, the work height is 44 to 48 inches which is 4.7 to 8.7 inches above optimum. When the bucket is placed on the scale (Figure 24b) the work height increases to between 51 and 55 inches. The effects of the work height can be seen by a dramatic increase in the angle of abduction of the upper arm. The end result in this incorrect work height is that the shoulders must be lifted to compensate for the height. This action may lead to painful cramps at the level of the shoulder blades and in the neck and shoulders. [12]

Figure 24a. Working Height of Ingredient Bucket.

Figure 24b. Working Height of Ingredient Bucket.

Straight Wrist

With work heights above optimum elevation, concerns also arise related to the use of the wrist. When the wrist is severely bent out of alignment repeatedly from the forearm, problems occur. In turning the material scoop downward the mixer attendant must bend his wrist (Figure 25). This bending action of the wrist will cause flexor tendons of the fingers to bend and bunch up in the carpal tunnel. [13]

Figure 25. Bent Wrist of Mixer Attendant.

This bending action can lead to tenosynovitis, an inflammation of the tendons and their sheaths. [14] The excessive bending of the wrist also can cause a condition called carpal tunnel syndrome. [15] Carpal tunnel syndrome is a disorder that is a result of injury to the median nerve where it goes through the carpal tunnel in the wrist. [16] The symptoms range from numbness, to loss of feeling with possible loss of hand functions. [17] The correction of work height and possible changes in material scoop design could help reduce the extent and frequency of wrist bending and avoid carpal tunnel syndrome.

The idea of bending the tool, and not the wrist, was studied by Tichauer (1976). Figure 26 shows the effects of bending a tool as it relates to reduction in possible wrist damage. Thus, it appears that efforts to produce a more natural alignment between the wrist and forearm could result in fewer problems with wrist disorders. Modifications to existing hand scoop or purchasing a new design hand scoop could help prevent wrist disorders.

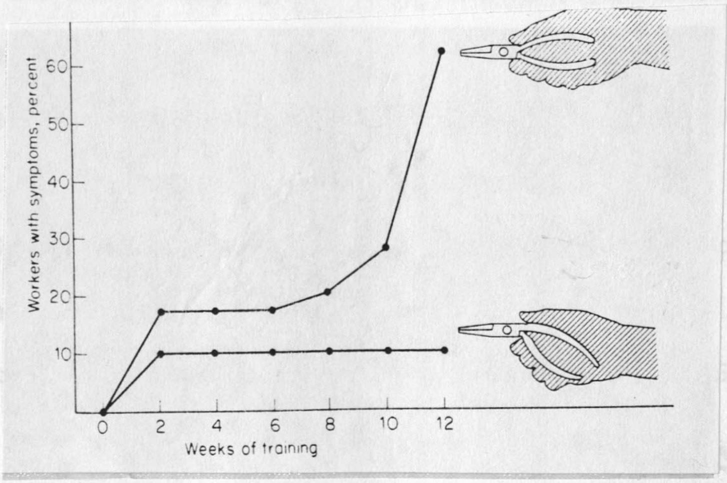


Figure 26. Bent Tool Study by Tichauer (1976).

Redesigned Work Area

With the problems of the current work place arrangement noted, a redesigned work area was developed. The new work place arrangement is shown in Figure 27a. The new work flow pattern is shown in Figure 27b. The new design allows for flow in one direction with reduced rehandling. The work height of the new design was modified with the intent of reducing the angle of abduction of the arm.

Work Area Layout

In the redesigned work area, the weighing of materials is reallocated into two physical locations instead of one as in the original design. With two work areas, the compounder required two scales. The old work area had a back-up scale available. This back-up scale was utilized in the redesigned work area. One work area is exclusively for the weight measurement of calcium carbonate because calcium carbonate accounts for 63% of the total batch weight. As seen in Figure 27a and Figure 28, a pallet of calcium carbonate is located behind the calcium carbonate work area. Also in the calcium carbonate work area is a work bench, 55-gallon drum and scale. With the new arrangement, the calcium carbonate flows in one direction toward the mixer hoppers. The weighed calcium carbonate can remain on the scale until it is loaded into the mixer hoppers

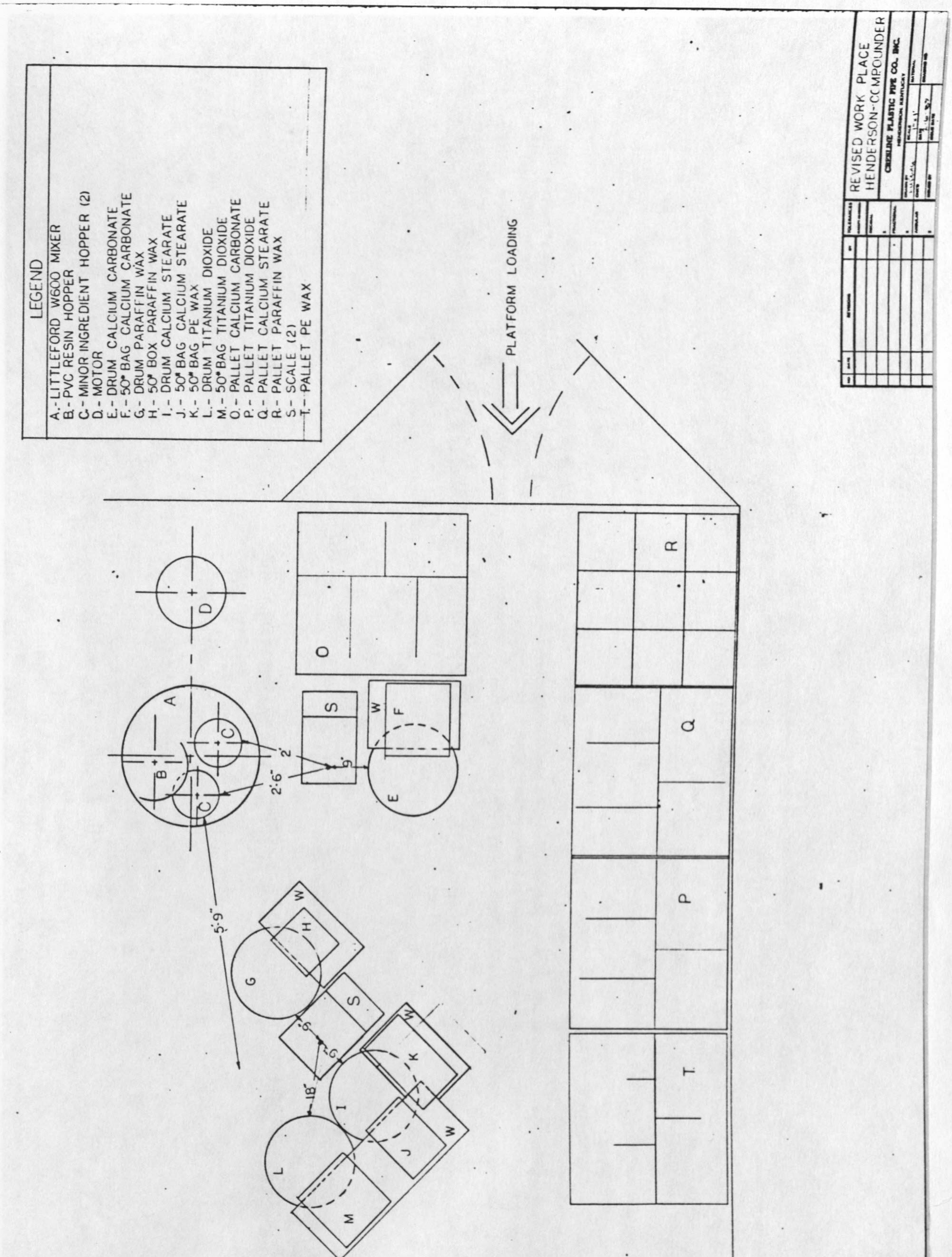


Figure 27a. Revised Work Place Arrangement.

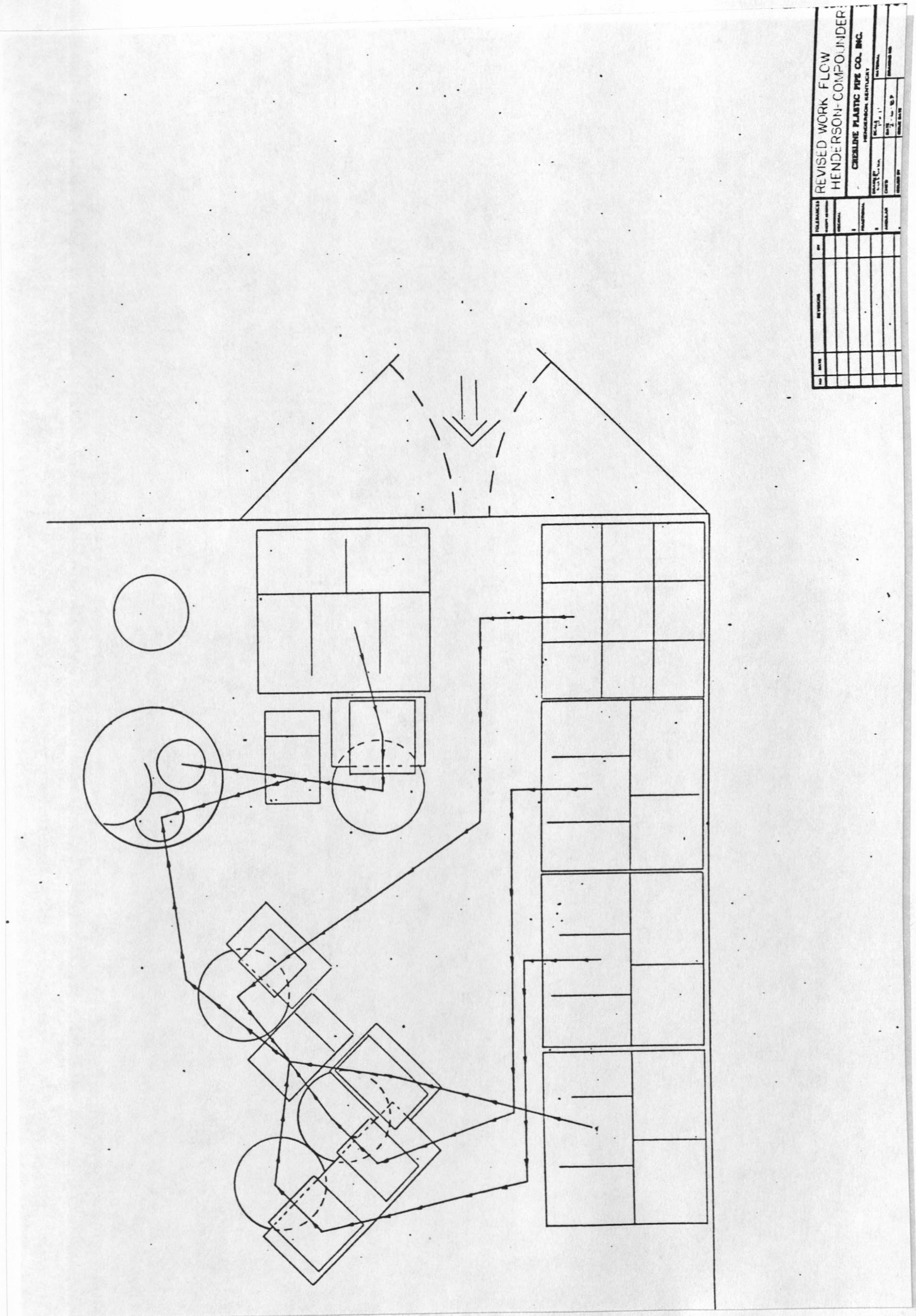


Figure 27b. Revised Work Flow Pattern.

Figure 28. Calcium Carbonate Work Area.

Figure 29. Calcium Carbonate on Scale.

(Figure 29), thus eliminating a lift. The second work area is used to handle the remaining batch minor ingredients. Calcium stearate, titanium dioxide, paraffin wax and PE wax are stored, handled, and weighed in this area. As shown in Figure 27a, a pallet of calcium stearate, titanium dioxide, and paraffin wax are now located on the mixer platform. The calcium stearate, titanium dioxide and paraffin wax account for 95% of the batch weight for the four minor ingredients in the second work area. The PE wax accounts for only 5% or a little over 1 pound on each batch. With the pallets of calcium stearate, titanium dioxide and paraffin wax on the platform, the minor ingredient pallet on the old work area design is no longer required. By placing full pallets on the mixer work platform, the required restocking of the minor ingredient pallet is also no longer needed. The work flow in the second work area, although not totally one-directional, is a vast improvement over the old design. Figure 30 shows the arrangement of the work area with the 3 drums and the PE wax bag located to the right of the scale. The four minor ingredients are weighed out with the bucket remaining on the scale until required addition of minor ingredients into the two small hoppers. This allows for complete removal of the old work bench located by the mixer in the old work area design.

Figure 30. Second Work Area.

Standard Work Height

Until recently, the data available for human dimensions came from military studies on healthy young men. [18]

However, the actual industrial workforce is comprised of men and women between the ages of 17 and 70. [19] Using military studies for human dimensions for workplace design can result in a non-optimal design for about 75% of the potential industrial workforce. [20] Designing workplaces to accommodate most workers can be a complex task. The design requires careful thought on how the design will affect both extremes of the population, making trade-offs for both extremes. [21] In the old work area layout, the work height was greatly above the suitable work height. To determine a new work height, several factors must be considered to meet the needs of the workforce. It was noted that the favorable work height for hard work while standing is 2 to 4 inches below elbow height, and that the average elbow height for man was 41.3 inches. A closer look at the 41.3 inch measurement reveals the height is from a study by Grandjean for an average European man.

In the redesigned work area, the work height still should be 2 to 4 inches below elbow height, but the elbow height should relate to the actual workforce population at Cresline. The anthropometric data used for determining elbow height is from a military study on a 50/50, male/female population. The actual anthropometric data are provided in Appendix C.

The 50/50, male/female, population is from military data. Thus, the dimensions for elbow heights are lower than for man alone and they should relate closer to the industrial population. Consideration of hiring a female mixer attendant, although slim, is possible. The elbow height for a 50/50, male/female population follows;

5th percentile, 38 inches

50th percentile, 42 inches

95th percentile, 46 inches

The range of elbow height is 8 inches. With the favorable work height for hard work while standing at 2 to 4 inches below elbow height, the ideal work height falls into the following;

5th percentile, 34 to 36 inches

50th percentile, 38 to 40 inches

95th percentile, 42 to 44 inches

If the work height is located at 42 inches for the 95th percentile, the height would be too high for over 50% of the work force. And if the work height is 34 inches, the work is below the favorable height for over 50% of the work force. By trading off between the too-high for short people and the too-low for tall people, the work surface is set at 36 inches. This height will accommodate a short person. The 36-inch work height allows the current hand scoop to be used and no modification or new design is required. The 36-inch work height should also help with respect to maintaining a straight wrist by providing a more natural alignment between the wrist and forearm. The minor ingredients in the 55-gallon drums are frequently restocked to maintain the new work height.

<u>Dimensions for Visual Work</u>

When standing, the area of the working field that needs to be kept in constant view must be placed so that the operators head remains comfortable. Too much tilt of the head either up or down results in aches in the neck muscles. [22]

The values for preferred viewing angles are shown in Figure 31. A 30 degree angle below the horizontal line of sight is the preferred viewing angle for standing work. [23] The viewing angle must be taken into account for the redesigned work area. The mixer attendant must

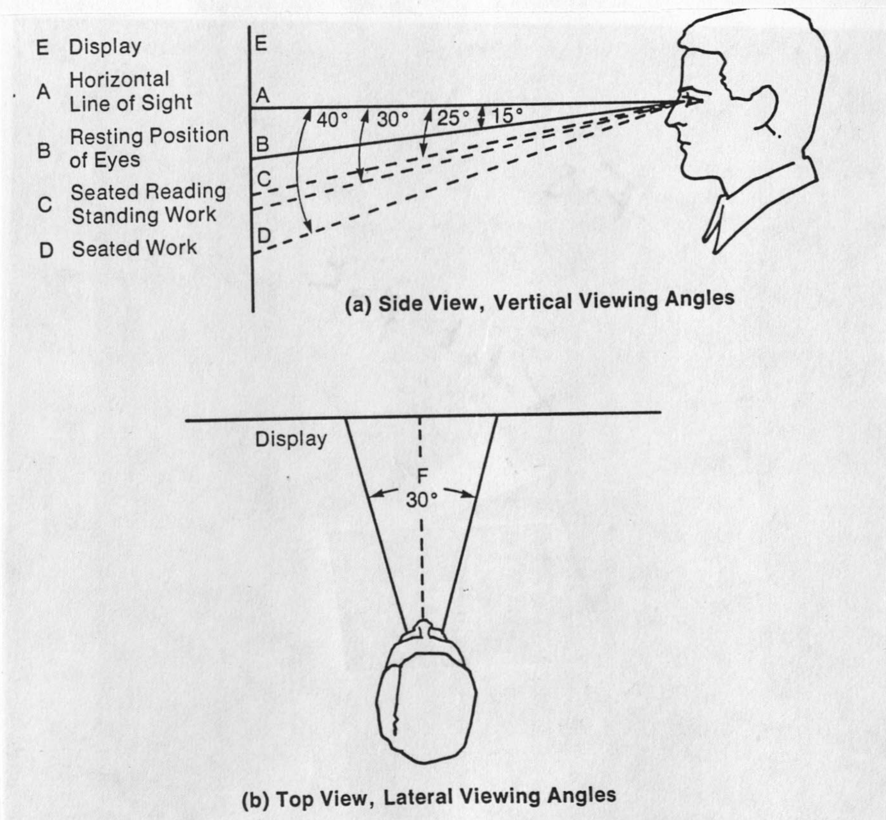


Figure 31. Preferred Viewing Angles (Eastman Kodak)

observe scale readings (Figure 32) for correct batch weight measurements. With the 36-inch work height, possible problems with viewing angles are exposed. The standing eye height measurement is from the floor to the eye. This height ranges from 58 to 69 inches in most industrial populations. [24] The 58 to 69-inch eye height assumes normal clothing, includes shoes, and accounts for normal postural slump.[25]

To find the 30 degree angle height, the distance from the scale face to the mixer attendant was determined by

Figure 32. Scale Readings.

actual physical measurements. For the three current mixer attendants at Cresline this distance averaged 31 inches. The visual range from horizontal line of sight to the 30 degree angle is then found by;

$$\tan 30^\circ = x / 31 \text{ inches}$$

$$x = 17.9 \text{ inches}$$

The dial markings of the scale should be located no lower than 40 to 51 inches to maintain the 30 degree angle. Ideally, the lower measurement values should be located no lower than 51 inches. The 51-inch value allows for visual angle less than 30 degrees for the 5th to 95th percentile of the workforce population.

New Work Height

Since the scale height placement affects the work height and viewing angle, both factors must be considered. The current scale used on the compounder is a Toledo dial scale. The distance from the bottom of the scale to the lowest dial marking is 20 inches. Placement of the scale so that the bucket is at the 36-inch work height results in the bottom dial markings of the scale at a height of 37 inches. Placement of the scale so that the bottom dial markings of the scale are at 51 inches, results in a work height of 50 inches. A compromise was required between work height and viewing angle. A series of trial heights of the scale resulted in a 39-inch work height preferred by the current mixer attendants. This 39-inch work height results in a bottom-of-the-scale face measurement value of 40 inches. The 39-inch work height does result in an increased angle of abduction of the arm above optimum, but the angle is still below the angle of the old work height (Figure 33). The 39-inch work height only affects the work area for the scale used to weigh the four minor ingredients.

Figure 33. Angle of Abduction in Revised Work Place.

The scale for the calcium carbonate can be placed at the 36-inch work height, since the scale dial markings corresponding to the commonly measured weights of calcium carbonate are close to the top of the scale dial. Since the back-up scale for the compounder was utilized in the second work area a new back-up scale is now required. The opportunity to obtain a scale to avoid the work-height/ viewing-angle compromise was possible. A Detecto bench scale, model 1450, was ordered. The Detecto scale information is provided in Appendix D. The new Detecto scale will have a remote weight readout that can be located at a distance up to 5 feet from the scale bench. The Detecto scale will replace the current Toledo scale and thus allow for the correct work height and optimum viewing angle. The current Toledo scale will then become the back-up scale for the redesigned workarea.

<u>Other Factors</u>

Several other factors affect work place design. Two other factors to be considered for this application are reach distance and clearances for walking. The left arm's reach can be considered a mirror image of the right arm's reach. Most people can reach 18 inches in front of their body without stretching or leaning forward as long as the object is 43 to 65 inches above the floor. [26]

Since a 55-gallon drum is 24 inches in diameter, the new work benches were designed to contain a material shelf which overlaps the drums by 6 inches. As shown in Figure 34a and 34b, the reach to the material bags is

18 inches or less. In the new work area design, clearance for walking between materials was considered. The minimum clearance for walking is 24 inches. [27] The 24-inch clearance includes a 2-inch clearance on either side of the shoulders of a very broad-shouldered person. In the new work area design, a minimum of 24-inch clearance was used between work areas and material pallets. [28]

Figure 34a. Reach to Material Bag.

Figure 34b. Reach to Material Bag.

CHAPTER 6

HANDLING LOADS

Manual material handling is the major source of compensable work injuries in the United States. [29] The problem of how much work a man should do and how much rest he should take is not a new problem. The development of "scientific management" by Taylor in the late nineteenth century was an effort to evaluate work rate for the job and appropriate fatigue allowances. [30]

With the old work area design, lifting of loads equalled over 20,000 pounds per work shift, and after debottlenecking of the compounder this value would have increased to over 22,600 pounds-per-shift. The new work area design does reduce the rehandling of minor ingredients. Review of the handling of the minor ingredients on pages 29 to 30, shows the new work area design removes lift 1 and lift 5. The new design also reduces the carrying distances by approximately 50%. Therefore, lift 3 would now become a 62% lift. The new design cuts the rehandling of the minor ingredients from 5 or 6 lifts-per-ingredient to an average of 3.6 lifts. Nevertheless, after debottlenecking the compounder operation, the mixer attendant with the new design layout will still handle 15,318 pounds-per-shift, despite the 32% reduction in lifting attributable to the redesigned layout of the work area. Even with the reduction in amount lifted per production shift, the values still warrant investigation.

Muscle Action

The lifting of material is accomplished by use of the muscle structure of the human body. The following section explains how muscles work and what effects over-use of muscles can have on the human body.

The actual work done is the result of the contraction of a single muscle or a group of muscles. This contraction of the muscles is accomplished by the breakdown of glycogen to lactic acid. Lactic acid is a poisonous by-product which is subsequently removed from the human body by oxidation to carbon dioxide and water. [31] Oxygen is used to remove the lactic acid caused by the energy-producing reaction, and this removal may continue for some time after the activity has ended. [32] The muscular activity does not depend primarily on oxygen to function. Thus we can perform work when the oxygen supply is insufficient. Also, this permits humans to make extreme efforts which would be impossible were the energy of the muscle obtained directly from the oxidation of some substance in the muscle fiber. [33] The oxygen supply has two sources, from oxygen-enriched blood or from storage in the red muscle fiber. If work is aerobic, the oxygen supply can remove all the lactic acid. [34] If the available oxygen supply is exhausted, a lactic acid build-up occurs. The build-up of lactic acid creates an "oxygen debt" which must be repaid when the work has ended. [35] The build-up of lactic acid results in the sensation of pain or muscle fatigue. An example of the build-up of lactic acid occurs when working with one's arms overhead such as when repairing or installing an electric fan on the ceiling. The lactic acid resulting from the work must be oxidized by the oxygen from the blood, but contraction of the muscles prevents the blood from flowing into the arm muscles. With the blood flow cut off, the lactic acid starts to build up and before very long the muscle becomes so painful that the arms must be lowered to allow the muscle to relax and permit the blood to flow through it and provide a source of oxygen to oxidize the lactic acid.

To prevent lactic acid build-up, muscular activity should be intermittent to allow the blood to flow through the muscle to supply oxygen or facilitate the paying back of an oxygen debt. [36]

When muscular exertion has been extended for a long time period, even without a build-up of oxygen debt, there may be an accumulation of intra-muscular fluid. [37] This fluid rests between the muscle fibers and results in swelling of the muscle and resulting in stiffness and soreness. [38] Resting the muscles will reduce this swelling. If the rest is insufficient and continued use of the muscle occurs, the intra-muscular fluid can increase. [39] A muscle which is continuously used may become distended by intra-muscular fluid with possible deposition of fibrous material which could ultimately interfere with the normal contraction of the muscle and cause permanent damage. [40]

Energy Consumption

Metabolism is a chemical process in which food products are transformed into two forms of energy, that being heat and motion. [41] The total energy consumption for a given day is made up of basal metabolism, leisure calories, and work calories.

Basal metabolism is the consumption of energy for bodily function. Measurements show that a resting person has a steady consumption depending on size, weight, and sex. [42] When the person is lying down, with the stomach empty, this quantity of energy use is known as basal metabolism. [43] For the average man this energy consumption amounts to 1700 Calories-per-day. [44] Everyday activities also consume energy which we call leisure calories. Leisure calories for the average man are 600 Calories-per-day. [45] As soon as physical work is performed, energy consumption rises sharply. The greater the demand made on the muscle the more energy is consumed. This type of energy consumption is related to work calories.

A study by Hettinger has shown that a healthy occupation should involve a daily energy consumption of 3000 to 3500 Calories-per-day for a man. [46] A graphical scale comparing level of work to energy consumption per 24 hours is shown in Figure 35. In other studies, the daily energy consumption has been shown to vary from 4,800 Calories (Lehmann) to 4,000 Calories (Edholm).[47] With the different values of energy consumption presented, the suggested value corresponding to a level at which work is maintained as an aerobic activity is about 5 Calories-per-minute. [48] In an 8-hour work day the suggested maximum of work calories would be 2,400 Calories, giving an overall total of 4,700 Calories for energy consumption. A 4,700 Calorie overall energy consumption in 24 hours corresponds to a severe level of work according to Hettinger and consequently should be considered a maximum guideline.

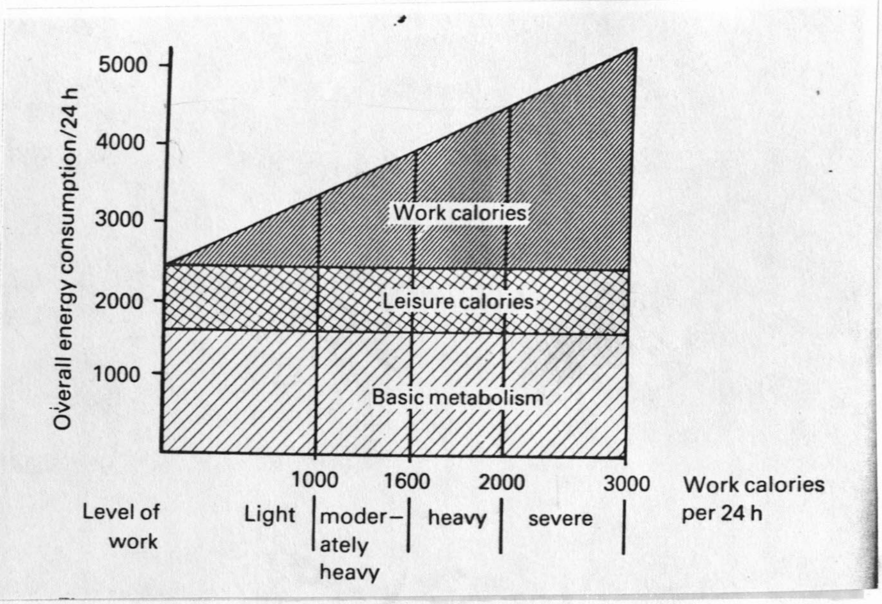


Figure 35. Work to Energy Consumption (Hettinger).

The most accurate method for measuring energy consumption is to measure oxygen consumption. The measurement of oxygen consumption can be done on an individual at work, but it is rather cumbersome as shown in Figure 36. Monitoring heart rate can also produce data that can be related to oxygen consumption, but this approach requires "calibration" of each individual. [49] The use of oxygen consumption equipment and the ability to calibrate heart rate to oxygen consumption requires trained personnel and a laboratory environment, both of which are out of the realm of this project.

To find the energy consumption for the mixer attendant, the work actually performed was compared to conditions

Figure 36. Measurement of Oxygen Consumption.

of work with known Calorie-per-minute values. Table 1 and Figure 37 were used to relate mixer tasks to examples of energy costs for various types of human activity. The task of scooping of minor ingredients was related to digging (garden spade in clay soil) from Table 1, with an energy cost of 7.5 to 8.7 Calorie-per-minute. For lifting the 50 pound bags and boxes the task was related to shoveling coal in Figure 37 at an energy cost of 10.2 Calorie-per-minute. For carrying the material the task was related to walking (load on back) from Table 1 at an energy cost of 5.3 Calorie-per-minute. With 70 batches of minor ingredients in 7 hours the mixer attendant is working in 6-minute cycles. A time study on the mixer attendant shows him scooping for 1 minute and 30 seconds, lifting bags and boxes for 40 seconds, carrying loads for 20 seconds, and resting for 3 minutes and 30 seconds. With the time for each event and energy cost relationship, the average energy

Activity	Conditions of work	kcal/min
Walking, empty-handed	Level, smooth surface 4 km/h	2.1
	Metalled road, heavy shoes 4 km/h	3.1
Walking, with load on back	Level, metalled road	
	10 kg load 4 km/h	3.6
	30 kg load 4 km/h	5.3
Climbing	16% gradient climbing speed 11.5 m/min	
	without load	8.3
	20 kg load	10.5
Climbing stairs	30.5° gradient climbing speed 17.2 m/min	
	without load	13.7
	with 20 kg load	18.4
Cycling	Speed 16 km/h	5.2
Pulling hand cart	3.6 km/h, level, hard surface tractive force 11.6 kg	8.5
Working with axe	Two-handed strokes 35 strokes/min	9.5–11.5
Working with hammer	Weight of hammer 4.4 kg vertical strokes, 15 per min	7.3
Filing iron	60 strokes/min, 2.82 kcal/g of filings	2.5
Shovelling	10 shovels per min, throwing 2 m horizontally and 1 m high	7.8
Sawing wood	Two-handed saw, 60 double strokes/min	9.0
Bricklaying	Normal rate 0.0041 m^3/min	3.0
Screwdriving	Screw horizontal	0.5
	Screw vertical	0.7–1.6
Digging	Garden spade in clay soil	7.5–8.7
Mowing	Clover	8.3
Household work	Cooking	1.0–2.0
	Light cleaning; ironing	2.0–3.0
	Making beds; beating carpets; washing floors	4.0–5.0
	Heavy washing	4.0–6.0

Table 1. Work Activity to Energy Consumption. (Source: Grandjean, E. 1981).

consumption per 6-minute cycle is 3.6 Calories-per-minute. The energy consumption for work during an 8-hour shift at 3.6 Calorie-per-minute, would be 1728 Calories. Energy consumption using 1700 Calories for basal metabolism, 600 Calories for leisure and 1728 Calories for work, results in a overall total of 4028 Calories. This would be rated as heavy work by

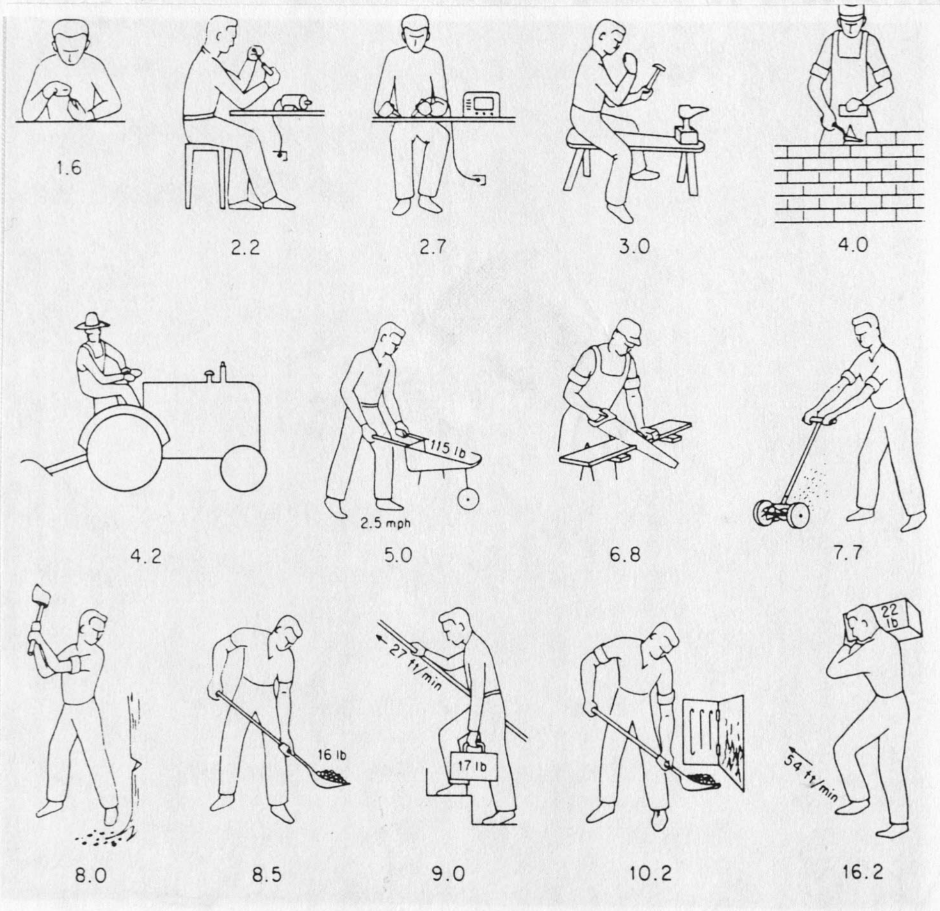


Figure 37. Work Activity to Energy Consumption. (Source: Passmore and Durnin, 1955 as adapted and presented by McCormick and Sanders, 1987).

Hettinger's measure. The 3.6 Calorie-per-minute consumption is the average energy consumption for the 6-minute cycle. The actual work of 2 minutes and 30 seconds corresponds to a 8.6 Calorie-per-minute energy consumption. The 8.6 Calorie-per-minute consumption rate is reduced to the 3.6 Calorie-per-minute value by the 3 minute and 30 second rest period. Since the energy consumption is less than 5 Calories-per-minute, the 3 minutes and 30 seconds should be sufficient time for rest. The estimated time of rest required for the mixer attendant using a 5 Calorie-per-minute standard can be found using the following formula from Murrell; [50]

$$R = T (K - S) / K - 1.5$$

R = Rest in minutes

T = Total work time (6 min.)

K = Avg. Calorie per min. of work (8.6)

S = Std. (5 Cal./min.)

1.5 = Resting level in Cal./min.

The minimum rest would be a little over 3 minutes per cycle.

CHAPTER 7

DEVELOPMENT AND TRAINING

The alteration of activities for the mixer attendant resulted in an operational change. The need for the change was the result of internal forces at Cresline. The internal forces that lead to the change are as follows;

1) Organizational Structure -- Growth or increase in required PVC compound to meet production needs.

2) Task Technology -- The modifications in the work area design resulting in a restructuring of existing tasks and a requirement for retraining.

3) People -- The mixer attendant attitude and level of motivation resulting from the debottlenecking and possible increase in work load.

With the debottlenecking of the PVC compounding operation, the change process was already affecting the mixer attendant. Cresline used a planned change format to avoid problems related to the changes. Planned change occurs when management develops and implements a program that serves to alter organization activities in a timely and orderly manner. [51]

In the change process for the mixer attendant work arrangement and job requirement, the Lewin-Schein model was used. In the change process, Lewin and Schein observed that most individuals found it difficult to alter attitudes and behaviors that have been practiced for a long time. [52] The Lewin-Schein model identifies three general steps to the change process: unfreezing, changing and refreezing. [53] The resistance to change can be countered by unfreezing the attitude of the individual through making the need for change so obvious that the individual will be willing to accept the change. [54] The mixer attendant survey was the main effort to bring the need for change to the mixer attendant. The survey let the mixer attendant list problems and suggest changes to help reduce the problems. This information exchange produced open communication and participation in the planning stages for the proposed changes.

The second step in the Lewin-Schein model is the actual changing from the prior work routine to the new modified design. Changing occurs when the mixer attendant accepts and internalizes the changes in attitude and behavior that are necessary. [55]

The third and final step is refreezing, which occurs when the changed attitude and behavior are supported and reinforced. [56] Even the use of the Lewin-Schein model to promote the change process did not totally eliminate the resistance to change by the mixer attendants. The implementation of a new idea or technique quite often results in resistance by those who will be affected most. [57] Resistance is a common occurrence and therefore it is helpful to understand the main reasons for resistance to change; [58]

1) Self-Interest -- Workers in a organization have interest in what benefits them directly. Changes that can adversely affect their interest result in resistance.

2) Uncertainty -- Workers may resist the change because they are worried and nervous about the way the change will affect their work and lives.

3) Lack of Understanding and Trust -- Failure to understand the change increases the likelihood of resistance. Bad prior experiences in change may result in a lack of trust and, in turn, increased resistance.

4) Different Perceptions -- Management and workers have differences of opinion about the need for change and what result the change will have, once implemented.

5) Lack of Tolerance for Change -- Some workers feel uncomfortable with change. Even when workers are shown that the change will not threaten

their self-interest, the outcomes are certain, a full understanding and trust is present, and perceptions are in agreement, the worker may still resist the change.

To help overcome resistance to the changes faced by the mixer attendant, several strategies were applied. The first strategy was use of education and communication in explaining the need and logic for the change. This involved explaining the compounding operation with respect to bottlenecking and effects of modifications to increase output. A great deal of time was spent explaining the human factors related to the job and how the revised workplace would help eliminate or reduce the human factor problems. The second strategy was participation and involvement of the mixer attendants through the use of surveys and group meetings. Several meetings attended by upper management and a representative for the mixer attendants were held to help keep an open channel on proposed plans and the effects of the plans on the compounding operation. Feedback from the mixer attendants was sought after changes in the compounding work area. The third strategy was support from management to help the mixer attendant adapt to the change. This involved explaining in detail and actual physical demonstrations to new procedures involved in the mixer attendants work pattern. After major changes in the work area, an individual from management would stay in the compounding area to explain the change and answer any questions. By using the three strategies, the mixer attendants felt that their participation was instrumental in the change and appreciated support with retraining after the change was implemented.

CHAPTER 8

MATERIAL HANDLING SYSTEMS

With the compounder at full capacity of 70 batches for a 7-hour production shift, the mixer attendant will be lifting 15,318 pounds. To help reduce the amount of lift, three material handling systems were considered. A description of the three systems follows;

1) Bucket Elevator -- The bucket elevator with a feed hopper would be placed in front of the mixer on the work platform. The bucket elevator would convey material from the feed hopper to a new larger capacity hopper replacing the current two small hoppers. The bucket elevator would reduce the handling of calcium carbonate by 1.5 lifts. The mixer attendant would be able to place a 50-pound bag of calcium carbonate directly over the feed hopper. After removing 12 pounds from the 50-pound bag, the remaining 38 pounds would be placed into the feed hopper. The work area for calcium carbonate would no longer require the 55-gallon drum and work bench. The system would also reduce the handling of the four other minor ingredients by the equivalent of a .5 lift. The four minor ingredients would also be placed in the bucket elevator feed hopper thereby

reducing the carry and final lift into the current two small hoppers. The cost of the bucket elevator is $1,303. This system would reduce the amount of lifting for a 7-hour period by 4,773 pounds.

2) Auger -- An auger assembly with a feed hopper could also be placed on the work platform. The auger would convey material to a new larger capacity hopper atop the mixer. Since the auger assembly requires more floor space, the auger assembly would have to be positioned farther away from the mixer than the bucket elevator. Installation of the auger would therefore reduce the handling of calcium carbonate by only one lift. The work area for the calcium carbonate would still require the 55-gallon drum and work bench. The auger, like the bucket elevator, would reduce the four other minor ingredients by the equivalent of a .5 lift. The cost of the auger assembly is $875. This system would reduce the amount of lifting for a 7 hour period by 3,443 pounds.

3) Vacuum System -- This system could have multiple feed hopper locations on the work platform. Such a system would also feed a new hopper atop the mixer. Like the bucket elevator, the vacuum system would reduce the handling of calcium carbonate by 1.5 lifts. The four other minor ingredients would have

a one lift reduction by using a second feed hopper located near the four minor ingredients. The cost of the vacuum system is $8,450. The vacuum system would reduce the amount of lifting for a 7-hour period by 5,556 pounds. A complete description of each system can be found in Appendix E.

Economic Analysis

Since the three systems do not produce comparable direct cost savings, an economic comparison using benefit/cost has been performed. The benefit would be the reduction of lift in pounds. The cost is the direct cost of each system. Cresline, uses a 3-year payback for new equipment consideration. The interest rate used is the prime rate. At the time of this project the prime rate was 11%. A economic yearly annual cost (A) is found for each system over the 3-year time period by;

$$A = P\ (A/P, I, N)$$

Where A = Annual cost, P = Present cost, I = 11%, N = 3 years. The annual cost for each system for the 3-year time period is;

Bucket Elevator = $538.20

Auger System = $358.06

Vacuum System = $3457.82

The benefit in pounds is based on a 7-hour time period with 70 batches per period and 250 weekdays and 50 weekends. The benefit for each system in pounds per year is;

Bucket Elevator = 1,431,835

Auger System = 1,032,885

Vacuum System = 1,666,770

The Benefit/Cost of each system in pounds reduction in lifting for yearly dollar cost for the 3-year time period is;

Bucket Elevator = 2,685 (lbs/$)

Auger System = 2,885 (lbs/$)

Vacuum System = 482 (lbs/$)

From the Benefit/Cost relationship alone, the auger system would be the first choice because it produces the largest reduction in lifting per dollar invested. Of course each system has several other advantages and disadvantages. The auger system has the best Benefit/Cost relationship but requires the largest amount of actual floor space. The bucket elevator would require almost half the floor space of the auger system and has a almost equal Benefit/Cost relationship of the auger system. The vacuum system due to its initial high cost has the worst Benefit/Cost relationship of the three systems. The vacuum system would require the same floor space as the bucket elevator, but could be positioned in almost any location on the mixer platform. With all factors considered, Cresline has chosen the bucket elevator system. The bucket elevator was chosen primarily on the basis of the Benefit/Cost analysis and the amount of floor space required compared to an auger system. The bucket elevator system is currently on order with expected installation in late July, 1989. With the bucket elevator installed, the mixer attendant will be lifting 10,545 pounds-per-shift. This reduces the amount of lifting for the new work arrangement design from 15,318 pounds to 10,545 pounds-per-shift; a 31% reduction.

CHAPTER 9

RESULTS AND FUTURE CONSIDERATIONS

A very significantly redesigned layout has been achieved in the compounding operation at Cresline-Henderson. Debottlenecking of the compounder equipment resulted in a 17% increase in output from 150,000 pounds to 175,000 pounds-per-day.

By using a video tape of the mixer attendant performing required work duties, several potential human factor problems were realized. Examination of work height, straight wrist, and vision angles resulted in a new work area design. The new work area design resulted in new work benches and required an additional weigh scale. This new work area design resulted in a 33% reduction in lifting requirements for the modified compounding operation from 22,695 to 15,318 pounds-per-shift. Three material handling systems were evaluated to help reduce the required lifting by the mixer attendant. Based on a benefit/cost comparison and other considerations, a bucket elevator was ordered for the compounding operation. The bucket elevator should reduce the lifting requirement by an additional 31% from 15,318 to 10,545 pounds-per-shift. The final ergonomic compounder project with the new work area design and bucket elevator results in an overall reduction in lifting of 53% from 22,695 to 10,545 pounds-per-shift. The mixer attendants performing required work duties in the new work area design have also been recorded on video tape. When the bucket elevator is installed its operation with respect to the mixer attendants will also be added to the video tape.

The new work area design has not only resulted in a significant reduction in lifting requirements but has improved overall working conditions and the attitude of the mixer attendants. The new work area design was a positive step in enhancing employee-management relationships.

The total cost breakdown of the ergonomic compounder project is;

1) New Work Benches -- Material cost to build new benches for scales and the work benches that overlap the 55-gallon drums. -- $70.00

2) New Scale (Detecto) -- $715.00

3) Bucket Elevator -- $1,303.00

Total $2,088.00

The total cost of $2,088 should result in a 53% reduction in the amount of lifting required by the mixer attendant from 22,695 to 10,545 pounds-per-shift. The Benefit/Cost for the ergonomic-compounder project in pounds reduction in lifting for yearly dollar cost for the 3-year time period is;

Ergonomic-Compounder (B/C) = 4,266 (lbs/$)

Considering human factors during the debottlenecking of the compounding operation allowed for expansion of output without increasing the number of mixer attendants. Evaluation of human factors in the revised work area actually decreased the physical burden on the mixer attendant.

As the effectiveness of the new design layouts are studied, consideration concerning the compounding operation layout with respect to human factors at the three other manufacturing sites arise. Also the bucket elevator, auger and vacuum system open areas of potential new designs in minor ingredient handling.

APPENDIX A

MIXER ATTENDANT SURVEY

MIXER ATTENDANT SURVEY

SHIFT 1st

AGE 33

HEIGHT 5'9

HOW LONG AT THIS POSITION? 2 YEARS

WHAT ARE YOUR MAJOR COMPLAINTS RELATED TO JOB TASK?

1. DUST
2. LIFTING MINOR ING.
3. FILLING HOPPERS OF BLEND'S
4. MINOR ING. FALLING OFF SKID
5. BATCH TOTALS
6. MATERIAL LINE IN FROM SILO'S - HAVE TO CLIMB ON STOOL
7. DUMPSTER TOO SMALL
8. DATA ON PROTECTION OF DUST

WHAT DO YOU FEEL CAN BE DONE TO RELIEVE THE ABOVE COMPLAINTS?

1. VENTING THE DUST
2. AUGER OR MOVING OF MINOR ING. FOR LESS LIFTIN
3. BUILD SILO'S TO HOLD ALL BLEND'S
4. NEW SKID WITH LIFT OFF SIDE RAIL'S
5. LIMIT'S ON OVERWORKING OF BODY
6. AUTOMATIC DIVERTER VALVE
7. LARGER SIZE TO HOLD TRASH
8. WHAT WE NEED TO PROTECT OUR SELVES

HAVE YOU EVER BEEN GIVEN LIFTING TECHNIQUE TRAINING?

NO

MIXER ATTENDANT SURVEY

SHIFT 2nd

AGE 43

HEIGHT 5' 6"

HOW LONG AT THIS POSITION? 3YRS

WHAT ARE YOUR MAJOR COMPLAINTS RELATED TO JOB TASK?

1. DUST

[redacted]

2. THE LIFTING INVOLVED.

WHAT DO YOU FEEL CAN BE DONE TO RELIEVE THE ABOVE COMPLAINTS?

1. A GOOD VENALATION SYSTEM.

2.

HAVE YOU EVER BEEN GIVEN LIFTING TECHNIQUE TRAINING?

NO

MIXER ATTENDANT SURVEY

SHIFT 3rd

AGE 22

HEIGHT 5'11"

HOW LONG AT THIS POSITION? 8 mounths

WHAT ARE YOUR MAJOR COMPLAINTS RELATED TO JOB TASK?

1. Dust FROM Minor ingredent.
2. Blowing Dust off MASHAIN
3. FANS Blowing in FACE.
4 TEMPATURE in the SUMMERTIME 100°+
5. SCUPING MATERIAL 4000+LBS A SHIFT
6. Dumpster to SMALL.
7. LACK OF NALLAGE OF MINOR ENG.
8. Not Enough Fresh Air.
9.

WHAT DO YOU FEEL CAN BE DONE TO RELIEVE THE ABOVE COMPLAINTS?

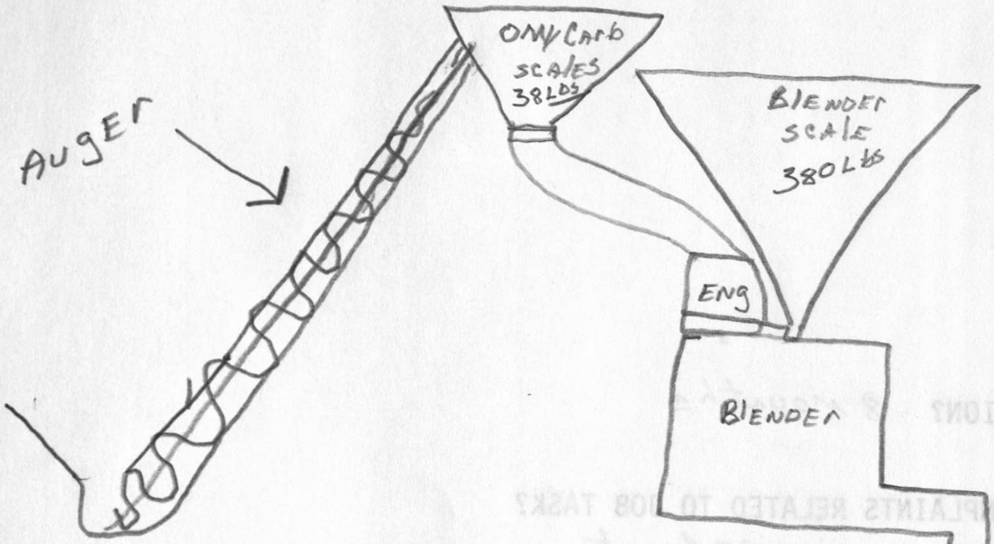
1. INTAKE of fresh Air + Exhast of dust
2. " + UACUM "
3. " "
4. " "
5. SEE ON BACK.
6. A Larger Dumpter
7. DATA SHEET ON All minor Eng.
8 INTAKE of fresh Air

HAVE YOU EVER BEEN GIVEN LIFTING TECHNIQUE TRAINING?

NO

89

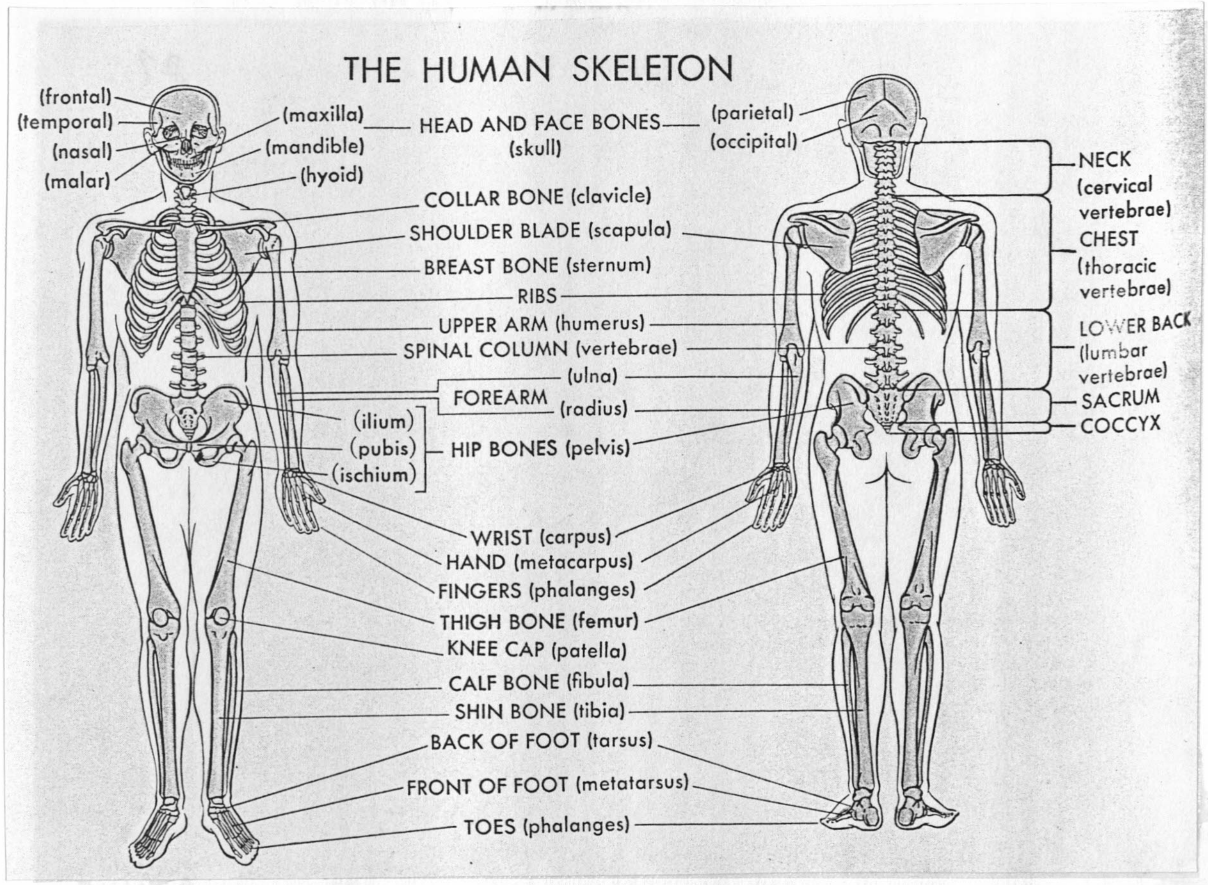
#5


ONLY Carb
scales
38LBS
Blender
scale
380LBS
Auger
ENG
Blender

39.46

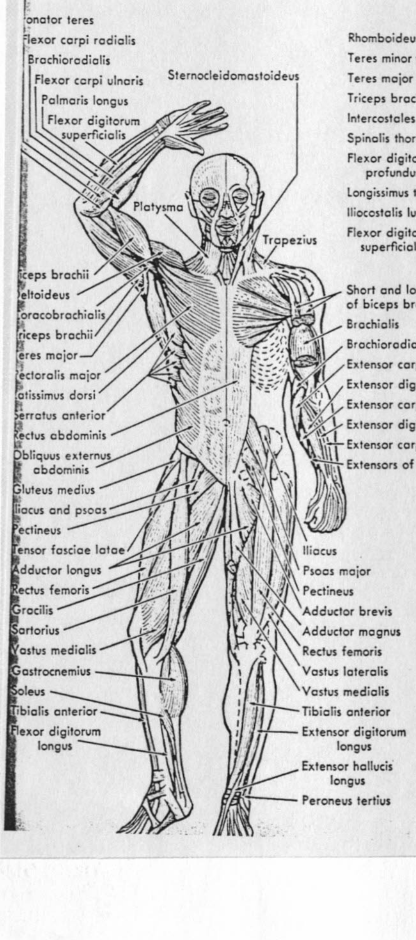
APPENDIX B

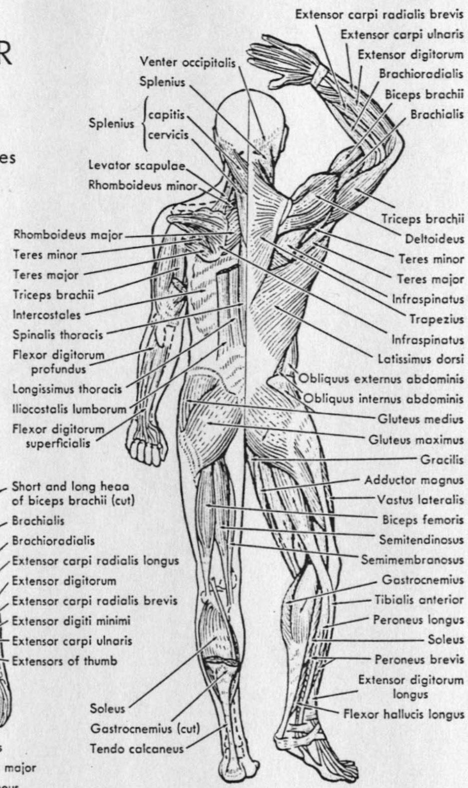
ANATOMICAL DIAGRAMS


THE HUMAN SKELETON
(frontal)
(temporal)
(nasal)
(malar)
(maxilla)
(mandible)
(hyoid)
HEAD AND FACE BONES
(skull)
(parietal)
(occipital)
NECK
(cervical
vertebrae)
CHEST
(thoracic
vertebrae)
LOWER BACK
(lumbar
vertebrae)
SACRUM
COCCYX
COLLAR BONE (clavicle)
SHOULDER BLADE (scapula)
BREAST BONE (sternum)
RIBS
UPPER ARM (humerus)
SPINAL COLUMN (vertebrae)
(ulna)
FOREARM
(radius)
(ilium)
(pubis)
(ischium)
HIP BONES (pelvis)
WRIST (carpus)
HAND (metacarpus)
FINGERS (phalanges)
THIGH BONE (femur)
KNEE CAP (patella)
CALF BONE (fibula)
SHIN BONE (tibia)
BACK OF FOOT (tarsus)
FRONT OF FOOT (metatarsus)
TOES (phalanges)

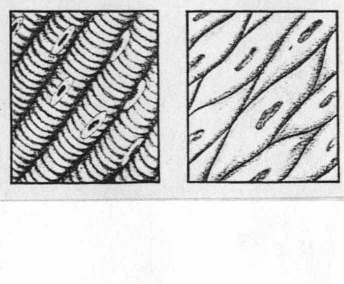
THE MUSCULAR SYSTEM

The External Skeletal Muscles





TYPES OF MUSCLES



APPENDIX C

ANTHROPOMETRIC DATA

Table VIA–3: Anthropometric Data, Inches (Adapted from P. C. Champney, 1979, and B. Muller-Borer, 1981, Eastman Kodak Company; NASA, 1978.)*

The data here are the same as the data in Table VIA–2, but they are expressed in inches rather than centimeters.

Measurement	Males		Females		Population Percentiles, 50/50 Males/Females		
	50th percentile	±1S.D.	50th percentile	±1S.D.	5th	50th	95th
STANDING							
1. Forward Functional Reach							
a. includes body depth at shoulder	32.5 (31.2)	1.9 (2.2)	29.2 (28.1)	1.5 (1.7)	27.2 (25.7)	30.7 (29.5)	35.0 (34.1)
b. Acromial Process to Functional Pinch	26.9	1.7	24.6	1.3	22.6	25.6	29.3
c. Abdominal Extension to Functional Pinch†	(24.4)	(3.5)	(23.8)	(2.6)	(19.1)	(24.1)	(29.3)
2. Abdominal Extension Depth	9.1	0.8	8.2	0.8	7.1	8.7	10.2
3. Waist Height	41.9 (41.3)	2.1 (2.1)	40.0 (38.8)	2.0 (2.2)	37.4 (35.8)	40.9 (39.9)	44.7 (44.5)
4. Tibial Height	17.9	1.1	16.5	0.9	15.3	17.2	19.4
5. Knuckle Height	29.7	1.6	28.0	1.6	25.9	28.8	31.9
6. Elbow Height	43.5 (45.1)	1.8 (2.5)	40.4 (42.2)	1.4 (2.7)	38.0 (38.5)	42.0 (43.6)	45.8 (48.6)
7. Shoulder Height	56.6 (57.6)	2.4 (3.1)	51.9 (56.3)	2.7 (2.6)	48.4 (49.8)	54.4 (55.3)	59.7 (61.6)

* These values should be adjusted for clothing and posture.
† Add the following for bending forward from hips or waist: Male: waist, 10 ± 3; hips, 16 ± 3. Female: waist, 8 ± 2; hips, 14 ± 4.

Table VIA–3: (Continued)

Measurement	Males 50th percentile	Males ±1S.D.	Females 50th percentile	Females ±1S.D.	Population Percentiles, 50/50 Males/Females 5th	50th	95th
8. Eye Height	64.7	2.4	59.6	2.2	56.8	62.1	67.8
9. Stature	68.7	2.6	63.8	2.4	60.8	66.2	72.0
	(69.9)	(2.6)	(64.8)	(2.8)	(61.1)	(67.1)	(74.3)
10. Functional Overhead Reach	82.5	3.3	78.4	3.4	74.0	80.5	86.9
SEATED							
11. Thigh Clearance Height	5.8	0.6	4.9	0.5	4.3	5.3	6.5
12. Elbow Rest Height	9.5	1.3	9.1	1.2	7.3	9.3	11.4
13. Midshoulder Height	24.5	1.2	22.8	1.0	21.4	23.6	26.1
14. Eye Height	31.0	1.4	29.0	1.2	27.4	29.9	32.8
15. Sitting Height, Normal	34.1	1.5	32.2	1.6	32.0	34.6	37.4
16. Functional Overhead Reach	50.6	3.3	47.2	2.6	43.6	48.7	54.8
17. Knee Height	21.3	1.1	20.1	1.0	18.7	20.7	22.7
18. Popliteal Height	17.2	1.0	16.2	0.7	15.1	16.6	18.4
19. Leg Length	41.4	1.9	39.6	1.7	37.3	40.5	43.9
20. Upper-Leg Length	23.4	1.1	22.6	1.0	21.1	23.0	24.9
21. Buttocks-to-Popliteal Length	19.2	1.0	18.9	1.2	17.2	19.1	20.9
22. Elbow-to-Fist Length	14.2	0.9	12.7	1.1	12.6	14.5	16.2
	(14.6)	(1.2)	(13.0)	(1.2)	(11.4)	(13.8)	(16.2)

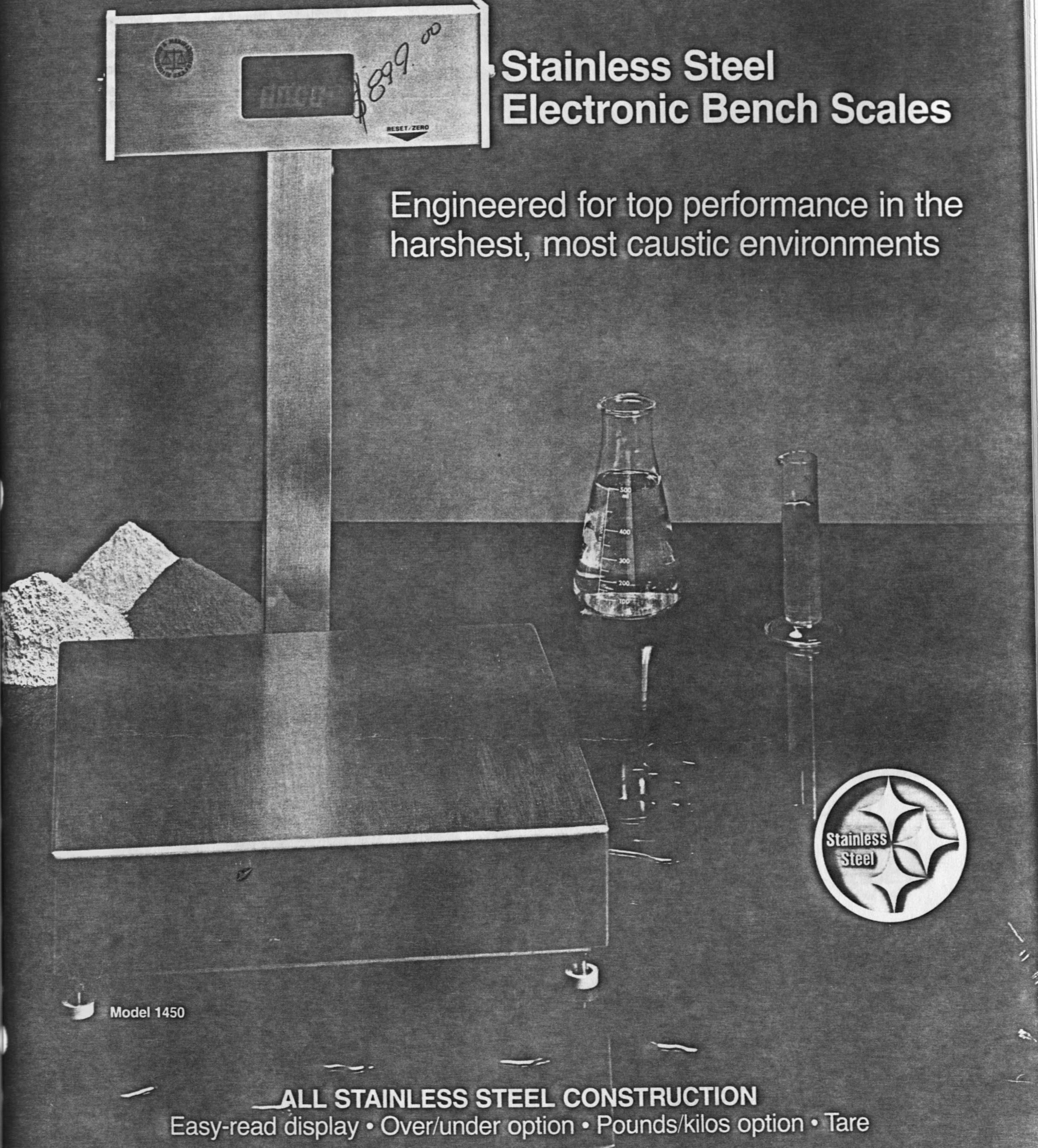
APPENDIX D

DETECTO #1450 SCALE DATA

DETECTO®

Stainless Steel Electronic Bench Scales

Engineered for top performance in the harshest, most caustic environments



ALL STAINLESS STEEL CONSTRUCTION

Easy-read display • Over/under option • Pounds/kilos option • Tare

Stainless steel bench scales. . .now with improved features to answer your needs

The most up-to-date improvements are now yours in these stainless steel bench scales built to function accurately in any environment - wet, dry or caustic. Notably, new "H" beam frame and bridge design with lift-off platform simplifies clean-up by providing unencumbered access underneath the scale (see view at right).

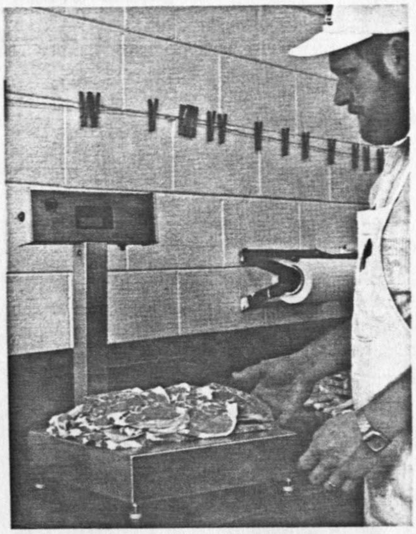
In addition, zero reset button is positioned and sealed on the underside of the scale head to prevent liquids and other materials from seeping into the unit. Load cell and instrument power cables are contained within the stainless steel support column to prevent accidental damage.

Built to endure abusive treatment, jostling and frequent washdowns, these scales feature easily readable weight displays for materials placed anywhere on their platforms. Available in capacities from 2 to 200 pounds, and with platform sizes from 10" x 10" to 18" x 18", this wide selection of models allows you to customize to your operation.

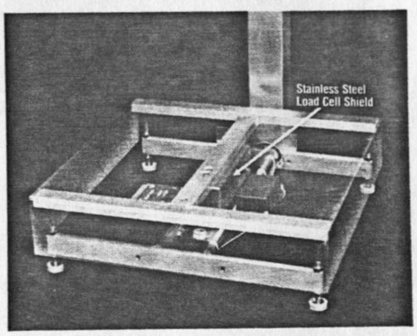
A popular option available on all models is an over and under checkweigher function with pounds/kilos conversion switch. Featuring instantaneous readout of load status via tri-colored over/under/accept annunciators, this option enables rapid, accurate checkweighing. Also available are three-digit calibrated tare and a stainless steel stand with casters and tower mount.

Whatever your need, we have a stainless steel bench scale that's right for the job. Built in the USA, these scales are backed by many years of manufacturing experience. Engineered for performance and accuracy, they will simplify your weighing tasks, reduce your maintenance time and, ultimately, increase your profits.

In chemical labs or in food processing areas, if fast, accurate checkweighing is the need, over/under models are the answer. Target zones are user-selectable from ±1 to ±15 scale divisions; weight is displayed in pounds or kilograms at the flip of a switch.



Rugged stainless steel scales are right at home in food packing areas or anywhere frequent washdowns are routine. Digital LED's mean accurate readings from any angle.



Simple lines of "H"-shape weighbridge facilitate clean-up operations; stainless steel platform lifts off for easy access to scale's understructure, including the rugged, heavy-duty load cell.

Specifications

Controls: Zero reset to set scale to zero.

Display: 4-digit, red, .56" high LED.

Temperature range: +30°F - +110°F

Accuracy: Designed to meet or exceed NBS Handbook #44.

Power: 12 Volt DC, 300 milli amp scale operating power. Scale supplied with power converter and 6' of cord for connection to customer's 115 VAC, 50/60 Hz supply. Optional 220 VAC, 50/60 Hz models available.

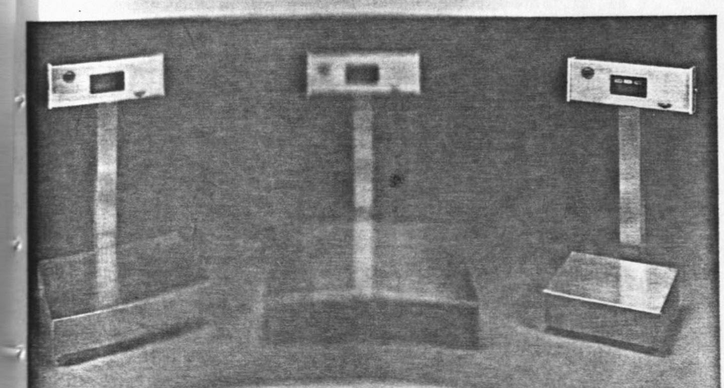
Options:
- Over and under function. Option includes switch-selectable target zone adjustments (internally located, adjustable from ± 1 graduation to ± 15 graduations by 1 graduation intervals). Tri-colored LED over/under/accept annunciators and pounds/kilos display selector switch.
- Three digit calibrated tare.
- Gimbal display mount with 10' load cell cable (Series 10 and 14).
- Tower mount (Series EF).
- Adjustable stainless steel stand with casters (Series EF).

Dimensions: Series 10 and 14 — 2, 5, 10 and 20-lb models: 22"H x 10"W x 14"D
40, 50 and 100-lb models: 22"H x 14"W x 18"D
Series EF (base only) — 4⅛"H x 18"W x 18"D

Model	Capacity	Platform Size
102	2 lb x .001 lb	10" x 10"
105	5 lb x .002 lb	10" x 10"
1010	10 lb x .005 lb	10" x 10"
1020	20 lb x .01 lb	10" x 10"
1440	40 lb x .01 lb	14" x 14"
1450	50 lb x .02 lb	14" x 14"
14100	100 lb x .05 lb	14" x 14"
EF-100-S6	100 lb x .05 lb	18" x 18"
EF-218-S6	200 lb x .1 lb	18" x 18"

899.00
1099.00

EVANSVILLE SCALE COMPANY
600 North Burkhardt Road
EVANSVILLE, INDIANA 47715
(812) 476-2312



From small checkweighing tasks to large-size weighing operations, there is a stainless steel bench scale built to handle the function accurately and dependably. Many pounds/kilos conversion models available.

2-7-89

w/ Mount & 5' cable no extra charge

DESIGNED & MANUFACTURED IN U.S.A.

Ed Roos

Our stainless steel bench scales are designed to meet with all requirements of UL, USDA and NBS Handbook #44.

Sold by: EVANSVILLE SCALE COMPANY
600 N. Burkhardt Rd.
Evansville, IN 47715
812-476-2312

DETECTO SCALE COMPANY®

DETECTO SCALE COMPANY
P.O. Box 191, [illegible] City, Missouri [illegible] USA
Ph. (417) 673-[illegible]

 Printed in USA D-133/287/10M/JP

APPENDIX E

MATERIAL HANDLING SYSTEMS

Specialists in:
Custom Metal Fabrication
Materials Handling Equipment
Installation & Erection
Installation Erection

se
STAHL EQUIPMENT INC.

718 W. Lincoln Ave.
Chandler, IN 47610
Ph. 812-925-3341

PROPOSAL SUBMITTED TO	PHONE	DATE
Cresline Plastics Company		January 26, 1989
STREET	JOB NAME	
Box 41		
CITY, STATE AND ZIP CODE	JOB LOCATION	
Henderson, KY 42420		
ARCHITECT	DATE OF PLANS	JOB PHONE
Paul Ludwig		

Stahl Equipment proposes to furnsih the following:

1 175GH Bucket Elevator with 6' discharge HT. which includes inlet hopper, (your choice) 1 H.P. TEFC 3-PH Motor. $1,178.00 2-15-89 w/ Hopper $1303

~~1 4" Auger with standard inlet hopper 1½ H.P. 3-PH TEFC Motor, Belt Drive $615.00~~

1 4" Auger with agitator hopper, same as above. $875.00

Capacity = 100# plus per minute

Includes Delivery

The terms and conditions on the reverse of this sheet constitute a part of this proposal and agreement.

Prices are F.O.B.

Price to be increased or decreased to extent of increase or decrease in freight rates at date of shipment with rate at date of quotation.

Terms 2% 10 Days/Net 30

Shipment Our Delivery

STAHL EQUIPMENT, INC.

By

NorbertStahl Norbert Stahl

The above Proposal is accepted:

By ____________ Buyer.

DATE ____________

Order Accepted

STAHL EQUIPMENT, INC.

By ____________ Seller.

DATE ____________

OVER

TERMS AND CONDITIONS

The Seller may at its option suspend work and deliveries under this contract except for cash, if in its opinion the credit of the Purchaser becomes doubtful or impaired, until the Seller has received full settlement or satisfactory security for shipments made and services rendered and is satisfied as to Purchaser's credit for further shipment. If Purchaser fails or refuses to make payment as provided, or to furnish such satisfactory security, the Seller shall have the right to enforce payment of the full contract value of the material and labor already furnished or in process, and may either cancel the unfinished portion of the contract, or may proceed with the contract, in which latter case the Seller shall be entitled to such an extension of time for the performance thereof, as is necessitated by the suspension. Seller's omission promptly to exercise its foregoing rights on account of failure of buyer to make payment or furnish security shall not be any waiver of Seller's rights to do so on the continuance or recurrence of any such default.

The Seller will not be responsible for delays arising from causes beyond its reasonable control and shall be responsible only for reasonable diligence in making shipments. Acceptance of materials on delivery shall constitute a waiver of any claims for damages on account of delays.

No claims for compensation for errors or defects in material or workmanship will be allowed unless Seller is given immediate notice and opportunity to investigate, inspect and correct the alleged errors and defects, and if such are found and are not corrected by Seller, the compensation allowed to Purchaser shall be only the reasonable cost of replacing the defective or correcting the error in the materials involved and Seller will under no circumstances pay or be liable for any claims resulting from use of improper, defective or damaged material. Purchaser shall carefully check material immediately upon arrival at destination, as no claims for shortage will be entertained unless filed with the Seller in writing within five days thereafter, and noted on the original freight bill by the local agent of the carrier.

No back charges for labor, or any other deductions, from the stated amount of this agreement, will be allowed by Seller unless specifically authorized in writing.

Until paid for, or incorporated in structure, the title to and ownership and right of possession of the material covered by this contract shall remain in the Seller, and in case the Purchaser shall become insolvent, or refuse or neglect to pay for material herein provided, the Seller may at its option, without process of law, retake possession of any or all material wherever the same may be found, except as provided above, and credit the amount of the Purchaser with the value thereof to the Seller, less the necessary cost and freight charges in retaking the same.

No one has authority to depart from the terms and conditions of sale as set forth on the face and the back hereof, nor to make any representations or arrangements other than those printed hereon whether in the execution or in the performance or pursuance of the contract, unless the same are written on this quotation or are given in writing with it or in pursuance of it, and are fully approved in writing by the Seller's Home Office.

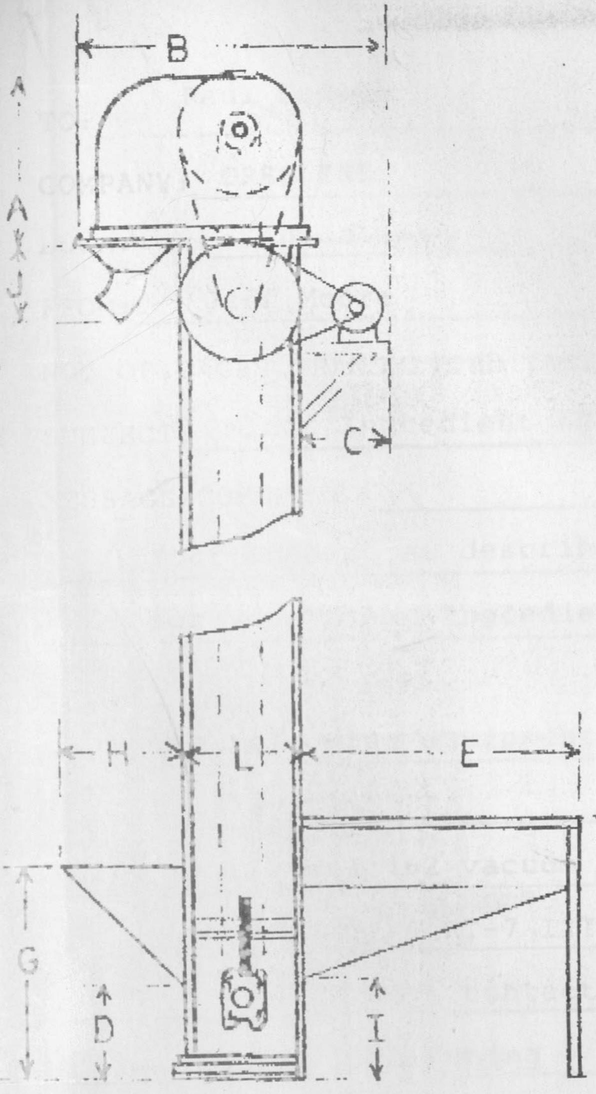
All materials in this contract are furnished in accordance with the conditions of the code of Standard Practice.

It is agreed, that in the event the Seller is required by law to pay any tax on the sale covered by this contract or any part of it, the amount of such tax will be added to the otherwise contracted price.

In the event it becomes necessary to file suit covering materials or labor furnished on this contract, Purchaser agrees to pay all necessary court costs and Seller's attorney's fees of 10% of the amount sued for.

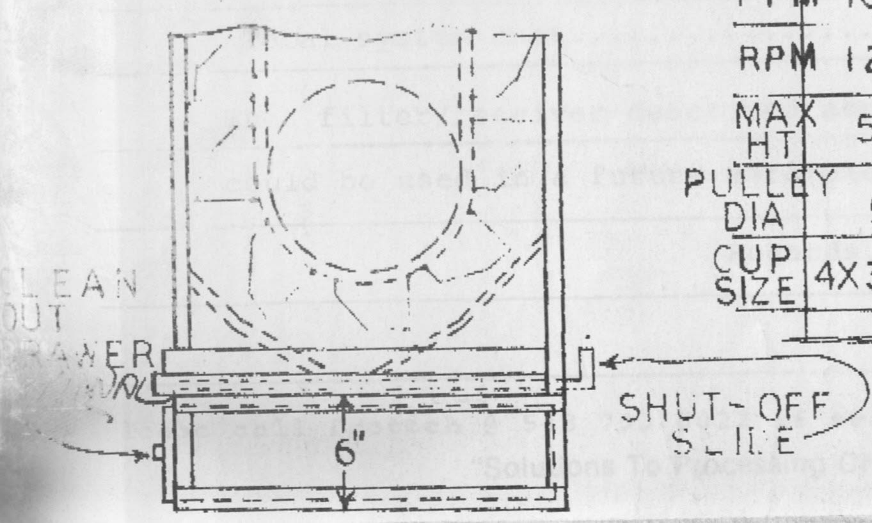
GENTLE HANDLING ELEV.

JACK SHAFT DRIVE



	110 / 150 / 175	195 / 290 / 390 / 470	450 / 580 / 900	550 / 835 / 1100
A	18	23	27	27
B	27	43	50	50
C	12	12	12	12
D	$5\frac{3}{4}$	9	9	9
E	24	24	24	24
F	24	24	24	24
G	18	21	21	21
H	12	12	12	12
I	$8\frac{1}{2}$	12	14	14
J	6	8	10	12
L	14	21	25	25
WIDTH	6	9	11	13
FPM	160	160	200	200
RPM	122	76	76	76
MAX HT	50	70	80	80
PULLEY DIA	5	8	10	10
CUP SIZE	4X3	6X4	7X5	9X5

V-SHAPED BOTTOM



PROTECH EQUIPMENT COMPANY

10979 Reed Hartman Highway Cincinnati, Ohio 45242 (513) 793-8022
FAX # 513/793-8025

TELEFAX TRANSMITTAL FORM

TO: Paul Ludwig DATE: 1-10-89

COMPANY: CRESLINE FAX #: 502-826-8319

LOCATION: Henderson

FROM: Jeff Moore DEPARTMENT:

NO. OF PAGES TRANSMITTED INCLUDING THIS FORM: 1

SUBJECT: Minor Ingredient Addition System

MESSAGE/COMMENTS:

Your concept as described in your January 3 fax looks good for your minor ingredients addition application.

The following equipment would be required to accomplish this system:

Mac Model 462 vacuum blower package (5 Hp) (Sutorbilt)

Mac Model 54 RT-7 III pulse-jet filter/receiver with type 304 SS dust contact construction

Convey line tubing - 2 1/2" O.D. aluminum

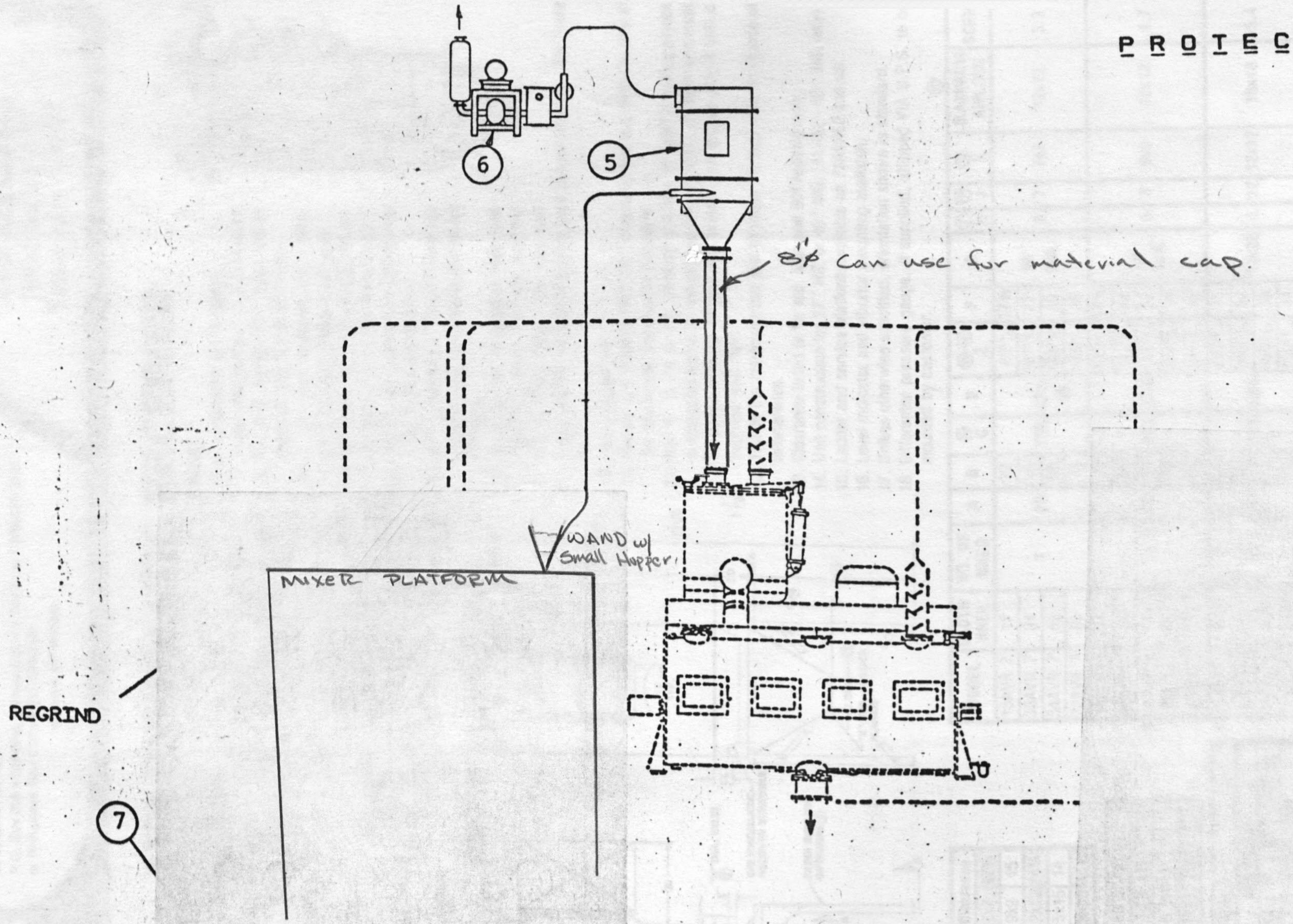
Material pickup wand with 2" hose

Total system cost..............................$ 8,450.00

The filter/receiver described above and vacuum blower package could be used in a future automated system.

Regards, Jeff Moore

PROTECH

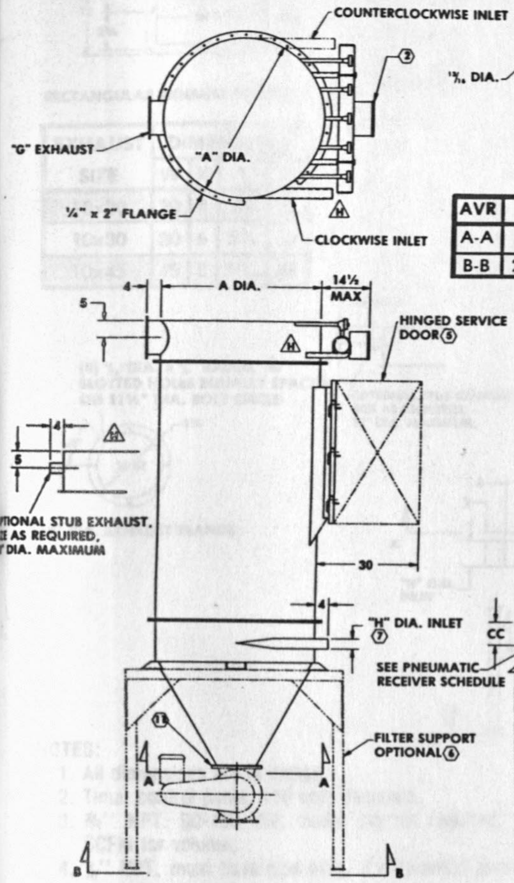

6
5
8" ⌀ can use for material cap.
WAND w/ Small Hopper
MIXER PLATFORM
REGRIND
7

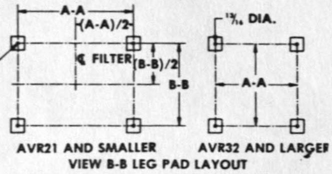
M

MAC
P.O. Box 205 • Sabetha, Kansas 66534 • Toll Free 1-800-223-2191
or in Kansas Call Collect 913-284-2191
Telex II No. 910-749-6500

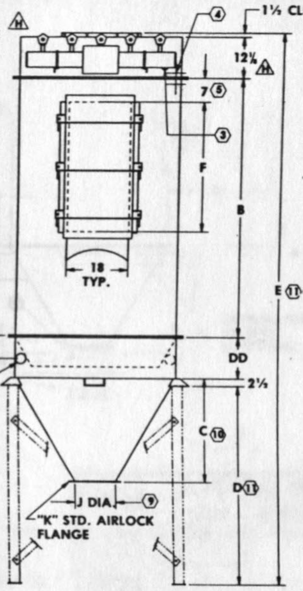
DATA SHEET
AVR RECEIVER
Effective 12-1-87
Supersedes 3-30-87

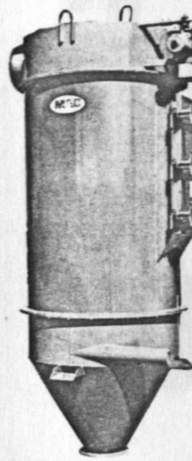
AVR PNEUMATIC RECEIVER





AVR	7	14	21	32	39	52
A-A	49	53	63 7/8	46 7/16	50 11/16	54 7/16
B-B	29 3/8	41 5/8	47 7/8	—	—	—





○ NOTES:

1. All dimensions are in inches.
2. Timer control panel, 110 volts required.
3. 3/4'' NPT. 90-100 PSI, clean, dry air required. See SCFM for volume.
4. 1/8'' NPT must have pipe plug if differential pressure gauge is not used.
5. Filters with 18'' bags have bolted service doors. This dimension will be 2''.
6. AVR32 and larger have bolted legs rather than support frame.
7. ''H'' is maximum. Larger inlets can be used, but can velocity should be checked.
8. Stack-up ''E'' is based on max. inlet size ''H''. When ''H'' dia. inlet line size is 2 1/2'', 3 1/2'', etc. use next larger size for sidewall and inner cone dimensions (I.E., 2 1/2''-use 3'').
9. May vary per unit.
10. Hopper is a constant 60°. ''C'' dimension will vary with the size of the discharge. See Hopper Schedule.
11. Add 4'' to the overall stack-up and legs on AVR7 if mating airlock is equipped with R/A reducer and XPL/PF motor. 4'' extension must be bolted between hopper and airlock. This applies only if unit is supplied with legs.
12. This is the maximum that will fit under the legs with no chance of interference.
13. Clearance listed is for std. legs and 60° hoppers only.
14. Unit construction for 17'' HG. or 40'' WG. (AVR52 - 40'' WG. only).
15. Ladder and service platform available on 72AVR52 and up.
16. Level indicator and vibrator mounting available.
17. Unless otherwise specified, orientation shown is standard.
18. Differential pressure gauge, if supplied, shipped VIA U.P.S. to be mounted by customer.

⑬ Min. Airlock Clearance

8x6	14 5/8	7x7	17 1/4
10x8	14 3/8	9x9	15
12x10	12 5/8	12x12	14 1/4
16x12	10	15x15	14
20x15	8 3/8	18x18	11 7/8

⑧ PNEUMATIC RECEIVER SCHEDULE

''H'' DIA.	1 1/2	2	3	4	5	6	8	10
CC	4	5	7	9	10	12	16	19
DD	5	7	9	12	13	16	21	24

⑩ HOPPER SCHEDULE

AIRLOCK FLANGE	''J'' DIA. Discharge	AVR FILTER 7	14	21	32	39	52
		''C'' DIMENSION					
8x6	6	19 1/4	29 5/8	—	—	—	—
7x7	7	18 3/8	28 3/4	34 7/8	—	—	—
10x8, 9x9	8	17 1/2	27 7/8	34	45 1/4	—	—
12x10	10	15 3/4	26 1/8	32 1/4	43 1/2	48 5/8	53 7/8
16x12, 12x12	12	—	—	30 1/2	41 3/4	47	52 1/8
15x15	14	—	—	28 3/4	40	45 1/4	50 3/8
20x15	15	—	—	27 7/8	39 1/8	44 3/8	49 1/2
18x18	18	—	—	25 1/4	36 1/2	41 3/4	47

MODEL	CLOTH AREA	NO. OF BAGS	A	B	⑩ C	D	⑪ ⑧ E	F	G	⑦ H	⑨ J	⑨ K	⑫ MAXIMUM AIRLOCK	SCFM
18AVR 7	17	7	28	22	18 3/8	42 1/2 ⑪	89 11/16	17 1/2	10'' DIA.	3	7	7x7	12x12	3.3
36AVR 7	34			40			107 11/16	22						
54AVR 7	52			58			125 11/16	30						
72AVR 7	69			76			143 11/16	38						
18AVR14	34	14	40	22	27 7/8	52 3/4	103 15/16	17 1/2	10'' DIA.	5	8	9x9	12x12	4.7
36AVR14	69			40			121 15/16	22						
54AVR14	104			58			139 15/16	30						
72AVR14	139			76			157 15/16	38						
96AVR14	185			100			181 15/16	48						
36AVR21	104	21	47	40	30 1/2	58 3/4	130 15/16	22	10x20	6	12	12x12	18x18	5.4
54AVR21	156			58			148 15/16	30						
72AVR21	209			76			166 15/16	38						
96AVR21	278			100			190 15/16	48						
54AVR32	239	32	60	58	41 3/4	70	160 3/16	30	10x20	6	12	12x12	12x12	6.5
72AVR32	318			76			178 3/16	38						
96AVR32	425			100			202 3/16	48						
54AVR39	291	39	66	58	47	75 1/4	170 7/16	30	10x30	8	12	12x12	12x12	7.5
72AVR39	388			76			188 7/16	38						
96AVR39	518			100			212 7/16	48						
72AVR52	518	52	72	76	50 3/8	80 3/8	193 1/2	38	10x30	8	14	15x15	15x15	9.1
96AVR52	690			100			217 1/2	48						

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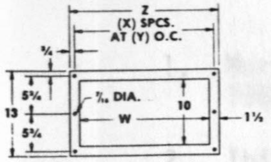
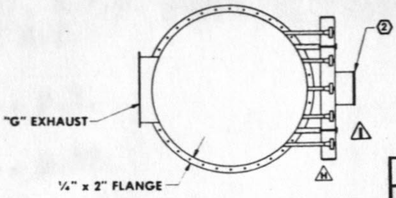
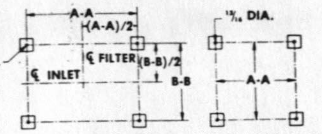
AVR FILTER



RECTANGULAR EXHAUST FLANGE DETAIL

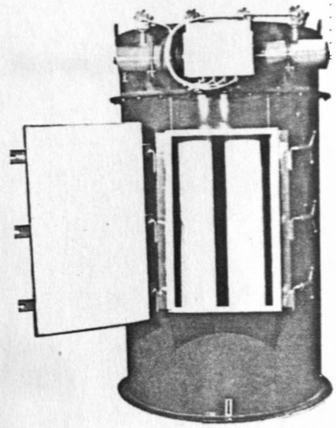
EXHAUST	DIMENSIONS			
SIZE	W	X	Y	Z
10x20	20	4	5 3/8	23
10x30	30	6	5 1/4	33
10x45	45	8	5 13/16	48

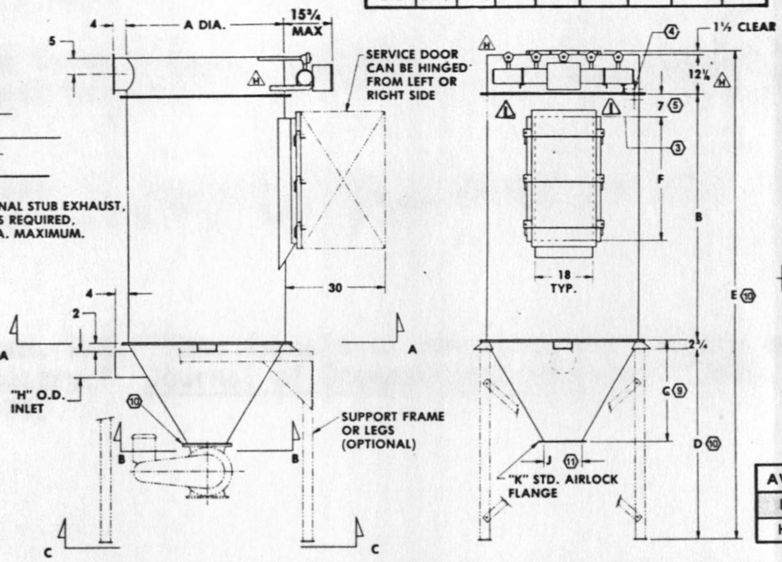


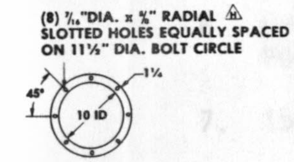


VIEW C-C LEG PAD LAYOUT

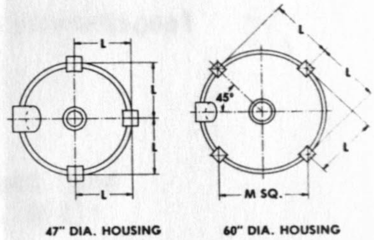
AVR	7	14	21	32	39	52	62	80
A-A	49	53	63 7/8	46 7/16	50 11/16	54 7/16	62 15/16	69 5/16
B-B	29 3/8	41 3/8	47 7/8	---	---	---	---	---







10" DIA. EXHAUST FLANGE



VIEW B-B MOUNT PAD LAYOUT

AVR	7	14	21	32	39	52	62	80
L	15 7/8	22	25 1/2	32 1/16	35 1/8	38 1/8	44 1/8	48 3/8
H	---	---	---	45 3/8	49 3/8	53 7/8	62 7/16	68 3/4

NOTES:

1. All dimensions are in inches.
2. Timer control panel, 110 volts required.
3. 3/4'' NPT. 90-100 PSI, clean, dry air required. See SCFM for volume.
4. 1/8'' NPT, must have pipe plug, if differential pressure gauge is not used.
5. Filters with 18'' bags have bolted service doors. This dimension will be 2''.
6. Ladder and service platform available on 72AVR62 and up.
7. Unit construction stressed for 17'' Hg., or 40'' Wg.
8. AVR52 thru AVR80 are not available stressed for 17'' Hg.
9. Hopper is a constant 60°. ''C'' will vary with the size of the discharge.
10. Add 4'' to the overall stack up and legs on AVR 7, if mating airlock is equipped with R/A reducer and X-PL proof motor. 4'' extension must be bolted between hopper and airlock.
11. May vary per job.
12. This is maximum airlock that will fit under assembly with standard leg frame.
13. Differential pressure gauge, if supplied, shipped via UPS to be mounted by customer.

8x6	14 3/4	7x7	17 3/8
10x8	14 1/2	9x9	15 1/8
12x10	12 3/4	12x12	14 3/8
16x12	10 1/8	15x15	14 1/8
20x15	8 1/2	18x18	12

MINIMUM CLEARANCE UNDER AIRLOCK
Using Standard Legs Only

For more information see Print #D00086.
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MODEL	CLOTH AREA	NO. OF BAGS	A	B	(9) C	D	(H) E (10)	F	G	(11) H	(11) J	K	MAXIMUM AIRLOCK	SCFM
18AVR 7	17	7	28	22	19 3/8	42 1/2 (10)	80 7/8	17 1/2	10'' DIA.	PER JOB	6	8x6	12x12 (12)	3.3
36AVR 7	34			40			98 7/8	22						
54AVR 7	52			58			116 7/8	30						
72AVR 7	69			76			134 7/8	38						
18AVR14	34	14	40	22	29 3/4	52 3/4	91 1/8	17 1/2	10'' DIA.	PER JOB	6	8x6	12x12	4.7
36AVR14	69			40			109 1/8	22						
54AVR14	104			58			127 1/8	30						
72AVR14	139			76			145 1/8	38						
96AVR14	185			100			169 1/8	48						
36AVR21	104	21	47	40	35 3/4	58 3/4	115 1/8	22	10x20	PER JOB	6	8x6	18x18	5.4
54AVR21	156			58			133 1/8	30						
72AVR21	209			76			151 1/8	38						
96AVR21	278			100			175 1/8	48						
54AVR32	239	32	60	58	43 9/16	70	144 3/8	30	10x20	PER JOB	10	12x10	12x12	6.5
72AVR32	318			76			162 3/8	38						
96AVR32	425			100			186 3/8	48						
54AVR39	291	39	66	58	48 3/4	75 1/4	149 5/8	30	10x30	PER JOB	10	12x10	12x12	7.5
72AVR39	388			76			167 5/8	38						
96AVR39	518			100			191 5/8	48						
72AVR52	518	52	72	76	54	80 3/8	172 3/4	38	10x30	PER JOB	10	12x10	12x12	9.1
96AVR52	690			100			196 3/4	48						
72AVR62	617	62	84	76	64 3/8	91	183 3/8	38	10x45	PER JOB	10	12x10	18x18	10.6
96AVR62	823			100			207 3/8	48						
72AVR80	797	80	93	76	72 1/8	98 3/4	191 1/8	38	10x45	PER JOB	10	12x10	18x18	13.2
96AVR80	1062			100			215 1/8	48						

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